VOL. 2

Azadi Ka Amrit Mahotsav

Agriculture and Allied Sciences

Restructured and Revised Syllabi of Post-graduate Programmes

- Physical Sciences
- Biotechnology & Bioinformatics
- Social Sciences
- Statistical Sciences
- Basic Sciences

भाकृअनुप
ICAR

Education Division
Indian Council of Agricultural Research
New Delhi

www.icar.gov.in

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

सत्यमेव जयते

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

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FNA, FNASc, FNAAS
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Foreword

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

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

(T. Mohapatra)

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

Preface

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

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

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

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

G. Venkateshwarlu
Member-Secretary

Arvind Kumar
Chairman, National Core Group

Overview

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

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

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

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

R.C. Agrawal

Contents

Common Academic Regulations for PG and Ph.D. Programmes

1. Academic Year and Registration

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

2. Credit requirements

2.1 Framework of the courses

The following nomenclature and Credit Hrs need to be followed while providing the syllabus for all the disciplines:

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

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

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

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

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

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

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

2.2 Supporting Courses

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

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

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

2.3 Syllabus of Common Courses for PG programmes

LIBRARY AND INFORMATION SERVICES (0+1)

Objective

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

Practical

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

TECHNICAL WRITING AND COMMUNICATIONS SKILLS (0+1)

Objective

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

Practical (Technical Writing)

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

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

Suggested Readings

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

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

Objective

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

Theory

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

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

Suggested Readings

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

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

BASIC CONCEPTS IN LABORATORY TECHNIQUES (0+1)

Objective

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

Practical

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

Suggested Readings

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

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

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

Objective

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

Theory

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

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

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

Suggested Readings

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

2.4 Mandatory requirement of seminars

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

3. Residential requirements

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

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

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

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

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

4. Evaluation of course work and comprehensive examination

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

5. Advisory System

5.1 Advisory Committee

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

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

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

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

Allotment of students to the retiring persons

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

Changes in the Advisory Committee:

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

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

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

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

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

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

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

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

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

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

6. Evaluation of research work

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

6.1 Prevention of plagiarism

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

7. Learning through online courses

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

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

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

8. Internship during Masters programme

Internship for Development of Entrepreneurship in Agriculture (IDEA)

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

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

The main objectives of the programme:

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

Following criteria for IDEA will be taken into consideration:

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

9. Teaching assistantship

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

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

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

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

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

11. Compliance with the National Education Policy-2020

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

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

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

Definitions of Academic Terms

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

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

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

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

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

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

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

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

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

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 2

Physical Sciences

- Agricultural Meteorology
- Agronomy
- Soil Science
- Agricultural Physics
- Organic Farming

Contents

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Organic farming in its modern shape with science-based practices and the entire value chain moderated through standards for organic production and backed with robust certification system is fast catching up as an alternative commercial agricultural enterprise. Keeping in view of its growing importance and growing interest of farmers, trade and industry, a need was being felt by ICAR to initiate a postgraduate course in "Organic Farming". ICAR, therefore, constituted a committee for developing the course curriculum for M.Sc.Agriculture in Organic Farming and the committee after due deliberations has developed the syllabus and other requirements and is being presented along with Physical Science group as per the decision of the National Core Committee.

We express our sincere thanks to the committee members Dr A.K. Yadav, Chairman of the committee and Former Director, National Centre of Organic Farming and Currently Advisor (MOVCDNER), DAC&FW, New Delhi; Dr N. Ravishankar, Principal Coordinator NPOF Research, ICAR-IIFSR, Modipuram; Dr R.K. Awasthe, Jt. Director, ICAR-NOFRI, Sikkim; Dr J.P. Saini, Head, Centre of Excellence on Organic Farming, CSKHPKVV, Palampur, Himachal Pradesh; Dr N. Devakumar, Dean, UAS, Bangalore, Karnataka and Dr Mahesh Chander, Head EE, ICAR-IVRI, Izzatnagar, UP constituted for development of course syllabus of "Organic Farming".

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Dr Laxman Singh Rathore, Chairman
Dr Dipti Kumar Borah, Convener
BSMA Committee, Physical Science

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Physical Sciences
– Agricultural Meteorology

Preamble

Agricultural Meteorology deals with the effects and impacts of weather and climate on agriculture and allied sectors. Climate, with its spatial and temporal variability, is a major influencing factor of crop production. Thus, any change in climatic elements is bound to have either positive or negative impacts on agricultural production. Along with this, climate change has led to increased intensity and frequency of extreme weather events such as heavy precipitation, cloud bursts, hail storm events, drought, etc. Here comes the importance of this discipline, which explores the principles of interaction of crops, livestock, fisheries, etc., with weather on a daily basis and with climate on a long-term basis. The relevance of the discipline is increasing over time, mainly due to the threats posed by climate variability and change in the present and future time. Considering the background and to promulgate the knowledge on role of weather for crop growth and development, new courses on Crop-weather relationship and Fundamentals of Agricultural Physics are included in the syllabus. Major changes are made in some courses considering the need of inclusion of recent advances and the new national initiatives. The repetition of content has been minutely scrutinized and modification has been done accordingly.

The provision of reliable weather information can be of great help for the decision making of farmers before and during the crop season for arranging the inputs and their optimum utilization. A well-timed agromet advisory can save inputs (fertilizers, seeds, plant protection chemicals, etc.), labour as well as the crop (especially at the harvest time after the crop reaches physiological maturity). Knowledge of Agricultural Meteorology helps in the efficient management of agro-climatic resources and crop microclimate modifications for the sustainability of agricultural production system. The students of this discipline should be sensitized towards the recent developments in information-communication technologies (ICT), which enables a faster, wider and timely dissemination of agromet advisories to the farmers of the country. Establishment of District-level Agromet Unit at different KVK is a great initiative by the Central Government and newly designed syllabus will empower the students to work in such types of project most efficiently.

The Agro-meteorologist requires not only a sound knowledge of Meteorology, but also of Agricultural Scince (Agronomy, Soil Science, Plant Sciences, and Animal Sciences), in addition to common agricultural practices. This branch ofscience is of particular relevance to India because of the high dependence of our agriculture on monsoon rainfall which has its own vagaries. A collective effort of agrometeorologist, agronomist, entomologist, pathologist and soil scientist make an information-rich agromet advisory, which will be of great help to the farmers. Another important area is the micrometeorology, which enables the farmers to modify the microclimate favourably to enhance the production.

Recent advances in space-borne (satellites), air-borne (UAVs) and ground remote sensing (spectro-radiometer) have improved the spatial and temporal capacity of the discipline for crop health monitoring, crop loss assessment, crop acreage estimation, etc. We are living in a world where tremendous advancement in computing power is enabling us to collect big data in agriculture, analyse it and arrive at conclusions, which helps to make farming a profitable business. The new syllabus will expose the students to the principles and practices of exploring remote sensing data, spatial analysis using Geographic information system (GIS), data analysis using computer programming with open source software like 'R' or/and 'Python'.The overall objective of this discipline is to educate students on the understanding of climate and weather elements, principles and processes, and their impact on agricultural activities and restructured course will help the students to achieve their goal.

Course Title with Credit Load
M.Sc. in Agriculture Meteorology

Course Code	Course Title	Credit Hours
AGM 501*	Fundamentals of Meteorology	2+1
AGM 502*	Fundamentals of Agricultural Meteorology	2+1
AGM 503	Crop-weather Relationships	2+0
AGM 504*	Agro-meteorological Measurements and Instrumentation	1+2
AGM 505	Crop Micrometeorology	2+1
AGM 506	Evapotranspiration and Soil Water Balance	2+1
AGM 507	Crop weather models	1+2
AGM 508	Applied Agricultural Climatology	1+2
AGM 509	Weather forecasting	2+1
AGM 510	RS and GIS Applications in Agricultural Meteorology	2+1
AGM 511	Strategic use of climatic information	2+1
AGM 512	Weather and climate risk management	2+0
AGM 513	Aerobiometeorology	2+1
AGM 591	Master's Seminar	1+0
AGM 599	Master's Research	30

*Indicates core courses for M.Sc.

Course Contents
M.Sc. in Agriculture Meteorology

I. Course Title : Fundamentals of Meteorology
II. Course Code : AGM 501
III. Credit Hours : 2+1
IV. Aim of the course

To impart theoretical and practical knowledge of physical processes occurring in atmosphere and techniques used in meteorology.

V. Theory

Unit I

Solar radiation and laws of radiation; greenhouse effect, albedo, and heat balance of the earth and atmosphere; variation in pressure and temperature with height, potential temperature, pressure gradient, cyclonic and anticyclonic motions; geostropic and gradient winds; equations of motion; general circulation, turbulence, vorticity, atmospheric waves.

Unit II

Gas laws, laws of thermodynamics and their application to atmosphere; water vapour in the atmosphere, various humidity parameters and their interrelationships; vapour pressure, psychrometric equation, saturation deficit, Lapse rates-ascent of dry and moist air, stability and instability conditions in the atmosphere.

Unit III

Agromet observatory and analysis of weather data; Condensation; clouds and their classification; evaporation and rainfall; the hydrological cycle; precipitation processes, artificial rainmaking, thunderstorms and dust storm; haze, mist, fog, and dew; air masses and fronts; tropical and extra-tropical cyclones.

Unit IV

Effect of Earth's rotation on zonal distribution of radiation, rainfall, temperature, and wind; the trade winds, equatorial trough and its movement;

Unit V

Monsoon and its origin; Indian monsoon and its seasonal aspects: Onset, advancement and retreat of monsoon in different parts of India, Walker and Hadley cell, El Nino, La Nina, Southern Oscillation Index and their impact on monsoon.

VI. Practical

- Agromet observatory- different classes of observatories (A, B, C)
- Site selection and installation procedures for meteorological instruments
- Measurement of weather parameters.
- Reading and recording, calculation of daily, weekly, monthly means.
- Totals of weather data.
- Weather chart preparation and identification of low pressure systems and ridges.
- Statistical technique for computation of climatic normals, moving average, etc.

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Basic knowledge on meteorology and climatology, physical laws governing atmosphere and monsoon

IX. Suggested Reading

- Ahrens. 2008. *Meteorology today*, 9th Edition. Wadsworth Publishing Co Inc.
- Barry RG and Richard JC. 2003. *Atmosphere, Weather and Climate*. Tailor & Fransics Group.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Ghadekar SR. 2001. *Meteorology*. Agromet Publishers (Nagpur).
- Ghadekar SR. 2002. *Practical Meteorology*. Agromet Publishers (Nagpur).
- Mcllveen R. 1992. *Fundamentals of Weather and Climate*. Chapman & Hall.
- Petterson S. 1958. *Introduction to Meteorology*. McGraw Hill.
- Trewartha Glenn T. 1954. *An Introduction to Climate*. McGraw Hill.
- Varshneya MC and Pillai PB. 2003. *Text Book of Agricultural Meteorology*. ICAR.

Journals

- *Mausam*
- *Journal of Agrometeorology*
- *Italian Journal of Agrometeorology*
- *Theoretical and Applied Climatology*

Websites

- http://www.imd.gov.in/pages/main.php
- https://public.wmo.int/en

I. Course Title : Fundamentals of Agricultural Meteorology

II. Course Code : AGM 502

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of physical processes occurring in relation to plant and atmosphere with advanced techniques.

V. Theory

Unit I

Meaning and scope of agricultural meteorology; components of agricultural meteorology; role and responsibilities of agricultural meteorologists.

Unit II

Importance of meteorological parameters in agriculture; efficiency of solar energy conversion into dry matter production; meteorological factors in photosynthesis, respiration and net assimilation; basic principles of water balance in ecosystems; soil-water balance models and water production functions.

Unit III

Crop weather calendars; weather forecasts for agriculture at short, medium and long range levels; agromet advisories, preparation, dissemination and economic impact analysis; use of satellite imageries in weather forecasting; synoptic charts and synoptic approach to weather forecasting.

Unit IV

Concept, definition, types of drought and their causes; prediction of drought; crop water stress index, crop stress detection; air pollution and its influence on vegetation, meteorological aspects of forest fires and their control.

Unit V

Climatic change, green house effect, CO_2 increase, global warming and their impact on agriculture; climate classification, agro-climatic zones and agro-ecological regions of India.

VI. Practical

- Preparation of crop weather calendars
- Development of simple regression models for weather, pest and disease relation in different crops.
- Preparation of weather based agro-advisories
- Use of automated weather station (AWS)

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Overall and basic knowledge on Agrometeorology

IX. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Kakde JR. 1985. *Agricultural Climatology*. Metropolitan Book Co.
- Mahi and Kingra. 2014. *Fundamentals of agrometeorology*. Kalyani publishers.
- Mavi HS and Tupper. 2004. *Principles and applications of climate studies in agriculture*. CRC Press
- Varshneya MC and Pillai PB. 2003. *Text Book of Agricultural Meteorology*. ICAR.

Journals

- *Journal of Agrometeorology*
- *Italian Journal of Agrometeorology*
- *Agricultural and Forest Meteorology*
- *Current Science*

Websites

- http://www.imd.gov.in/pages/main.php
- http://www.fao.org/home/en/
- www.wmo.org
- www.ipcc.org

I. Course Title : Crop-weather Relationships

II. Course Code : AGM 503

III. Credit Hours : 2+0

IV. Aim of the course

To study and understand the role of weather on crop growth and development.

V. Theory

Unit I

Understanding the influence of weather elements on crop growth, impact of climatic variability and extremes on crop production, climatic normals for crop production.

Unit II

Climatic requirements of major crops, temperature effect on crop growth, radiation impact and radiation utlilization efficiency, humidity effect on crop performance, effect of soil temperature on seed germination and root growth, wind variation and crop growth.

Unit III

Meteorological indices to predict crop production, Interpretation of weather forecasts for various agricultural operations towards improved productivity, crop-weather relationship in dryland areas. Crop weather relationship of major horticultural crops of the region and agroforestry system.

Unit IV

Rhizosphere and microorganisms in relation to weather, fertilizer and water use efficiency in relation to weather.

VI. Teaching methods/activities

Classroom teaching

VII. Learning outcome

To enhance the knowledge on intricate relationship between crop and weather.

VIII. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Jerry L. Hatfield, Mannava VK, Sivakumar and John H. Prueger. 2017. *Agroclimatology: Linking Agriculture to climate*. Agronomy Monographs 60.
- Mavi HS. 1994. *Introduction to Agrometeorology*. Oxford & IBH.
- Prasada Rao GSLHV. 2008. *Agricultural Meteorology*. PHI Learning Publishers.

Journals

- *Journal of Agrometeorology*
- *Agricultural and Forest Meteorology*

Websites

- http://www.imd.gov.in/pages/main.php
- http://www.fao.org/home/en/

I. Course Title : Agro-meteorological Measurements and Instrumentation

II. Course Code : AGM 504

III. Credit Hours : 1+2

IV. Aim of the course

To impart the theoretical and practical knowledge of instruments/equipments used for measurement of agro-meteorological variables.

V. Theory

Unit I

Fundamentals of measurement techniques; theory and working principles of barometer, thermometer, psychrometer, hair hygrometer, thermohygrograph; exposure and operation of meteorological instruments/ equipments in agromet observatories.

Unit II

Radiation and temperature measuring instruments: working principles of albedometer, photometer, spectro-radiometer, sunshine recorder, dew recorder, quantum radiation sensors, pressure bomb apparatus, thermographs, and infra-red thermometer.

Unit III

Precipitation and dew instruments: working principles of rain gauge, self recording rain gauge, Duvdevani dew gauges. Wind instruments: working principles of anemometer, wind vane, anemograph.

Unit IV

Evapotranspiration and photosynthesis instruments: working principles of lysimeters, open pan evaporimeters, porometer, photosynthesis system, leaf area meter.

Unit V

Boundary layer fluxes, Flux tower, soil heat flux plates, instruments to measure soil moisture and soil temperature.

Unit VI

Automatic weather station – data logger and sensors, nano-sensors for measurement of weather variables; computation and interpretation of data.

VI. Practical

- Working with the above instruments in the meteorological observatory, fields and laboratory, Recording observations of relevant parameters.
- Computation and interpretation of the data.
- Analysis of AWS data.

VII. Teaching methods/activities

Mostly practical classes with demonstration and hands-on use of met-instruments

VIII. Learning outcome

Practical classes and theory

IX. Suggested Reading

- Anonymous. 1987. *Instructions to Observers at Surface Observatories*. Part I, IMD, New Delhi.
- Byers HR. 1959. *General Meteorology*. McGraw Hill.
- Ghadekar SR. 2002. *Practical Meteorology: Data Acquisition Techniques, Instruments and Methods*. Agromet Publ.
- Middleton WE and Spilhaws AF. 1962. *Meteorological Department*. University of Toronto Press.
- Tanner CB. 1973. *Basic Instrumentation and Measurements for Plant Environment and Micrometeology*. University of Wisconsin, Madison.
- WMO. 2008. *Guide to Meteorological Instruments and Methods of Observation*. WMO-No.8

Journals

- *International Journal of Biometeorology*
- *Agricultural and Forest Meteorology*
- *Journal of Agrometeorology*

Website

https://public.wmo.int/en

I. **Course Title : Crop Micrometeorology**

II. **Course Code : AGM 505**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To impart the theoretical and practical knowledge of physical processes occurring in lower atmosphere and within crop canopy concerning crop growth.

V. **Theory**

Unit I

Properties of atmosphere near the Earth's surface; exchange of mass momentum and energy between surface and overlaying atmosphere, exchange coefficient, similarity hypothesis, shearing stress, forced and free convection.

Unit II

Molecular and eddy transport of heat, water vapour and momentum, frictional effects, eddy diffusion, mixing; zero plane displacement, temperature instability, eddy covariance technique, microclimate near the bare ground, unstable and inversion layers, variation in microclimate under irrigated and rainfed conditions, soil moisture and temperature variation with depth; Richardson number, Raymonds analogy, Exchange coefficients.

Unit III

Micrometeorology of plant canopies; distribution of temperature, humidity, vapour pressure, wind and carbon dioxide; modification of microclimate due to cultural practices, intercropping; radiation distribution and utilization by plant communities, leaf temperature and its biological effects; influence of topography on microclimate; shelter belts and wind breaks, microclimate in low plant area of meadows and grain fields, microclimate within forests, glass house and plastic house climates; instruments and measuring techniques in micrometeorology.

Unit IV

Effects of ambient weather conditions on growth, development and yield of crops; measurement of global and diffuse radiation; measurement of albedo over natural surfaces and cropped surfaces; net radiation measurement at different levels; PAR distribution in plant canopies and interception; wind, temperature and humidity profiles in (a) short crops and (b) tall crops; energy balance over crops and LAI and biomass estimation; remote sensing and its application in relation to micrometeorology.

VI. **Practical**

- Micrometerological measurements in crop canopies
- Quantification of crop microclimate
- Determination of ET and its computation by different methods.

VII. **Teaching methods/activities**

Theory and practical classes

VIII. **Learning outcome**

Knowledge of microclimatic conditions governing crop growth

IX. Suggested Reading

- Pal AS. 1988. *Introduction to Micrometeorology*. Academic Press.
- Bishnoi OP. 2007. Principles of Agricultural Meteorology. Oxford Book Co.
- Chang, Jen-Hu. 1968. *Climate and Agriculture: An Ecological Survey*. Aldine Publishing Company.
- Gates DM. 1968. *Energy Exchange in the Biosphere*. UNESCO.
- Goudriaan J. 1983. *Crop Micrometeorology: A Simulation Study*. Scientific Publ.
- Grace J. 1983. *Plant Atmospheric Relationships: Outline Studies in Ecology*. Chapman & Hall.
- Gupta PL and Rao VUM. 2000. *Practical Manual on Micrometeorology*. Dept. of Agril. Meteorology, CCS HAU Hisar, India.
- Jones HG. 1992. *Plants and Microclimate*. Cambridge Univ. Press. Munn RE. 1970. Biometeorological Methods. Academic Press.
- Monteith and Unsworth. 2013. *Principles of Environmental Physics*. Elsevier.
- Rosenberg NJ. 1974. *Microclimate – The biological Environmet*. John Wiley & Sons.
- Sellers W. 1967. *Physical Climatology*. The University of Chicago Press.

Journals

- *International Journal of Biometeorology*
- *Agricultural and Forest Meteorology*
- *Journal of Agrometeorology*

Website

- https://public.wmo.int/en

I. Course Title : Evapotranspiration and Soil Water Balance

II. Course Code : AGM 506

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of ET estimation and determination of the components of soil water balance

V. Theory

Unit I

Energy concept of soil water, hydraulic conductivity and soil water flux; theory on hydraulic conductivity in saturated and unsaturated soils; physical factors concerning water movement in soil; concepts on evaporation, evapotranspiration, potential and actual evapotranspiration.

Unit II

Theories of evapotranspiration and their comparison; aerodynamic, eddy correlation, energy balance, water balance and other methods, their application under different agroclimatic conditions; concepts of potential, reference and actual evapotranspiration - modified techniques.

Unit III

Influence of microclimatic and cultural factors on soil water balance; techniques of lysimetry in measuring actual evapotranspiration. water use efficiency and scheduling of irrigation based on evapotranspiration; water use efficiency and antitranspirants, computation of Kc values and their use; irrigation scheduling based on climatological approaches.

Unit IV

Yield functions; water use efficiency and scheduling of irrigation based on evapotranspiration; dry matter yield ET functions; radiation instruments; advanced techniques for measurement of radiation and energy balance; estimation of evapotranspiration through remote sensing.

VI. Practical

- Measurement of various components of soil water balance
- Evaluation of hydraulic conductivity vs. soil moisture relationship by water balance approach
- Computation and comparison of evapotranspiration by different methods - energy balance method, aerodynamic method, Penman method, remote sensing and other methods
- Soil moisture retention characteristics by pressure plate method.

VII. Teaching methods/activities

Theory and practical classes

VIII. Learning outcome

To know the estimation procedures and interlinkages among different components of field water balance

IX. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Burman R and Pochop LO. 1994. *Evaporation, Evapotranspiration and Climatic Data*. Elsevier.
- Grace J.1983. *Plant Atmospheric Relationships: Outline Studies in Ecology*. Chapman & Hall.
- Mavi HS and Tupper GJ. 2004. *Agrometeorology: Principles and Applications of Climate Studies in Agriculture*. The Haworth Press.
- Murthy VRK. 2002. *Basic Principles of Agricultural Meteorology*. BS Publ.
- Niwas R, Singh D and Rao VUM. 2000. *Pratical Manual on Evapotranspiration*. Dept. of Agril. Meteorology, CCS HAU Hisar.
- Rosenberg NJ, Blad BL and Verma SB. 1983. *Microclimate –The Biological Environment*. John Wiley & Sons.
- Subramaniam VP. 1982. *Water balance and its application*. Andhra University Press, Waltair, India.

Journals

- *Journal of Agrometeorology*
- *Archives of Agronomy and Soil Science*
- *Agricultural Water Management*
- *Journal of Hydrology*
- *Journal of Plant Ecology*

Websites

- https://www.icrisat.org/
- http://www.iwmi.cgiar.org/
- http://www.iiwm.res.in/

I. Course Title : Crop Weather Models

II. Course Code : AGM 507

III. Credit Hours : 1+2

IV. Aim of the course

To impart the theoretical and practical knowledge of various models for estimation of crop weather responses.

V. Theory

Unit I

Principles of crop production; effect of weather elements on crop responses; impact of natural and induced variability of climate on crop production.

Unit II

Introduction and application to crop modeling, types of models, Empirical and statistical crop weather models their application with examples; concept of crop growth model in relation to weather, soil, plant and other environmental related parameters and remote sensing inputs; growth and yield prediction models;

Unit III

Dynamic crop simulation models, e.g. DSSAT, InfoCrop, APSIM, CropSyst, etc.; optimization, calibration and validation of models. Weather data and physiology-based approaches to modeling of crop growth and yield; forecasting of pests and diseases; stochastic models; advantages and limitation of modeling.

VI. Practical

Working with statistical and simulation models, DSSAT models, InfoCrop, Oryza, etc.

VII. Teaching methods/activities

Theory and practical classes. Demonstration and hands-on practicals using crop models

VIII. Learning outcome

To utilize the crop weather model for observing weather influence on crop growth

IX. Suggested Reading

- Wallach D *et al*. *Working with dynamic crop models*.
- DeWit CT, Brouwer R and de Vries FWTP. 1970. *The Simulation of Photosynthetic Systems*. pp. 7-70. In. Prediction and Measurement of Photosynhetic Activity. Proc. Int. Biological Programme Plant Physiology Tech. Meeting Trebon PUDOC. Wageningen.
- Duncan WG. 1973. *SIMAI- A Model Simulating Growth and Yield in Corn*. In: The Application of Systems Methods to Crop Production (D.N. Baker, Ed.). Mississippi State Univ. Mississipi.
- Frere M and Popav G. 1979. *Agrometeorological Crop Monitoring and Forecasting*. FAO.
- Hanks RJ. 1974. *Model for Predicting Plant Yield as Influenced by Water Use*. Agron. J. 66: 660-665.
- Hay RKM and Porter JR. 2006. *The physiology of crop yield* (2nd Edition).
- Keulen H Van and Seligman NG. 1986. *Simulation of Water Use, Nitrogen Nutrition and Growth of a Spring Wheat Crop*. Simulation Monographs. PUDOC, Wageningen.
- Singh P. *Modelling of crop production systems: Principles and applications*.
- Weixing Cao *et al*. *Crop modeling and decision support*.

Journals

- *Journal of Agrometeorology*

- *Global Environmental Change*
- *Global Change Biology*
- *Mitigation and Adaptation Strategies for Global Change*

Websites

- https://www.apsim.info/
- https://dssat.net/

I. Course Title : Applied Agricultural Climatology

II. Course Code : AGM 508

III. Credit Hours : 1+2

IV. Aim of the course

To impart the theoretical and practical knowledge of computation of different bio-parameters and their applications in the agriculture.

V. Theory

Unit I

Climatic statistics: measures of central tendency and variability, skewness, kurtosis, homogeneity, correlation, regression and moving averages; probability analysis using normal, binomial, Markov-chain and incomplete gamma distribution; parametric and non parametric tests; assessment of frequency of disastrous events.

Unit II

Precipitation indices; Climatic water budget: potential and actual evapotranspiration and their computation; measurement of precipitation, calculation of water surplus and deficit; computation of daily and monthly water budget and their applications; assessment of dry and wet spells, available soil moisture, moisture adequacy index and their applications.

Unit III

Thermal indices and phenology: cardinal temperatures; heat unit and growing degree day concepts for crop phenology, crop growth and development; insect-pest development; crop weather calendars; agroclimatic requirement of crops.

Unit IV

Bioclimatic concepts: evaluation of human comfort, comfort indices (temperature, humidity index and wind chill) and clothing insulation; climate, housing and site orientation; climatic normals for animal production.

VI. Practical

- Use of statistical approaches in data analysis
- Preparation of climatic water budget
- Estimation of agro-meteorological variables using historical records
- Degree day concept and phenology forecasting and preparation of crop calendar
- Evaluation of radiation, wind and shading effects in site selection and orientation
- Study of weather-pest and disease interactions, calculation of continentality factors; calculation of comfort indices and preparation of climograph.

VII. Teaching methods/activities

Theory and practical classes

VIII. Learning outcome

Knowledge on how to use the meteorological observations and derived indices are applied in agricultural field

IX. Suggested Reading

- Anonymous 1980. *ICRISAT Climatic Classification – A Consultation Meeting*. ICRISAT.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Lal DS. 1989. *Climatology*. Chaitanya Publ. House.
- Mather JR. 1977. *Work Book in Applied Climatology*. Univ. of Delware, New Jersey.
- Mavi HS and Tupper Graeme J. 2004. *Agrometeorology: Principles and Applications of Climate Studies in Agriculture*. The Haworth Press.
- Stigter K (Ed.). 2010. *Applied Agrometeorology*. Springer
- Subramaniam VP. 1977. *Incidence and Spread of Continental Drought*. WMO/IMD Report No. 2, WMO, Geneva, Switzerland.
- Thompson R. 1997. *Applied Climatology: Principles and Practice*. Routledge.
- Walter J Saucier. 2003. *Principles of Meteorological Analysis*. Dover Phoenix Eds.

Journals

- *Theoretical and Applied Climatology*
- *Atmospheric Research Journal*
- *Journal of Agrometeorology*
- *Agricultural Climatology and Meteorology*
- *Journal of Applied Meteorology and Climatology*

Websites

- http://www.imd.gov.in/pages/main.php
- https://public.wmo.int/en

I. Course Title : Weather Forecasting

II. Course Code : AGM 509

III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical and practical knowledge of forecasting techniques used for weather prediction and preparation of agro-advisories.

V. Theory

Unit I

Weather forecasting system: definition, scope and importance; types of forecasting: short, medium and long-range; study of synoptic charts with special reference to location of highs and lows, jet streams, synoptic features and weather anomalies and zones of thermal advection and interpretation of satellite pictures of clouds in visible and infra-red range; weather forecasting network.

Unit II

Approaches for weather forecasts: methods of weather forecasts - synoptic, numerical prediction, statistical, analogue, persistence and climatological approach, nano-technological approach, Indigenous Technical Knowledge (ITK) base- signals from flora, fauna, insects, birds, animals behavior; various methods of verification of location-specific weather forecast.

Unit III

Special forecasts: special forecasts for natural calamities such as drought, floods, high winds, cold (frost) and heat waves, hail storms, cyclones and protection measures against such hazards.

Unit IV

Modification of weather hazards: weather modification for agriculture; scientific advances in artificial rain making, hail suppression, dissipation of fog and stratus clouds, modification of severe storms and electric behavior of clouds.

Unit V

Weather based advisories: interpretation of weather forecasts for soil moisture, farm operations, pest and disease development and epidemics, crops and livestock production; preparation of weather-based advisories and dissemination.

VI. Practical

- Exercise on weather forecasting for various applications
- Preparation of weather-based agro-advisories based on weather forecast using various approaches and synoptic charts.

VII. Teaching methods/ activities

Theory and practical classes

VIII. Learning outcome

Enhancing knowledge on weather forecast and its use

IX. Suggested Reading

- Watts A. 2005. *Instant Weather Forecasting*. Water Craft Books.
- Ram Sastry AA. 1984. *Weather and Weather Forecasting*. Publication Division, GOI, New Delhi.
- Singh SV, Rathore LS and Trivedi HKN. 1999. *A Guide for Agrometeorological Advisory Services*. Department of Science and Technology, NCMRWF, New Delhi.
- Wegman and Depriest. 1980. *Statistical Analysis of Weather Modification Experiments*. Amazon Book Co.

Journals

- *Journal of Climatology and Weather Forecasting*
- *Theoretical and Applied Climatology*
- *Atmospheric Research Journal*
- *Journal of Agrometeorology*
- *Agroclimatology*

Websites

- https://www.ipcc.ch/
- https://www.imd.gov.in/pages/main.php

I. Course Title : RS and GIS Applications in Agricultural Meteorology

II. Course Code : AGM 510

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of remote sensing principles and their use to estimate of agro-meteorological variables.

V. Theory

Unit I

Basic components of remote sensing- signals, sensors and sensing systems; active and passive remote sensing.

Unit II

Characteristics of electromagnetic radiation and its interaction with matter; spectral features of earth's surface features; remote sensors in visible, infrared and microwave regions.

Unit III

Imaging and non-imaging systems; framing and scanning systems; resolution of sensors; sensor platforms, their launching and maintenance. Drone technology.

Unit IV

Data acquisition system, data preprocessing, storage and dissemination; digital image processing and information extraction.

Unit V

Microwave remote sensing; visual and digital image interpretation; introduction to GIS and GPS.

Unit VI

Digital techniques for crop discrimination and identification; crop stress detection - soil moisture assessment, inventory of ground water and satellite measurement of surface soil moisture and temperature; drought monitoring, monitoring of crop disease and pest infestation. Use of satellite data in weather forecasting.

Unit VII

Soil resource inventory; land use/land cover mapping and planning; integrated watershed development; crop yield modeling and crop production forecasting.

VI. Practical

- Acquisition of maps
- Field data collection
- Map and imagery scales
- S/W and H/W requirements and specifications for remote sensing
- Data products, their specifications, media types, data inputs, transformation, display types, image enhancement
- Image classification methods
- Evaluation of classification errors
- Crop discrimination and acreage estimations
- Differentiation of different degraded soils
- Time domain reflectometry
- Use of spectrometer and computation of vegetation indices
- Demonstration of case studies
- Hands on training

VII. Teaching methods/activities

Hands on practicals and theory

VIII. Learning outcome

Knowledge on RS-GIS technique for application in Agricultural Meteorology

IX. Suggested Reading

- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Campbell JB. 1996. *Introduction to Remote Sensing*, 2nd ed., The Guilford Press, New York.
- Colwell RN. (Ed.). *Manual of Remote Sensing*. Vols. 1, II. Am. Soc. Photogrammetry, Virginia.
- Curan PJ. *Principles of Remote Sensing*. ELBS/Longman.
- Georg Joseph 2005.*Fundamentals of Remote Sensing*. University Press (India).
- Jain AK. 1989. *Fundamentals of Digital Image Processing*, Prentice Hall of India.
- Lilisand TM, Kiefer RW and Chipman JW. 2003. *Remote Sensing and Image Interpretation*, 5th ed., John Wiley & Sons, Inc., New York.
- Narayan LRA. 1999. *Remote Sensing and its Applications*. Oscar Publ.
- Panda BC. 2008. *Principles and Applications of Remote Sensing*, Viva Publications.
- Patel AN and Surender Singh. 2004. *Remote Sensing: Principles and Applications*. Scientific Publ.

Journals

- *Journal of Global Environmental Change*
- *Journal of Remote Sensing and GIS*
- *Journal of Agrometeorology*

Websites

- https://www.nrsc.gov.in/
- http://www.imd.gov.in/pages/main.php
- https://public.wmo.int/en

I. Course Title : Strategic Use of Climatic Information

II. Course Code : AGM 514

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of climatic hazards and their mitigations.

V. Theory

Unit I

Increasing awareness on potential climate hazards and mitigations: history of climate-related disasters in the concerned continent/ region/ country/ sub-region and their documented or remembered impacts; Climatic hazards and extreme weather events (Cyclone, Hailstorm, drought, flood, etc.), Impact of climatic hazard on agricultural production; efforts made in mitigating impacts of (future) disasters (prevention); trends discernible in occurrence and character of disasters, if any.

Unit II

Selection of appropriate land use and cropping patterns: types and drivers of agricultural land use and cropping patterns based on climatic situation; history of present land use and cropping patterns in the sub-region concerned as related to environmental issues; successes and difficulties experienced by farmers with present land use and cropping patterns; outlook for present land use and cropping patterns and possible alternatives from an environmental point of view.

Unit III

Adoption of preparedness strategies: priority settings for preparedness strategies in agricultural production; preparedness for meteorological disasters in development planning; permanent adaptation strategies that reduce the vulnerabilities to hazards; preparedness as a coping strategy.

Unit IV

Making more efficient use of agricultural inputs: agro-meteorological aspects of agricultural production inputs and their history; determination of input efficiencies based on weather conditions; other factors determining inputs and input efficiency; actual use of inputs in main land use and cropping patterns of the region.

Unit V

Adoption of microclimate modification techniques: review of microclimate management and manipulation methods; history of microclimate modification techniques practiced in the continent/ country/ sub-region concerned; possible improvements in adoption of microclimate modification techniques, given increasing climate variability and climate change; local trends in adoption of such techniques.

Unit VI

Protection measures against extreme climate: history of protection measures against extreme climate in the continent/ region/ country/ sub region concerned; successes and difficulties experienced by farmers with present protection measures; outlook for present protection measures and possible alternatives; trends in protection methods against extreme climate.

Practical

- Outlook for present land use and cropping patterns and possible alternatives from environmental point of view
- Recent trends in land use and cropping patterns
- Agro-meteorological services to increase farmers design abilities of land use and cropping patterns
- Systematic and standardized data collection on protection measures against extreme climate.

VI. Teaching methods/activities

Theory and practical classes

VII. Learning outcome

Application of climatic information for agriculture and natural resource management

VIII. Suggested Reading

- Anonymous. *Clean Development Mechanism: Building International Public-Private Partnership under Kyoto Protocol.* UNEP, UNDP Publ.
- Anonymous. *IPCC Assesment Reports on Climate Change Policy: Facts, Issues and Anlysis*. Cambridge Univ. Press.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Pretty J and Ball A. 2001. *Agricultural Influence on Carbon Emission and Sequestration: A Review of Evidence and the Emerging Trading Options*. Univ. of Essex.
- Pretty JN. 1995. *Regenerating Agriculture: Policies and Practices for Sustainable and Self Reliance*. Earthscan.

Journals

- *Climate Risk Management*, *Journal* of *Climate* (JCLI),
- *International Journal of Climatology*
- *Journal of Agrometeorology*

Website

https://www.ncdc.noaa.gov/climate-information

I. Course Title : Weather and Climate Risk Management

II. Course Code : AGM 515

III. Credit Hours : 2+0

IV. Aim of the course

To impart the theoretical and practical knowledge of weather modification techniques with risk management strategies

V. Theory

Unit I

Risk characterization – definitions and classification of risks; characterization of weather and climate related risks in agriculture; water related risks; radiation/ heat related risks; air and its movement related risks; biomass related risks; social and economic risk factors related to weather and climate.

Unit II

Risks in agricultural production, history of weather and climate as accepted risk factors in agriculture in the continent/ region/ country/ sub-region concerned and the related documented risk concepts; preparedness for weather and climate risks.

Unit III

Risks of droughts; monitoring, prediction and prevention of drought; drought proofing and management; modern tools including remote sensing and GIS in monitoring and combating droughts.

Unit IV

Theories of weather modification; scientific advances in clouds and electrical behavior of clouds; hails suppression, dissipation of fog, modification of frost intensity and severe storms; shelter belts and wind breaks, mulches and anti-transpirants; protection of plants against climatic hazards; air and water pollution; meteorological conditions in artificial and controlled climates - green, plastic, glass and animal houses, etc.

Unit V

Approaches and tools to deal with risks - history of methods for weather and climate related risk assessments in the continent/ region/ country/ subregion concerned and their documented evidence of application to agricultural/farming systems; strategies of dealing with risks- mitigating practices before occurrence; preparedness for the inevitable; contingency planning and responses; disaster risk mainstreaming.

Unit VI

Perspectives for farm applications - farm applications not yet dealt with, such as making risk information products more client friendly and transfer of risk information products to primary and secondary users of such information; heterogeneity of rural people in education, income, occupation and information demands and consequences for risk information products and their transfer; livelihood-focused support, participation and community perspectives; challenges for developing coping strategies including transferring risks through insurance schemes.

Unit VII

Challenges to coping strategies-combining challenges to disaster risk mainstreaming, mitigation practices, contingency planning and responses, basic preparedness; preparedness approaches reducing emergency relief necessities; the role that insurances can play in risk spreading and transfer; application of methods that permit the incorporation of seasonal and long-term forecasts into the risk assessment models.

VI. Teaching methods/ activities

Theory classes

VII. Learning outcome

Knowledge on different weather extremes and how to modify weather to reduce risk

VIII. Suggested Reading

- Anonymous 2003. *Critical Issues in Weather Modification Research Board of Atmoshperic Science and Climate*. National Research Council, USA.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Chritchfield HJ. 1994. *General Climatology*. Prentice Hall.
- Lenka D. 1998. Climate, Weather and Crops in India. Kalyani.
- Mavi HS and Graeme J Tupper. 2004. *Agrometeorology: Principles and Applications of Climate Studies in Agriculture*. The Haworth Press.
- Mavi HS. 1994. *Introduction to Agrometeorology*. Oxford & IBH.
- Menon PA. 1989. *Our Weather*. National Book Trust.
- Pearce RP. 2002. *Meteorology at the Millennium*. Academic Press.
- Rosenberg NJ, Blad BL and Verma SB. 1983. *Microclimate – The Biological Environment*. John Wiley & Sons.
- Samra JS, Narain P, Rattan RK and Singh SK. 2006. *Drought Management in India*. Bull. Indian Society of Soil Science 24, ISSS, New Delhi.

Journals

- *International Journal of Biometeorology*
- *Agricultural and Forest Meteorology*
- *Journal of Agrometeorology*

Website

- https://www.icrisat.org/

I. Course Title : Aerobiometeorology

II. Course Code : AGM 516

III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical knowledge on insect, pest and plant biometeorology

V. Theory

Unit I

Definition and structure of Aerobiometeorology, role of Agrometeorology and Biogeography in forecasting pests and disease outbreak, insect movement in the atmosphere, intensification, Effect of weather and climate parameters on reproduction, growth, development, movements, food, habitat and dispersal of pests and diseases. Influence of weather and climate on Migratory pests (Desert locust, BPH etc.).

Unit II

Benevolent and malevolent weather conditions for salient pests & diseases of the concerned agro-climatic zones. Effects of sudden weather changes and extreme weather conditions on population built-up of the pest, heat stress and heat related mortality, climate change impact on pest and diseases.

Unit III

Biometeorology in integrated pest and disease management program, modification of plant canopy and its impact of plant diseases, management of segments of disease triangle: environment manipulation and host manipulation, weather based forewarning system for pest and diseases.

Unit IV

Soil borne pathogens, their biology, management and challenges, soil borne diseases and their control, abiotic factor in soil borne disease management, Managing of pests & diseases in controlled environment, Environmental management for pest and disease

VI. Practical

- Identification of different pests
- Pest population, observations and their index calculation
- Identification of various diseases
- Disease initiation and their intensity, percent disease index
- Relation between weather parameters and pests and disease

VII. Teaching methods/activities

Classroom teaching and practical, visit to fields

VIII. Learning outcome

Knowledge on interactions between atmospheric processes and living organisms, mainly pest and diseases

IX. Suggested Reading

- Yazdani, SS and Agarwal ML. 2002. *Elements of insect ecology*. Narosa Publishing House.
- Odum EP. *Fundamentals of insect ecology*.
- Dhaliwal GS and Arora R. *Integrated pest management*.
- Jerry L. Hatfield and Ivan J. Thomason. 1982. *Biometeorology in integrated pest management*, Academic press.

Journals

- *Aerobiologica*
- *Journal of Agrometeorology*
- *International Journal* of *Biometeorology*

Website

- http://www.imd.gov.in

Course Title with Credit Load
Ph.D. in Agricultural Meteorology

Course Code	Course Title	Credit Hours
AGM 601*	Climate change and sustainable development	2+1
AGM 602	Meteorology of air pollution	2+2
AGM 603	Livestock and fisheries meteorology	2+2
AGM 604	Hydrometeorology	2+1
AGM 605	Analytical tools and methods for Agro-meteorology	1+1
AGM 606	Research and publication ethics	2+0
AGM 607	Environmental Physics for Agricultural Meteorology	3+0
AGM 608*	Computer Programs and Software for Agrometeorological data Management	1+1
AGM 691	Doctoral seminar	1+0
AGM 692	Doctoral seminar	1+0
AGM 699	Doctoral research	75

*Indicates core courses for PhD

Course Contents
Ph.D. in Agricultural Meteorology

I. Course Title : Climate Change and Sustainable Development
II. Course Code : AGM 601
III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of climate change and the cause, effect, mitigation of climate change.

V. Theory

Unit I

Climate change and global warming: definitions of terms; causes of climate change and global warming; greenhouse gases, ozone depletion; past records, present trends, extreme weather events and future projections; Case studies on various climatic projections and consequences thereof in relation to agriculture.

Unit II

Impacts of climate change on various systems: impacts resulting from projected changes on agriculture and food security; hydrology and water resources; terrestrial and freshwater ecosystems; coastal zones and marine ecosystems; human health; human settlements, energy, and industry; insurance and other financial services; climate change and crop diversification, loss of biodiversity, microbes and pest dynamics; climate change and storage, climate change and weed management. Advance methodology of assessing the impact of climate change on crops.

Unit III

Sensitivity, adaptation and vulnerability: system's sensitivity, adaptive capacity and vulnerability to climate change and extreme weather events; regional scenarios of climate change and variability.

Unit IV

Mitigation strategies for sustainable development: international policies, protocols, treaties for reduction in greenhouse gases and carbon emissions; carbon sequestration; carbon credit; Clean Development Mechanism (CDM) and land use, Crop management options for low emission, land use change and forestry mechanism, alternate energy sources, etc.

Unit V

Agricultural food security: reduction in carbon and GHG emission; fuel conservation and reduction in energy use, conservation tillage, biofuels for fossil fuels, reduction in machinery use etc; increasing carbon sinks; resource conservation technologies, mixed rotations of cover and green manure crops, minimization of summer fallow and no ground cover periods, etc.

VI. Practicals

- Case studies on various climatic projections and consequences thereof in relation to agriculture
- Advance methodology of assessing the impact of climate change on crops

VII. Teaching methods/ activities

Classroom teaching, showing climatic models (GCMs and RCMs) though PPT, Hands on practical

VIII. Learning outcome

Will be aware on causes, impacts, mitigation and adaptations to climate change in the field of agriculture

IX. Suggested Reading

- Anonymous. *Clean Development Mechanism: Building International Public-Private Partnership under Kyoto Protocol*. UNEP, UNDP Publ.
- Anonymous. *IPCC Assessment Reports on Climate Change* (2001, 2007). WMO, UNEP Publ.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Jepma CJ and Munasinghe M. 1998. *Climate Change Policy: Facts, Issues and Analysis.* Cambridge Univ. Press.
- Mintzer IM. 1992. *Confronting Climate Change: Risks, Implications and Responses*. Cambridge Univ. Press.
- Pretty J and Ball A. 2001. *Agricultural Influence on Carbon Emission and Sequestration: A Review of Evidence and the Emerging Trading Options*. Univ. of Essex.
- Pretty JN. 1995. *Regenerating Agriculture: Policies and Practices for Sustainable and Self Reliance*. Earthscan.
- Salinger J, Sivkumar MVK and Motha RP. 2005. *Increasing Climate Variability of Agriculture and Forestry*. Springer.
- Sinha SK. 1998. *Dictionary of Global Climate Change*. Commonwealth Publ.

Journal

- *Mitigation and Adaptation strategies for Global Change*
- *Climate Change*
- *Climate Risk Management*
- *Journal of Agrometeorology*

Website

- https://www.ipcc.ch/
- www.environment.gov.au/climate-change/climate-science-data/climate-science/ipcc

I. Course Title : Meteorology of Air Pollution

II. Course Code : AGM 602

III. Credit Hours : 2+2

IV. Aim of the course

To impart the theoretical and practical knowledge of air pollutants.

V. Theory

Unit I

Introduction to air pollution- history, definition: clean air definition; natural versus polluted atmosphere; atmosphere before the industrial revolution, Real time air quality index and National air quality index.

Unit II

Sources of air pollution; classification and properties of air pollutants; emission sources, importance of anthropogenic sources; behaviour and fate of air pollutants; photochemical smog; pollutants and trace gases. Acid rain and development of Gas Washing

Unit III

Meteorological factors in the dispersion of air pollutants; topographical, geographical and large scale meteorological factors attached air pollution; Planetary Boundary Layer (PBL) and mixing layer; meteorological conditions and typical plume forms; air pollution forecasting – Gaussian diffusion models, Numerical dispersion models.

Unit IV

Air quality standards; effect of air pollution on biological organisms; ozone layer depletion; air pollution control technologies; management of air pollution; principles of diffusion of particulate matter in the atmosphere; air pollution laws and standards. Scales of air pollution: local, urban, regional, continental and global.

Unit V

Air pollution sampling and measurement: types of pollutant sampling and measurement, ambient air sampling, collection of gaseous air pollutants, collection of particulate pollutants, stock sampling; analysis of air pollutants - sulfur dioxide, nitrogen dioxide, carbon monoxide, oxidants and ozone, hydrocarbons, particulate matter.

VI. Practicals

- Measurement of different air pollutants
- Measurement of different air pollution gases
- Measurement of visibility
- Measurement of ozone and aerosol optical thickness (AOT)
- To study the temperature profile at different heights
- To study the stability of the atmosphere
- To determine height of partial flume through chimani
- To study the effect of temperature on vegetables, orchards and agricultural crops

VII. Teaching methods/activities

Classroom teaching and practical

VIII. Learning outcome

Knowledge of sources and dispersal of pollutants, indexing, the influence of meteorological activities and analysis of pollutants

IX. Suggested Reading

- Arya SP. 1998. *Air Pollution Meteorology and Dispersion*. Oxford Univ. Press.
- Bishnoi OP. 2007. *Principles of Agricultural Meteorology*. Oxford Book Co.
- Chhatwa GR. 1989. *Environmental Air Pollution and its Control*. Anmol Publ.
- Mishra PC. 1990. *Fundamentals of Air and Water Pollution*. Ashish Publ.
- Mudd J Brian and Kozlowski TT. (Ed.). 1975. *Responses of Plants to Air Pollution*. Academic Press.
- Pickett EE. 1987. Atmopheric Pollution. Hemisphere Publ. Corp.
- Sharma SH and Khan TI. 2004. *Ozone Depletion and Environmental Impacts*. Pointer Publ.
- Weber E. 1982. *Air Pollution Assessment Methodology and Modeling*. Plenum Press.
- Yunus M and Iqbal M. (Eds.). 1996. *Plant Response to Air Pollution*. John Wiley & Sons.

Journals

- *Atmospheric Pollution* Research,
- *Environmental Pollution,*
- *Journal of Agrometeorology*

Website

- https://www.nationalgeographic.com/environment/global-warming/pollution/

I. Course Title : Livestock and Fisheries Meteorology

II. Course Code : AGM 603

III. Credit Hours : 2+2

IV. Aim of the course

To impart the theoretical and practical knowledge of weather, climate for livestock and fisheries management.

V. Theory

Unit I

Thermal balance in animals; energy exchange processes at the skin of the animals and the need for the maintenance of thermal balance in the animals. Animal traits and physiological responses.

Unit II

Effects of weather on animal production, loss of water from the body, growth rate and body weight, reproduction, grazing habit, food intake, milk production, sun burns and photosensitive disorders.

Unit III

Meteorological conditions prevailing in glass-house, green house, animal shed, poultry house and grain storage barns; heating, cooling and ventilation of these structures as governed by meteorological factors. Environmental modification within the shelters of livestock. Applications of biometeorological information for rational planning, design and management. Weather and animal diseases and parasites; diseases of poultry and its relation with weather and thermal comfort.

Unit IV

Livestock production and climate change, Management of livestock to reduce greenhouse gas emission.

Unit V

Weather effect on fish behaviour. Water temperature affecting fish activity. Marine weather and fishing. Climate change and fisheries production.

VI. Practical

- Measurement of meteorological parameters within the shelters of livestock
- Calculation of animal comfort zone index
- Radiation of animal farm house and body
- Estimation of enegy fluxes on body
- Measurements of CO_2 and methane in animal farm house.

VII. Teaching methods/activities

Class room teaching for theory part, visit to farm house for practical

VIII. Learning outcome

Enhanced knowledge on weather influence on livestock and farm environment

IX. Suggested Reading

- GSLHV Prasada Rao, GG Varma and Beena (Eds). 2017. *Livestock meteorology*. New India Publishing Agency- Nipa. 542 pages
- Kaiser HM and Drennen TE. (Eds). 1993. *Agricultural Dimensions of Global Climate Change*. St. Lucie Press, Florida.
- Monteith L and Unsworth M. 2007. *Principles of Environmental Physics*. 2nd Ed. Academic Press. Takahashi J, Young BA, Soliva CR and Kreuzer M. 2002. *Greenhouse Gases and Animal Agriculture*. Proc. 1st International Conference on Greenhouse Gases and Animal Agriculture.
- Tromp SW. 1980. *Biometeorology. The Impact of the Weather and Climate on Humans & their Environment*. (Animals and Plants). Heyden & Son Ltd.

Journals

- *Agricultural and Forest Meteorology,*
- *Journal* of *Animal Behaviour and Biometeorology,*
- *Journal of Agrometeorology*

Website

- www.wmo.org

I. Course Title : Hydrometeorology

II. Course Code : AGM 604

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of different components of hydrologic cycle.

V. Theory

Unit I

Hydrologic cycle and its modification; rainfall and its interception by plants and crops. Interpolation and measurement of missing rainfall data; adequacy of rain gauges; average rainfall on an area depth basis; presentation and processing of precipitation data.

Unit II

Measurement of runoff, infiltration, moisture retention of soil, percolation, evaporation, evapotranspiration and its importance to agriculturists, irrigation engineers and flood forecasting personnel; water holding capacity of soils, plant available water, cultural practices on soil moisture in relation to different phases of crop growth; evaporation from snow, lakes, reservoirs and crop fields.

Unit III

Classifying rainfall data into class interval; ranking of rainfall data; relationship between intensity and duration; methods of predicting runoff rate; factors affecting runoff; rainfall-runoff relation; estimation of evapotranspiration from water balance methods; response of crops to water stresses under different agroclimatic situation on India.

Unit IV

Moisture availability indices and their application for Indian condition; wet and dry spell by Markov-chain model; drought and its classification, hydrological drought, drought indices and their applications under Indian conditions.

VI. Practical

- Analysis of rainfall data
- Determination of effective rainfall
- To estimate missing rainfall data for a given station.
- To find out the optimum number of rain gauges for a given catchment.
- To find out the mean rainfall for a given drainage basin by Thiessen polygon method and isohyetal method.
- To estimate the volume of runoff by SCS method.
- Estimation of evopotranspiration from field based water balance method.

VII. Teaching methods/activities

Theory and practical classes

VIII. Learning outcome

Knowledge on rainfall analysis, runoff estimation, calculation of evaporation and the relationship among different hydrological parameters

IX. Suggested Reading

- Chow, Ven Te (Ed.). 1964. *Handbook of Applied Hydrology*. McGraw-Hill.
- Hillel D. 1971. *Soil and Water*. Academic Press.
- Hillel D. 1980. *Application of Soil Physics*. Academic Press.
- Hillel D. 1998. *Environmental Soil Physics*. Academic Press.

Journal

- *Journal* of *Hydrology, Journal* of *Hydrology and Meteorology,*
- *Agricultural Water Management,*
- *Journal of Agrometeorology*

Website

- https://has.arizona.edu/meteorology-hydrology-and-hydrometeorology
- www.abb.com/cawp/seitp161/4f39ac092c0598c9c1256fb8004f7726.aspx

I. Course Title : Analytical Tools and Methods for Agro-meteorology

II. Course Code : AGM 605

III. Credit Hours : 1+1

IV. Aim of the course

To impart the theoretical and practical knowledge of new tools for analysis of agro-climatic features.

V. Theory

Unit I

Review of agro-climatic methods; characterization of agroclimatic elements; sampling of atmosphere; temporal and spatial considerations; micro-meso-macro climates.

Unit II

Network spacing; spatial and temporal methods; GIS fundamentals and applications; numerical characterization of climatic features; crop response to climate, time lags, time and distance constants, hysteresis effects.

Unit III

Influence of climate on stress-response relations; thermal time approach in agroclimatology- heat and radiation use efficiency in crop plants; applications to insect-pest development and prediction; comfort indices for human and animals; impact of natural and induced variability and change of climate on crop production.

Unit IV

Instrumentation and sampling problems; design of agro-meteorological experiments.

Unit V

Basic knowledge of application of computers in agriculture; theories of computer language BASIC, FORTRAN, C, C++ and Visual basic.

Unit VI

Empirical and statistical crop weather models and their application with examples; incorporating weather, soil, plants and other environment related parameters as subroutine and remote sensing inputs in models; growth and yield prediction models; crop simulation models; forecasting models for insects and diseases.

VI. Practical

- Calculation of continentality factors.
- Climatic indices and climogram.
- Agrometeorological indices: Degree-days, photothermal units, heliothermal units, phenothermal index.
- Heat and radiation use efficiency and other indices of crops.
- Crop growth rates.
- Analysis of thermogram, hygrogram, hyetogram, sunshine cards etc. stream lines and wind roses and statistical analysis of climatic data.
- Working with statistical models: crop yield forecasting, crop weather relationship and insect & disease forecasting models.
- Working with crop simulation models
- Small programme writing in computer languages like BASIC, FORTRAN, C, C++ and Visual basic.
- Geographical Information System.

VII. Teaching methods/activities

Theory and practical classes, learning of computer language

VIII. Learning outcome

Knowledge on collection of agromet data, sampling design for agrometeorology, calculation of different indices and analysis of data

IX. Suggested Reading

- Cooper M. 2006. *The Spirit of C. An Introduction to Modern Programming*. Jaico Publ.
- Malczewski J. 1999. *GIS & Multicriteria Decision Analysis*. John Wiley & Sons.
- WMO. 2010. *Guide to agricultural meteorological practices*. Chapter 3: agricultural meteorological data, their presentation and statistical analysis

Journals

- *The International Journal* of *Database Management* Systems
- Journal of Agrometeorology

Website

- https://www.tropmet.res.in/~icrp/icrpv12/adach.html
- www.wmo.int/pages/prog/wcp/agm/gamp/documents/WMO_No134_en.pdf

I. Course Title : Research and Publication Ethics

II. Course Code : AGM 606

III. Credit Hours : 2+0

IV. Theory

Unit I

Introduction to philosophy: definition, nature and scope, concept, branches

Unit II

Ethics: definition, moral philosophy, nature of moral judgements and reactions

Unit III

Scientific conduct: Ethics with respect to science and research, intellectual honesty and research integrity, Scientific misconducts- falsifications, fabrications and plagiarism (FFP): Redundant publications: duplicate and overlapping publications, salami slicing; selective reporting and misrepresentation of data

Unit IV

Publication ethics: Defination, introduction and importance. Best practices/ standard setting initiatives and guidelines: COPE, WAME etc., conflicts of interest. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, type, violation of publication ethics, authorship and contributorship, Identification of publication misconduct, complaints and appeals, predatory publishers and journals

Unit V

Open access publishing: open access publication and initiatives: SHERPA, RoMEO online resource to check publisher copy right and self archiving policies; software tool to identify predatory publications developed by SPPU, Journal finder/journal suggestions tools, viz., JANE, Elsevier Journal Finder, Springer Journal Suggester etc.

Unit VI

Publication misconduct: Group discussions- subject specific ethical issues, FFP, authorship, conflicts of interest, complaints and appeals examples and fraud from India and abroad. Software tools: Use of plagiarism software like Turnitin, Urkund and other open source software tools.

Unit VII

Database and Research metrics: Indexing data base, citation database, web of science, scopus, etc. Impact factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, Gindex, i 10 index altmetrics

V. Teaching methods/activities

Classroom teaching and field and laboratory activities

VI. Learning outcome

To familiarize the students about field and laboratory activities to be performed during the study period

I. **Course Title : Weather and Climate Risk Management**

II. **Course Code : AGM 607**

III. **Credit Hours : 3+0**

IV. **Aim of the course**

To impart the theoretical knowledge of Physics applied to atmosphere and meteorology

V. **Theory**

Unit I

Thermodynamics of the atmosphere. Physics of radiation: origin and nature of radiation, radiation geometry in Cartesian, spherical cylindrical coordinate systems, conservation principles for radiant energy; fluid motion: laminar and turbulent transfer, fluctuation theory for turbulent transfer of momentum, heat and water vapour.

Unit II

Physics of evaporation: aerodynamic approach, energy balance approach and combination approach for evaporation estimates.

Unit III

Physics of soil water system: the concept of potential as applied to soil water system, total potential and components, movements of water on soil, fundamental equation, hydraulic conductivity, infiltration, field drainage and water vapour movement in soil.

Unit IV

Physics of water use: a physical introduction to plant-water system and relationships, water transport through soil-plant-atmosphere systems, measurement of crop water use in terms of water conservation equation.

VI. **Teaching methods/activities**

Classroom teaching

VII. **Learning outcome**

Knowledge and application of physical laws governing the agrometeorological parameters

VIII. **Suggested Reading**

- Hillel D. 1971. *Soil and Water*. Academic Press.
- Hillel D. 1980. *Application of Soil Physics*. Academic Press.
- Hillel D. 1998. *Environmental Soil Physics*. Academic Press.
- Monteith JL .1973. *Principles of Environmental Physics.* Edward Arnold.
- Rose CW. 1966. *Agricultural Physics.* Pergamon Press.
- Sellers WD. 1965. *Physical Climatology*. University of Chicago Press.
- Van Wizk WR. 1963. *Physics of Plant Environment.* North-Holland Publishing.
- Waggoner PE. (Ed.). 1965. *Agricultural Meteorology*. American Meteorological Society.

Journals

- *Journal of Meteorological Research,*
- *Agricultural and Forest Meteorology*

Website

- https://fmph.uniba.sk/.../enviromentalna-fyzika-obnovitelne-zdroje-energie-meteorolo...

I. Course Title : Computer Programs and Software for Agrometeorological Data Management

II. Course Code : AGM 608

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge on management of agromet data and train the students in commercialization of agrometeorological data through e-services.

V. Theory

Unit I

Data and information; types of data; climate, soil and crop data; Importance of database management, Softwares related to database management; data requirements; data collection and recording (Automatic and manual).

Unit II

Data structure/format; quality control of data through computer software; techniques of climatic data generation; missing data; introduction to different software for database management.

Unit III

Processing and analysis of data and data products; value addition of data and data products; data users, public, commercial, academic or research. Availability, accessibility and security of data; evaluating the cost of data; e-management of data. Meta analysis: Advantages and problems, Steps, Approaches and methods, Applications.

Unit IV

Computer Programming: History, Quality requirements, Readability of source code, Algorithmic complexity, Debugging, Programming languages

VI. Practical

- Types of instruments and data recording
- AWS data retrieval, storage and transfer
- Exposure to different software for Agromet data analysis; exposure to Statistical software
- Temporal and spatial analysis of data; exposure to GIS
- Value addition to data
- Introduction to internet protocols
- Uploading and downloading data, password and security of data
- E-management of data
- Introduction to computer programming

VII. Teaching methods/activities

Hands on practical and theory

VIII. Learning outcome

Learning computer programming to manage and analyze agromet data

IX. Suggested Reading

- Ghadekar R. 2002. *Practical Meteorology – Data Acquisition Techniques, Instruments and Methods*. 4th Ed. Agromet Publ.
- IMD/ WHO. 1988. *Users Requirements for Agrometeorological Services*. IMD.
- Miles MB and Huberman AM. 1994. *Qualitative Data Analysis*. Sage Publ.
- Panse VG and Sukhatme PV. 1983. *Statistical Methods for Agricultural Workers*, ICAR.
- Potter GB. 1994. *Data Processing: An Introduction*. Business Publ.
- Ramakrishnan R and Gehrke J. 2003. *Database Management System*. McGraw-Hill.
- Sinha PK and Sinha P. 2004. *Computer Fundamentals*. BPB Publications. (6th Edn).

Journals

- *The Journal* of *Database Management*
- *International Journal* of Data Mining
- *Modelling and Management*

Websites

- https://www.cics.umass.edu/research/area/data-management
- https://www.referenceforbusiness.com/management/.../Data-Processing-and-Data-Man.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Physical Sciences
– Agronomy

Preamble

Agronomy is a discipline which deals with various processes such as cultivation, interculture, management of field through various measures like weed management, soil fertility development, proper use of water resources and so on. Agronomy has a major component of agro ecology which includes several activities that affect the environment and human population. An Agronomist remains in the centre of effort to work with issues related to environmental and ecological concerns and to increase the production of food, feed, fuels and fibre for growing population in world. Agronomist today are involved with many issues including producing food, creating healthier food, managing environmental impacts and creating energy from plants. Research activities in Agronomy focus on system analysis and simulation modeling of environmental and management impacts on agricultural production, these are key to the sustainability of agricultural production system.

Hence, it is very much essential to revise the course curriculum of Agronomy so that students even teachers may be well acquainted with the present concept of development of the discipline. This will help bringing competency in students along with confidence so as to develop himself/ herself for being tackling field problems and management of land.The existing M.Sc. (Ag) courses of Agronomy have been modified taking into account of present day need by incorporating the necessary and important topics in the respective courses.

Minor changes have been made in most of the existing courses. As a part of course curriculum, M. Sc.(Ag) Agronomy was restructured to equip students to tackle emerging issues by inclusion of one new course on “Conservation agriculture”. All the Ph.D courses of Agronomy was slightly revised by adding/ deleting some some portion in the existing courses. The course “Fundamentals of Meteorology” is dropped from Agronomy department and interested students can take the course from department of Agril.Meteorology. The course “Agroecology” offered by the department for Ph D programme is also dropped. Similarly, the Ph.D. course “Crop production and system modeling” is also deleted and the contents are merged with Agron 601, i.e. “Current trends in Agronomy”.

It was proposed by some members to include new courses like “Seed production technology”, “Experimental technique in Agronomy” and “Management of Problem soils and water”. But finally, it was decided that these courses should be offered by the core departments such as Department of Seed Technology, Department of Statistics and Department of Soil Science, respectively. There are few courses in the existing syllabus which are not offered by in many universities. Hence these courses are merged and thereby reduced the number of courses to limit choice so that complete knowledge of the subject can be given to the students. In all the courses, the practical aspects are strengthened.

Topics such as automated irrigation systems, value chain addition/ post harvest processing, variable rate application, precision farming, protected agriculture, soil less farming, farm mechanization of practical operations, practical applications of advanced tools for big data analysis and interpretation, artificial intelligence, drones etc are included in the revised syllabus so that students can show competency at national and international level.

Course Title with Credit Load
M.Sc. in Agronomy

Course Code	Course Title	Credit Hours
Agron 501*	Modern Concepts in Crop Production	3+0
Agron 502*	Principles and practices of soil fertility and nutrient management	2+1
Agron 503*	Principles and Practices of Weed Management	2+1
Agron 504*	Principles and Practices of Water Management	2+1
Agron 505	Conservation Agriculture	1+1
Agron 506	Agronomy of major Cereals and Pulses	2+0
Agron507	Agronomy of oilseed, fibre and sugar crops	2+1
Agron 508	Agronomy of medicinal, aromatic & underutilized crops	2+1
Agron 509	Agronomy of fodder and forage crops	2+1
Agron 510	Agrostology and Agro- Forestry	2+1
Agron 511	Cropping System and Sustainable Agriculture	2+0
Agron 512	Dryland Farming and Watershed Management	2+1
Agron 513	Principles and practices of organic farming	2+1
Agron-550	Master's Seminar	(1+0)
Agron -560	Master's research	-30

*Indicates core course which is Compulsory course for M Sc.(Agri)

Course Contents
M.Sc. in Agronomy

I. Course Title : Modern Concepts in Crop Production
II. Course Code : Agron 501
III. Credit Hours : 3+0

IV. Aim of the course

To teach the basic concepts of soil management and crop production.

V. Theory

Unit I

Crop growth analysis in relation to environment; geo-ecological zones of India.

Unit II

Quantitative agro-biological principles and inverse yield nitrogen law; Mitscherlich yield equation, its interpretation and applicability; Baule unit.

Unit III

Effect of lodging in cereals; physiology of grain yield in cereals; optimization of plant population and planting geometry in relation to different resources, concept of ideal plant type and crop modeling for desired crop yield.

Unit IV

Scientific principles of crop production; crop response production functions; concept of soil plant relations; yield and environmental stress, use of growth hormones and regulators for better adaptation in stressed condition.

Unit V

Integrated farming systems, organic farming, and resource conservation technology including modern concept of tillage; dry farming; determining the nutrient needs for yield potentiality of crop plants, concept of balance nutrition and integrated nutrient management; precision agriculture.Modern crop production concepts: soil less cultivation, Aeroponic, Hydroponic, Robotic and terrace farming. use of GIS, GPS and remote sensing in modern agriculture, precision farming and protected agriculture.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VII. Learning outcome

Basic knowledge on soil management and crop production

VIII. Suggested Reading

- Balasubramaniyan P and Palaniappan SP. 2001. *Principles and Practices of Agronomy*. Agrobios.
- Fageria NK. 1992. *Maximizing Crop Yields*. Marcel Dekker.
- Havlin JL, Beaton JD, Tisdale SL and Nelson WL. 2006. *Soil Fertility and Fertilizers*. 7th

Ed. Prentice Hall.
- Paroda R.S. 2003. *Sustaining our Food Security*. Konark Publ.
- Reddy SR. 2000. *Principles of Crop Production*. Kalyani Publ.
- Sankaran S and Mudaliar TVS. 1997. *Principles of Agronomy*. The Bangalore Printing & Publ.
- Singh SS. 2006. *Principles and Practices of Agronomy*. Kalyani.
- Alvin PT and kozlowski TT (ed.). 1976. *Ecophysiology of Tropical Crops*. Academia Pul., New York.
- Gardner PP, Pearce GR and Mitchell RL. 1985. *Physiology of Crop Plants*. Scientific Pub. Jodhpur.
- Lal R. 1989. *Conservation tillage for sustainable agriculture: Tropics versus Temperate Environments. Advances in Agronomy* 42: 85-197.
- Wilsie CP. 1961. *Crop Adaptation and Distribution*. Euresia Pub., New Delhi.

I. Course Title : Principal and Practices of Soil Fertility and Nutrient Management

II. Course Code : Agron 502

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge of fertilizers and manures as sources of plant nutrients and apprise about the integrated approach of plant nutrition and sustainability of soil fertility.

V. Theory

Unit I

Soil fertility and productivity - factors affecting; features of good soil management; problems of supply and availability of nutrients; relation between nutrient supply and crop growth; organic farming - basic concepts and definitions.

Unit II

Criteria of essentiality of nutrients; Essential plant nutrients – their functions, nutrient deficiency symptoms; transformation and dynamics of major plant nutrients.

Unit III

Preparation and use of farmyard manure, compost, green manures, vermicompost, biofertilizers and other organic concentrates their composition, availability and crop responses; recycling of organic wastes and residue management. Soil less cultivation.

Unit IV

Commercial fertilizers; composition, relative fertilizer value and cost; crop response to different nutrients, residual effects and fertilizer use efficiency; agronomic, chemical and physiological, fertilizer mixtures and grades; methods of increasing fertilizer use efficiency; nutrient interactions.

Unit V

Time and methods of manures and fertilizers application; foliar application and its concept; relative performance of organic and inorganic nutrients; economics of fertilizer use; integrated nutrient management; use of vermincompost and residue wastes in crops.

VI. Practical

- Determination of soil pH and soil EC
- Determination of soil organic C
- Determination of available N, P, K and S of soil
- Determination of total N, P, K and S of soil
- Determination of total N, P, K, S in plant
- Computation of optimum and economic yield

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Basic knowledge on soil fertility and management

IX. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils.* 13th Ed. Pearson Edu.
- Fageria NK, Baligar VC and Jones CA. 1991. *Growth and Mineral Nutrition of Field Crops.* Marcel Dekker.
- Havlin JL, Beaton JD, Tisdale SL and Nelson WL. 2006. *Soil Fertility and Fertilizers.* 7th Ed. Prentice Hall.
- Prasad R and Power JF. 1997. *Soil Fertility Management for Sustainable Agriculture.* CRC Press.
- Yawalkar KS, Agrawal JP and Bokde S. 2000. *Manures and Fertilizers.* Agri-Horti Publ.

I. Course Title : Principles and Practices of Weed Management
II. Course Code : Agron 503
III. Credit Hours : 2+1

IV. Aim of the course

To familiarize the students about the weeds, herbicides and methods of weed control.

V. Theory

Weed biology, and ecology and classification, crop-weed competition including allelopathy; principles and methods of weed control and classification management; weed indices, weed shift in different eco-systems

Unit II

Herbicides introduction and history of their development; classification based on chemical, physiological application and selectivity; mode and mechanism of action of herbicides.

Unit III

Herbicide structure - activity relationship; factors affecting the efficiency of herbicides; herbicide formulations, herbicide mixtures, sequential application of herbicides, rotation; weed control through use ofnano-herbicides and bio-herbicides, myco-herbicides bio-agents, and allelochemicals; movement of herbicides in soil and plant, Degradation of herbicides in soil and plants; herbicide resistance, residue, persistence and management; development of herbicide resistance in weeds and crops and their management, herbicide combinationand rotation.

Unit IV

Weed management in major crops and cropping systems; alien, invasive and parasitic weeds and their management; weed shifts in cropping systems; aquatic and perennial weed control; weed control in non-crop area.

Unit V

Integrated weed management; recent development in weed management- robotics, use of drones and aeroplanes, organic etc., cost: benefit analysis of weed management.

VI. Practical

- Identification of important weeds of different crops, Preparation of a weed herbarium, Weed survey in crops and cropping systems, Crop-weed competition studies, Weed indices calculation and interpretation with data, Preparation of spray solutions of herbicides for high and low-volume sprayers, Use of various types of spray pumps and nozzles and calculation of swath width, Economics of weed control, Herbicide resistance analysis in plant and soil,
- Bioassay of herbicide resistance residues,
- Calculation of herbicidal herbicide requirement

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, field visit to identify weeds.

VIII. Learning outcome

Basic knowledge on weed identification and control for crop production

IX. Suggested Reading

- Böger, Peter, Wakabayashi, Ko, Hirai, Kenji (Eds.). 2002. *Herbicide Classes in Development. Mode of Action*, *Targets*, *Genetic Engineering*, *Chemistry*. Springer.
- Chauhan B and Mahajan G. 2014. *Recent Advances in Weed Management*. Springer.
- Das TK. 2008. *Weed Science: Basics and Applications*, Jain Brothers (New Delhi).
- Fennimore, Steven A and Bell, Carl. 2014. *Principles of Weed Control*, 4th Ed, California Weed Sci. Soc.
- Gupta OP. 2007. *Weed Management*: *Principles and Practices*, 2nd Ed.
- Jugulan, Mithila (ed). 2017. *Biology, Physiology and Molecular Biology of Weeds*. CRC Press
- Monaco TJ, Weller SC and Ashton FM. 2014. *Weed Science Principles and Practices*, Wiley
- Powles SB and Shaner DL. 2001. Herbicide Resistance and World Grains, CRC Press.
- Walia US. 2006. *Weed Management*, Kalyani.
- Zimdahl RL. (ed). 2018. *Integrated Weed Management for Sustainable Agriculture, B. D. Sci. Pub.*

I. Course Title : Principles and Practices of Water Management

II. Course Code : Agron 504

III. Credit Hours : 2+1

IV. Aim of the course

To teach the principles of water management and practices to enhance the water productivity

V. Theory

Unit I

Water and its role in plants; Irrigation: Definition and objectives, water resources and irrigation development in of India and concerned state, major irrigation projects, extent of area and crops irrigated in India and in different states.

Unit II

Field water cycle, water movement in soil and plants; transpiration; soil-water-plant relationships; water absorption by plants; plant response to water stress, crop plant adaptation to moisture stress condition. Water availability and its relationship with nutrient availability and loses.

Unit III

Soil, plant and meteorological factors determining water needs of crops, scheduling, depth and methods of irrigation; micro irrigation systems; deficit irrigation; fertigation; management of water in controlled environments and polyhouses. Irrigation efficiency and water use efficiency.

Unit IV

Water management of crop and cropping system, Quality of irrigation water and management of saline water for irrigation, water use efficiency, Crop water requirement- estimation of ET and effective rainfall; Water management of the major crops and cropping systems. Automated irrigation system.

Unit V

Excess of soil water and plant growth; water management in problem soils, drainage requirement of crops and methods of field drainage, their layout and spacing; rain water management and its utilization for crop production.

Unit VI

Quality of irrigation water and management of saline water for irrigation, water management in problem soils

Unit VII

Soil moisture conservation, water harvesting, rain water management and its utilization for crop production.

Unit VIII

Hydroponics,

Unit IX

Water management of crops under climate change scenario.

VI. Practical

- Determination of Field capacity by field method
- Determination of Permanent Wilting Point by sunflower pot culture technique
- Determination of Field capacity and Permanent Wilting Point by Pressure Plate Apparatus
- Determination of Hygroscopic Coefficient
- Determination of maximum water holding capacity of soil
- Measurement of matric potential using gauge and mercury type tensiometer
- Determination of soil-moisture characteristics curves
- Determination of saturated hydraulic conductivity by constant and falling head method
- Determination of hydraulic conductivity of saturated soil below the water table by auger hole method
- Measurement of soil water diffusivity
- Estimation of unsaturated hydraulic conductivity

- Estimation of upward flux of water using tensiometer and from depth ground water table
- Determination of irrigation requirement of crops (calculations)
- Determination of effective rainfall (calculations)
- Determination of ET of crops by soil moisture depletion method16. Determination of water requirements of crops
- Measurement of irrigation water by volume and velocity-area method
- Measurement of irrigation water by measuring devices and calculation of irrigation efficiency
- Determination of infiltration rate by double ring infiltrometer

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and field visit

VIII. Learning outcome

Basic knowledge on water management for optimization of crop yield

IX. Suggested Reading

- Majumdar DK. 2014. *Irrigation Water Management: Principles and Practice*. PHL Learning private publishers
- Mukund Joshi. 2013. *A Text Book of Irrigation and Water Management Hardcover*, Kalyani publishers
- Lenka D. 1999. *Irrigation and Drainage*. Kalyani.
- Michael AM. 1978. *Irrigation: Theory and Practice*. Vikas Publ.
- Paliwal KV. 1972. *Irrigation with Saline Water*. IARI Monograph, New Delhi.
- Panda SC. 2003. *Principles and Practices of Water Management*. Agrobios.
- Prihar SS and Sandhu BS. 1987. *Irrigation of Food Crops - Principles and Practices*. ICAR.
- Reddy SR. 2000. *Principles of Crop Production*. Kalyani.
- Singh Pratap and Maliwal PL. 2005. *Technologies for Food Security and Sustainable Agriculture*. Agrotech Publ.

I. Course Title : Conservation Agriculture

II. Course Code : Agron 505

III. Credit Hours : 1+1

IV. Aim of the course

To impart knowledge of conservation of agriculture for economic development.

V. Theory

Unit I

Conventional and conservation agriculture systems, sustainability concerns, conservation agriculture: Historical background and present concept, global experiences, present status in India.

Unit II

Nutrient management in CA, water management, weed management, energy use, insect-pest and disease management, farm machinery, crop residue management, cover crop management.

Unit III

Climate change mitigation and CA, C-sequestration, soil health management, soil microbes and CA.

Unit IV

CA in agroforestry systems, rainfed / dryland regions

Unit V

Economic considerations in CA, adoption and constraints, CA: The future of agriculture

VI. Practicals

- Study of long-term experiments on CA,
- Evaluation of soil health parameters,
- Estimation of C-sequestration,
- Machinery calibration for sowing different crops, weed seedbank estimation under CA, energy requirements, economic analysis of CA.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of various types of conservation of agriculture.

IX. Suggested Reading

- Arakeri HR and Roy D. 1984. *Principles of Soil Conservation and Water Management*. Oxford & IBH.
- Bisht JK, Meena VS, Mishra PK and Pattanayak A. 2016. Conservation Agriculture-An approach to combat climate change in Indian Himalaya. Publisher: Springer Nature. Doi: 10/1007/978-981-10-2558-7.
- Dhruvanarayana VV. 1993. *Soil and Water Conservation Research in India*. ICAR.
- FAO. 2004. *Soil and Water Conservation in Semi-Arid Areas. Soils Bull.,* Paper 57.
- Gracia-Torres L, Benites J, Martinez-Vilela A and Holgado-Cabera A. 2003. Conservation Agriculture- Environment Farmers experiences, innovations Socio-economic policy.
- Muhammad F and Kamdambot HMS. 2014. Conservation Agriculture. Publisher: Springer Cham Heidelberg, New Yaork Dordrecht London. Doi: 10.1007/978-3-319-11620-4.
- Yellamanda Reddy T and Sankara Reddy GH. 1992. *Principles of Agronomy*. Kalyani.

I. Course Title : Agronomy of Major Cereals and Pulses

II. Course Code : Agron 506

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge of crop husbandry of cereals and pulse crops.

V. Theory

Origin and history, area and production, classification, improved varieties, adaptability, climate, soil, water and cultural requirements, nutrition, quality components, handling and processing of the produce for maximum production of:

Unit I: *Rabi* cereals.

Unit II: *Kharif* cereals.

Unit III: *Rabi* pulses.

Unit IV: *Kharif* pulses.

VI. Practical

- Phenological studies at different growth stages of crop
- Estimation of crop yield on the basis of yield attributes
- Formulation of cropping schemes for various farm sizes and calculation of cropping and rotational intensities
- Working out growth indices (CGR, RGR, NAR, LAI, LAD, LAR, LWR, SLA, SLW etc)
- Assessment of land use and yield advantage (Rotational intensity, Cropping intensity, Diversity Index, Sustainable Yield Index Crop Equivalent Yield, Land Equivalent ration, Aggressiveness, Relative Crowding Coefficient, Competition Ratio and ATER etc)
- Estimation of protein content in pulses
- Planning and layout of field experiments
- Judging of physiological maturity in different crops
- Intercultural operations in different crops
- Determination of cost of cultivation of different crops
- Working out harvest index of various crops
- Study of seed production techniques in selected crops
- Visit of field experiments on cultural, fertilizer, weed control and water management aspects
- Visit to nearby villages for identification of constraints in crop production

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Basic knowledge on cereals and pulse growing in the country .

IX. Resources

- Das NR. 2007. *Introduction to Crops of India*. Scientific Publ.
- Hunsigi G and Krishna KR. 1998. *Science of Field Crop Production*. Oxford & IBH.
- Jeswani LM and Baldev B. 1997. *Advances in Pulse Production Technology*.ICAR.
- Khare D and Bhale MS. 2000. *Seed Technology*. Scientific Publ.
- Kumar Ranjeet and Singh NP. 2003. *Maize Production in India: Golden Grain in Transition*. IARI, New Delhi.
- Pal M, Deka J and Rai RK. 1996. *Fundamentals of Cereal Crop Production*.Tata McGraw Hill.
- Prasad Rajendra. 2002. *Text Book of Field Crop Production*. ICAR.
- Singh C, Singh P and Singh R. 2003. *Modern Techniques of Raising FieldCrops*. Oxford & IBH.
- Singh SS. 1998. *Crop Management*. Kalyani.
- Yadav DS. 1992. *Pulse Crops*. Kalyani.

I. Course Title : Agronomy of Oilseed, Fibre and Sugar Crops

II. Course Code : Agron 507

III. Credit Hours : 2+1

IV. Aim of the course

To teach the crop husbandry of oilseed, fiber and sugar crops

V. Theory

Origin and history, area and production, classification, improved varieties, adaptability, climate, soil, water and cultural requirements, nutrition, quality component, handling and processing of the produce for maximum production of:

Unit I

Rabi oilseeds – Rapeseed and mustard, Linseed and Niger

Unit II

Kharif oilseeds - Groundnut, Sesame, Castor, Sunflower, Soybean and Safflower

Unit III

Fiber crops - Cotton, Jute, Ramie and Mesta.

Unit IV

Sugar crops – Sugar-beet and Sugarcane.

VI. Practical

- Planning and layout of field experiments
- Cutting of sugarcane setts, its treatment and methods of sowing, tying and propping of sugarcane
- Determination of cane maturity and calculation on purity percentage, recovery percentage and sucrose content in cane juice phenological studies at different growth stages of crop
- Intercultural operations in different crops
- Cotton seed treatment
- Working out growth indices (CGR, RGR, NAR, LAI, LAD, LAR, LWR, SLA, SLW etc)
- Assessment of land use and yield advantage (Rotational intensity, Cropping intensity, Diversity Index, Sustainable Yield Index Crop Equivalent Yield, Land Equivalent ration, Aggressiveness, Relative Crowding Coefficient, Competition Ratio and ATER etc)
- Judging of physiological maturity in different crops and working out harvest index
- Working out cost of cultivation of different crops
- Estimation of crop yield on the basis of yield attributes
- Formulation of cropping schemes for various farm sizes and calculation of cropping and rotational intensities
- Determination of oil content in oilseeds and computation of oil yield
- Estimation of quality of fibre of different fibre crops
- Study of seed production techniques in various crops
- Visit of field experiments on cultural, fertilizer, weed control and water management aspects
- Visit to nearby villages for identification of constraints in crop production

VIII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

IX. Learning outcome

Basic knowledge on production of oil seed, sugar and fibre crops.

X. Suggested Reading

- Das NR. 2007. *Introduction to Crops of India*. Scientific Publ.
- Das PC. 1997. *Oilseed Crops of India*. Kalyani.
- Lakshmikantam N. 1983. *Technology in Sugarcane Growing*. 2nd Ed. Oxford & IBH.
- Prasad Rajendra. 2002. *Text Book of Field Crop Production*. ICAR.

- Singh C, Singh P & Singh R. 2003. *Modern Techniques of Raising FieldCrops*. Oxford & IBH.
- Singh SS. 1998. *Crop Management*. Kalyani.

I. Course Title : Agronomy of Medicinal, Aromatic and Under Utilized Crops

II. Course Code : Agron 508/PSMA 503

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students about different medicinal, aromatic and underutilized field crops, their package of practices and processing.

V. Theory

Unit I

Importance of medicinal and aromatic plants in human health, national economy and related industries, classification of medicinal and aromatic plants according to botanical characteristics and their uses, export potential and indigenous technical knowledge.

Unit II

Climate and soil requirements; cultural practices; yield and important constituents of medicinal plants (Mulhati, Isabgol, Rauwolfia, Poppy, *Aloe vera*, Satavar, *Stevia*, Safed Musli, Kalmegh, Asaphoetida, *Nuxvomica*, Rosadle, etc).

Unit III

Climate and soil requirements; cultural practices; yield and important constituents of aromatic plants (Citronella, Palmarosa, Mentha, Basil, Lemon grass, Rose, Patchouli, Geranium).

Unit IV

Climate and soil requirements; cultural practices; yield of under-utilized crops (Rice bean, Lathyrus, Sesbania, Clusterbean, French bean, Fenugreek, Grain Amaranth, Coffee, Tea and Tobacco).

Unit V

Post harvest handling –drawing, processing, grading, packing and storage, value addition and quality standards in herbal products.

VI. Practical

- Identification of crops based on morphological and seed characteristics
- Raising of herbarium of medicinal, aromatic and under-utilized plants
- Quality characters in medicinal and aromatic plants
- Methods of analysis of essential oil and other chemicals of importance in medicinal and aromatic plants.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and field visit

VIII. Learning outcome

Acquainted with various MAP and their commercial base for developing entrepreneurship.

IX. Suggested Reading

- Chadha KL and Gupta R. 1995. *Advances in Horticulture*. Vol. II. *Medicinal and Aromatic Plants*. Malhotra Publ.
- Das NR. 2007. *Introduction to Crops of India*. Scientific Publ.
- Handa SS. 1984. *Cultivation and Utilization of Medicinal Plants*. RRL, CSIR, Jammu.
- Hussain A. 1984. *Essential Oil Plants and their Cultivation*. CIMAP, Lucknow.
- Hussain A. 1993. *Medicinal Plants and their Cultivation*. CIMAP, Lucknow.
- ICAR 2006. *Hand Book of Agriculture*. ICAR, New Delhi.
- Kumar N, Khader Md. Abdul, Rangaswami JBM & Irulappan 1997. *Introduction to Spices, Plantation Crops, Medicinal and Aromatic Plants*. Oxford & IBH.
- Prajapati ND, Purohit SS, Sharma AK and Kumar T. 2003. *A Hand Book of Medicinal Plants: A Complete Source Book*. Agrobios.
- Sharma R. 2004. *Agro-Techniques of Medicinal Plants*. Daya Publ. House.

I. Course Title : Agronomy of Fodder and Forage Crops

II. Course Code : Agron 509

III. Credit Hours : 2+1

IV. Aim of the course

To teach the crop husbandry of different forage and fodder crops along with their processing.

V. Theory

Unit I

Adaptation, distribution, varietal improvement, agro-techniques and quality aspects including anti-quality factors of important fodder crops like sorghum, maize, *bajra*, *guar*, cowpea, oats, barley, berseem, *senji*, lucerne, etc.

Unit II

Adaptation, distribution, varietal improvement, agro-techniques and quality aspects including anti-quality factors of important forage crops/grasseslime, Napier grass, *Panicum, Lasiuras, Cenchrus,* etc.

Unit III

Year-round fodder production and management, preservation and utilization of forage and pasture crops.

Unit IV

Principles and methods of hay and silage making; chemical and biochemical changes, nutrient losses and factors affecting quality of hay and silage; use of physical and chemical enrichments and biological methods for improving nutrition; value addition of poorquality fodder. Fodder production through hydroponics. Azolla cultivation.

Unit V

Economics of forage cultivation uses and seed production techniques of important fodder crops.

VI. Practical

- Practical training of farm operations in raising fodder crops;
- Canopy measurement, yield, Leaf: Stem ratio and quality estimation, viz. crude protein, NDF, ADF, lignin, silica, cellulose and IVDMD, etc. of various fodder and forage crops

- Anti-quality components like HCN in sorghum and such factors in other crops
- Hay and silage making and economics of their preparation.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and field visit

VIII. Learning outcome

Acquainted with various fodder and forage crops and their commercial base for developing entrepreneurship.

IX. Suggested Reading

- Chatterjee BN. 1989. *Forage Crop Production - Principles and Practices*. Oxford & IBH.
- Das NR. 2007. *Introduction to Crops of India*. Scientific Publ.
- Narayanan TR and Dabadghao PM. 1972. *Forage Crops of India*. ICAR.
- Singh P and Srivastava AK. 1990. *Forage Production Technology*. IGFRI, Jhansi.
- Singh C, Singh P and Singh R. 2003. *Modern Techniques of Raising Field Crops*. Oxford & IBH.
- Tejwani KG. 1994. *Agroforestry in India*. Oxford & IBH.

I. Course Title : Agrostology and Agro-forestry
(To be taught jointly by Agronomy and Forestry)

II. Course Code : Agron 510

III. Credit Hours : 2+1

IV. Theory

V. Aim of the course

To teach crop husbandry of different forage, fodder and agroforestry crops/trees along with their processing.

Unit I

Agrostology: definition and importance; principles of grassland ecology: grassland ecology – community, climax, dominant species, succession, biotype, ecological status of grasslands in India, grass cover of India; problems and management of grasslands.

Unit II

Importance, classification (various criteria), scope, status and research needs of pastures; pasture establishment, their improvement and renovation-natural pastures, cultivated pastures; common pasture grasses.

Unit III

Agroforestry: definition and importance; agroforestory systems, agrisilviculture, silvipasture, agrisilvipasture, agrihorticulture, aquasilviculture, alley cropping and energy plantation.

Unit IV

Crop production technology in agro-forestory and agrostology system; silvipastoral system: meaning and importance for wasteland development; selection of species, planting methods and problems of seed germination in agro-forestry systems; irrigation and manuring in agro-forestry systems, associative influence in relation to above ground and underground interferences; lopping and coppicing in agro-forestry systems; social acceptability and economic viability, nutritive value of trees; tender operation; desirable tree characteristics.

VI. Practical

- Preparation of charts and maps of India showing different types of pastures and agro-forestry systems
- Identification of seeds and plants of common grasses, legumes and trees of economic importance with reference to agro-forestry
- Seed treatment for better germination of farm vegetation
- Methods of propagation/ planting of grasses and trees in silvipastoral system
- Fertilizer application in strip and silvipastroal systems
- After-care of plantation
- Estimation of protein content in loppings of important fodder trees
- Estimation of calorie value of wood of important fuel trees
- Estimation of total biomass and fuel wood
- Economics of agro-forestry
- Visit to important agro-forestry research stations

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and field visit

VIII. Learning outcome

Basic knowledge on agro forestry, forage crops and their utility

IX. Suggested Reading

- Chatterjee BN and Das PK. 1989. *Forage Crop Production. Principles and Practices.* Oxford & IBH.
- Dabadghao PM and Shankaranarayan KA. 1973. *The Grass Cover in India.* ICAR.
- Dwivedi AP. 1992. *Agroforestry- Principles and Practices.* Oxford & IBH.
- Indian Society of Agronomy. 1989. *Agroforestry System in India. Research and Development,* New Delhi.
- Narayan TR and Dabadghao PM. 1972. *Forage Crop of India.* ICAR, New Delhi.

I. Course Title : Cropping Systems and Sustainable Agriculture

II. Course Code : Agron 511

III. Credit Hours : 2+0

IV. Aim of the course

To acquaint the students about prevailing cropping systems in the country and practices to improve their productivity.

V. Theory

Unit I

Cropping systems: definition, indices and its importance; physical resources, soil and water management in cropping systems; assessment of land use.

Unit II

Concept of sustainability in cropping systems and farming systems, scope and objectives; production potential under monoculture cropping, multiple cropping, alley cropping, sequential cropping and intercropping, mechanism of yield advantage in intercropping systems.

Unit III

Above and below ground interactions and allelopathic effects; competition relations; multi-storied cropping and yield stability in intercropping, role of non-monetary inputs and low cost technologies; research need on sustainable agriculture.

Unit IV

Crop diversification for sustainability; role of organic matter in maintenance of soil fertility; crop residue management; fertilizer use efficiency and concept of fertilizer use in intensive cropping system. Advanced nutritional tools for big data analysis and interpretation.

Unit V

Plant ideotypes for drylands; plant growth regulators and their role in sustainability.

Unit VI

Artificial Intelligence- Concept and application.

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, assignment.

VIII. Learning outcome

Basic knowledge on cropping system for sustainable agriculture.

IX. Suggested Reading

- Panda SC. 2017. *Cropping Systems and Sustainable Agriculture*. Agrobios (India)
- Panda SC. 2018. *Cropping and Farming Systems*. Agrobios.
- Palaniappan SP and Sivaraman K. 1996. *Cropping Systems in the Tropics; Principles and Management*. New Age.
- Panda SC. 2003. *Cropping and Farming Systems*. Agrobios.
- Reddy SR. 2000. *Principles of Crop Production*. Kalyani.
- Sankaran S and Mudaliar TVS. 1997. *Principles of Agronomy*. The Bangalore Printing & Publ. Co.
- Singh SS. 2006. *Principles and Practices of Agronomy*. Kalyani.
- Tisdale SL, Nelson WL, Beaton JD and Havlin JL. 1997. *Soil Fertility and Fertilizers*. Prentice Hall.

I. Course Title : Dryland Farming and Watershed Management

II. Course Code. : Agron 512

III. Credit Hours : 2+1

IV. Aim of the course

To teach the basic concepts and practices of dry land farming and soil moisture conservation.

V. Theory

Unit I

Definition, concept and characteristics of dry land farming; dry land versus rainfed farming; significance and dimensions of dry land farming in Indian agriculture.

Unit II

Soil and climatic parameters with special emphasis on rainfall characteristics; constraints limiting crop production in dry land areas; types of drought, characterization of environment for water availability; crop planning for erratic and aberrant weather conditions.

Unit III

Stress physiology and resistance to drought, adaptation of crop plants to drought,

drought management strategies; preparation of appropriate crop plans for dry land areas; mid contingent plan for aberrant weather conditions.

Unit IV

Tillage, tilth, frequency and depth of cultivation, compaction in soil tillage; concept of conservation tillage; tillage in relation to weed control and moisture conservation; techniques and practices of soil moisture conservation (use of mulches, kinds, effectiveness and economics); antitranspirants; soil and crop management techniques, seeding and efficient fertilizer use.

Unit V

Concept of watershed resource management, problems, approach and components.

VI. Practical

- Method of Seed Priming
- Determination of moisture content of germination of important dryland crops
- Determination of Relative Water Content and Saturation Deficit of Leaf
- Moisture stress effects and recovery behaviour of important crops
- Estimation of Potential ET by Thornthwaite method
- Estimation of Reference ET ny Penman Monteith Method
- Classification of climate by Thornthwaite method (based on moisture index, humidity index and aridity index)
- Classification of climate by Koppen Method
- Estimation of water balance by Thornthwaite method
- Estimation of water balance by FAO method
- Assessment of drought
- Estimation of length of growing period
- Estimation of probability of rain and crop planning for different drought condition
- Spray of anti-transpirants and their effect on crops
- Water use efficiency
- Visit to dryland research stations and watershed projects

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment.

VIII. Learning outcome

Basic knowledge on dry land farming and soil moisture conservation.

IX. Suggested Reading

- Reddy TY. 2018. *Dryland Agriculture Principles and Practices*, Kalyani publishers
- Das NR. 2007. *Tillage and Crop Production*. Scientific Publ.
- Dhopte AM. 2002. *Agrotechnology for Dryland Farming*. Scientific Publ.
- Dhruv Narayan VV. 2002. *Soil and Water Conservation Research in India*. ICAR.
- Gupta US. (Ed.). 1995. *Production and Improvements of Crops forDrylands*. Oxford & IBH.
- Katyal JC and Farrington J. 1995. *Research for Rainfed Farming*. CRIDA.
- Rao SC and Ryan J. 2007. *Challenges and Strategies of Dryland Agriculture*. Scientific Publ.
- Singh P and Maliwal PL. 2005. *Technologies for Food Security and Sustainable Agriculture*. Agrotech Publ. Company.
- Singh RP. 1988. *Improved Agronomic Practices for Dryland Crops*. CRIDA.
- Singh RP. 2005. *Sustainable Development of Dryland Agriculture in India*. Scientific Publ.
- Singh SD. 1998. *Arid Land Irrigation and Ecological Management*. Scientific Publ.
- Venkateshwarlu J. 2004. *Rainfed Agriculture in India. Research and Development Scenario*. ICAR.

I. Course Title : Principles and Practices of Organic Farming

II. Course Code : Agron 513

III. Credit Hours : 2+1

IV. Aim of the course

To study the principles and practices of organic farming for sustainable crop production.

V. Theory

Unit I

Organic farming - concept and definition, its relevance to India and global agriculture and future prospects; principles of organic agriculture; organics and farming standards; organic farming and sustainable agriculture; selection and conversion of land, soil and water management - land use, conservation tillage; shelter zones, hedges, pasture management, agro-forestry.

Unit II

Organic farming and water use efficiency; soil fertility, nutrient recycling, organic residues, organic manures, composting, soil biota and decomposition of organic residues, earthworms and vermicompost, green manures, bio-fertilizers and biogas technology.

Unit III

Farming systems, selection of crops andcrop rotations, multiple and relay cropping systems, intercropping in relation to maintenance of soil productivity.

Unit IV

Control of weeds, diseases and insect pest management, biological agents and pheromones, bio-pesticides.

Unit V

Socio-economic impacts; marketing and export potential: inspection, certification, labeling and accreditation procedures; organic farming and national economy.

VI. Practical

- Method of making compost by aerobic method
- Method of making compost by anaerobic method
- Method of making vermicompost
- Identification and nursery raising of important agro-forestry tress and tress for shelter belts
- Efficient use of biofertilizers, technique of treating legume seeds with *Rhizobium* cultures, use of *Azotobacter*, *Azospirillum*, and PSB cultures in field
- Visit to a biogas plant
- Visit to an organic farm
- Quality standards, inspection, certification and labeling and accreditation procedures for farm produce from organic farms

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment. exposure visit

VIII. Learning outcome

Basic knowledge on organic farming for sustainable agriculture and development of entrepreneurship on organic inputs.

IX. Suggested Reading

- Ananthakrishnan TN. (Ed.). 1992. *Emerging Trends in Biological Control of Phytophagous Insects*. Oxford & IBH.
- Gaur AC. 1982. *A Manual of Rural Composting*, FAO/UNDP Regional Project Document, FAO.
- Joshi M. 2016. *New Vistas of Organic Farming*. Scientific Publishers
- Lampin N. 1990. *Organic Farming*. Press Books, lpswitch, UK.
- Palaniappan SP and Anandurai K. 1999. *Organic Farming – Theory and Practice*. Scientific Publ.
- Rao BV Venkata. 1995. *Small Farmer Focused Integrated Rural Development: Socio-economic Environment and Legal Perspective*: Publ.3, ParisaraprajnaParishtana, Bangalore.
- Reddy MV. (Ed.). 1995. *Soil Organisms and Litter Decomposition in the Tropics*. Oxford & IBH.
- Sharma A. 2002. *Hand Book of Organic Farming*. Agrobios.
- Singh SP. (Ed.). 1994. *Technology for Production of Natural Enemies*. PDBC, Bangalore.
- Subba Rao NS. 2002. *Soil Microbiology*. Oxford & IBH.
- Trivedi RN. 1993. *A Text Book of Environmental Sciences*, Anmol Publ.
- Veeresh GK, Shivashankar K and Suiglachar MA. 1997. *Organic Farming and Sustainable Agriculture*. Association for Promotion of Organic Farming, Bangalore.
- WHO. 1990. *Public Health Impact of Pesticides Used in Agriculture*. WHO.
- Woolmer PL and Swift MJ. 1994. *The Biological Management of Tropical Soil Fertility*. TSBF & Wiley.

Course Title with Credit Load
Ph.D. in Agronomy

Course Code	Course Title	Credit Hours
Agron 601*	Current trends in Agronomy	3+0
Agron 602	Recent trends in crop growth and productivity	2+1
Agron 603	Irrigation management	2+1
Agron 604	Recent trends in weed management	2+0
Agron 605	Integrated farming systems for sustainable Agriculture	2+0
Agron 606	Soil Conservation and Watershed Management	2+1
Agron 607	Stress Crop Production	2+1
Agron 608*	Research and Publication ethics	2+0
Agron-691	Doctoral Seminar	1+0
Agron 692	Doctoral Seminar	1+0
Agron 699	Doctoral Research	75

*Indicates Core course for Ph.D.

Course Contents
Ph.D. in Agronomy

I. Course Title : Current Trends in Agronomy
II. Course Code : Agron 601
III. Credit Hours : 3+0

IV. Aim of the course

To acquaint the students about recent advances in agricultural production.

V. Theory

Unit I

Agro-physiological basis of variation in yield, recent advances in soilplant-water relationship.

Unit II

Globalization of agriculture and WTO, precision agriculture, contract farming, organic farming, marketing and export potential of organic products, certification, labeling and accreditation procedures and ITK in organic farming.

Unit III

Crop residue management in multiple cropping systems; latest developments in plant managementMechanizationin crop production: modern agricultural precision tools and technilogies, weed management, cropping systems, grassland management, agro-forestry, allelopathy.

Unit IV

GIS, GPS and remote sensing for crop management, global warming, GM crops, seed production technology; seed certification, seed multiplication, hybrid seed production etc.

Unit V

Concepts of system agriculture; holistic approach of farming systems, dryland farming, sustainable agriculture and research methodology in Agronomy. Conservation agriculture, principles, prospects and importance, potential benefits of CA under climate change scenario, policy issues.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Recent advances in agricultural production

VIII. Suggested Reading

- Agarwal RL. 1995. *Seed Technology*. Oxford & IBH.
- Dahiya BS and Rai KN. 1997. *Seed Technology*. Kalyani.
- Govardhan V. 2000. *Remote Sensing and Water Management in Command Areas: Agroecological Prospectives*. IBDC.

- ICAR. 2006. *Hand Book of Agriculture*. ICAR.
- Narasaiah ML. 2004. *World Trade Organization and Agriculture*. Sonali Publ.
- Palaniappan SP and Annadurai K. 2006. *Organic Farming - Theory and Practice*. Scientific Publ.
- Sen S and Ghosh N. 1999. *Seed Science and Technology*. Kalyani.
- Tarafdar JC, Tripathi KP and Kumar M. 2007. *Organic Agriculture* Scientific Publ.
- Kumar, R, Swarnkar KS, Singh KS and Narayan S. 2016. *A Text Book of Seed Technology*. Kalyani Publication.
- Reddy SR and Prabhakara G. 2015. *Dryland Agriculture*. Kalyani Publishers.
- Gururajan B, Balasubhramanian R and Swaminath V. 2013. *Recent Strategies on Crop Production*. Kalyani Publishers.
- Venkateswarlu B and Shanker Arun K. 2009. *Climate change and agriculture: Adaptation and mitigation strategies*. *Indian Journal of Agronomy* **54**(2): 226-230.

I. Course Title : Recent Trends in Crop Growth and Productivity

II. Course Code : Agron 602

III. Credit Hours : 2+1

IV. Aim of the course

To study the physiology of vegetative and reproductive growth in relation to productivity of different crops in various environments.

V. Theory

Unit I

Plant density and crop productivity; plant and environmental factors, yield, plant distribution, strategies for maximizing solar energy utilization; leaf area; interception of solar radiation and crop growth; photosynthesis: the photosynthetic apparatus, factors essential for photosynthesis; difference in photosynthetic rates among and within species; physiological limitations to crop yield; solar radiation concept and agro-techniques for harvesting solar radiation.

Unit II

Growth analysis: concept, CGR, RGR, NAR, LAI, LAD, LAR; validity and Limitations in interpreting crop growth and development; growth curves: sigmoid, polynomial and asymptotic; root systems; root-shoot relationship; principles involved in inter and mixed cropping systems under rainfed and irrigated conditions; concept and differentiation of inter and mixed cropping; criteria in assessing the yield advantages.

Unit III

Competitive relationship and competition functions; biological and agronomic basis of yield advantage under intercropping; physiological principles of dry land crop production, constraints and remedial measures; heat unit concept of crop maturity: concept and types of heat units.

Unit IV

Concept of plant ideotypes: crop physiological and new ideotypes; characteristics of ideotype for wheat, rice, maize, etc.; concept and types of growth hormones; their role in field crop production; efficient use of resources.

VI. Practical

- Field measurement of root-shoot relationship in crops at different growth stages
- Estimation of growth evaluating parameters like CGR, RGR, NAR, LAI etc., at

different stages of crop growth
- Computation of harvest index of various crops
- Assessment of crop yield on the basis of yield attributing characters
- Construction of crop growth curves based on growth analysis data
- Computation of competition functions, viz. LER, IER aggressivity competition index etc in intercropping
- Senescence and abscission indices
- Analysis of productivity trend in un-irrigated areas
- Analysis of productivity trend in irrigated areas

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of crop growth for agricultural production

IX. Suggested Reading

- Chopra VL and Paroda RS. 1984. *Approaches for Incorporation of Drought and Salinity Resistance in Crop Plants*. Oxford & IBH.
- Delvin RM and Vitham FH. 1986. *Plant Physiology*. CBS Publ.
- Evans LT. 1975. *Crop Physiology*. Cambridge Univ. Press.
- Evans LT. 1996. *Crop Evolution, Adaptation and Yield*. Cambridge Univ. Press.
- Gupta US. (Ed.). 1995. *Production and Improvement of Crops for Drylands*. Oxford & IBH.
- Gupta US. 1988. *Progress in Crop Physiology*. Oxford & IBH.
- Kramer PJ and Boyer JS. 1995. *Water Relations of Plant and Soils*. Academic Press.
- Mukherjee S and Ghosh AK. 1996. *Plant Physiology*. Tata McGraw Hill.
- Narwal SS, Politycka B and Goswami CL. 2007. *Plant Physiology: Research Methods*. Scientific Pub.
- Tiaz L. and Zeiger E. 2006. Plant Physiology. Sinauer Associates, Inc.

I. Course Title : Irrigation Management

II. Course Code : Agron 603

III. Credit Hours : 2+1

IV. Aim of the course

To teach students about optimization of irrigation in different crops under variable agro climatic conditions.

V. Theory

Unit I

Global water resources; Water resources of India, irrigation projects during pre and post independence period and their significance in crop production; irrigation needs, atmospheric, soil, agronomic, plant and water factors affecting irrigation need; water deficits and crop growth.

Unit II

Movement of water in soil-water movement under saturated and unsaturated conditions, Poiseulle's and Darcy's law, general equation of saturated and unsaturated flow of water in soil.

Soil-plant-water relationships, evaporation, transpiration and evapotranspiration, significance of transpiration, energy utilization in transpiration, physiological processes and crop productivity.

Unit III

Water requirement, irrigation needs, factors affecting irrigation need; water use efficiency, Infiltration; water movement under saturated and unsaturated conditions; management practices for improving water use efficiency of crops.

Unit IV

Soil and plant water potential, SPAC, transpiration and evapotranspiration, significance of transpiration, energy utilization in transpiration, factors affecting ET, control of ET by mulching and use of anti-transpirents; fertilizer use in relation to irrigation.

Unit V

Crop water stress – water deficits and crop growth, adoptability to the crops. Water availability with relation to nutrient availability.

Unit VI

Application of irrigation water, conveyance and distribution system, irrigation efficiency; agronomic considerations in the design and operation of irrigation projects; characteristics of irrigation and farming systems affecting irrigation management.

Unit VII

Strategies of using limited water supply; factors affecting ET, control of ET by mulching and use of anti-transpirants; fertilizer use in relation to irrigation; optimizing the use of given irrigation supplies.

Unit VIII

Land suitability for irrigation, land irrigability classification; integrated water management in command areas, institution of water management in commands, farmer's participation in command areas; irrigation legislation.

Unit IX

Economic analysis of irrigation and cop planning for optimum use of irrigation water

Unit X

Crop water production function

VI. Practical

- Determination of water infiltration characteristics and water holding capacity of soil profiles.
- Determination Moisture extraction pattern of crops
- Determination of water balance component of transplanted rice by drum culture technique
- Determination of consumptive use and water requirement of a given cropping pattern
- Determination of crop efficient of one important crop
- Planning, designing and installation of drip irrigation system
- Planning, designing and installation of sprinkler irrigation system
- Designing of drainage channel
- Measurement of irrigation efficiencies
- Determination of irrigation timing under different methods of irrigation
- Visit to irrigation command area

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Management of irrigation water for sustainable agriculture

IX. Suggested Reading

- MP. Singh 2017. Recent advances in Irrigation water management. Kalyani Publishers
- FAO. 1984. *Irrigation Practice and Water Management*. Oxford & IBH.
- Michael AM. 1978. *Irrigation: Theory and Practice*. Vikas Publ.
- Mishra RR and Ahmad M. 1987. *Manual on Irrigation and Agronomy*. Oxford & IBH.
- Panda SC. 2003. *Principles and Practices of Water Management*. Agrobios.
- Reddy SR. 2000. *Principles of Crop Production*. Kalyani.
- Sankara Reddy GH and Yellamananda Reddy. 1995. Efficient Use of Irrigation Water. In: Gupta US. (Ed.). *Production and Improvement of Crops for Drylands*. Oxford & IBH.
- Singh SS. 2006. Principles and Practices of Agronomy. In: Gupta US.(Ed.). *Production and Improvement of Crops for Drylands*. Oxford & IBH

I. Course Title : Recent Trends in Weed Management

II. Course Code : Agron 604

III. Credit Hours : 2+0

IV. Aim of the course

To teach about the changing weed flora, new herbicides, their resistance, toxicity, antidotes and residue management under different cropping systems.

V. Theory

Unit I

Crop-weed competition in different cropping situations; changes in weed flora, various causes and effects; different methods of weed management. Migration, introduction, adaptation of weeds, Invasive weeds – biology and management. Different mechanisms of invasion – present status and factors influencing weed invasion.

Unit II

Physiological and biological aspects of herbicides, their absorption, translocation, metabolism and mode of action; selectivity of herbicides and factors affecting them.

Unit III

Climatic factors and phytotoxicity of herbicides; fate of herbicides in soil and factors affecting them, Degradation of herbicides in soil and plants- factors affecting it, primary and secondary metabolites, residue management of herbicides, adjuvants.

Unit IV

Advances in herbicide products and application techniques and methods; herbicide resistance; antidotes and crop protection compatibility of herbicides of different groups; compatibility of herbicides with other pesticides; herbicide rotation and herbicide mixtures.

Unit V

Development of transgenic herbicide resistant crops; herbicide development, registration procedures.

Unit VI

Relationship of herbicides with tillage, fertilizer, and irrigation, cropping system; bioherbicides, allelochemical and alleloherbicides, herbicide bioassays. Recent advances in nonchemical weed management including deleterious rhizobacteria, robotics, biodegradable film, etc.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of new herbicides, their resistance, toxicity, antidotes and residue management under different cropping systems.

VIII. Suggested Reading

- Böger, Peter, Wakabayashi, Ko, Hirai, Kenji (Eds.). 2002. *Herbicide Classes in Development. Mode of Action, Targets, Genetic Engineering, Chemistry*. Springer.
- Das TK. 2008. *Weed Science: Basics and Applications*, Jain Brothers (New Delhi)
- Fennimore, Steven A and Bell, Carl. 2014. *Principles of Weed Control*, 4th Ed, California Weed Sci. Soc.
- Gupta OP. 2007. *Weed Management: Principles and Practices*, 2nd Ed.
- Jugulan M, (ed). 2017. *Biology, Physiology and Molecular Biology of Weeds*. CRC Press
- Monaco TJ, Weller SC and Ashton FM. 2014. *Weed Science Principles and Practices*, Wiley
- Powles SB and Shaner DL. 2001. *Herbicide Resistance and World Grains*, CRC Press.
- Walia US. 2006. *Weed Management*, Kalyani.
- Zimdahl RL. (ed). 2018. *Integrated Weed Management for Sustainable Agriculture, B. D. Sci. Pub*

I. Course Title : Integrated Farming Systems and Sustainable Agriculture

II. Course Code : Agron 605

III. Credit Hours : 2+0

IV. Aim of the course

To apprise about different enterprises suitable for different agroclimatic conditions for sustainable agriculture.

V. Theory

Unit I

Integrated Farming systems (IFS): definition, scope and importance; classification of IFS based on enterprises as well as under rainfed/irrigated condition in different land situation. farming systems according to type of rotation, intensity of rotation, degree of commercialization, water supply, enterprises.

Unit II

Concept of sustainability in of Integrated farming systems; efficient Integrated farming systems based on economic viability and natural resources - identification and management.

Unit III

Production potential of different components of Integrated farming systems; interaction and mechanism of different production factors; stability of Integrated Farming system based on research/long term information. in different systems through research; eco-physiological approaches to intercropping. Integration of components and adaptability of different farming system based on land situations and climatic condition of a region; evaluation of IFS.

Unit IV

Simulation models for intercropping; soil nutrient in intercropping; preparation of different farming system models; evaluation of different farming systems. Formation of different Integrated Farming system Models; evaluation of different Integrated Farming system models. Recycling of organic waste in farming system, in IFS.

Unit V

New concepts and approaches of farming system and organic farming; value addition, waste recycling, quantification and mitigation of Green House gases; case studies/ success stories of different Integrated Farming systems. cropping systems and organic farming; case studies on different farming systems. Possible use of ITK in Integrated farming system.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of enterprises suitable for different agroclimatic conditions for sustainable agriculture and their proper utilization .

VIII. Suggested Reading

- Ananthakrishnan TN. (Ed.). 1992. *Emerging Trends in Biological Control of Phytophagous Insects*. Oxford & IBH.
- Baishya A, Borah M, Das AK, Hazarika J, Gogoi B and Borah AS 2017. *Waste Recycling Through Integrated Farming systems. An Assam Agriculture Experience*. Omni Scriptum Gmbh & Co. KG, Germany.
- Balasubramanian P and Palaniappan SP. 2006. *Principles and Practices of Agronomy*. Agrobios.
- Edens T. 1984. *Sustainable agriculture and integrated farming system*. Michigan State Univ. press.
- Jayanthi C. 2006. *Integrated Farming systems-A way to sustainable Agriculture*. Tamil Nadu Agricultural University, Coimbatore
- Joshi M and Parbhakarasetty TK. 2005. *Sustainability through Organic Farming*. Kalyani.
- Kolhapure A and Madhukar D. *A text book of farming system and sustainable agriculture*.
- Palaniappan SP and Anandurai K. 1999. *Organic Farming - Theory and Practice*. Scientific Publ.
- Panda SC. 2004. *Cropping systems and Farming Systems*. Agribios.
- Lampin N. 1990. *Organic Farming*. Farming Press Books.
- Ravisankar D and Jayanthi C. 2015. *Farming systems: concepts and approaches*. Agrobios,

I. Course Title : Soil Conservation and Watershed Management

II. Course Code : Agron 606

III. Credit Hours : 2+1

IV. Aim of the course

To teach about different soil moisture conservation technologies for enhancing the agricultural productivity through holistic approach watershed management.

V. Theory

Unit I

Soil erosion: definition, nature and extent of erosion; types of erosion, factors affecting erosion.

Unit II

Soil conservation: definition, methods of soil conservation; agronomic measures - contour cultivation, strip cropping, cover crops; mulching, tillage, cropping system vegetative barriers; improved dry farming practices; mechanical measures - bunding, gully control, bench terracing; role of grasses and pastures in soil conservation; wind breaks and shelter belts.

Unit III

Watershed management: definition, objectives, concepts, approach, components, steps in implementation of watershed; development of cropping systems for watershed areas.

Unit IV

Land use capability classification, alternate land use systems; agro-forestry; ley farming; *jhum* management - basic concepts, socio-ethnic aspects, its layout.

Unit V

Drainage, methods of drainage, Drainage considerations and agronomic management; rehabilitation of abandoned *jhum* lands and measures to prevent soil erosion.

VI. Practical

- Study of different types of erosion
- Determination of dispersion ratio
- Estimation of soil loss by Universal Soil Loss Equation
- Estimation of soil loss by wind erosion
- Measurement of runoff and soil loss
- Field studies of different soil conservation measures
- Laying out run-off plot and deciding treatments
- Identification of different grasses and trees for soil conservation
- Visit to watershed areas
- Visit to a soil conservation research centre, demonstration and training centre

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil moisture conservation technologies for enhancing the agricultural productivity through holistic approach watershed management.

IX. Suggested Reading

- Arakeri HR and Roy D. 1984. *Principles of Soil Conservation and Water Management*. Oxford & IBH.
- Dhruvanarayana VV. 1993. *Soil and Water Conservation Research in India*. ICAR.
- FAO. 2004. *Soil and Water Conservation in Semi-Arid Areas. Soils Bull.,* Paper 57.
- Frederick RT, Hobbs J, Arthur D and Roy L. 1999. *Soil and Water Conservation: Productivity and Environment Protection.* 3rd Ed. Prentice Hall.

- Gurmel Singh, Venkataraman CG, Sastry B and Joshi P. 1990. *Manual of Soil and Water Conservation Practices*. Oxford & IBH.
- Murthy VVN. 1995. *Land and Water Management Engineering*. Kalyani.
- Tripathi RP and Singh HP. 1993. *Soil Erosion and Conservation*. Wiley Eastern.
- Yellamanda Reddy T and Sankara Reddy GH. 1992. *Principles of Agronomy*. Kalyani.

I. Course Title : Stress Crop Production

II. Course Code : Agron 607

III. Credit Hours : 2+1

IV. Aim of the course

To study various types of stresses in crop production and strategies to overcome them.

V. Theory

Unit I

Stress and strain terminology; nature and stress injury and resistance; causes of stress.

Unit II

Low temperature stress: freezing injury and resistance in plants, measurement of freezing tolerance, chilling injury and resistance in plants, practical ways to overcome the effect of low temperature tress through, soil and crop manipulations.

Unit III

High temperature or heat stress: meaning of heat stress, heat injury and resistance in plants, practical ways to overcome the effect of heat stress through soil and crop manipulations.

Unit IV

Water deficit stress: meaning of plant water deficient stress and its effect on growth and development, water deficit injury and resistance, practical ways to overcome effect of water deficit stress through soil and crop, manipulations.

Unit V

Excess water or flooding stress: meaning of excess water stress, its kinds and effects on crop plants, excess water stress injury and resistance, practical ways to overcome excess water stress through soil and crop manipulations.

Unit VI

Salt stress: meaning of salt stress and its effect on crop growth, salt stress injury and resistance in plants, practical ways to overcome the effect of salt stress through soil and crop manipulations.

Unit VII

Mechanical impedance of soil and its impact on plant growth; measures to overcome soil mechanical impedance.

Unit VIII

Environmental pollution: air, soil and water pollution, and their effect on crop growth and quality of produce; ways and means to prevent environmental pollution.

VI. Practical

- Determination of electrical conductivity of plant cell sap
- Determination of osmotic potential and tissue water potential
- Measurement of transpiration rate
- Measurement of stomatal frequency
- Measurement of Relative Water Content of leaf
- Measurement of electrolytic leakage
- Growing of plants in sand culture under salt stress for biochemical and physiological studies
- Studies on effect of osmotic and ionic stress on seed germination and seedling growth
- Measurement of low temperature injury under field conditions
- Studies on plant responses to excess water.

VIII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

IX. Learning outcome

Experience on the knowledge of various types of stresses in cropproduction and strategies to overcome these.

X. Suggested Reading

- Baker FWG.1989. *Drought Resistance in Cereals*. Oxon, UK.
- Gupta US. (Ed.). 1988. *Physiological Aspects of Dryland Farming*. Oxford & IBH.
- Kramer PJ.1983. *Water Relations of Plants*. Academic Press.
- Levitt J. 1980. *Response of Plants to Environmental Stresses*. Vols. I, II. Academic Press.
- Mavi HS.1978. *Introduction to Agro-meteorology*. Oxford & IBH.
- Michael AM and Ojha TP.1981. *Principles of Agricultural Engineering*. Vol II. Jain Bros.
- Nilsen ET and Orcut DM. 1996. *Physiology of Plants under Stress – Abiotic Factors*. John Wiley & Sons.
- Singh K. 2000. *Plant Productivity under Environmental Stress*. Agribios.
- Singh KN and Singh RP. 1990. *Agronomic Research Towards Sustainable Agriculture*. Indian Society of Agronomy, New Delhi.
- Somani LL and Totawat KL. 1992. *Management of Salt-affected Soils and Waters*. Agrotech Publ.
- Virmani SM, Katyal JC, Eswaran H and Abrol IP. 1994. *Stressed Ecosystem and Sustainable Agriculture*. Oxford & IBH.

I. Title : Research and Publication Ethics

II. Course Code : Agron 608

III. Credit Hours : 0+2

IV. Theory

Unit I

Introduction to philosophy: definition, nature and scope, concept, branches

Unit II

Ethics: definition, moral philosophy, nature of moral judgements and reactions

Unit III

Scientific conduct: Ethics with respect to science and research, intellectual honesty and research integrity, Scientific misconducts- falsifications, fabrications and plagiarism (FFP): Redundant publications: duplicate and overlapping publications, salami slicing; selective reporting and misrepresentation of data

Unit IV

Publication ethics: Defination, introduction and importance. Best practices/standard setting initiatives and guidelines: COPE, WAME, etc., conflicts of interest. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, type, violation of publication ethics, authorship and contributorship, Identification of publication misconduct, complaints and appeals, predatorypublishers and journals

Unit V

Open access publishing: open access publication and initiatives: SHERPA, RoMEO online resource to checkpublisher copy right and selfarchivingpolicies; software tool to identify predatory publications developed by SPPU, Journal finder/journal suggestions tools viz., JANE, Elsevier Journal Finder, Springer Journal Suggesteretc.

Unit VI

Publication misconduct: Group discussions- subject specific ethical issues, FFP, authorship, conflicts of interest, complaints and appeals examples and fraud from India and abroad. Software tools: Use of plagiarism software like Turnitin, Urkund and other open sourcesoftware tools

Unit VII

Database and Research metrics: Indexing data base, citation database, web of science, scopus, etc. Impact factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g-index, i10-index altmetrics.

V. Teaching methods/activities

Classroom teaching with AV aids, group discussion, field practicals and laboratory visit.

VI. Learning outcome

Developed skill for research management, quality publication.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Physical Sciences
– Soil Science

Preamble

Soils comprise a multiple phase system consisting of numerous solid phases (about 50%), a liquid phase (about 25%) and a gas phase (about 25%). The solids include rock consisting of many different primary and secondary minerals. Superimposed on this inorganic matrix is what Truog (1951) described as the 'living phase' which includes bacteria, fungi, actinomycetes, algae, protozoa, nematodes and other forms of life. These living organisms are continuously breaking down organic residues and synthesizing many of the products into body tissues while others are released to the surroundings Many physical, chemical and biological changes continually take place in soils. Physical processes such as wetting, drying, freezing, thawing changing temperatures and leaching modify the surface areas of soil particles. Primary minerals change to secondary minerals as ionic species in solution seek lower free energy levels. In addition, plants capture energy from sun and store in the form of organic compounds. Because of dynamic nature of soils, various changes take place regularly in soils and therefore, it is very essential to know the behaviour of soil solution, matrix potential so that proper technology can be achieved through research works.

Our knowledge has increased rapidly during the last decade concerning the role of macro and micro nutrients in soils, plants, animal nutrition and in food for man. The skills of several scientific disciplines, combined with sophisticated instruments, have extended our knowledge about nutrients in plants and soils to molecular level and to microenvironments of roots in soil. One of the cherished objectives of the salient feature of the revised syllabi is to foster high standard in education system of soil science. A paradigm shift is necessary in education prioritization to meet the challenges of the present and future in soil science.

Students, therefore have to be acquainted with the modern concepts of different processes, concepts and development so as to develop competencies on the area of specialization of the subject. For the purpose, it is proposed to revise the course syllabus of Soil Science in the light of the present days need incorporating the basic concepts, developments of the discipline.

The existing M.Sc. (Ag) courses of soil science have been modified taking into account of present day need by incorporating the necessary and important topics in the respective courses such as basic principle of physics applied to soils, fertility status of major soil groups of India, Long term effect of manures and fertilizers on soil fertility and crop productivity, Soil health quality in relation to human health, Speciality fertilizers, Concept of quantity/ intensity relationship, Soil mapping, Interaction of clay with humus, pesticides and heavy metals, Soil enzyme, Humus formation, Root rhizosphere and Biodegradation of pesticide. The new topics are covered in Ph.D courses as Soil-plant-atmospheric continuum (SPAC), Kinetics studies of nutrients in soils, Climate change on soil properties and Carbon sequestration. Major changes have been made in some of the existing courses like soil fertility and fertilizer uses, soil biology and biochemistry and Analytical technique and instrumental methods in soil and plant analysis under MSc programme and Biochemistry of soil organic matter under PhD programme. As a part of course curriculum, M. Sc.(Ag) soil science was restructured to equip students to tackle emerging issues by inclusion of two new courses on (i) Soil survey and land use planning (ii) Introduction to nanotechnology. The Ph.D. courses of soil science was revised by adding four important new courses (i) Recent trend in soil microbial diversity (ii) Soil resource management (ii) Modelling of soil plant system (iv) Clay mineralogy.

Course Title with Credit Load
M.Sc. in Soil Science

Course Code	Course Title	Credit Hours
*Soil 501	Soil physics	(2+1)
*Soil 502	Soil fertility and fertilizer use	(2+1)
*Soil 503	Soil chemistry	(2+1)
*Soil 504	Soil mineralogy, genesis and classification	(2+1)
Soil 505	Soil erosion and conservation	(2+1)
Soil 506	Soil Biology and Biochemistry	(2+1)
Soil 507	Radioisotopes in soil and plant studies	(1+1)
Soil 508	Soil, water and air pollution	(2+1)
Soil 509	Remote sensing and GIS technique for soil and crop studies	(2+1)
Soil 510	Analytical technique and instrumental methods in soil and plant analysis	(0+2)
Soil 511	Management of problematic soils and water	(1+1)
Soil 512	Land degradation and restoration	(1+0)
Soil 513	Soil Survey and Land use Planning	(2+0)
Soil 514	Introduction to nanotechnology	(2+1)
Soil 591	Master's Seminar	(1+0)
Soil 599	Master's Research	-30

*Indicates Core Courses which are Compulsory for Master Programme

Course contents
M.Sc. in Soil Science

I. Course Title : Soil Physics
II. Course Code : Soil 501
III. Credit Hours : 2+1

IV. Aim of the course

To impart basic knowledge about soil physical properties and processes in relation to plant growth.

V. Theory

Unit I

Basic principles of physics applied to soils, soil as a three phase system.

Unit II

Soil texture, textural classes, mechanical analysis, specific surface.

Unit III

Soil consistence; dispersion and workability of soils; soil compaction and consolidation; soil strength; swelling and shrinkage - basic concepts.Alleviation of soil physical constraints for crop production. Soil erosion and edibility

Unit IV

Soil structure - genesis, types, characterization and management soil structure; soil
aggregation, aggregate stability; soil tilth, characteristics of good soil tilth; soil crusting -mechanism, factors affecting and evaluation; soil conditioners; puddling, its effect on soil physical properties; clod formation.

Unit V

Soil water: content and potential, soil water retention, soil-water constants, measurement of soil water content, energy state of soil water, soil water potential, soil-moisture characteristic curve; hysteresis, measurement of soil-moisture potential.

Unit VI

Water flow in saturated and unsaturated soils, Poiseuille's law, Darcy's law; hydraulic conductivity, permeability and fluidity, hydraulic diffusivity; measurement ofhydraulic conductivity in saturated and unsaturated soils.

Unit VII

Infiltration; internal drainage and redistribution; evaporation; hydrologic cycle, field water balance; soil-plant-atmosphere continuum.

Unit VIII

Composition of soil air; renewal of soil air - convective flow and diffusion; measurement of soil aeration; aeration requirement for plant growth; soil air management.

Unit IX

Modes of energy transfer in soils; energy balance; thermal properties of soil; measurement of soil temperature; soil temperature in relation to plant growth; soiltemperature management.

VI. Practical

- Determination of B.D, P.D and mass volume relationship of soil, Mechanical analysis by hydrometer and international pipette method,
- Measurement of Atterberg limits, Aggregate analysis - dry and wet, Measurement of soil-water content by different methods, Measurement of soil-water potential by using tensiometer and gypsum Blocks, Determination of soil-moisture characteristics curve and computation of pore-size, distribution, Determination of hydraulic conductivity under saturated and unsaturated conditions, Determination of infiltration rate of soil, Determination of aeration porosity and oxygen diffusion rate, Soil temperature measurements by different methods, Estimation of water balance components in bare and cropped fields.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

IX. Suggested Reading

- Baver LD, Gardner WH and Gardner WR. 1972. *Soil Physics*. John Wiley & Sons.
- Ghildyal BP and Tripathi RP. 2001. *Soil Physics*. New Age International.
- Hanks JR and Ashcroft GL. 1980. *Applied Soil Physics*. Springer Verlag.
- Hillel D. 1972. *Optimizing the Soil Physical Environment toward Greater Crop Yields*. Academic Press.
- Hillel D. 1980. *Applications of Soil Physics*. Academic Press.
- Hillel D. 1980. *Fundamentals of Soil Physics*. Academic Press.
- Hillel D. 1998. *Environmental Soil Physic*s. Academic Press.
- Hillel D. 2003. *Introduction to Environmental Soil Physics*. Academic Press.
- Indian Society of Soil Science. 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Kirkham D and Powers WL. 1972. *Advanced Soil Physics*. Wiley-Interscience.
- Kohnke H. 1968. *Soil Physics*. McGraw Hill.
- Lal R and Shukla MK. 2004. *Principles of Soil Physics*. Marcel Dekker.
- Oswal MC. 1994. *Soil Physics*. Oxford & IBH.

I. Course Title : Soil Fertility and Fertilizer Use

II. Course Code : Soil 502

III. Credit Hours : 3+1

IV. Aim of the course

To impart knowledge about soil fertility and its control, and to understand the role of fertilizers and manures in supplying nutrients to plants so as to achieve high fertilizer use efficiency.

V. Theory

Unit I

Soil fertility and soil productivity; fertility status of major soils group of India;

nutrient sources – fertilizers and manures; Criteria of essentiality, classification, law of minimum and maximum, essential plant nutrients - functions and deficiency symptoms, Nutrient uptake, nutrient interactions in soils and plants; long term effect of manures and fertilizers on soil fertility and crop productivity.

Unit II

Soil and fertilizer nitrogen – sources, forms, immobilization and mineralization, nitrification, denitrification; biological nitrogen fixation -types, mechanism, microorganisms and factors affecting; nitrogenous fertilizers and their fate in soils; management of fertilizer nitrogen in lowland and upland conditions for high fertilizer use efficiency.

Unit III

Soil and fertilizer phosphorus - forms, immobilization, mineralization, reactions in acid andalkali soils; factors affecting phosphorus availability in soils; phosphatic fertilizers - behavior in soilsand management under field conditions. Potassium - forms, equilibrium in soils and its agriculturalsignificance; mechanism of potassium fixation; management of potassium fertilizers under fieldconditions.

Unit V

Sulphur - source, forms, fertilizers and their behavior in soils; roleincropsandhuman health; calcium and magnesium– factors affecting their availability in soils; management of sulphur, calcium and magnesium fertilizers.

Unit VI

Micronutrients – critical limits in soils and plants; factors affecting their availability and correction of their deficiencies in plants; role of chelates in nutrient availability.

Unit VII

Common soil test methods for fertilizer recommendations; quantity–intensityrelationships; soil test crop response correlations and response functions.

Unit VIII

Fertilizer use efficiency; site-specific nutrient management; plant need based nutrient management; integrated nutrient management; specialityfertilizersconcept, needand category.CurrentstatusofspecialityfertilizersuseinsoilsandcropsofIndia;

Unit IX

Soil fertility evaluation - biological methods, soil, plant and tissue tests; soilquality in relation to sustainable agriculture, Determination of critical limit, DRIS

Unit X

Definition and concepts of soil health and soil quality; Longterm effects of fertilizers and soil quality.

VI. Practical

- Soil and plant sampling and processing for chemical analysis
- Determination of soil pH, total and organic carbon in soil
- Chemical analysis of soil for total and available nutrients(major and micro)
- Analysis of plants for essential elements(major and micro)

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil fertility and fertilizers in relation to plant growth and development.

IX. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.
- Kabata-Pendias A and Pendias H. 1992. *Trace Elements in Soils and Plants*. CRC Press.
- Kannaiyan S, Kumar K and Govindarajan K. 2004. *Biofertilizers Technology*. Scientific Publ.
- Leigh J G. 2002. *Nitrogen Fixation at the Millennium*. Elsevier.
- Mengel K and Kirkby EA. 1982. *Principles of Plant Nutrition*. International Potash Institute, Switzerland.
- Mortvedt JJ, Shuman LM, Cox FR and Welch RM. 1991. *Micronutrients in Agriculture*. 2nd Ed. SSSA, Madison.
- Pierzinsky GM, Sims TJ and Vance JF. 2002. *Soils and Environmental Quality*. 2nd Ed. CRC Press.
- Stevenson FJ and Cole MA. 1999. *Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulphur, Micronutrients*. John Wiley & Sons.
- Tisdale SL, Nelson SL, Beaton JD and Havlin JL. 1999. *Soil Fertility and Fertilizers*. 5th Ed. Prentice Hall of India.
- Troeh FR and Thompson LM. 2005. *Soils and Soil Fertility*. Blackwell.

I. Course Title : Soil Chemistry

II. Course Code : Soil 503

III. Credit Hours : 2+1

IV. Suggested Reading

To introduce the classical concepts of soil chemistry and to familiarize students with modern developments in chemistry of soils in relation to using soils as a medium for plant growth.

V. Theory

Unit I

Chemical (elemental) composition of the earth's crust, soils, rocks and minerals

Unit II

Elements of equilibrium thermodynamics, chemical equilibria, electrochemistry and chemical kinetics.

Unit III

Soil colloids: inorganic and organic colloids - origin of charge, concept of point of zero-charge (PZC) and its dependence on variable-charge soil components, surface charge characteristics of soils; diffuse double layer theories of soil colloids, zeta potential, stability, coagulation/flocculation and peptization of soil colloids; electrometric properties of soil colloids; sorption properties of soil colloids; soil organic matter - fractionation of soil organic matter and different fractions, Characterization of OM; clay-organic interactions.

Unit IV

Ion exchange processes in soil; cation exchange- theories based on law of massaction (Kerr-Vanselow, Gapon equations, hysteresis, Jenny's concept), adsorptionisotherms, Donnan-membrane equilibrium concept, clay-membrane electrodes and ionicactivity measurement, thermodynamics, statistical mechanics; anion and ligand exchange–

innersphere and outer-sphere surface complex formation, fixation of oxyanions, hysteresisin sorption-desorption of oxy-anions and anions, shift of PZC on ligand exchange, AEC, CEC; experimental methods to study ion exchange phenomena and practical implications in plant nutrition.

Unit V

Potassium, phosphate and ammonium fixation in soils covering specificand non-specific sorption; precipitation-dissolution equilibria; Conceptof quantity/intensity(Q/I)relationship; step and constant-rate K; managementaspects.

Unit VI

Chemistry of acid soils; active and potential acidity; lime potential, chemistry of acid soils; sub-soil acidity.

Unit VII

Chemistry of salt-affected soils and amendments; soil pH, ECe, ESP, SAR and important relations; soil management and amendments.

Unit VIII

Chemistry and electrochemistry of submerged soils, geochemistry of micronutrients, environmental soil chemistry

VI. Practical

Preparation of saturation extract, measurement of pH, EC, CO, HCO, Ca, Mg, K and Na, Determination of CEC and AEC of soils, Analysis of equilibrium soil solution for pH, EC, Eh by the use of Eh-pH meter andconductivity meter, Determination of point of zero-charge and associated surface charge characteristics by the serial potentiometric titration method, Extraction of humic substances, Potentiometric and conductometric titration of soil humic and fulvic acids, (E4/E6) ratio of soil humic and fulvic acids by visible spectrophotometric studies and the D (E4/E6) values at two pH values, Adsorption-desorption of phosphate/sulphate by soil using simple adsorption isotherm, Construction of adsorption envelope of soils by using phosphate/fluoride/sulphate and ascertaining the mechanism of the ligand exchange process involved, Determination of titratable acidity of an acid soil by BaCl2-TEA method, Determination of Q/I relationship of potassium, Determination of lime requirement of an acid soil by buffer method, Determination of gypsum requirement of an alkali soil.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of chemical behaviour of soil and their utility in research for solving field problem.

IX. Suggested Reading

- Bear RE. 1964. *Chemistry of the Soil*. Oxford and IBH.
- Bolt GH and Bruggenwert MGM. 1978. *Soil Chemistry*. Elsevier.
- Greenland DJ and Hayes MHB. 1981. *Chemistry of Soil Processes*. John Wiley & Sons.
- Greenland DJ and Hayes MHB. *Chemistry of Soil Constituents*. John Wiley & Sons.
- McBride MB. 1994. *Environmental Chemistry of Soils*. Oxford University Press.
- Sposito G. 1981. *The Thermodynamics of Soil Solutions*. Oxford University Press.
- Sposito G. 1984. *The Surface Chemistry of Soils*. Oxford University Press.

- Sposito G. 1989. *The Chemistry of Soils*. Oxford University Press.
- Stevenson FJ. 1994. *Humus Chemistry*. 2nd Ed. John Wiley & Sons.
- Van Olphan H. 1977. *Introduction to Clay Colloid Chemistry*. John Wiley & Sons.

I. Course Title : Soil Mineralogy, Genesis and Classification

II. Course Code : Soil 504

III. Credit Hours : 2+1

IV. Aim of the course

To acquaint students with basic structure of alumino-silicate minerals and genesis of clay minerals; soil genesis interms of factors and processes of soil formation, and to enable students conduct soil survey and interpret soil survey reports in terms of land use planning.

V. Theory

Unit I

Fundamentals of crystallography, space lattice, coordination theory, isomorphism and polymorphism.

Unit II

Classification, structure, chemical composition and properties of clay minerals; genesis and transformation of crystal line and non-crystal line clay minerals; identification techniques; amorphous soil constituents and other non-crystalline silicate minerals and their identification; clay minerals in Indian soils, role of clay minerals in plant nutrition, interaction of clay with humus, pesticides and heavy metals.

Unit III

Factors of soil formation, soil formation models; soil forming processes; weathering of rocks and mineral transformations; soil profile; weathering sequences of minerals with special reference to Indian soils.

Unit IV

Concept of soil individual; soil classification systems – historical developments and modern systems of soil classification with special emphasis on soil taxonomy; soil classification, soil mineralogy and soil maps – usefulness.

VI. Practical

- Separation of sand, silt and clay fraction from soil
- Determination of specific surface area and CEC of clay
- Identification and quantification of minerals in soil fractions
- Morphological properties of soil profile in different land forms
- Classification of soils using soil taxonomy
- Calculation of weathering indices and its application in soil formation
- Grouping soil susing available database in terms of soil quality

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil taxonomy and genesis and and their utility in research for solving field problem.

IX. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu. Buol EW, Hole ED, MacCracken RJ and Southard RJ. 1997. *Soil Genesis*
- *and Classification*. 4th Ed. Panima Publ.
- Dixon JB and Weed SB. 1989. *Minerals in Soil Environments*. 2nd Ed. Soil Science Society of America, Madison.
- Grim RE. 1968. *Clay Mineralogy*. McGraw Hill.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Sehgal J. 2002. *Introductory Pedology: Concepts and Applications*. New Delhi
- Sehgal J. 2002. *Pedology - Concepts and Applications*. Kalyani.
- USDA. 1999. *Soil Taxonomy*. Hand Book No. 436. 2nd Ed. USDA NRCS, Washington.
- Wade FA and Mattox RB. 1960. *Elements of Crystallography and Mineralogy*. Oxford & IBH.
- Wilding LP and Smeck NE. 1983. *Pedogenesis and Soil Taxonomy*: II. *The Soil Orders*. Elsevier.
- Wilding NE and Holl GF. (Eds.). 1983. *Pedogenesis and Soil Taxonomy*. I.

I. Course Title : Soil Erosion and Conservation

II. Course Code : Soil 505

III. Credit Hours : 2+1

IV. Aim of the course

To enable students to understand various types of soil erosion and measures to betaken for controlling soil erosion to conserve soil and water.

V. Theory

Unit I

History, distribution, identification and description of soil erosionproblems in India.

Unit II

Forms of soil erosion; effects of soil erosion and factors affecting soilerosion; types and mechanisms of water erosion; raindrops and soil erosion; rainfall erosivity - estimation as EI30 index and kinetic energy; factors affectingwater erosion; empirical and quantitative estimation of water erosion; methods of measurement and prediction of runoff; soil losses in relation to soil properties andprecipitation.

Unit III

Wind erosion- types, mechanism and factors affecting wind erosion; extent of problem in the country.

Unit IV

Principles of erosion control; erosion control measures – agronomical and engineering; erosion control structures - their design and layout.

Unit V

Soil conservation planning; land capability classification; soil conservation in special problem areas such as hilly, arid and semi-arid regions, waterlogged and wet lands.

Unit VI

Watershed management - concept, objectives and approach; water harvesting and recycling; flood control in watershed management; socioeconomic aspects of watershed management; case studies in respect to monitoring and evaluation of watersheds; use of remote sensing in assessment and planning of watersheds, sediment measurement

VI. Practical

- Determination of different soil erodibility indices - suspension percentage, dispersion ratio, erosion ratio, clay ratio, clay/moisture equivalent ratio, percolation ratio, raindrop erodibility index
- Computation of kinetic energy of falling rain drops
- Computation of rainfall erosivity index (EI30) using rain gauge data
- Land capability classification of a watershed
- Visits to a watersheds

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil conservation and their utility in research for solving field problem.

IX. Suggested Reading

- Biswas TD and Narayanasamy G. (Eds.) 1996. *Soil Management in Relation to Land Degradation and Environment*. Bull. Indian Society of Soil Science No. 17.
- Doran JW and Jones AJ. 1996. *Methods of Assessing Soil Quality*. Soil Science Society of America, Spl Publ. No. 49, Madison, USA.
- Gurmal Singh, Venkataramanan C, Sastry G and Joshi BP. 1990. *Manual of Soil and Water Conservation Practices*. Oxford & IBH.
- Hudson N. 1995. *Soil Conservation*. Iowa State University Press.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Oswal MC. 1994. *Soil Physics*. Oxford & IBH.

I. Course Title : Soil Biology and Biochemistry

II. Course Code : Soil 506

III. Credit Hours : 2+1

IV. Aim of the course

To teach students the basics of soil biology and biochemistry, including biogeochemical cycles, plant growth promoting rhizobacteria, microbial interactions in soil and other soil activities.

V. Theory

Unit I

Soilbiota, soil microbialecology, types of organisms indifferent soils; soil microbial biomass; microbial interactions; un-culturable soilbiota.

Unit II

Microbiology and biochemistry of root-soil interface; phyllosphere; soil enzymes, origin, activities and importance; soil characteristics influencing growth and activity of microflora; Root rhizosphere and PGPR.

Unit III

Microbial transformations of nitrogen, phosphorus, sulphur, iron and manganese in soil; biochemical composition and biodegradation of soil organic matter and crop residues, microbiology and biochemistry of decomposition of carbonaceous and protenaceous materials, cycles of important organic nutrients.

Unit IV

organic wastes and their use for production of biogas and manures; biotic factors in soil development; microbial toxins in the soil.

Unit V

Preparation and preservation of farmyard manure, animal manures, rural and urban composts and vermicompost.

Unit VI

Biofertilizers–definition, classification, specifications, method of production and role in crop production; FCO specifications and quality control of biofertilizers.

Unit VII

Biological indicators of soil quality; bioremediation of contaminated soils; microbial transformations of heavy metals in soil; role of soil organisms inpedogenesis – important mechanisms and controlling factors; soil genomics and bioprospecting; soil sickness due to biological agents; xenobiotics; antibiotic production in soil.

VI. Practical

- Determination of soil microbial population
- Soil microbial biomass carbon
- Elemental composition, fractionation of organic matter and functional groups
- Decomposition of organic matter in soil
- Soil enzymes
- Measurement of important soil microbial processes such as ammonification, nitrification, N_2 fixation, S oxidation, P solubilization and mineralization of other micronutrients

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil microbes and their utility in research for solving field problem.

IX. Suggested Reading

- Paul EA and Clark FE. *Soil Microbiology and Biochemistry.*
- Lynch JM. *Soil Biotechnology*
- Willey JM, Linda M. Sherwood and Woolverton CJ. *Prescott's Microbiology.*
- Subba Rao NS. *Advances In Agricultural Microbiology.*

I. Course Title : Radioisotopes in Soil and Plant Studies

II. Course Code : Soil 507

III. Credit Hours : 1+1

IV. Aim of the course

To train students in the use of radio isotopes in soil and plant research.

V. Theory

Unit I

Atomic structure, radio activity and units; radio isotopes-properties and decay principles; nature and properties of nuclear radiations; interaction of nuclear radiations with matter, artificial radioactivity

Unit II

Principles and use of radiation monitoring instruments-proportional, Geiger Muller counter, solid and liquids cintillation counters; neutron moisture meter, mass spectrometry, autoradiography

Unit III

Isotopic dilution techniques used in soil and plant research; use of stable isotopes; application of isotopes in studies on organic matter, nutrient transformations, ion transport, rooting pattern and fertilizer use efficiency; carbon dating

Unit IV

Doses of radiation exposure, radiation safety aspects regulatory aspects, collection, storage and disposal of radioactive wastes

VI. Practical

- Storage and handling of radioactive materials
- Determination of half-life and decay constant
- Preparation of soil and plant samples for radioactive measurements
- Settingup of experiment on fertilizer use efficiency and cation exchange equilibria using radio isotopes
- Determination of A, E and L values of soil using 32P/65Zn
- Use of neutron probe for moisture determination
- Sample preparation and measurement of 15N enrichment by mass spectro photometery/ emission spectrometry

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of radio activity and their utility in research for solving field problems.

IX. Suggested Reading

- Comer CL. 1955. *Radioisotopes in Biology and Agriculture: Principles and Practice*. Tata McGraw Hill.
- Glasstone S. 1967. *Source Book on Atomic Energy*. East West Press.
- Michael FL and Annunziata. 2003. *Handbook of Radioactivity Analysis*. Academic Press.

I. Course Title : Soil, Water and Air Pollution

II. Course Code : Soil 508

III. Credit Hours : 2+1

IV. Aim of the course

To make the student saw are of the problems of soil, water and air pollution associated with use of soils for crop production.

V. Theory

Unit I

Soil, water and air pollution problems associated with agriculture, nature and extent.

Unit II

Nature and sources of pollutants – agricultural, industrial, urban wastes, fertilizers and pesticides, acid rains, oil spills etc.; air, water and soil pollutants- their CPC standards and effect on plants, animals and human beings.

Unit III

Sewage and industrial effluents–their composition and effecton soil properties/ health, and plant growth and humanbeings; soil as sink for waste disposal.

Unit IV

Pesticides–their classification, behaviour in soil and effecton soil microorganisms.

Unit V

Toxic elements–their sources, behaviour in soils, effect on nutrients availability, effect on plant and human health.

Unit VI

Pollution of water resources due to leaching of nutrients and pesticides from soil; emission of green house gases–carbondioxide, methane and nitrous oxide.

Unit VII

Risk assessment of polluted soil, Remediation/ amelioration of contaminated soil and water; remote sensing applications in monitoring and management of soil and water pollution.

VI. Practical

Sampling of sewage waters, sewage sludge, solid/ liquid industrial wastes, polluted soils and plants and their processing, Estimation of dissolved and suspended solids, chemical oxygen demand (COD), biological demand (BOD), measurement of coliform (MPN), nitrate and ammoniacal nitrogen and phosphorus, heavy metal content in effluents, Heavy metals in contaminated soils and plants, Management of contaminants in soil and plants to safe guard food safety, Air sampling and determination of particulate matter and oxides of sulphur, NO_2 and O_2 conc**.** Visit to various industrial sites to study the impact of pollutants on soil and plants.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Management of soil and water pollution

IX. Suggested Reading

- Lal R, Kimble J, Levine E and Stewart BA. 1995. *Soil Management and Greenhouse Effect*. CRC Press.
- Middlebrooks EJ. 1979. *Industrial Pollution Control*. Vol. I. *Agro-Industries*. John Wiley Interscience.
- Ross SM. *Toxic Metals in Soil Plant Systems*. John Wiley & Sons.
- Vesilund PA and Pierce 1983. *Environmental Pollution and Control*. Ann Arbor Science Publ.

I. Course Title : Remote Sensing and GIS Technique for Soil, Water and Crop Studies

II. Course Code : Soil 509

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about the basic concepts of remote sensing, aerial photographs and imageries, and their interpretation; application of remote sensing in general and with special reference to soil, plants and yield forecasting; to impart knowledge about geo-statistical techniques with special reference to krigging, and GIS and applications in agriculture.

V. Theory

Unit I

Introduction and history of remote sensing; sources, propagation of radiations in atmosphere; interactions with matter, basic concepts and principles; hardware and software requirements; common terminologies of geographic information system (GIS)

Unit II

Sensor systems-camera, microwave radio meters and scanners; fundamentals of aerial photographs and multispectral imaging, hyperspectral imaging, thermal imaging; image processing and interpretations.

Unit III

Application of remote sensing techniques-landuse soil surveys, crop stress and yield forecasting, prioritization in watershed and drought management, waste land identification and management.

Unit IV

Significance and sources of the spatial and temporal variability in soils; variability in relation to size of sampling; classical and geo-statistical techniques of evolution of soil variability.

Unit V

Applications of GIS for water resources, agriculture, precision farming, disaster management, e-governance, Agricultural Research Information System (ARIS).

VI. Practical

Familiarization with different remote sensing equipments and data products, Interpretation of aerial photo graphs and satellite data for mapping of land resources, Analysis of variability of different soil properties with classical and geostatistical techniques, Creation of datafiles in a database programme, Use of GIS for soil spatial simulation and analysis, To enable the students to conduct soil survey and interpret soil survey reports in terms of land use planning.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of remote sensing and their utility in research for solving field problem.

IX. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.
- Elangovan K. 2006. *GIS Fundamentals, Applications and Implementations*. New India Publ. Agency.
- Lillesand TM and Kiefer RW. 1994. *Remote Sensing and Image Interpretation*. 3rd Ed. Wiley.
- Nielsen DR and Wendroth O. 2003. *Spatial and Temporal Statis*tics. Catena Verloggmbh.
- Star J and Esles J. 1990. *Geographic Information System: An Introduction*. Prentice Hall.

I. Course Title	:	**Analytical Technique and Instrumental Methods in Soil and Plant Analysis**
II. Course Code	:	**Soil 510**
III. Credit Hours	:	**0+2**

IV. Aim of the course

To familiarize the students with commonly used instruments – their working, preparations of common analytical reagents for qualitative and quantitative analysis of both soil as well as plant samples.

V. Practical

Unit I

Preparation of solutions for standard curves, indicators and standard solutions for acid-base, oxidation reduction and complexometric titration; soil, water and plant sampling techniques, their processing and handling.

Unit II

Determination of nutrient potentials and potential buffering capacities of soils for phosphorus and potassium; estimation of phosphorus, ammonium and potassium fixation capacities of soils.

Unit III

Principles of visible, ultra violet and infrared spectrophotometery, atomic absorption, flame-photometry, inductively coupled plasma spectrometry; chromatographic techniques, mass spectrometry and X-ray defractrometery; identification of minerals by X-ray by different methods, CHNS analyzer.

Unit IV

Electrochemical titration of clays; estimation of exchangeable cations (Na, Ca, Mg, K); estimation of root cation exchange capacity.

Unit V

Wet digestion/fusion/extraction of soil with aquaregia with soil for elemental analysis; triacid/di-acid digestion of plant samples; determination of available and total nutrients (N, P, K, S, Ca, Mg, Zn, Cu, Fe, Mn, B, Mo) in soils; determination of total nutrients (N, P, K, S, Ca, Mg, Zn, Cu, Fe, Mn, B, Mo) in plants

Unit VI

Drawing normalized exchange isotherms; measurement of redox potential.

VI. Teaching methods/activities

Classroom teaching and laboratory practicals

VII. Learning outcome

Development of confidence for setting soil testing laboratory.

VIII. Suggested Reading

- Hesse P. 971. *Textbook of Soil Chemical Analysis*. William Clowes & Sons.
- Jackson ML. 1967. *Soil Chemical Analysis*. Prentice Hall of India.
- Keith A Smith 1991. *Soil Analysis; Modern Instrumental Techniques*. Marcel Dekker.
- Kenneth Helrich 1990. *Official Methods of Analysis*. Association of Official Analytical Chemists.
- Page AL, Miller RH and Keeney DR. 1982. *Methods of Soil Analysis*. Part II. SSSA, Madison.
- Piper CE. *Soil and Plant Analysis*. Hans Publ.
- Singh D, Chhonkar PK and Pandey RN. 1999. *Soil Plant Water Analysis - A Methods Manual*. IARI, New Delhi.
- Tan KH. 2003. *Soil Sampling, Preparation and Analysis*. CRC Press/Taylor & Francis.
- Tandon HLS. 1993. *Methods of Analysis of Soils, Fertilizers and Wat*ers. FDCO, New Delhi.
- Vogel AL. 1979. *A Textbook of Quantitative Inorganic Analysis*. ELBS Longman.

I. Course Title : Management of Problem Soils and Water

II. Course Code : Soil 511

III. Credit Hours : 2+1

IV. Aim of the course

To educate students about basic concepts of problem soils and brackish water, and their management. Attention will be on management of problem soils and safe use of brackish water in relation to crop production.

V. Theory

Unit I

Area and distribution of problem soils–acidic, saline, sodic and physically degraded soils; origin and basic concept of problematic soils, and factors responsible.

Unit II

Morphological features of saline, sodic and saline-sodic soils; characterization of salt-affected soils-soluble salts, ESP, pH; physical, chemical and microbiological properties.

Unit III

Management of salt-affected soils; salt tolerance of crops- mechanism and ratings; salt stress meaning and its effect on crop growth, monitoring of soils alinity in the field; management principles for sandy, clayey, red lateritic and dryland soils.

Unit IV

Acid soils-nature of soil acidity, sources of soil acidity; effect on plant growth, lime requirement of acid soils; management of acid soils; biological sickness of soils and its management.

Unit V

Quality of irrigation water; management of brackish water for irrigation; salt balance under irrigation; characterization of brackish waters, area and extent; relationship in water use and quality.

Unit VI

Agronomic practices in relation to problematic soils; cropping pattern for utilizing poor quality groundwaters.

VI. Practical

Characterization of acid, acid sulfate, salt-affected and calcareous soils, Determination of cations (Na+, K+, Ca++ and Mg++) in groundwater and soil samples, Determination of an ions (Cl^-, SO_4^-, CO_3^- and HCO_{3-}) in ground waters and soil samples, Lime and gypsum requirements of acid and sodic soils.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on solving field problem of problem soil and waters.

IX. Resources

- Bear FE. 1964. *Chemistry of the Soil*. Oxford & IBH.
- Jurinak JJ. 1978. *Salt-affected Soils*. Department of Soil Science & Biometeorology. Utah State University
- USDA Handbook No. 60. 1954. *Diagnosis and improvement of Saline and Alkali Soils*. Oxford & IBH.

I. Course Title : Land Degradation and Restoration

II. Course Code : Soil 512

III. Credit Hours : 1+0

IV. Aim of the course

To impart knowledge related to various factors and processes of land degradation and their restoration techniques.

V. Theory

Unit I

Type, factors and processes of soil/land degradation and its impact on soil productivity including soil fauna, biodegradation and environment.

Unit II

Land restoration and conservation techniques-erosion control, reclamation of salt-affectedsoils; minelandreclamation, afforestation, organic products.

Unit III

Extent, diagnosis and mapping of land degradation by conventional and modern RS-GIS tools; monitoring land degradation by fast assessment, modern tools, land use policy, incentives and participatory approach for reversing land degradation; global issues for twenty first century.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on restoration of degraded soil for optimization of crop yield.

VIII. Suggested Reading

- Biswas TD and Narayanasamy G. (Eds.). 1996. *Soil Management in Relation to Land Degradation and Environment*. Bull. Indian Soc. Soil Sci. 17, New Delhi.
- Doran JW and Jones AJ. 1996. *Methods of Assessing Soil Quality*. Soil Science Society of America, Madison.
- Greenland DJ and Szabolcs I. 1994. *Soil Resilience and Sustainable Land Use*. CABI.
- Lal R, Blum WEH, Vailentine C and Stewart BA. 1997. *Methods for Assessment of Soil Degradation*. CRC Press.
- Sehgal J and Abrol IP. 1994. *Soil Degradation in India - Status and Impact*. Oxford & IBH.

I. Course Title : Soil Survey and Land Use Planning

II. Course Code : Soil 513

III. Credit Hours : 2+0

IV. Aim of the course

To teach the better utilization of land for agricultural purposes, and better management of run-off or surplus/ excessive rain-water in the catchment area for agricultural purposes in a watershed.

V. Theory

Unit I

Soil survey and its types; soil survey techniques- conventional and modern; soil series–characterization and procedure for establishing soil series; benchmark soils and soil correlations; soil survey interpretations; thematic soil maps, cartography, mapping units, techniques for gene ration of soil maps, application of remote sensing and GIS in soil survey and mapping of major soil group of India

Unit II

Landform–soil relationship; major soil groups of India with special reference to respective states; land capability classification and land irrigability classification; land evaluation and land use type (LUT)–concept and application; approaches for managing soils and landscapes in the framework of agro-ecosystem.

Unit III

Concept and techniques of land use planning; factors governing present land use; Land evaluation method sand soil-site suitability evaluation for different crops; land capability classification and constraints in application.

Unit IV

Agro-ecological regions/sub-regions of India and their characteristics in relation to crop production. Status of LUP in India.

VI. Practical

- Aerial photo and satellite data interpretation for soil and land use
- Cartographic techniques for preparation of base maps and thematic maps, processing of field sheets, compilation and obstruction of maps in differentscales
- Land use planning exercises using conventional and RS tools

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, field visit and exposure visit

VIII. Learning outcome

Planning for land use in proper way for higher crop productivity.

IX. Suggested Reading

- Boul SW, Hole ED, MacCraken RJ and Southard RJ. 1997. *Soil Genesis and Classification*. 4th Ed. Panima Publ.
- Brewer R. 1976. *Fabric and Mineral Analysis of Soils*. John Wiley & Sons.

I. Course Title : Introduction to Nanotechnology

II. Course Code : Soil 514

III. Credit Hours : 2+1

IV. Aim of the course

To impart basic knowledge about nanoscience, properties of nanoparticles and their applications in biology

V. Theory

Unit I

General introduction: Basics of quantum mechanics, harmonic oscillator, magnetic phenomena, band structure in solids, Mössbauer effect and spectroscopy, optical phenomena, bond in solids, an isotropy.

Unit II

Nanostructures: growth of compound semiconductors, super lattices, self-assembled quantum dots, nano-particles, nano tubes and nanowires, fullerenes (buckballs, graphene). Nanofabrication and nano-patterning: Optical, X-ray, and electron beam lithography, self-assembled organic layers, process of synthesis of nanopowders, electrode position, important nanomaterials.

Unit III

Mechanical properties, magnetic properties, electrical properties, electronic conduction with nanoparticles, investigating and manipulating materials in the nanoscale: Electron microscopy

Unit IV

Nano-biology: Interaction between biomolecules and nano-particle surface, different types of in organic materials used for the synthesis of hybrid nano-bioassemblies, application of nano-inagriculture, current status of nano-biotechnology, future perspectives of nano-biology, nano-sensors.

VI. Practical

- Sources of nanoparticles and its preparation by different approaches
- Electrospinning and its use in agriculture and allied sector.
- Equipments used in Nanotechnology: its principle and uses
- Acquaintances with different equipments used in nanotechnology.
- Synthesis and characterization of Ag and ZnO nanoparticles.
- Mode of action of ZnO nanoparticles against soil borne diseases
- Study on efficacy of ZnO nanoparticles as seed treating agent on plant growth parameters.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of nano science and their utility in research for solving field problem.

IX. Suggested Reading

- Balandin AA and Wang KL. 2006. *Handbook of semiconductor nano structures and nano devices.* California: American Scientific Publishers.
- Timp G. 1999. *Nanotechnology*. New York: Springer Verlag.
- Challa Kumar SSR. 2006. *Nanotechnologies for the life sciences*. Weinheim: Wiley-VCHGmbH.
- Kohler M and Frintzsche W. 2007. *Nanotechnology: Introduction to nanostructuring techniques* W Weinheim: Wiley-VCH Verlag GmbH.
- Kosal ME. 2009. *Nanotechnology for chemicao and biological defense*. Dordrecht: Stringer.

Course Title with Credit Load
Ph.D. in Soil Science

Course Code	Course Title	Credit Hours
Soil 601	Recent trends in soil physics	2+0
Soil 602	Modern concept in soil fertility	2+0
Soil 603*	Physical chemistry of soil	2+0
Soil 604*	Soil genesis and micromorphology	2+0
Soil 605	Bio-chemistry of soil organic matter	2+0
Soil 606	Soil resource management	3+0
Soil 607	Modelling of soil plant system	2+0
Soil 608	Clay Mineralogy	2+1
Soil 609	Recent trends in soil microbial biodiversity	2+1
Soil 691	Doctoral seminar	1+0
Soil 692	Doctoral seminar	1+0
Soil 699	Doctoral Research	-75

*Indicates Core Courses which are Compulsory for PhD Programme

Course Contents
Ph.D. in Soil Science

I. Course Title : Recent Trends in Soil Physics
II. Course Code : Soil 601
III. Credit Hours : 2+0

IV. Aim of the course

To provide knowledge of modern concept sin soil physics.

V. Theory

Unit I

Soil-water interactions, soil water potential, free energy and thermodynamic basis of potential concept, chemical potential of soil water and entropy of the system, soil-plant-atmospheric continuum (SPAC).

Unit II

Fundamentals of fluid flow, Poiseuilles law, Laplace's equation, Darcy's law in saturated and unsaturated flows; development of differential equations in saturated and unsaturated waterflow, capillary conductivity and diffusivity; limitations of Darcy's law; numerical solution for one dimensional waterflow.

Unit III

Theories of horizontal and vertical infiltration under different boundary conditions.

Unit IV

Movement of salts in soils, models formiscible-immiscible displacement, diffusion, mass flow and dispersion of solutes and their solutions through differential equations; break-through curves.

Unit V

Soil air and aeration, mass flow and diffusion processes; thermal properties of soil, heat transfer in soils, differential equation of heatflow, measurement of thermal conductivity of soil; Soil, Plant, Water relations- Plant uptake of soil moisture, Water balance and energy balance in the field; irrigation and water use efficiency.

Unit VI

Soil crust and clod formation; structural management of puddled rice soils; soil conditioning-concept, soils conditioners-types, characteristics, working principles, significance in agriculture.

Unit VII

Solar and terrestrial radiation measurement, dissipation and distribution in soil-crop systems; prediction of evapotranspiration using aerodynamic and canopy temperature-based models; canopy temperature and leaf diffusion resistance in relation to plant water deficit; evaluation of soil and plant water status using infra-red thermometer.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

VIII. Suggested Reading

- Baver LD, Gardner WH and Gardner WR. 1972. *Soil Physics*. John Wiley & Sons.
- Hanks and Ascheroft. 1980. *Applied Soil Physics*. Springer Verlag.
- Hillel D. 1980. *Applications of Soil Physics*. Academic Press.
- Hillel D. 1980. *Environmental Soil Physic*s. Academic Press.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Kirkham D and Powers WL. 1972. *Advanced Soil Physics*. Wiley Interscience.
- Lal R and Shukla MK. 2004. *Principles of Soil Physics*. Marcel Dekker.
- Oswal MC. 1994. *Soil Physics*. Oxford & IBH.

I. Course Title : Modern Concept in Soil Fertility

II. Course Code : Soil 602

III. Credit Hours : 2+0

IV. Aim of the course

To provide knowledge of modern concepts of soil fertility and nutrient use in crop production.

V. Theory

Unit I

Nutrient availability-concept and relationships, modern concepts of nutrient s availability; soil colloids and nutrient availability; soil amendments and availability maintenance of nutrients, soil solution and plant growth; nutrient response functions and availability indices.

Unit II

Nutrient movement in soils; nutrient absorption by plants; mechanistic approach to nutrient supply and uptake by plants; models for transformation and movement of major micronutrients in soils.

Unit III

Chemical equilibria (including solid-solution equilbria) involving nutrientions in soils, particularly in submerged soils; Kinetic studies of nutrients in soils.

Unit IV

Modern concepts of fertilizer evaluation, nutrient use efficiency and nutrient budgeting.

Unit V

Modernconcepts in fertilizer application; soil fertility evaluation techniques; role of soil tests in fertilizer use recommendations; site-specific nutrient management for precision agriculture.

Unit VI

Monitoring physical, chemical and biological changes in soils; permanent manurial trials and long-term fertilizer experiments; soil productivity under long-term intensive cropping; direct, residual and cumulative effect of fertilizer use.

Unit VII

Carbon– a nutrient central to soil fertility; carbon cycle in nature, stocks, pools and fluxes; greenhouse effect and climate change; carbon sequestration vis-à-vis sustenance of soil quality and crop productivity.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil fertility and fertilizers in relation to plant growth and development.

VIII. Suggested Reading

- Barber SA. 1995. *Soil Nutrient Bioavailability*. John Wiley & Sons.
- Barker V Allen and Pilbeam David J. 2007. *Handbook of Plant Nutrition*. CRC / Taylor & Francis.
- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Educ.
- Cooke GW. 1979. *The Control of Soil Fertility*. Crossby Lockwood & Sons.
- Epstein E. 1987. *Mineral Nutrition of Plants - Principles and Perspectives*. International Potash Institute, Switzerland.
- Kabata- Pendias Alina 2001. *Trace Elements in Soils and Plants*. CRC / Taylor & Francis.
- Kannaiyan S, Kumar K and Govindarajan K. 2004. *Biofertilizers Technolog*y. Scientific Publ.
- Mortvedt JJ, Shuman LM, Cox FR and Welch RM. (Eds.). 1991. *Micronutrients in Agriculture.* 2nd Ed. Soil Science Society of America, Madison.
- Prasad R and Power JF. 1997. *Soil Fertility Management for Sustainable Agriculture*. CRC Press.
- Stevenson FJ and Cole MA. 1999. *Cycles of Soil: Carbon, Nitrogen, Phosphorus, Sulphur, Micronutrients*. John Wiley & Sons.
- Stevenson FJ. (Ed.). 1982. *Nitrogen in Agricultural Soils*. Soil Science Society of America, Madison.
- Tisdale SL, Nelson WL, Beaton JD and Havlin JL. 1990. *Soil Fertility and Fertilizers.* 5th Ed. Macmillan Publ.
- Wild A. (Ed.). 1988. *Russell's Soil Conditions and Plant Growth*. 11th Ed. Longman.

I. Course Title : Physical Chemistry of Soil

II. Course Code : Soil 603

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge about modern concepts of physical chemistry of soils and clays, with emphasis on understanding the processes involved with practical significance.

V. Theory

Unit I

Colloidal chemistry of in organic and organic components of soils–their formation, clay organic interaction.

Unit II

Predictive approaches for cation exchange equilibria- thermodynamics, empirical and diffuse double layer theory (DDL)- relationships among different selectivity coefficients; structure and properties of diffuse double layer.

Unit III

Thermodynamics of nutrient transformations in soils; Climate change effects on minerology and surface properties of variable charge; cationic and anionic exchange and their models, molecular interaction.

Unit IV

Adsorption/desorption isotherms-Langmuir adsorption isotherm, Freundlich adsorption isotherm, normalized exchange isotherm, BET equation; selective and non-selective adsorption of ions on in organic surfaces and organic surfaces of soil materials (citation of utility in agricultural system).

Unit V

Common solubility equilibria-carbonates, ironoxide and hydroxides, aluminum silicate, aluminum phosphate; electrochemical properties of clays (citation of examples from agricultural use).

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil chemical behaviour on research for solving field problems.

VIII. Suggested Reading

- Bear RE. 1964. *Chemistry of the Soil*. Oxford & IBH.
- Bolt GH and Bruggenwert MGM. 1978. *Soil Chemistry*. Elsevier.
- Fried M and Broeshart H. 1967. *Soil Plant System in Relation to Inorganic Nutrition*. Academic Press.
- Greenland DJ and Hayes MHB. 1981. *Chemistry of Soil Processes*. John Wiley & Sons.
- Greenland DJ and Hayes MHB. 1978. *Chemistry of Soil Constituents*. John Wiley & Sons.
- Jurinak JJ. 1978. *Chemistry of Aquatic Systems*. Department of Soil Science and Biometeorology, Utah State University
- McBride MB. 1994. *Environmental Chemistry of Soils*. Oxford University Press.
- Sparks DL. 1999. *Soil Physical Chemistry*. 2nd Ed. CRC Press.
- Sposito G. 1981. *The Thermodynamics of Soil Solutions*. Oxford University Press.
- Sposito G. 1984. *The Surface Chemistry of Soils*. Oxford University Press.
- Sposito G. 1989. *The Chemistry of Soils*. Oxford University Press.
- Stevenson FJ. 1994. *Humus Chemistry*. 2nd Ed. John Wiley.
- van Olphan H. 1977. *Introduction to Clay Colloid Chemistry*. John Wiley & Sons.

I. Course Title : Soil Genesis and Micromorphology

II. Course Code : Soil 604

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge about the pedogenic processes in soils and to acquaint with the micro-pedological study of soil profile.

V. Theory

Unit I

Pedogenic evolution of soils; soil composition and characterization.

Unit II

Weathering and soil formation–factors and pedogenic processes; stability and weathering sequences of minerals.

Unit III

Assessment of soil profile development by mineralogical and chemical analysis.

Unit IV

Micro-pedological features of soils–their structure, fabric analysis, role in genesis and classification.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil micro pedology and soil taxonomy on research for solving field problems.

VIII. Suggested Reading

- Brady NC and Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.
- Buol EW, Hole ED, MacCracken RJ & Southard RJ. 1997. *Soil Genesis and Classification*. 4th Ed. Panima Publ.
- Dixon JB and Weed SB. 1989. *Minerals in Soil Environments*. 2nd Ed. Soil Science Society of America, Madison.
- Grim RE. 1968. *Clay Mineralogy*. McGraw Hill.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Sehgal J. 2002. *Introductory Pedology: Concepts and Applications*. New Delhi
- Sehgal J. 2002. *Pedology - Concepts and Applications*. Kalyani.
- USDA. 1999. *Soil Taxonomy*. Hand Book No. 436. 2nd Ed. USDA NRCS, Washington.
- Wade FA and Mattox RB. 1960. *Elements of Crystallography and Mineralogy*. Oxford & IBH.

I. Course Title : Biochemistry of Soil Organic Matter

II. Course Code : Soil 605

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge related to chemistry and reactions of organic substances and their significance in soils.

V. Theory

Unit I

Organic matter in soils and its maintenance Role of organic matter in soil productivity; humus levels in soils; current thinking on the maintenance of organic matter in the soils. Carbon retention and sequestration.

Unit II

Biochemistry of the humus formation; different pathways for humus synthesis in soil; soil carbohydrates and lipids.

Unit III

Nutrient transformation–N, P, S; tracemetal interaction with humic substances, significance of chelation reactions in soils.

Unit IV

Reactive functional groups of humic substances, adsorption of organic compounds by clay and role of organic substances in pedogenic soil aggregation processes; clay-organic matter complexes.

Unit V

Humus-pesticide interactions in soil, mechanisms.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of soil biochemistry on research for solving field problems.

VIII. Reading Materials

- Lynch JM, Willey JM. *Soil Biotechnology*.
- Paul EA and Clark FE. *Soil Microbiology and Biochemistry*
- Sherwood LM and Woolverton CJ. *Prescott's Microbiology*.
- Subba Rao NS. *Advances In Agricultural Microbiology*

I. Course Title : Soil Resource Management

II. Course Code : Soil 606

III. Credit Hours : 3+0

IV. Aim of the course

To impart the students basic holistic knowledge on soil resource and latest developments in its sustainable use.

Unit I

Relevance of soil management to sustainable agriculture; soil as a natural resource for biomass production, filtering, buffering, transportation of solutes, genereserves, and geogenic source of raw materials; soil as a source and sink of greenhouse gases.

Unit II

Concept of sustainable land management (SLM); spatial variability of soils; soil quality and food security; soil quality indices, conservation agriculture in relation to soil quality; soil resilience and resistance.

Unit III

Types, factors and causes of land degradation and desertification; GLASOD classification; application of GIS and remote sensing in monitoring, diagnosis and mapping land degradation; history, distribution, identification and description of soil erosion problems in India; forms of soil erosion; impact of soil erosion-on-site and off-site effects; strategies for erosion control and conservation; soil conservation in hilly, arid, semiarid, coastal and diaralands. Management of forest, peat and muck soils.

Unit IV

Soil conservation planning; land capability classification; soil conservation in special problem are as such as hilly, arid and semi-arid regions, waterlogged and wetlands; land restoration and conservation techniques–erosion control, reclamation of salt affected soils; mine land reclamation, afforestation, organic products, soil fauna and biodegradation.

Unit V

Watershed management-concept, objectives and approach; water harvesting and recycling; flood control in watershed management; socio-economic aspects of watershed management; case studies in respect to monitoring and evaluation of watersheds.

Unit VI

Agro-ecological regions of India; potentials and constraints of soils of different regions; land evaluation and rationalizing land use, decision support system with relation to land management; national and international soil policy considerations.

V. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VI. Learning outcome

Experience on the knowledge of soil resources on research for solving field problems.

VII. Suggested Reading

- Abrol IP and Dhruvanarayana VV. 1990. *Technology for Wasteland Development*. ICAR, New Delhi.
- Andriesse JP. 1988. *Nature and Management of Tropical Peat Soils*, Soil Resources, FAO Soils Bulletin 59, Management and Conservation Service, Land and Water Development Division, FAO, Rome
- Blackwell, Dent D and Young A. 1981. *Soil Survey and Land Evaluation*. George Allen and Unwin, London.
- Burrough A and McDonnell RK. 1998.*Principles of Geographical Information System*. Oxford University Press.
- Dan Binkley D and Fisher R. 2012. *Ecology and Management of Forest Soils*,4th Edition, Wiley.
- FAO. 1996. *Land Quality Indicators and their Use in Sustainable Agriculture and Rural Development*. FAO Land and Water Bulletin.5. FAO, Rome.
- Faroq M and Siddique K. (Ed.). 2015. *Conservation Agriculture*, Springer Nature, Chennai, India.
- FESL. 1993. *An International Framework for Evaluating Sustainable Land Management, FAO World Soil Resources Report No. 73*, Land Development Division, FAO, Rome.
- ISSS. 1994. *Management of Land and Water Resources for Sustainable Agriculture and Environment*. Diamond Jubilee Symposium Publication, Indian Society of Soil Science, New Delhi.
- Lal R, Blum WEH, Valentine C and Stewart BA. (Editors). 1988. *Methods for Assessment of Soil Degradation*. CRC Press, Boca Raton.
- Mulders MA. 1987. *Remote Sensing in Soil Science*. Elsevier Science Publishers, Amsterdam.
- Sehgal J. 2014. *A Text Book of Pedology Concepts and Application*. Kalyani publishers, New Delhi.
- SSSA 1996. *Methods for Assessing Soil Quality*. SSSA Publication Number 49, Madison, Wisconsin, USA.

I. Course Title : Modelling of Soil Plant System

II. Course Code : Soil 607

III. Credit Hours : 2+0

IV. Aim of the course

To train the students in concepts, methodology, technology and use of systems simulation in soil and crop studies

V. Theory

Unit I

Introduction, terms and definitions; classification of models; Taylor series; numerical methods of differentiation and integration.

Unit II

High level computer language: FORTRAN-its commands and usage; testing and evaluation of model.

Unit III

Description of spatially homogeneous models; K transformation model; nitrogen and phosphorus dynamics in soil.

Unit IV

Spatially heterogeneous models; equation of continuity; Simulation of water flow through soil; Explicit and Explicit-Implicit method; simulation of solute movement through soil with variable moisture flux by explicit-implicit method.

Unit V

Nutrient uptake model: Integration of nutrient movement in soil (mass flow and diffusion) and uptake by plants (Michaelis-Menten kinetics); Nutrient uptake model: Solubility and free ion activity model.

IV. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on soil modelling concept for forecasting productivity

VIII. Suggested Reading

- Datta SC. 2008. *Theory and Principles of Simulation Modeling in Soil-Plant System*. Capital Publishing Company, New Delhi.
- Frame J and Thornley JHM. 1984. *Mathematical Models in Agriculture—A Quantitative approach to problems in agriculture and related science*. Butterworth and Co. Ltd.
- Freud PJ and Minton PD. 1979. *Regression Methods—A tool for data Analysis*. Marcel Dekker Inc., New York.
- Frissel MJ and Reinger P. 1974. *Simulation of Accumulation and Leaching in Sils*. Oxford and IBM Pub. Co., New Delhi.
- Hanks J and Richie JT. (Eds.). 1991. *Modeling Plant and Soil System*. Agronomy Bulletin No. 31, ASA, SSSA Madison, Wisconsin, USA.
- Lipschutz S and Poe A. 1978. *Schaum's Outline Series–Theory and Problems of programming with Fortran*. McGraw-Hill Book Co., Singapore.
- Penning de Vries FWT, Jansen DM, Ten Berge HFM and Baker A. 1989. *Simulation of ecophysiological processes of growth in several annual crops*. PUDOC, Wageningen.
- Shaffer MJ, Ma L and Hansen S. 2001. *Modeling Carbon and Nitrogen Dynamics for Soil Management*. Lewis Publishers, Boca Raton.

I. Course Title : Clay Mineralogy

II. Course Code : Soil 608

III. Credit Hours : 2+1

IV. Theory

Unit I

Definition and concepts of clays and clay minerals, Fundamentals of crystallography – unit cell, external characteristics of crystals, crystallographic notations, crystal systems.

Unit II

Structures and classification of silicate minerals, basics of phyllosilicates, laws governing structural characteristics of phyllosilicates, Goldschmitdt's laws – Laws I and Law II, Classification of Phyllosilicates.

Unit III

Kaolonite group of minerals, Dioctahedral kaolins and Trioctahedral kaolins.

Unit IV

Smectites; properties of smectites, Reference models of structure, principal types based on Hofmann-Marshal-Hendricks (H-M-H) models, occurrence of smectites, transformation and formation in soils.

Unit V

Micas: occurrence and origin in soils, polytypes of micas, structure and formation of muscovites and illite.

Unit VI

Vermicullites: structure, occurrence in soils, formation, relation between vermiculites and montmorillonite.

Unit VII

Chlorite: occurrence and structure of chlorites, "swelling chlorites", formation of chlorite.

Unit VIII

Non-crystalline clays (amorphous materials), subgroups and chemical composition, morphology and structure, physico-chemical properties, influence of non-crystalline clays on soil properties.

Unit IX

Interstratified clay minerals, occurrence and formation in soils, regularly interstratified and partially random interstratified minerals.

Unit X

Genesis and transformation of clay minerals, Generalized conditions for formation and persistence of common clay-size minerals in soils.

Unit XI

Surface chemistry of clay minerals, clay-organic complexes, nanoclay mineralogy.

Unit XII

Clay minerals in different soil orders, role of clay minerals in soil fertility management.

V. Practicals

- Separation of clay for mineralogical study
- X-ray diffraction analysis of clay
- Selective dissolution of clay minerals
- IR, DTA and SEM of clay minerals
- Identification and quantification of clay minerals
- Determination of surface charge of clay minerals
- Potentiometric titration of clay minerals.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on soil clays and utility in soil research.

VIII. Suggested Reading

- Dixon JB and Weed SB (Co-editors). *Minerals in Soil Environment.*
- Gieseking JE (Ed). *Soil Component*, Vol. 2. Inorganic Components.
- Grim RE. *Clay Mineralogy*.
- Mukherjee SK and Biswas TD (Editors). *Mineralogy of Soil Clays and Clay Minerals.*
- Read HH. *Rutley's Elements of Mineralogy.*
- Wilding LP and Smeck NE. 1983. *Pedogenesis and Soil Taxonomy Part II – Soil Orders.*

I. Course Title : Recent Trends in Soil Microbial Biodiversity

II. Course Code : Soil 609

III. Credit Hours : 2+1

IV. Theory

Unit I

Microbial evaluation and biodiversity, Microbial communities in ecosystems, New insights in below ground diverse of plant performance.

Unit II

Qualitative ecology of microorganisms; Biomass and activities.

Unit III

Nitrogen fixing organisms, Trends in diversity of N fixing organisms. Molecular approaches in characterising N fixing microorganisms.

Unit IV

Serology and molecular characterization, ecological aspects of bio determination, soil waste and water management

Unit V

Biodegradability, testing and monitoring of the bioremediation of xerobiotic pollutants and bacterial fertilizers.

V. Practicals

- Determination of soil microbes using classical techniques.
- Determination of soil microbial diversity using molecular techniques.
- Estimation of soil microbial biomass carbon, nitrogen and phosphorus.
- Estimation of key soil enzyme activities.
- Community level physiological profiling of microbial diversity.

VI. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, field visit

VII. Learning outcome

Experience on soil microbial diversity and planning for proper utilization.

VIII. Suggested Reading

- Lynch JM, Willey JM. *Soil Biotechnology*.
- Paul EA and Clark FE. *Soil Microbiology and Biochemistry*.
- Sherwood LM and Woolverton CJ. *Prescott's Microbiology*.
- Subba Rao NS. *Advances In Agricultural Microbiology*.

I. Course Title : Research and Publication Ethics

II. Course Code : Soil 610

III. Credit Hours : 2+0

IV. Theory

Unit I

Introduction to philosophy: definition, nature and scope, concept, branches

Unit II

Ethics: definition, moral philosophy, nature of moral judgements and reactions

Unit III

Scientific conduct: Ethics with respect to science and research, intellectual honesty and research integrity, Scientific misconducts- falsifications, fabrications and plagiarism (FFP): Redundant publications: duplicate and overlapping publications, salami slicing; selective reporting and misrepresentation of data

Unit IV

Publication ethics: Defination, introduction and importance. Best practices/standard setting initiatives and guidelines: COPE, WAME, *etc*., conflicts of interest. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, type, violation of publication ethics, authorship and contributorship, Identification of publication misconduct, complaints and appeals, predatory publishers and journals

Unit V

Open access publishing: open access publication and initiatives: SHERPA, RoMEO online resource to check publisher copy right and self archiving policies; software tool to identify predatory publications developed by SPPU, Journal finder/journal suggestions tools, viz., JANE, Elsevier Journal Finder, Springer Journal Suggester etc.

Unit VI

Publication misconduct: Group discussions- subject specific ethical issues, FFP, authorship, conflicts of interest, complaints and appeals examples and fraud from India and abroad. Software tools: Use of plagiarism software like Turnitin, Urkund and other open source software tools

Unit VII

Database and Research metrics: Indexing data base, citation database, web of science, scopus, *etc*. Impact factor of journal as per journal citation report, SNIP, SJR, IPP, Cite Score; Metrics: h-index, g index, i10 index altmetrics

V. Teaching methods/activities

Classroom teaching with AV aids, group discussion, field, laboratory and library visit

VI. Learning outcome

Quality research output and outstanding research publication with excellent impact factor.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Physical Sciences
– Agricultural Physics

Preamble

Agricultural Physics is the discipline dealing with the application of the Principles and laws of Physics in agriculture to study soil, plant and atmosphere for eco-friendly and sustainable exploitation of agricultural resources. Considering the recent advancement of knowledge and the need to make our students to be well aware of the recent developments in Science the syllabi for the discipline of Agricultural Physics was modified. Agricultural Physics is gaining importance in view of its potential to serve as a tool to solve the challenges of feeding a growing population, providing a livelihood for farmers, and protecting the environment. The need for Agricultural Physics as a discipline in M.Sc. and Ph.D. program is emphasized due to the recent applications in crop modelling as a decision tool, satellite remote sensing based near real time crop condition monitoring, drone-based crop disease, pest surveillance, digital soil mapping, artificial intelligence based crop status characterization through image processing, nano biosensors for quick and effective detection and management of crop requirement, etc. This could be possible in future, by starting the M.Sc. and Ph.D. programs in the discipline of Agricultural Physics in all the state agricultural universities and research institutions of ICAR.

In the present syllabus emphasis on knowledge enrichment through field-based studies in the discipline of Agricultural Physics is made by introducing new courses on Satellite Meteorology, Nanotechnology, Image processing and development of sensors for Soil, Crop and Environment Monitoring in agriculture. In view of the various national program like Fasal Bhima Yojana the new modified syllabus for the Agricultural Physics include course content on Remote sensing for crop status monitoring, biomass burning, crop acreage and harvest etc. Similarly, in view of the various Government scheme like Soil Health Card, more crop per drop, etc. Our modified syllabus includes topics on Digital soil mapping, Farmers' participatory GIS, Nanobiosensors for monitoring crop irrigation, fertigation, etc. As per the under New Education Policy 2020, the present syllabus will ensure the students of Agricultural Physics discipline to become holistic individuals with identified set of skillsand values.

The modified syllabus with courses on Physics of Soil and Water Conservation, Fundamentals of Meteorology, General Climatology, Sensors for Soil, Crop and Environment Monitoring and Weather Hazards and its Management are related to the global developments to meet the triple challenges of feeding the growing global population, providing a livelihood for farmers, and protecting the environment. With the rise in the requirement for Biophysics, Remote sensing, nanotechnology, crop simulation modelling, biosensors, big data analytics artificial intelligence, etc. students of the discipline of Agricultural Physics will be a skilled work force as they will have the blend of multidisciplinary ability across the different disciplines of agricultural sciences.

Course Title with Credit Load
M.Sc. in Agricultural Physics

Course Code	Course Title	Credit Hours
AP 501*	Basic Concepts of Agricultural Physics -I	2+1
AP 502*	Basic Concepts of Agricultural Physics -II	3+0
AP 503	Fundamentals of Soil Physics	2+1
AP 504*	Mathematics in Agriculture	3+0
AP 505	Fundamentals of Meteorology	2+1
AP 506*	Principles of Biophysics	2+1
AP 507	Principles of Remote Sensing	2+1
AP 508	Physics of Soil and Water Conservation	2+1
AP 509	General Climatology	2+1
AP 510	Soil Physical Environment and Plant growth	2+1
AP 511	Simulation of Soil, Plant and Atmospheric Processes	2+1
AP 512	Principles of Physical techniques in agriculture	2+1
AP 513	Principles and Applications of GIS and GPS	2+1
AP 514	Nanoscience and Technology for Agriculture	2+0
AP 515	Remote Sensing in Agriculture	2+1
AP 591	Master's Seminar	1+0
AP 599	Master's Research	30

*the core courses compulsorily to be taken

Course Contents
M.Sc. in Agricultural Physics

I. Course Title : Basic Concepts of Agricultural Physics-I

II. Course Code : AP 501*

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on the concepts of Agricultural Physics and physics laws.

V. Theory

Unit I

Relevance of Linear, circular, relative motions, conservation of mass, energy and momentum, forces in nature, range of their operation, action at a distance, gravitational field, potential, in agriculture.

Unit II

Concepts of Elasticity, stress-strain relations – moduli of elasticity, Hooke's law, molecular and structural basis of strengths of materials, hydrostatic pressure; surface tension, capillary rise, contact angle, hydrodynamics – laminar and streamline flow, Poiseuille's equation, Stoke's law and their application in agriculture.

Unit III

Principles of Thermometry, measurement of heat, specific heat, transfer of heat - conduction, convection and radiation, Change of phase, equation of state, vapour pressure and relative humidity, laws of thermodynamics, free energy, chemical potential along with their importance in agriculture.

Unit IV

Concepts of Kinetic theory of gases, Brownian motion, mean free path, simple harmonic motion, concepts of phase, phase difference, interference and reflection of sound waves, ultrasonic, along with their relevance in agriculture.

Unit V

Agricultural significance of Wave theory of light, Huygen's principle, reflection, refraction, diffraction, polarization, interference and scattering of light waves; electromagnetic theory of light, geometrical optics, aberrations, resolving power, principles of optical instruments, illuminated and luminous objects and light sources; luminescence, incandescence, fluorescence, auto-fluorescence, phosphorescence, bioluminescence, qualitative and quantitative measurement of light, colour, optical spectrometry.

Unit VI

Principles of Electric charges, potential, field, intensity and strength of electric field, current, Coulomb's law, dielectrics, capacitance, electrostatic units, resistance, resistivity, Ohm's law, steady currents in conductors, insulators and semi-conductors, magnetic materials, induced magnetism, electromagnetism, measurement of magnetic field, geomagnetism, effects of the earth's magnetic field on life, electromagnetic inductions and applications in agriculture

VI. Practical

Use of the instruments in agriculture: Vernier/ Screw Gauge/ Spherometer, Sextant, Surface Tension, Viscosity, Interference Phenomenon, Optical Instruments (diffraction grating), Resistivity measurement (Potentiometer/ Wheatstone bridge), Young's Modulus.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge ofprinciples and loaws of Physics and their application in agriculture

IX. Suggested Reading

- Rose CW, Ashhurst W, Flint HT. (Eds). 1966 *Agricultural Physics*. ISBN: 9781483139258, p. 248.
- Halliday D, Resnick R, Walker J. *Fundamentals of Physics.*
- Young HD, Freedman RA. *University Physics with Modern Physics.*
- Feynman RP, Leighton RB and Sands M. *The Feynman Lectures on Physics*
- Kittel C, Knight W and Ruderman MA. *Berkeley physics course: Mechanics* Vol. 1.
- Purcell EM. *Berkeley physics course: Electricity and Magnetism*, Vol. II.
- Crawford FS, Jr. *Berkeley physics course: Waves.* Vol. III
- Krishna R. 1960. *General Properties of Matter*, Kitab Mahal, Allahabad.
- Mathur DS. 1956. *Elements of Properties of Matter*, S Chand & Co, New Delhi.
- Sengupta PC and Kohli BS. 1967. *Text Book of Physics*, Vol I, II, Kitab Ghar, New Delhi.

I. Course Title : Basic Concepts of Agricultural Physics-II

II. Course Code : AP 502*

III. Credit Hours : 3+0

IV. Aim of the course

To impart knowledge on the concepts of Agricultural Physics and physics laws.

V. Theory

Unit I

Agricultural relevance of Maxwell's theory of electromagnetism, Atomic structure, Avogadro hypothesis and molecules, Atomic and molecular weights, atomic sizes, Quantum mechanics: uncertainty principle, De-Broglie hypothesis, Wave function, Eigen state, Schrodinger equation.

Unit II

Principles of Spectroscopy: atomic and molecular spectra, Spectroscopy: atomic and molecular spectra, Cathode rays; positive rays; Radio activity; alpha-, beta-, and gamma-rays; Rutherford's theory of the scattering of alpha particles; X-rays, nature and properties; scattering of X-rays by atoms; Diffraction of X-rays and Bragg's law; characteristic X-ray spectra.

Unit III

Principles of Quantum theory in agriculture: Planck's quantum theory of thermal radiation; Quantum theory and Photo-electric effect; Elements of special theory of relativity, Atomic Nucleus and its constitution, Angular momentum of the nucleus; Nuclear transmutation of elements; proton-neutron hypothesis; Cosmic rays; elementary particles.

Unit IV

Radioactivity in agriculture: Natural radioactivity, types of radiations Interaction of radiation with matter and decay; Isotopes; isotopic masses and abundances; mass spectrograph; Stable isotopes; atomic masses, packing fractions & binding energy, Theory of radioactive disintegration; half-life and mean life; Mass spectrometers

Unit V

Application of radioactivity in agriculture: Nuclear fission, fusion, Nuclear reactions, neutron moderation, Nuclear energy, atomic power; Production of artificial isotope. Physical principles of Radiation detection; Types of radiation detectors; efficiency of detectors; Uses of radiation detectors, Elements of radioactive sources, handling, Radiation protection and cardinal principles of radiation safety.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge ofphysics and its application in soil, plant and atmospheric continuum.

VIII. Suggested Reading

- Chandrasekharan H and Gupta N. 2006. *Fundamentals of Nuclear Science: Application in Agriculture*, Northern Book Centre, New Delhi.
- David H, Robert R, Jearl W. *Fundamentals of Physics*
- Young HD, Freedman RA. *University Physics with Modern Physics*
- Feynman RP, Leighton RB and Sands M. *The Feynman Lectures on Physics*
- Wichmann EH. *Berkeley physics course: Quantum physics.* Vol IV
- Slater John C. 1960. *Quantum Theory of Atomic Structure*, Vol.1, McGraw Hill, New York.
- Burcham E. 1995. *Nuclear Physics*, ELBS/Longman.
- Kapoor SS and Ramamurthy VS. 1986. *Nuclear Radiation Detectors*, Wiley Eastern Ltd, New Delhi.
- Pochin E. 1983. *Nuclear Radiation: Risks and Benefits*, Clarendon Press, Oxford.
- Rajam JB. 2000. *Atomic Physics*, S Chand and Co, New Delhi.
- Any Graduate level Text book of Physics, Lecture notes/hand-outs given in selected classes

I. Course Title : Fundamentals of Soil Physics

II. Course Code : AP 503

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge (both theoretical and practical) of the physical aspects of the soil and explains the processes of retention and transport of water, solute, heat and air in soil and their role for its proper management.

V. Theory

Unit I

Soil as a disperse polyphase system; mass-volume relationships of soil constituents; sample problems.

Unit II

Soil texture; nature and behaviour of soil particles; textural classes; particle-size analysis.

Unit III

Soil structure- genesis, classification and evaluation; soil aggregation and dispersion; soil conditioners; soil tilth.

Unit IV

Consistency; consistency limits; soil strength and its measurement; swelling and shrinkage; soil compaction; soil crusting; phenomenon and implications.

Unit V

Soil water retention; soil water constants; energy concept of soil water; different components of soil water potential; measurement of soil water content and potential; soil moisture characteristics; hysteresis.

Unit VI

Flow of water in soils; saturated and unsaturated flow; hydraulic conductivity of soils; soil-water diffusivity; measurement of saturated and unsaturated hydraulic conductivity.

Unit VII

Infiltration, redistribution and evaporation of water; soil water balance; permeability; drainage.

Unit VIII

Soil aeration and its characterization; measurement of soil aeration; gaseous diffusion; factors affecting.

Unit IX

Soil temperature and significance; thermal properties of soils; energy balance and mode of heat transfer in soils; factors affecting soil temperature; measurement of soil temperature; management of extreme soil temperatures.

VI. Practical

- Particle-size analysis by hydrometer method and international pipette method
- Determination of particle density and bulk density of soils
- Soil water content determination
- Measurement of soil water potential by using tensiometer
- Soil-moisture characteristics
- Aggregate analysis by wet and dry sieving methods
- Measurement of Atterberg limits
- Measurement of soil strength
- Determination of saturated and unsaturated hydraulic conductivity
- Determination of infiltration rates

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

IX. Suggested Reading

- Baruah TC and Barthakur HP. 2001. *Textbook of Soil Analysis*. Vikas Publishing House Pvt. Ltd, New Delhi.
- Ghildyal BP and Tripathi RP. 1987. *Soil Physics*. Wiley Eastern and New Age International, New Delhi.
- Hillel D. 1980. *Applications of Soil Physics*. Academic Press, New York.
- Hillel D. 1998. *Environmental Physics*, Academic Press, New York.
- Jury WA, Gardner W and Horton R. 2004. *Soil Physics*. John Wiley and Sons, New York.
- Klute A. (Ed). 2006. *Methods of Soil Analysis*. Part 1. *Physical and Minerological Methods* (SSSA Book Series No. 5), ASA and SSSA, Madison, Wisconsin.
- Lal R and Shukla MK. 2004. *Principles of Soil Physics*, Marcel Dekker, New York.
- Warrick AW. (Ed). 2002. *Soil Physics Companion*, CRC Press, Boca Raton.

I. Course Title : Mathematics in Agriculture

II. Course Code : AP 504*

III. Credit Hours : 3+0

IV. Aim of the course

To impart the theoretical and practical knowledge of mathematical concept in agriculture.

V. Theory

Unit I

Vectors, matrices and determinants, inversion of matrices, Eigen values and Eigen vectors, Orthogonality, Grahm-Schmidt processes, least square problems.

Unit II

Trigonometric functions and relations.

Unit III

Differentiation, Integration, Integration, applications, linear equations, Non-linear equations, Polynomials, Partial differential equations.

Unit IV

System of coordinates, Cartesian, cylindrical, spherical and polar coordinates, Three-dimensional geometry, Relative motion of frame of reference.

Unit V

Probability, probability distributions and applications, Curve fitting, Regression, Correlation, Linear and non-linear.

Unit VI

Geo-statistics, Averaging and scaling methods, Fourier analysis, Numerical approximation, Numerical analysis, finite element method, Monte carlo analysis, Stochastic methods, Iterative and optimal techniques.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Experience on the knowledge of mathematics in developing models in relation to plant growth, soil dynamics and atmospheric processes.

VIII. Suggested Reading

- Pal SK. *Statistics for Geoscientist-Techniques and application*
- Reddick HW. *Advanced Mathematics for Engineers*
- Ray M and Sharma HS. *Mathematical statistics*
- Wylie CR. *Advanced Engineering Mathematics*

I. Course Title : Fundamentals of Meteorology

II. Course Code : AP 505

III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical and practical knowledge about basic physical processes in the atmosphere which have direct and indirect relevance to agriculture.

V. Theory

Unit I

Atmosphere and its constituents, weather and climate; meteorology- meaning and scope; historical development; meteorological elements, instruments for measurement of meteorological elements; different branches of meteorology.

Unit II

Meteorological observatory and its classes; theory and working principles of surface meteorological instruments; automatic weather station; meteorological organizations – IMD, NCMRWF, IITM, WMO.

Unit III

Sun and earth; solar radiation and Laws of radiations-Plancks law, Stefan-Boltzman Law, Wiens displacement law, Kirchoffs law, solar constant; radiation receipt on earth surface; atmospheric and astronomical factors affecting solar radiation; ozone hole; albedo and net radiation sensible and latent heat, direct and diffuse radiation; radiation balance of the earth and atmosphere.

Unit IV

Thermal profile of the atmosphere; variation of pressure with height; hydrostatic equation and its application in atmosphere; geopotential, standard atmosphere, altimetry; concept of specific heat at constant volume and pressure; First and second law of thermodynamics, gas laws.

Unit V

Atmospheric moisture, vapour pressure, relative humidity, absolute humidity, specific humidity, mixing ratio, dew point temperature, vapour pressure deficit, psychromatric equations, T-phi diagram; lapse rates; Vertical stability of atmosphere, Virtual and potential temperature, moist and dry adiabatic process; tropical convection.

Unit VI

Atmospheric motion; balancing forces- pressure gradient and Coriolis forces; isobar; pressure systems; geostrophic, cyclostrophic, thermal and gradient winds; trough, ridge and col; Divergence and vertical motion Rossby, Richardson, Reynolds and Froude numbers.

Unit VII

Cyclonic and anticyclonic motions, tropical and extra-tropical cyclones and their structure, cyclone tracks over Indian regions; Air masses and fronts; Land and sea breeze; Mountain and valley winds.

Unit VIII

Clouds and their classification, theories of cloud formation, condensation nuclei, precipitation processes; artificial rain making, thunderstorms and dust storms; haze, mist, fog and dew, hail, hail suppression, fog and cloud – dissipation.

Unit IX

Weather charts and its reading, weather forecasting – now-cast, short, medium and long-range forecasting, numerical weather prediction; synoptic charts and synoptic approach to weather forecasting. Meteorological satellites for weather forecasts; forecast of Indian monsoon rainfall.

VI. Practical

- Visit to meteorological observatory; meteorological instruments, Recording of weather parameters;
- Calculation of daily, weekly and monthly statistics;
- Exploration of meteorological websites – IMD, NCMRWF, IITM and WMO;
- Calculation of standard meteorological weeks and Julian days;
- Visual classification of clouds;
- Understanding synoptic weather charts;
- Climatic normal, climatic chart and identification of low and high pressure systems.

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Basic knowledge on meteorology and climatology, physical laws governing atmosphere and monsoon

X. Suggested Reading

- Barry RG and Chorley RJ. 1982. *Atmosphere Weather and Climate*. ELBS (UK).
- Byers HR. 1959. *General Meteorology*. McGraw Hill (New York).
- Ghadekar SR. 2001. *Meteorology*. Agromet Publishers (Nagpur)
- Ghadekar SR. 2002. *Practical Meteorology*. Agromet Publishers (Nagpur).
- Menon PA. 1989. *Our Weather*. NBT (New Delhi).
- Petterssen S. 1958. *Introduction to Meteorology*. McGraw Hill (New York).
- Trewartha GT. 1954. *An Introduction to Climate*. McGraw Hill (New York).

I. Course Title : Principles of Biophysics

II. Course Code : AP 506*

III. Credit Hours : 2+1

IV. Aim of the course

To impart theoretical and practical knowledge of interactive effects of various physical forces on life processes and their applications.

V. Theory

Unit I

Introduction and scope of biophysics, Weak and strong interactions in biological systems, Structure and property of water, Physical, chemical and biological origin of life

Unit II

Experimental techniques used for separation and characterization of bio-molecules: sedimentation, ultra-centrifugation, diffusion, osmosis, viscosity, polarization and electrophoresis, chromatography, amino acid and nucleotide sequence analysis.

Unit III

Spectroscopic techniques for bio-molecular characterization: UV-Visible, IR, NMR, EPR spectroscopy, X-ray diffraction & its application in biology

Unit IV

Physics of photosynthesis, transpiration, chlorophyll fluorescence, principles of thermal and fluorescence imaging and its application in agriculture

Unit V

Principles of magnetic seed treatment and its application in agriculture, Transport phenomena in biological systems, active and passive transport; absorption and germination kinetics of seeds, tissue water status and its characterization by NMR, principles of NIR and its application in non-destructive characterization of grain quality

Unit VI

Fiber physics; strength, physical properties, micronaire, elastic properties, tensile strength, thermal resistance, water absorption, breaking, elongation, crystallinity

Unit VII

Bio-energetic- First and second laws of thermodynamics- Heat, work, entropy and free energy, Concept of negative entropy & its application in living systems; Information theory.

VI. Practical

- Spectroscopy-Verification of Beer-Lambert's law;
- Spectroscopy-Absorption spectrum of chlorophyll a & b;
- Viscometer-Measurement of intrinsic viscosity and molecular mass;
- Polarimeter-Measurement of molar rotation;
- Measurement of leaf water potential;
- Measurement of Osmotic potential of seed;
- NMR spectroscopy- Relaxation time measurements, NMR Spectroscopy oil content measurement;
- Leaf Photosynthesis, Measurement of LAI.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Basic knowledge on biological parameters in relation to crop development and yield

IX. Suggested Reading

- Cotterill RMJ. 2002. *Biophysics- An Introduction*, John Wiley & Sons, Ltd.
- Daniel M. 2005. Agrobios. *Basic Biophysics for Biologists.*
- Narayanan P. 2003. *Essentials of Biophysics* New Age International Publishers.
- van Holde KE, Johnson WC and P Shing Ho. 2006. *Principles of Physical Biochemistry.* Printice-Hall International, Inc.
- Wilson K and Walker J. *Practical Biochemistry-Principles and Techniques* Cambridge University Press.

I. **Course Title** : **Principles of Remote Sensing**

II. **Course Code** : **AP 507**

III. **Credit Hours** : **2+1**

IV. **Aim of the course**

To teach about basic principles and techniques of remote sensing and introduce its applications.

V. **Theory**

Unit I

Introduction, electromagnetic radiation, electromagnetic spectrum, physics of remote sensing, radiation interactions with the atmosphere and target, radiometric quantities, BRDF/BRF, remote sensing systems, characteristics of images

Unit II

Platforms, orbits, classification of sensors, satellite characteristics, pixel size, and scale, spectral, radiometric and temporal resolution

Unit III

Spectral signatures of natural targets in optical and thermal regions, physical basis of signatures, spectral indices.

Unit IV

Imaging and nonimaging systems, multispectral imaging, hyperspectral imaging, thermal imaging, microwave and LIDAR, Fluorescence imaging, aerial remote sensing

Unit V

Weather, land, ocean and other observation satellites, Indian remote sensing satellites, data reception, data products

Unit VI

Thermal remote sensing: Principles, signature, measurements, IR detection and imaging technology

Unit VI

Microwave remote sensing: principles, signatures, interferometry, radar basics, viewing geometry and spatial resolution, image distortion, target interaction, image properties.

Unit VII

Image analysis: Visual interpretation, digital image processing, pre-processing, enhancement, transformations, classification, accuracy, integration, processing of multispectral, hyperspectral, thermal and microwave images.

Unit VIII

Overview of remote sensing applications in earth resource management: agriculture, meteorology, forestry, land cover/land use, water resources

VI. **Practical**

- Use of Spectroradiometer, Use of FTIR, Spectral signatures of different materials; Derivation and analysis of vegetation indices;
- Analysis of emissivity spectra;
- Familiarization with satellite imagery (FCC);

- Visual Image Interpretation;
- Satellite data acquisition and satellite Data Receiving Station;
- Digital Image processing – Introduction to software, GPS and Ground truth Collection;
- Digital image processing: Pre-processing, Enhancement and training site collection, classification and Post Classification Accuracy Assessment.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of remote sensing and their utility in research for solving field problem.

IX. Suggested Reading

- Campbell JB. 1996. *Introduction to Remote Sensing*, 2nd ed., The Guilford Press, New York.
- Colwell RN. (Ed.) 1983. *Manual of Remote Sensing*, Vol.I, American Society of Photogrammetry, Falls Church, Va.
- Curran PJ. 1985. *Principles of Remote Sensing*, Longman, London.
- David L Verbyla. 1995. *Satellite Remote Sensing of Natural Resources*, Lewis Pub.
- George Joseph. 2005. *Fundamentals of Remote Sensing*, 2nd ed., University Press.
- Jansen JR. 2004. *Introductory Digital Image Processing: A Remote Sensing Perspective*, 3rd ed., Prentice Hall.
- Lilisand TM, Kiefer RW and Chipman JW. 2003. *Remote Sensing and Image Interpretation*, 5th ed., John Wiley & Sons, Inc., New York.
- Panda BC. 2008. *Principles and Applications of Remote Sensing*, Viva Publications.
- Sabins FF. 1996. *Remote Sensing: Principles and Interpretations*, 3rd ed., W.H. Freeman.

I. Course Title : Physics of Soil and Water Conservation

II. Course Code : AP 508

III. Credit Hours : 2+1

IV. Aim of the course

To teach about extent and significance of different forms of soil erosion and their control measures.

V. Theory

Unit I

History of soil erosion; geological and accelerated erosion; agents of soil erosion; acceptable limits of soil erosion.

Unit II

Physics of soil erosion by water; types of water erosion - sheet erosion, splash erosion, rill erosion, gully erosion; specialized forms of soil erosion- pedestal erosion, pinnacle erosion, piping, slumping.

Unit III

Soil erodibility; factors affecting soil erodibility - soil physical characteristics, land management, crop management; soil erodibility indices; empirical constants.

Unit IV

Rainfall erosivity; estimation of rainfall erosivity - EI_{30}index and kinetic energy, and their calculations; erosivity indices.

Unit V

Runoff measurements – current meters, flumes, weirs and orifice, stage level recorder, hydrographs; runoff estimation - quantities and rates of runoff, Rational formula, Cook's method.

Unit VI

Sediment measurement - multiplot divisor, Coshocton wheel sampler, point and depth integrated sediment samplers; universal soil loss equation; estimation of soil loss and its prediction.

Unit VII

Physics of wind erosion - wind velocity, initiation and movement of soil particles; saltation, suspension and surface creep; soil physical properties affecting wind erosion.

Unit VIII

Overview of soil and water conservation in India; soil and water conservation research; techniques for soil and water conservation for agricultural and non-agricultural land - use of mechanical structures and biological methods; wind erosion control.

Unit IX

Concept of watershed development and management - size and shape of watershed; characterization and management of watersheds using remote sensing and GIS; understanding concept of integrated watershed management through case studies.

VI. Practical

- Determination of soil erodibility indices - suspension percentage, dispersion ratio, erosion ratio, clay ratio, clay/moisture equivalent ratio, percolation ratio, raindrop erodibility index; computation of kinetic energy of falling rain drops
- Measurement of land slope using Abney's level
- Computation of rainfall erosivity index (EI_{30}) using rain gauge data
- Estimation of surface runoff/water flow using different techniques
- Estimation of soil losses
- Visit to a watershed

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil water environment and their utilization in crop growth

IX. Suggested Reading

- Fangmeier DD, Elliot WF, Wookman SR, Huffman RL and Schwab GO. 2006. *Soil and Water Conservation Engineering*. Delmer Learning.
- Flanagan DC. (Ed.). 1990. *WEPP* Second Edition, USDA-Water Erosion Prediction Project; Hill Slope Profile Model Documentation Corrections and Additions. NSERL Rpt. No. 4. National Soil Erosion Res. Services, USDA.
- Hudson N. 1995. *Soil Conservation*. Iowa State University Press.
- Pierce FJ and Frge WW. 1998. *Advances in Soil and Water Conservation*. CRC Press.
- Renald KG, Foster GR, Weesies GA, Cool DK and Yoder DC. 2000. *Predictory Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)*. Agricultural Handbook AH 703. USDA.

- Singh G, Babu R and Chandra S. 1981. *Soil Loss Prediction Research in India*. Central Soil and Water Conservation Research and Training Institute, Dehradun. Bull. No. T12/D9.

I. Course Title : General Climatology

II. Course Course : AP 509

III. Credit Hours : 2+1

IV. Aim of the course

To learn about the climatic controls, climatic classifications, and their relevance in agriculture

V. Theory

Unit I

Sun and earth, solar system, solar constant; latitudes and longitudes of the earth, seasons, rotation and revolution, solstices and equinoxes, radiation receipt on earth surface, radiation balance of the earth and atmosphere.

Unit II

Earth's environment- atmosphere, hydrosphere, lithosphere and biosphere: Atmospheric constituents: Weather and climate- weather and climatic elements.

Unit III

Climatic controls, latitudinal and seasonal variation of insolation, temperature, pressure belts & wind system, precipitation.

Unit IV

Climatic classification: Koppen and Thornthwaite systems, Hargreaves, Troll, Trewartha and Papadakis systems. Climatic types- continental, maritime and monsoon climate; climatic indices, climatic zones.

Unit V

Climatology of India; monsoons -origin, branches onset, progress and withdrawal of south-west monsoon monsoon breaks, rainfall variability; El Nino, La Nina, QBO (quasi-biennial oscillation) and ENSO and their impacts on Indian economy. North-east monsoon. North- western disturbances and nor 'wester shower.

Unit VI

Climate change and global warming, disastrous weather and climatic events in different regions and their frequencies. Heat & cold wave, frost, dust storm, lightning & thunderstorm, cyclone, cloud burst, drought and flood - their impacts on public life and agriculture.

Unit VII

Drought climatology- Concept, definition, types of drought and their causes; rainfall and its variability, intensity, duration, beginning and end of drought and wet spells; moisture availability indices; Monitoring of drought; drought indices, crop water stress index, crop stress detection;

VI. Practical

- Calculations of climatic normal;
- Determination of climate type of particular station using different climate classification systems;

- Rainfall probability analysis;
- Computation of drought indices;
- Indices for extreme weather events;
- Climatic water balance for climate classification.

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Basic knowledge on meteorology and climatology, physical laws governing atmosphere and monsoon

IX. Suggested Reading

Books

- Barry RG and Chorley RJ. 1982. *Atmosphere Weather and Climate*. ELBS (UK)
- Critchfield HJ. 1982. *General Climatology*. Prentice Hall of India (New Delhi).
- Das PK. 1995. *The Monsoon*. NBT (New Delhi).
- Haurwitz B and Austin JM. 1944. *Climatology*. McGraw-Hill.
- Lal DS. 2011. *Climatology* Sharda Pustak Bhavan, (Allahabad).

Journals

- *Journal of Climate*
- *International Journal of Climatology*
- *Climate and Development*
- *Climate Change*
- *Nature- Climate Change*

I. Course Title : Soil Physical Environment and Plant Growth

II. Course Code : AP 510

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about characterization and management of soil physical environment in relation to plant growth and yield.

V. Theory

Unit I

Introduction: Effect of soil physical properties on plant growth - soil water, soil air, soil temperature, mechanical impedance and tillage practices.

Unit II

Soil water: Soil moisture – plant water relations, available water, newer concepts of water availability, least limiting water range, soil-plant-atmosphere system as a physical continuum, plant uptake of soil moisture, evaporation, transpiration and evapotranspiration, dynamics of water in the soil-plant-atmosphere continuum.

Unit III

Root growth – germination and seedling emergence, hydraulic properties of roots, characterization of root growth parameters, water balance of the root zone, soil physical properties and root growth, flow of water to roots.

Unit IV

Soil Temperature – effect of soil temperature on plant growth, soil temperature management, thermal regimes, mulching, radiation – heat budget and energy balance in the field, radiation use efficiency, radiation exchange in the field, exchange of heat and vapour to the atmosphere.

Unit V

Aeration – critical oxygen concentration and factors affecting.

Unit VI

Field water balance – field water balance, irrigation and water use efficiency, consumptive use, plant uptake of soil moisture

Unit VII

Nutrient uptake and use by plants, managing soil physical condition for improved nutrient use efficiency, integrated nutrient management in relation to soil physical condition.

Unit VIII

Resource conservation technologies- bed planting & zero-tillage - types, suitability and effect on soil physical properties, other resource conservation technologies and the impact (short and long term) on soil health.

Unit IX

Modelling: Interactions of soil, management and climatic factors on plant growth, development of sustainability indices.

VI. Practical

- Measurement of penetration resistance and LLWR, Plant water potential;
- Field saturated hydraulic conductivity, transpiration using Porometer;
- Root Length Density, Root Diameter, Root weight using Root Scanner, plant N content;
- Germination percentage as affected by temperature;
- Estimation of evapotranspiration losses, estimation of consumptive water use, production functions, field water balance components, water uptake by plants.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Basic knowledge on soil physical environment to solve field problem

IX. Suggested Reading

- Doorenbos J and Pruitt WO. 1975. *Crop Water Requirements*. FAO Irrigation and Drainage Paper 24. Rome.
- Hanks and Ascheroft. 1980. *Applied Soil Physics*. Springer Verlag.
- Hillel D. 1971. *Soil and Water: Physical Principles and Processes*. Academic Press.
- Hillel D. 1998. *Environmental Soil Physics*. Academic Press. Slatyer RO. 1967. P*lant- Water Relations*. Academic Press.

I. Course Title : Simulation of Soil, Plant and Atmospheric Processes

II. Course Code : AP 511

III. Credit Hours : 2+1

IV. Aim of the course

To impart the theoretical and practical knowledge of using simulation models for crop-environment interactions

V. Theory

Unit I

Fundamentals of dynamic simulation, systems, models and simulation.

Unit II

Descriptive and explanatory models, modelling techniques steps, states, rates and driving variables, feedbacks and relational diagrams.

Unit III

Numerical integration, introduction to FST language.

Unit IV

Modelling crop environment and crop pest interactions, soil water, nitrogen and balance, introduction to a simple crop ecological model, applications of simulation modelling in environmental impact assessment and greenhouse gas emission.

Unit V

Data requirements and limitations of modelling; modelling crop-environment and pest interaction, soil, water, nitrogen and C balance; assessing crop growth, scheduling and management practices and water use planning through simulation tools.

VI. Practical

- Scheduling planting and harvesting of crops;
- Drawing relational diagrams;
- Applying numerical integration techniques;
- Fitting probability distribution functions;
- Hands on model validation through statistical indices;
- FST programming language;
- Hands on to InfoCrop model;
- Assessing crop growth through InfoCrop model;
- Hands on to USAR model, Crop rotation & water use planning through USAR model.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Basic knowledge on simulation model for solving problems in field.

IX. Suggested Reading

- Cox GW, Atkins MD. 1979. *Agriculture Ecology*. Freeman & Co.
- Etherington JR. *Environmental and Plant Ecology*. John Wiley Sons.
- Mitchell R. *The analysis of Indian agro-ecosystem*.
- Odum OP. *Ecology*. Oxford & IBM Publishing Co.
- Sinclair TR and Gardener FP (Eds). *Principle of ecology in plant production*. CABI, UK.

I. Course Title : Principles of Physical Techniques in Agriculture

II. Course Code : AP 512

III. Credit Hours : 2+1

IV. Aim of the course

To educate about different optical, electrical, colorimetric and nuclear techniques used in agriculture.

V. Theory

Unit I

Principles of measurements; laboratory, field and regional scales.

Unit II

Principles of optical and polarized microscopes; reflection, transmission and absorption in relation to properties of object; colorimetric techniques; single and double beam instruments; spectrophotometry; Beer and Lambert law; fluorescence; Raman spectra.

Unit III

Sensors and transducers; principles of leaf area meter, canopy analyser, quantum sensor, Spectro-radiometer, laser land leveller; photosynthetic system analyser for determination of plant water and photosynthetic parameters.

Unit IV

Principles of infrared thermometry; thermal imaging, emissivity laws; characteristics of agricultural materials.

Unit V

Principles of X-ray and its applications in clay mineralogy; small angle scattering.

Unit VI

Principles and applications of electron microscopes; transmission and scanning electron microscopes; confocal microscope and its applications.

Unit VII

Atomic absorption spectroscopy - principles, detection limits and sensitivity.

Unit VIII

Nuclear techniques - detection and measurements of charged particles, radiation monitoring instruments, radiation hazards evaluation and protection. Tracer methodology - isotopes and their applications in agriculture, gamma irradiation for genetic variability

Unit IX

Concepts of Nano Science and technology and their applications in agriculture

Unit X

NMR, NIR, mass spectrometer - principles and applications.

V. Practical

- Discharge of electricity through gases
- Ionization current measurements
- Photoelectric effect and measurements
- Geiger Muller counter- quenching time
- Thickness measurement of thin films/ foils/ paper sheets
- Half-life determination
- Tracer applications of artificial radionuclides
- Multi-channel analyser
- Neutron moisture meter
- Use of NMR spectrometer
- Seed irradiation with gamma rays
- Radiocarbon dating.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Basic knowledge on, electrical, colorimetric and nuclear techniques used in agriculture.

VIII. Suggested Reading

- Arnikar HJ. 1989. *Isotopes in the Atomic Age*. Wiley Eastern.
- Bhaskaran S, Ghosh SK and Sethi GR. 1973. *Proceedings of the International Symposium on Use of Isotopes and Radiation in Agriculture and Animal Husbandry Research,* Nuclear Research Laboratory, IARI, New Delhi.
- Broetjes C. 1965. *The Use of Induced Mutations in Plant Breeding*. Pergamon Press.
- Burcham E. 1995. *Nuclear Physics*. ELBS/Longman.
- Glasstone S. 1967. *Source Book of Atomic Energy*. Affiliated East West Press.
- Kapoor SS and Ramamurthy VS. 1986. *Nuclear Radiation Detectors*. Wiley Eastern.
- Pochin E. 1983. *Nuclear Radiation: Risks and Benefits*. Clarendon Press.
- Rajan JB. 2000. *Atomic Physics*. S Chand & Co.
- Tiwari PN. 1985. *Nuclear Techniques in Agriculture*. Wiley Eastern. Wolf G. 1964. *Isotopes in Biology*. Academic Press.

I. Course Title : Principles and Applications of GIS and GPS

II. Course Code : AP 513

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge on dealing with spatial data and its applications in natural resource management.

V. Theory

Unit I

Introduction; History of cartography and maps.

Unit II

Basic concepts and principles; hardware and software requirements; common terminologies of geographic information system (GIS).

Unit III

Geographical data structures; relational database management system; overview of MS Access.

Unit IV

Maps and projections: principles of cartography; Basic geodesy: Geoid/ Datum/ Ellipsoid; cartographic projections, coordinate systems, types and scales; accuracy of maps.

Unit IV

GIS data collection, linking spatial and non-spatial data; Errors and quality control, data output.

Unit V

Raster based GIS: spatial referencing, definition and representation, data structure, advantages and disadvantages; Vector based GIS: Definition, concept, data structure, capture and Vector and raster formats, vector to raster and raster to vector conversion, advantages and disadvantages

Unit VI

Principles of graph theory, topology and geometry; spatial analysis: statistical analysis, measurement, proximity (buffering), overlay analysis, classification, network analysis, multicriteria analysis, site suitability analysis, nearest neighbour analysis.

Unit VII

Surface modelling: Thiessen polygon, interpolation, DEM; Geostatistical analyses, spatial and non-spatial query.

Unit VII

Software and hardware requirements of GIS; Integrated image analysis and GIS; GIS for modelling.

Unit VIII

Web GIS/ Geoportal, 3D GIS, object-oriented GIS, mobile GIS, knowledge-based GIS; data warehousing, data mining; metadata, data interoperability, open GIS consortium, GIS customization, DSS and SDSS.

Unit IX

Applications of GIS for water resources, agriculture, precision farming, disaster management, e-governance, Agricultural Research Information System (ARIS).

Unit X

Basic Concepts, segments, working principles; Measuring distance and timing, errors in GPS data and correction; Differential GPS; Integration of GPS data with GIS data, use of GPS in remote sensing analysis; Past, present and future status of GPS; Applications of GPS in agriculture and natural resource management.

VI. Practical

- Overview of current GIS software: ArcMap/ArcGIS/QGIS;
- Introduction to MS Access;
- Data input (spatial data); digitization and scanning;
- Data input: editing, Data input: non-spatial attributes and linking with spatial data;
- Database creation and map registration;
- Spatial analysis: Surface modelling, overlaying, buffering, neighbourhood analysis, Coordinate data collection through GPS and its integration with GIS.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of remote sensing and GPS and their utility in research for solving field problem.

IX. Suggested Reading

- Burroughs PA. 1986. *Geographical information systems for land resources assessment.* Oxford University Press
- Chakraborty D and Sahoo RN. *Fundamentals of Geographic Information System*, Viva Books Pvt. Ltd, New Delhi.

- Laurini R and Thompson D. 1992. *Fundamentals of Spatial Information Systems*. London, Academic Press, New York.
- Longley PA, Goodchild MF, Maguire DJ and Rhind DW. 1997. *Geographical Informatics Systems*. II Edition, New York, John Wiley. Online useful materials

Websites

http://www.gisdevelopment.net/tutorials/tuman006.htm
- http://www.colorado.edu/geography/gcraft/notes/datacon/datacon_f.html
- http://egsc.usgs.gov/isb/pubs/gis_poster/ http://www.quantdec.com/SYSEN597/
- http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Tutorials (especially for ArcGIS user)

I. Course Title : Nanoscience and Technology for Agriculture
II. Course Code : AP 514
III. Credit Hours : 2+0

IV. Aim of the course

To impart basic knowledge about nanoscience, properties of nanoparticles and their applications in biology.

V. Theory

Unit I

Outline of the course; Nanostructure: growth of compound semiconductors, super lattices, self-assembled quantum dots, Nano-particles, nano tubes and Nano wires, fullerenes (buck balls, grapheme), Nanofabrication and nano-patterning; Optical, X-ray, and electron beam lithography, self-assembled organic layers, Process of synthesis of nano powders, Electro-deposition, Important nano materials.

Unit II

Mechanical properties, Magnetic properties, Electrical properties, Electronic conduction with nano particles, Investigating and manipulating materials in the nanoscale; Electron microscopy, scanning probe microscopy, optical microscopy for nano science and technology, X-ray diffraction, scanning tunnelling microscopy, atomic force microscopy.

Unit III

Nano-biology: Interaction between biomolecules and nano-particle surface, Different types of inorganic materials used for the synthesis of hybrid nano-bio assemblies. Applications of nano in agriculture, current status of nano biotechnology, Future perspectives of Nanobiology, Nano sensors.

Unit IV

Types of nanomaterial hazard their identification, toxicity and exposure assessment, threshold limit, characterization, health risk assessment.

V. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VI. Learning outcome

Experience on the knowledge of nano science and their utility in agricultural research.

VII. Suggested Reading

- Balndin AA and Wang KL. (Ed.) 2006. *Handbook of semiconductor nanostructure and nanodevices*. American Scientific Publishers, California.
- Challa Kumar (Ed.). 2006. *Nanotechnologies for the life sciences*. Willey-VCH GmbH, Weinheim.
- Gregory Timp. 1999. *Nanotechnology*. Springer Verlag, New York.
- Margaret E Kosal. 2009. *Nanotechnology for chemical and biological defence*. Springer, Dordrecht.
- Michael Kohler and Wolfgang Frintzsche. 2007. *Nanotechnology: Introduction to nano structuring techniques*. Wiley-VCH Verlag GmbH, Weinheim.

I. Course Title : Remote Sensing in Agriculture (Pre-requisite AP 507 Principles of Remote Sensing)

II. Course Code : AP 515

III. Credit Hours : 2+1

IV. Aim of the course

To impart knowledge about the remote Sensing techniques and their applications in agriculture.

V. Theory

Unit I

Scope of remote sensing in agriculture, sensors platforms and data availability for agricultural remote sensing and recent developments.

Unit II

Remote Sensing of soil spectroscopy of soils, differentiation and identification of soils, soil parameters by hyperspectral remote sensing, soil survey and resource mapping, soil health.

Unit III

Crop identification and discrimination, crop acreage estimation, monitoring of crop growth and phenology, yield modelling and forecasting.

Unit IV

Retrieval of crop biophysical parameters – empirical and radiative transfer approaches, assessing crop abiotic and biotic stresses, monitoring agricultural drought and early warning, crop loss assessment and insurance using remote sensing.

Unit V

Land use/ land cover mapping and change detection analysis, land use modelling, cropping system analysis land planning with reference to different agro eco-regions, land degradation process (Salinity, waterlogging, etc) and their evaluation by remote sensing.

Unit VI

Role of remote sensing in water resource development and management, identification of ground water potential zones, generation of different thematic maps for integrated watershed management; Microwave remote sensing for crop and soil studies, soil moisture mapping, flood assessment and management by remote sensing.

Unit VII

Precision farming principles - VRT, Modern techniques and machines. Remote sensing for plant phenotyping, post-harvest quality assessment.

VI. Practical

- Use of Infrared thermometry and spectral data for crop stress monitoring;
- Hyperspectral data for soil and crop characterization;
- Computation of Spectral Indices for Soil and Vegetation;
- BRDFs and Radiative transfer modelling, processing of microwave remote sensing data;
- Salinity mapping from remote sensing data; Pre-processing of time series satellite data;
- Crop discrimination and acreage estimation;
- Crop yield modelling from satellite data;
- Land use land cover classification and change detection;
- Drought and crop condition monitoring, processing of image data for plant phenotyping.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of remote sensing and GPS and their utility in research for solving field problem.

IX. Suggested Reading

- Barret EC and Curtis LF. 1982. *Introduction to Environmental Remote Sensing*, Chapman & Hall, London.
- Colwell RN. (Ed.) 1983. *Manual of Remote Sensing*, Vol. II, American Society of Photogrammetry, Falls Church, Va.
- Jensen JR. 2006. *Remote Sensing of the Environment: An Earth Resource Perspective*, 2nd ed., Prentice Hall.
- Narayan LRA. 1999. *Remote Sensing and its Applications,* Oscar Publ.
- Patel AN and Singh S. 2004. *Remote Sensing: Principles and Applications*. Scientific Publ.
- Thenkabail P, Turral H, Biradar C and Lyon JG. (Eds) 2009. *Remote Sensing of Global Croplands for Food Security,* CRC Press.
- Ustin S. 2004. *Remote Sensing for Natural Resource Management and Environmental Monitoring*, 3rd ed., Wiley.

Course Title with Credit Load
Ph.D. in Agricultural Physics

Course Code	Course Title	Credit Hours
AP 601*	Principles of Soil Physics	2+1
AP 602	Applied Soil Physics	2+1
AP 603	Crop Micrometeorology and Evapotranspiration	2+1
AP 604*	Digital Image Processing	1+1
AP 605	Satellite Agrometeorology	2+1
AP 606	Sensors for Soil, Crop and Environment Monitoring	2+1
AP 607	Weather Hazards and its Management	2+0
AP 691	Doctoral Seminar I	1+0
AP 692	Doctoral Seminar II	1+0
AP 699	Doctoral Research	75

*the core courses compulsorily to be taken

Course Contents
Ph.D. in Agricultural Physics

I. Course Title : **Advanced Soil Physics**
(Pre-requisite AP 503 Fundamentals of Soil Physics)

II. Course Code : **AP 601**

III. Credit Hours : **2+1**

IV. Aim of the course

To study the physical processes for transport of water, solute, heat and air in soil using advanced mathematical tools and techniques.

V. Theory

Unit I: Mathematical tools

Vector calculus: gradient, divergence and curl of a vector. Fourier series, Laplace and inverse Laplace transforms and their applications for solving flow and transport equations in soil analytically; Numerical approximations: finite difference methods for solving transport equations. Iterative procedures for solving linear and nonlinear equations, Monte Carlo simulation.

Unit II: Soil water transport

Saturated flow equations: Poiseuille's and Darcy's equations, Laplace equation of steady flow and Poisson equation for unsteady flow, three-dimensional saturated hydraulic conductivity and fluxes, Specific Storage Coefficient, Aquifer Transmissivity, conductance coefficient, Effective hydraulic conductivity for layered soils.

Unsaturated flow equations of Vadose zone: Buckinghum-Darcy equation, Richards equation; Unsaturated flow parameters: Unsaturated Hydraulic conductivity: Models for estimation – Gardener's model, van Genucheten model, Brooks and Corey model and Kosugi model; Capillary Length Scales: Macroscopic and microscopic capillary lengths; Woodings equation for steady infiltration from a shallow ponded ring. Preferential flow: Macropore Flow, fingering and Funnel flow; Measurement of saturated and unsaturated hydraulic conductivity**:** Lab methods- constant head and falling head methods, Field methods- infiltrometers and permeameters, instantaneous profile and field inverse methods; Numerical models of water flow - finite difference method.

Infiltration models: Empirical models-Kostikov model, Horton model, Physical models - Green-Ampt and Philip models both for horizontal and vertical infiltration, Boltzmann transformation of wetting front for solving water flow during horizontal and vertical infiltration, computation of profile controlled and supply controlled infiltration along with time of ponding, homogeneous and layered soil infiltration, curve number method, preferential flow.

Solute transport: solute transport mechanisms: mass flow, diffusion, hydrodynamic dispersion, miscible and immiscible displacement, hypothetical and experimental breakthrough curves, Convective-Diffusive equation (CDE), linear and non-linear adsorption, solution of CDE, analytical solution by Laplace transformation, numerical solutions by finite difference and finite element methods, applications, methods of determination of dispersion and diffusion coefficients.

Unit III: Soil heat flow

Equation of heat transport by conduction and its sine wave solution, damping depth and its significance. Measurement of soil thermal conductivity by single and dual probe and thermal diffusivity by time lag and amplitude-based methods. Computation of volumetric heat capacity by de Vries method. Soil heat flux measurement by heat flux plates. Estimation of thermal diffusivity by finite difference method.

Unit IV: Movement and exchange of gases in soils

Darcy's law for advective transport (non-isobaric system) of gases, deviation from Darcy's law, gas transport by diffusion in isobaric system (Fick's law). Multi component gas transport- Dusty Gas model, Stefan Maxwell equation. Gas permeability: laboratory and field measurement of gas permeability.

VI. Practical

- Guelph Permeameter for field saturated hydraulic conductivity;
- Hydraulic conductivity by instantaneous profile method;
- Computation of dispersion and diffusion coefficients of CDE;
- Calibration of parameters of Green and Ampt and Philip models and calculation of time of ponding, measuring thermal properties in field;
- Bruce and Klute method for computing hydraulic diffusivity under horizontal infiltration, Modelling water and heat transport in soil.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

IX. Suggested Reading

- Daniel Hillel. *Advanced Soil Physics.*
- Kirkham and Powers. *Advanced Soil physics.*
- Warrick AW. *Soil Physics Companion.*

I. Course Title : Applied Soil Physics
(Pre-requisite AP 503 Fundamentals of Soil Physics)

II. Course Code : AP 602

III. Credit Hours : 2+1

IV. Aim of the course

To map soil properties for precision farming, assessment of soil quality, structural problems of different soils and their amelioration through appropriate conservation tillage, soil conditioning.

V. Theory

Unit I: Techniques for mapping soil properties and their use

Classical methods of interpolation: IDW, spline, global polynomial; Geostatistics:

Spatial variability of soil properties: spatial dependence and spatial structure studies – empirical semi variogram and semi variogram models, kriging for interpolation – type of kriging, Geostistical analyst, 3D analyst and spatial analyst tools of GIS for mapping soil properties, Use of soil maps for soil health assessment and reducing input use in precision farming.

Unit II: Assessment of Soil quality

Definitions of soil quality, selection of minimum data set of physical, chemical and biological characteristics for quality assessment, indices of soil quality: Physical rating of soils, least limiting water range (LLWR) as an indicator of structural quality, Proctor compaction test, soil erodibility indices.

Unit III: Soil structural problems of major soil types and their amelioration

Management of highly permeable soils, slow permeable black soils, hardening of redchalka soils, shallow soils, soils with subsurface hardpan, tal lands, paddy soils, soil crusting

Unit IV: Soil tillage

Role of tillage for modification of soil structure, Assessment of site-specific tillage requirement based on soil and climatic properties, conservation tillage, effect of tillage on water and solute transport in soil.

Unit V: Soil conditioners

Water soluble conditioners and soil hydrogels – mode and rate of their application and modification in soil water retention curve of different soil types. Influence of atmospheric demand on hydrothermal regimes of soils with conditioners.

Unit VI: Applications of remote sensing in surface soil moisture estimation:

Estimation of surface soil moisture by thermal and passive microwave techniques

VI. Practical

- Empirical semi variogram and fitting appropriate semi variogram model;
- Preparation of prediction map of a soil property by kriging;
- Soil physical health assessment of a farm;
- Comparison of soil water retention curves of a soil with variable rates of applied conditioner;
- Computation of LLWR under different soil management practices.

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Experience on the knowledge of soil physical properties and processes in relation to plant growth.

IX. Suggested Reading

- Daniel Hillel. *Advanced Soil Physics*.
- Gupta RP and Ghildyal BP. *Soil Structure*.
- Warrick AW. *Soil Physics Companion*.
- ARC GIS manual.

I. Course Title : **Crop Micrometeorology and Evapotranspiration (Pre-requisite AP 505 Fundamentals of Meteorology)**

II. Course Code : **AP 603**

III. Credit Hours : **2+1**

IV. Aim of the course

To impart advanced theoretical and practical knowledge about the physical processes in the atmosphere near the ground for growing crop plants with special emphasis of evapotranspiration process.

V. Theory

Unit I

Micro-, meso- and macro-climates and their importance, Atmosphere near the ground – bare soil and crop surfaces, exchange of mass, momentum and energy between surface and overlaying atmosphere, exchange coefficients, Richardson number & Reynold's analogy, Mixing length theory, boundary layer equations, surface layer, Ekman layer, frictional affects, eddy diffusion, forced & free convection. Wind profile near the ground; roughness and zero plane displacement.

Unit II

Micrometeorology of plant canopies: Radiation, temperature, wind, humidity and carbon dioxide profiles in crops; Influence of topography on microclimate; variation in microclimate under irrigated and rainfed conditions; Micrometeorology of field crops rice and wheat, forest and orchards etc.

Unit III

Hydrological cycle and concept of water balance, concepts of evaporation. evapotranspiration, potential, reference and actual evapotranspiration, consumptive use, different approaches of ET determination by empirical methods, energy balance and Bowen's ratio methods, water balance single and multi-layered soil methods, aerodynamic, eddy correlation and combination approaches, field lysimetric approaches and canopy temperature-based methods; Advantages and limitations of different methods.

Unit IV

Measurement of water use efficiency/water productivity, irrigation scheduling and yield functions; Advective energy determination and its effect on water use by crops; Physiological variation in relation to crop growth and development.

VI. Practical

- Micromet sensors and automatic weather station;
- Global and net radiation diurnal variations;
- Temperature profile, Humidity profile and Wind profile in the crops at different stages;
- Energy balance components for IARI station;
- PET by Thornthwaite's method, Blaney Criddle method, Radiation (Makkink's) method;
- Bowen's Ratio, Aerodynamic method, Combination (FAO-56) method, Pan Evaporation, Lysimeter, Eddy Covariance.

VII. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VIII. Learning outcome

Basic knowledge on meteorology and climatology, physical laws governing atmosphere and monsoon

IX. Suggested Reading

Books

- *Disaster Management in India*, Ministry of Home Affairs, Govt. of India, 2011.
- *Manual of Drought Management*, Ministry of Agriculture, Govt. of India, 2016.
- *Textbook of Disaster Management*, by Nitesh Kumar, Satish Serial Publishing House.

Journals

- *Natural Hazards*
- *Disasters*
- *Agriculture & Forest Meteorology*

I. Course Title : Digital Image Processing (Pre-requisite: AP 507 Principles of Remote Sensing)

II. Course Code : AP 604

III. Credit Hours : 1+1

IV. Aim of the course

To impart advanced technical and practical knowledge about the image processing procedures with emphasis on their applications in agriculture

V. Theory

Unit I

Introduction - Image processing display systems. Initial statistical extraction - univariate and multivariate image statistics, histogram and its significance in remote sensing data. Pre-processing - Introduction, missing scan lies, desk tripping methods, geometric correction and registration, atmospheric corrections, illumination and view angle effects.

Unit II

Image reduction, image magnification, contrast enhancement; linear, non-linear, ratioing, edge enhancement; linear, non-linear; low pass filters, high pass filters, edge detection, point and neighbourhood operation Image transform - Arithmetic operations'-based image transforms, principle component analysis, discriminate analysis. Fourier transforms, Fast Fourier frequency domain filters and vegetation indices.

Unit III

Image compression fundamentals: Coding, interpixel and Psyco-visual redundancy, and fidelity criteria. Image compression models: Source encoder and decoder, channel encoder décor, Elements of information theory: Measuring information, entropy, the information channel fundamental coding theorems and using information theory, Image Fusion.

Unit IV

Image segmentation: Detection of points, lines and edge detection and combined detection Edge linking and boundary detection: Local processing, Global processes via Hough transform; Thresholding: foundation, role of illumination, simple global thresholding, optimal thresholding. Split and merge and Texture based Segmentation.

Unit V

Classification: Geometrical basis, unsupervised & supervised techniques; Advance classification techniques: Use of external data, contextual information, feature - sub-feature study, classification accuracy; Change detection - the nature of change detection, change detection algorithms, image differencing, and image rationing and classification comparisons; Imaging Spectroscopy, Data Processing techniques, data mining techniques, Spectral angle mapping, Spectral unmixing, Construction digital terrain models, Application of DTMs – contour generation, fill, fly though; slope and aspect; viewshed analysis; watershed and drainage extraction; volumetric analysis; preparation of orthoimages

VI. Practical

- Digital Image processing –Introduction to software, MATLAB and R software, Image acquisition;
- Digital image processing: Pre-processing, Enhancement and training site collection, classification;
- Post Classification, Accuracy Assessment;
- Processing of microwave image;
- Processing of thermal image;
- Processing of Hyperspectral image: Pre-processing and classification, Multi-resolution image Fusion.

V. Teaching methods/activities

Classroom teaching and practical-classes, visit to Agromet Observatory

VI. Learning outcome

Basic knowledge on image processing procedures with emphasis on their applications in agriculture

VII. Suggested Reading

Books

- Gonzalez RC and Woods RE. 2014. *Digital Image Processing*. Pearson.
- Jensen JR. 1986. *Introductory Digital Image Processing: A Remote Sensing Perspective*. Prentice Hall.
- Qihao Weng 2011. *Advances in Environmental Remote Sensing: Sensors, Algorithms and Applications*, CRC Press.

Journal

- *IEEE Trans. Geoscience and Remote Sensing*
- *IEEE Transactions on Image Processing*
- *International Journal of Image Processing - IJIP - CSC Journals*
- *Signal Processing: Image Communication - Journal - Elsevier*

I. **Course Title** : **Satellite Agrometeorology**
(Pre-requisite: AP 505 Fundamental of Meteorology)

II. **Course Code** : **AP 605**

III. **Credit Hours** : **2+1**

IV. **Aim of the course**

To learn the use of satellite images for retrieval agro-meteorological parameters and their applications in agriculture.

V. **Theory**

Unit I

Scope and importance of agrometeorology from space, types of meteorological satellites – Geostationary and Polar orbiting.

Unit II

International satellite systems and their payloads – NOAA, S-NPP, TERRA and AQUA, DMSP, METEOSAT, GOES, TRMM, etc., National satellite systems and their payloads – INSAT, IRS/RESOURCESAT, MEGHA-TROPIQUES, RISAT, OCEANSAT, etc., Agromet parameter's requirements and satellite data products available.

Unit III

Retrieval of cloud type and structure in visible and infrared regions, estimation of rainfall by visible, infrared and passive and active microwave techniques.

Unit IV

Retrieval of land surface emissivity and temperature – single channel and split window algorithms, components of surface radiation balance – global radiation, surface albedo and outgoing long wave radiation, estimation of latent heat flux (ET), sensible heat and roughness parameter.

Unit V

Retrieval of surface soil moisture by thermal and passive microwave, retrieval of crop biophysical parameters by empirical and physical techniques.

Unit VI

Vegetation phenology and dynamics, crop yield modelling, linking Simulation models and remote sensing, crop growth monitoring system

Unit VII

Drought monitoring, assessment and management, modelling net primary productivity of agroecosystems, agroecological zoning using remote sensing and GIS, remote sensing of air pollutants and greenhouse gases.

VI. **Practical**

- Handling MODIS image products (Reflectance, LAI, fAPAR, LST);
- Handling SPOT VGT Products, PROSAIL MODEL, Retrieval of: LST, Albedo, Radiation, Estimation of Crop Phenology from multi-temporal satellite images, Spectral yield model, Remote sensing-based Drought indices and Drought assessment and Spatial Net Primary Productivity modelling.

VII. **Teaching methods/activities**

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Basic knowledge on satellite remote sensing in meteorology.

IX. Suggested Reading

- Lecture Notes Module II: *RS & GIS Applications in Agriculture & Soil Science*, CCSTEAP, Indian Institute of Remote Sensing, Dehradun, India
- Lecture Notes on *Satellite Meteorology & Global Change*, Vol 1, 2 & 3, CSSTEAP, Space Applications Centre, ISRO, Ahmedabad, India
- Molly E. Brown. 2008. *Famine Early Warning Systems and Remote Sensing Data*, Springer. Okamoto K. (Ed.). 2001. *Global Environment Remote Sensing*, IOS Press.
- Shivkumar MVK, Roy PS, Harmsen K and Saha SK. 2004. *Satellite Remote Sensing and GIS Applications in Agricultural Meteorology*, WMO, Geneva.
- Special Issue on Remote Sensing Applications in Meteorology, *Mausam*, Vol 54, No. 1, Jan 2003. Toselli F. (Ed.). 1989. *Applications of Remote Sensing to Agrometeorology*, Kluwer Academic Publishers, London.
- Ustin S. 2004. *Remote Sensing for Natural Resource Management and Environmental Monitoring*, 3rd ed., Wiley.
- Vaughan RA. 1987. *Remote Sensing Applications in Meteorology and Climatology*, NATO Science Series C.

I. Course Title : Sensors for Soil, Crop and Environment monitoring

II. Course Code : AP 606

III. Credit Hours : 2+1

IV. Aim of the course

To teach the applications of sensors for soil, crop and environment monitoring

V. Theory

Unit I

Sensing strategies: Traditional field scouting and sampling –laborious and time consuming, Sampling approaches.

Unit II

Sensor platforms and location of sensors: Remote airborne - Satellite, Airplane, UAV (1 m to 100 m); Proximal mobile, earthbound: Continuous moving, Stop - and - go, Proximal & in - situ, stationary Towers Probes in soil and on crop.

Unit III

Criteria for selecting sensors: Spatial sampling: Extend, coverage, sample area/volume Temporal: Turnaround time, temporal resolution Data processing: post processing / real - time Use in management: Predictive / reactive approach Costs Robustness Accuracy Handling: User - friendliness and safety, off - line, on-line, and on-line with map overlay.

Unit IV

Sensors for Environmental Monitoring: 1 Weather radar, 2 Satellite, 3 Aircraft, 4 UAV, 5 Atmospheric, Lidar, 6 Sensor network, 7 Radiometer, 8 Deposition sampler, 9 Atmospheric profiler, 10 Weather station & eddy - covariance 11 Groundwater level monitor, 12 Surface water level monitor, 13 Automatic water sampler, 14 Gas exchange sensor.

Unit V

Soil sensors: Plant nutrients (pools): Macro and Micro nutrients, Water content and water potential, Acidity (pH), Buffering, CEC, AEC, Redox Potential, Toxic substances like U, Cd, Pb, Physical properties: Soil strength, Permeability, Porosity Soil biota: Biological activity, pathogens, Organic matter, penetrometers, Geo-electrical sensors, Gamma ray soil sensing, potentiometric sensors, sensors for soil mapping, multi sensors, Visible and near - infrared diffuse reflectance spectroscopy (Vis - NIRS), sensor fusion, handheld XRF.

Unit VI

Plant sensors: Target parameters: Water Potential, Yield quality, Nutrients- macro and micro, Morphology: Biomass, Leaf area, Distribution of plants and organs, Biological threats: disease, pest and weeds, Principles of measurement: (a) mechanical, (b) optical (spectral, spatial resolution, geometry) (c) Acoustics.

Unit VII

Applications in agriculture: Principle of N application based on chlorophyll sensing with spot sensors, On - line application with map - overlay, weedSeeker, CropCircle & OptRXWEEDit Ag, CropSpec, Fluorescence sensor for agriculture, Laser: Crop morphology - leaf area, Imaging and Non-imaging crop sensors, site specific weed management, hyperspectral video cameras, 3D imaging, stereo vision, sensor based VRT, Thermal imaging, multi reflection ultra-sonic sensor, smart phone based sensors.

Unit VIII

Challenges of sensor technology in agriculture: Direct assessment of relevant properties/ better distinction between various factors, Robustness & user - friendliness, Costs, Data processing and interpretation.

VI. Practical

- Demonstration of various soil sensors, moisture pH, EC monitoring systems, crop sensors - Green seeker, SPAD meters, Leaf area meters, line quantum sensors, sensors for environment monitoring - humidity, temperature, radiation recorders, comparison of different sensors, optical, mechanical.

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VIII. Learning outcome

Basic knowledge on sensors for soil, crop and environment monitoring.

IX. Suggested Reading

- Raphael A. Viscarra Rossel, Alex B. McBratney and Budiman Minasny. 2010. *Proximal Soil Sensing*. Springer Netherlands. ISBN 904818858X, 9789048188581, 448 pages.
- Subhas Chandra Mukhopadhyay. 2012. *Smart Sensing Technology for Agriculture and Environmental Monitoring*. Springer. 486 pages.
- Vanden Berg E. 2011. *Agricultural sensors*. ASAE publication. ISBN: 0916150984, 9780916150983, 81 pages.

I. Course Title : Weather Hazards and its Management

II. Course Code : AP 607

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge about natural hazards, their management and best practices

V. Theory

Unit I

Importance & scope of subject in the context of agriculture and developing countries; Concepts, definitions & fundamentals of Hazard, Disaster, Vulnerability, Resilience and Risk

Unit II

Classification of hazards: Natural & Human Induced, Geological – Hydrometeorological – Environmental – Biological, Sudden & creeping, Global and regional trends in hazards; Cycle and Steps in Disaster Management: Risk Management vs crisis management, Activities before, during and after disasters

Unit III

International treaties and mechanisms of disaster management, National institutional mechanisms

Unit IV

Early Warning and Communication system: Characteristics and Components of Early Warning System (formulation, issuance, reception and response), Disaster Specific National and International Early Warning Systems (Drought, Flood, Cyclone, Tsunami), Types of Communication Networks for Disaster Management (Terrestrial, Satellite, Wireless, Mobile), National Disaster Communication System

Unit V

Natural Disasters (Drought, Flood, Cyclone, Heat Wave / Cold Wave): their preparedness, Early warning & dissemination, response, recovery, mitigation

Unit VI

Biological Disasters (Epidemics, Pest attack of crops and livestock): their preparedness, Early warning & dissemination, response, recovery, mitigation

Unit VII

Risk Transfer and Insurance; Climate Change & Disaster Management

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, oral presentation by students.

VII. Learning outcome

Basic knowledge on natural hazards, their management and best practices

VIII. Suggested Reading

Books

- *Disaster Management in India*, Ministry of Home Affairs, Govt. of India, 2011.
- *Manual of Drought Management*, Ministry of Agriculture, Govt. of India, 2016.
- *Textbook of Disaster Management*, by Nitesh Kumar, Satish Serial Publishing House.

Journals

- *Natural Hazards*
- *Disasters*
- *Agriculture and Forest Meteorology*

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Physical Sciences
– Organic Farming

Preamble

Although, India had been traditionally organic and its farmers are 40 century farmers with large pool of traditional wisdom on best practices in organic agriculture, the modern standards based organic agriculture started only recently with the growing demand for organic food and fiber in the western world. Movement got major push when civil society organizations and farmer association brought in the focus on sustainability and food safety in the wake of deteriorating soil health and fertility, depleting natural resources, diminishing returns to the farmers and growing chemical residues in food. Growing demand for organic food nationally and internationally with the increased awareness for safe and healthy food further added to the strength of organic farming and attracted the attention of agricultural scientists and planners to look for alternative environment friendly ways which are not only productive enough to meet our growing demands but are also resource conserving and continuously contributing to the improvement of soil health and fertility. Organic agriculture emerged as the viable alternative to all such concerns. Ardent promoters of organic farming consider that present day organic agriculture, which is a mix of traditional wisdom and modern science and technology, can meet all these demands and become the mean for complete development of rural areas, especially in the developing countries like India where large chunk of farmers are small, with limited resources and with limited access to water, mainly through seasonal rains.

Institutional development such as National Programme for Organic production (NPOP) launched during 2001, followed by setting up of National Centre of Organic Farming (NCOF) under Ministry of Agriculture and Farmers Welfare and initiation of Network Project on Organic Farming (NPOF) Research by ICAR during 2004 laid the foundation for systematic development of the sector in the country. Started with just 42,000 ha during 2003-04, it has now grown almost 39-fold, touching a figure of 1.64 million ha during 2017-18. India is now the ninth largest in terms of total arable land under organic farming and largest in terms of total number of organic producers. Market started with exports is also catching up domestically and is now a 5000 crore industry. Dedicated stores and retail chains catering to the demand of organic food can be seen in almost all tier I and tier II cities in the country.

But this growth story has also many shortcomings and weaknesses. In the absence of technology and continuous research support, farmers are struggling to maintain yields. Availability of organic seeds and quality inputs for nutrient and pest management is one of the major bottlenecks. Absence of knowledge for diversified cropping systems (a pre-requisite for organic farming) keeps farmers relying on mono-crops which often yields poorly. Absence of trained manpower for extension, certification management and value chain management is also widely experienced and industry make do with less competent experts and personals. To take the organic farming fast forward it is necessary that efforts are made in value chain mode with an aim to transform farmers into entrepreneurs and create an infrastructure that cater to the ever evolving technology needs through research, extension and education. Although a National Organic Farming Research Institute (NOFRI) at Sikkim and some Institutes of Organic Farming in SAUs has started functioning but still there is lacking of institutions that can cater to the need of trained manpower. ICARs proposal to launch postgraduate programme in organic farming is the first of the efforts to bridge that gap. This report summarizes the recommendations of the committee constituted by the ICAR for drafting the course curriculum for M.Sc. Agriculture in Organic farming:

By the end of March 2017, India has brought more than 3.42 million ha area under organic certification, comprising of 1.64 million ha (47.95%) under cultivation and 1.780 million ha (52.05%) under wild harvest collection. India is producing wide range of crops under organic management with oilseeds, sugar crops, fiber crops, cereals and millets and pulses occupy the large chunk of the basket.

With mainstreaming of organic farming there is growing requirement for first generation extension personals trained in organic farming. Similarly, for research the country requires first generation scientists with actual organic farming background and passionate-will to work for the sector. As on March 2018 there are more than 3500 grower groups comprising of about 1 million farmers. These groups are known as ICS units and each group comprising of an average of 250-350 farmers and are managed by not less than 5-7 technical persons for documentation management, internal inspections, certification, collective input purchases and sales. Besides third-party certification another farmer group centric certification under PGS-India programme is also certifying farmers. To manage the certification of PGS there are more than 400 Regional Councils and all these require technical manpower, not only in organic crop and livestock management, but also in certification and quality assurance. As on March 2018, there are 28 certification bodies and another 10 are in the pipeline. Each certification body requires an average of 20-150 technical persons. Similarly, for PGS management there are more than 400 Regional Councils requiring more than 4000 technical staff. There are more than 950 organic food processors in the country. As organic system requires complete integrity, therefore processing needs to be dedicated, away from conventional processing units. This is a fast-growing sector and may require large number of organic food professionals in the years to come.Therefore, to feed to the existing and future requirement of technical manpower it is essential that a postgraduate course in organic farming is launched and state Agricultural Universities be encouraged to offer such course.

Minimum Requirements for starting postgraduate course in the University:

1. **Faculty**

University having Centre of Excellence in Organic farming or having dedicated Institutes for Organic farming are ideal for launching such programme. In cases, if there is no such existing infrastructure then the university must aim to start such Department with multidisciplinary faculty or must be in a position to spare competent faculty for undertaking such course. Initially it may be possible that the institute do not have faculty for each subject, then in such cases faculty may be contracted as visiting faculty for specific course content.

2. **Land**

As organic farming is a farming system approach, therefore, there is a needfor a dedicated organic farmof not less than 5 ha. This farm must be kept organic for long term as frequent switching of land under conventional and organic is not allowed and may not be advisable.

3. **Laboratory**

There must be fully equipped laboratory for the following:

(i) Soil testing laboratory having facilities for micronutrient analysis along with the usual soil test parameters. Facilities should also be available for estimation of soil microbial carbon, soil enzymatic analysis and soil respiration studies.

(ii) General microbiological laboratory

(iii) General entomology and plant pathology laboratory

(iv) Access to plant analysis equipment and residue analysis laboratories.

Course Title with Credit Load
M.Sc. (Ag) in Organic Farming

Course Code.	Course Title	Credit Hours
OF 501	Concepts and Principles of organic farming	2+0
OF 502	Soil fertility, Crop Nutrition and Nutrients input	3+1
OF 503	Organic Crop Production Systems	2+1
OF 504	Plant Health Management	2+1
OF 505	Post harvest handling of organic produce	1+1
OF 506	Farming systems suitable for organic managements	2+1
OF 507	Organic certification Standards and regulation	2+1
OF 508	Value Chain Management	2+2
OF 509	Marketing	2+0
OF 510	Research Methodology and Biostatistics	2+1
OF 511	Organic Input Management and Production Technologies	2+1
Soil 591	Masters Seminar	1+0
Soil 599	Masters Research/ Thesis	0+30

Course Contents
M.Sc. (Ag) in Organic Farming

I. Course Title : Concepts and Principles of Organic Farming
II. Course Code : OF 501
III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge on the basic concept of organic farming

V. Theory

Unit I: Concepts and principles of organic farming

History and evolution of organic farming in the world and India. Scenario of organic farming in India and world, global market for organic products, IFOAM's Guiding principles of organic farming, conversion to organic agriculture, advantages and limitations.

Unit II: Definitions and types of organic farming

Definitions of organic farming, types of organic farming such as natural farming, zero chemical natural farming, bio dynamic farming, biological farming, compost farming, Natueco culture, integrated farming, homa farming, permaculture etc, traditional farming systems in India and evolving indigenous knowledge systems

Unit III: Conventional *vs* Organic farming

Philosophy of two farming systems, fundamental differences, productivity issues, management protocols, food quality, nutritional differences and impact of conventional practices on soil fertility, natural resources, environment and overall social perception. Myths and realities about organic farming in addressing nutritional security and food safety need *vis-à-vis* national food security.

Unit IV: Advocacy, Ethics, health and social issues in organic farming

Advocacy for organic farming with sustainability, resource conservation and food safety issues. Advocacy through overall farm productivity under diversified cropping systems. Spirituality values and ethics in organic farming. Socio economic importance of organic farming: concept measurements and issues. Need for ethical practices and values across the organic agriculture value chain including trading and reaching to consumers.

Unit V: Organic farming for sustainability, resource conservation, climate change issues and safe and healthy food

General concerns on sustainability, climate change issues threatening sustainability, potential of organic farming practices in addressing sustainability and climate change. Resource conservation through organic farming, rainwater conservation and preservation of native seeds and germplasm an essential component of organic farming, Consumers concerns on food quality and safety, organic farming for safe and healthy food, ITKs potential and role in sustainability of modern organic farming practices

Teaching methods/ activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

Learning outcome

Basic knowledge on organic farming so as to be an organic trainer, promoter and grower.

Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition.
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B.Singh. Published by Jain Brothers
- *Basics of Organic Farming:* Deshpande, WR, 2009, All India Biodynamic and Organic Farming Association, Indore, MP, India P-306.
- Eyhorn, F, Heeb M and Weidmann, Gilles IFOAM *Training Manual for Organic Agriculture in the Tropics*, FiBL and IFOAM.

I. Course Title : Soil Fertility, Crop Nutrition and Nutrient Inputs

II. Course Code : OF 502

III. Credit Hours : 3+1

IV. Aim of the course

To provide knowledge on fertility of soil and also different organic inputs to be used in organic farming

V. Theory

Unit I: Soil – Source of Infinite Life

Soil as source of life, fundamentals of soil structure and quality, soil fertility, physico-chemical parameters and soil as living entity in organic farming.

Unit II: Soil fertility and productivity

History of soil fertility and plant nutrition. Factors affecting; features of good management; problems of supply and availability of nutrients; relation between nutrient supply and crop growth; Criteria of essentiality of nutrients; Essential plant nutrients – their functions, nutrient deficiency symptoms; transformation and dynamics of major plant nutrients.

Unit III: Soil fertility evaluation

Physico-chemical soil testing, biological methods for soil health evaluation, plant and tissue tests; soil quality in relation to sustainable agriculture. Nutrient requirement modeling based on soil health and resources availability.

Unit IV: Soil Conservation and Soil Water Management

Principles of soil and water conservation, general practices for soil and water conservation, soil carbon buildup and biomass recycling.

Unit V: Soil biology and role of microorganisms in soil fertility management

Soil as a habitat for microorganisms, Soil microorganisms, Soil microbial ecology, Soil microbial biomass, Soil enzymes – origin, activity and importance. Microbial management of agricultural, domestic and industrial wastes for potential application in organic farming. Microbiology of composting and bio-methanation. Biodegradation of xenobiotics. Bioremediation – principles and application.

Unit VI: Nutrient recycling

Nitrogen, phosphorus and potash cycles, management for nutrient recycling, methods for recycling and reducing nutrient losses.

Unit VII: Management practices

Management practices in organic agriculture (mulching, fallowing, intercropping, manuring, crop rotation, agro-forestry, mixed farming).

Unit VIII: Organic fertilizers and composting technology

Compositing principles and factors affecting composting, dynamics of compositing, methods of composting, different forms of composts with nutrient profiles, Rapid methods of composting, liquid manures, compost enrichment through concentrates, minerals and micronutrients. Field application of compost and their response to crops.

Unit IX: Vermicomposting technology

Earthworm biology, principles of vermicomposting, methods for vermicompost production, nutrient profiling, field application and its response to crop yields

Unit X: Biofertilizers

Different types of biofertilizers, their contribution to soil fertility and nutrient pool, factors affecting their application and response, assessment of biofertilizers application to crop yields.

Unit XI: Addressing nutrient deficiencies and mineral fortification of composts (P, K, S and micro nutrients)

Identification of deficiency, need assessment, identification of mineral resource, fortification of composts and impact assessment on application

Unit XII: Indigenous practices in soil fertility and nutrient management

Indigenous inputs such as liquid manures, Jivamrit, Panchgavya, on-farm protein hydrolysates, plant extracts, dung-urine slurries etc, their production methods and effect of their application on soil fertility and crop productivity.

VI. Practical

- Introduction of analytical instruments and their principles, calibration and applications, Determination of soil pH, electrical conductivity, organic carbon, total and available nitrogen, phosphorus, potassium, calcium, magnesium, sulphur and DTPA extractable micronutrients in soil and their interpretations.
- Biological health assessment through dehydrogenases, soil microbial carbon and soil respiration
- Making of composts through aerobic and anaerobic methods
- Making of vermicomost using earthworms
- Analysis of manures and composts for NPK and heavy metals
- Microbial profiling of Jivamrit/ panchgavya

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Basic knowledge on soil fertility and management in organic farming

IX. Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B.Singh. Jain Brothers
- *Manufacture of Biofertilizer and Organic Farming*. AB publisher

I. Course Title : Organic Crop Production systems

II. Course Code : OF 503

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on organic crop production system

V. Theory

Unit I: Fundamentals of organic farm management and conversion

Salient features of organic farm management, strategies for conversion to organic, step-by-step planning, integration of contamination control measures, planning for on-farm input production and supplementary off-farm inputs, planning for rain water harvesting and water conservation approaches including efficient irrigation systems and moisture preservation techniques, visit to organic farms and study on farmer's best practices for conversion.

Unit II: Management of diversity and cropping systems

Importance of diversity, installation of diversity through plantation of utility trees, nitrogen fixing tree hedges, habitat management for friendly insects and birds and nitrogen fixing crops as intercrops. Importance of cropping systems management with long term planning, crop rotations, intercropping, multi cropping, relay cropping, multi-layered cropping.

Unit III: Nutrient management

Components of nutrient management in organic crop production, assessment of crop nutrient requirements, calculation of nutrient credits from on-farm practices and resources such as intercrops, cover crops, biomass mulching, calculating additional input requirements. Managing nutrient needs through use of organic manures, viz. FYM, compost, Vermicompost, oil cakes, *in-situ* and *ex-situ* green manuring, crop residue management, use of restricted organic nutrient sources, liquid organic manures and dung urine slurries, methods of manuring and biomass application, split application of manures, foliar feeding as replacement of top dressing, ITKs and farmers innovations in nutrient management

Unit IV: Integration of microbial and mineral inputs

Importance of bio fertilizers, types of biofertilizers, nutrient potential, methods of application, enriching manures/ composts with biofertilizers, identifying the need for use of supplementary mineral sources and their integration in nutrient management package.

Unit V: Weed management

Prevention of weeds through cropping systems management, crop geometry, stale seedbed technique, summer ploughing, soil solarisation, cover crops, mulching, flooding, biological weed management, selection of suitable physical and mechanical approaches and biological and plastic mulches.

Unit VI: Water and Irrigation Management

Soil-water relation, theories of water availability, water use efficiency management, methods of irrigation and automation in irrigation systems, irrigation scheduling in different crops.

Unit VII: Modeling of agronomic practices and nutrient management protocols for some important agricultural and horticultural crops

Identification of compatible associate and intercrops/ companion crops, placing trap crops and insectary plants in cropping geometry, making provisions for nutrient credits from biomass mulching, intercrops and green manures, making provisions for nutrient credits from microbial enrichment with microbial/ liquid manure inputs, balance nutrient requirement modeling and identification of inputs and planning for quantity and time of application.

Unit VIII: Crop growth and yield analysis

Crop growth expressions in plants, growth measurements, important growth indices and forms of growth analysis in field crops. Factors determining yield. Use of growth analysis technique to study variation in yield due to planting season, planting density, fertilizer treatment, other agronomic practices, light, temperature, water, growth substances, varietal differences. Crop response curves. Dynamics of crop growth and modeling.

Unit IX: Success stories of effective crop management with optimum yields of practicing organic farmers (one in irrigated systems and one in rainfed systems)

Field visit, documentation of farming system with inputs and outputs, identification of practices important for organic systems, nutrient management practices, pest management protocols, yields and economics. Salient features for success and for further replication in crop production modeling.

VI. Practical

- Visit to organic farms and study general nutrient management practices, documentation of farming system with inputs and outputs and crop growth analysis using crop growth analysis techniques
- Getting acquainted with different tilling methods and rain water harvesting and water conservation techniques
- Production of liquid manures and dung-urine slurries
- Production of customized composts using FYM/ Compost, mineral nutrients and biofertilizers, assessment of nutrient profiles in enriched composts
- Methods of application for biofertilizers
- Weed management practices, tools and efficacy of different approaches
- Modelling of agronomic practices for a given cropping system with use of available resources.

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Basic knowledge on organic crop production system

IX. Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B. Singh. Jain Brothers.

I. Course Title : Plant Health Management

II. Course Code : OF 504

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on plant health management for optimization of crop yield due to organic farming

V. Theory

Unit I: Classification of pest organisms

Classification of pests, viz. weeds, bacteria, nematodes, fungi, insects, viruses, vertebrates, *etc*, identification of pests and beneficial organisms.

Unit II: General principles of plant health management in organic farming

Principles of pest management in organic crop production; Pest surveillance and pest population estimation; concept of economic injury levels (EILs) and economic threshold levels (ETLs), principles of Agro Eco-System Analysis (AESA) based pest management, estimation of Pest: Defender (P: D) ratio, understanding AESA methodology.

Unit III: Biology of pests and population dynamics

Population dynamics in relation to environment, distribution, identification; Life cycle of key pests of cereals, pulses, vegetables, stored grains, fruit crops and protected cultivation.

Unit IV: Ecological strategies for pest management

Proper sanitation, appropriate fertilization, necessary pruning, timing of planting to escape infection, crop rotation, avoidance of endemic sites, space management for sunlight and air, plant quarantine, *etc.*

Unit V: Cultural and physical control strategies

Importance and use of traps, coloured plates, pheromones, use of insectary plants, trap crops and planning for diversity plant integration as border crops, hedge rows, intercrops, *etc.*

Unit VI: Biological control

Conservation of natural enemies, classical biological control systems, important beneficial insects and their integration and use in different cropping systems.

Unit VII: Biopesticides

Biopesticides, types, mode of action, production, methods of application and impact assessment on crops and pest load.

Unit VIII: Botanical pest management

Using different plants for management of different pests, methods for using such plants and active ingredient extraction methodologies, formulation of usable solutions and methodologies for application. Integrated strategies, development of crop specific integrated management modules, importance and need for chemical alternatives permitted in organic farming, methods for use and application.

Unit IX: Indigenous practices and their importance in plant protection

Indigenous practices of avoiding pests, managing pests, important plants being used since ages and innovative botanical and fermentation inputs developed by farmers for pest management.

Unit X: Pest control of produce in storage

Physical, mechanical and biological approaches, modified environment, management of hygiene and phyto-sanitary approaches, use of organically acceptable fumigants such as carbon dioxide and nitrogen.

VI. Practical

- Collection and Identification of major/ key pests and plant diseases,
- Estimation of pest population, nature of damage, assessment of crop losses,
- Familiarization with important crop pests & diseases and their biological control agents,
- Demonstration/ familiarization with various tools of insect-pest & disease management,
- Mass rearing techniques of important biological control agents,
- Preparation of organic/ natural formulations for insect-pest & disease management,
- Evaluation of organic formulations for determining their pesticidal properties and field efficacy.
- Preparation and validation of traditional formulations.

VII. Teaching methods/ activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Plant health will be taken care of for optimization of higher crop yield due to organic farming

IX. Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B. Singh. Jain Brothers
- *Principles of Organic Farming:* S.R. Reddy. Kalyani Publisher

I. Course Title : Post Harvest-handling of Organic Produce

II. Course Code : OF 505

III. Credit Hours : 1+1

IV. Aim of the course

To provide knowledge on post harvest handling of organic produce for optimization of crop yield due to organic farming

V. Theory

Unit I: Pre/Postharvest Factors for Post-harvest Losses of Organic Produce

Pre and post-harvest factors responsible for causing organic produce losses.

Principles and practices responsible for losses of organic agricultural produce. Qualitative, quantitative, nutritional and socioeconomic losses. Loss assessment and estimation techniques and their limitations and methods for reducing postharvest losses.

Unit II: Introduction to Value Chain and Handling of Fresh Organic Products for Processing

Management of hygiene and phyto-sanitary measures, measures to reduce field heat, cleaning and washing, control of enzymatic and non-enzymatic changes, transportation, sorting, grading, peeling, sampling and size reduction, packaging, labelling; handling methods for fresh fruits, vegetables and flowers.

Unit III: Organic Food Processing and Preservation

Fundamental principles for food processing in organic farming, acceptable processing techniques, use of preservatives, processing aids, flavouring agents and nutrient supplement in organic food and feed processing.

Unit IV: Food Standards and Residue Analysis/ Toxicology

Fundamental principles of food standards, HACCP system, US and European Export/ Import standards for different crops, MRLs, sources of contamination, assessment and management of residues and toxins in food, critical control points, heavy metals and pesticide residue analysis, analytical methods and tools. Interpretation of residue analysis reports, analysis protocols and GMO report analysis.

Unit V: Principles of Packaging

Characteristics of packaging materials for organic food, packaging requirements for fresh and processed organic food for local and international markets, labelling requirements for fresh and processed organic food for local and international markets, labelling requirements and management integrity.

VI. Practicals

- Study of maturity indices for harvest of organic fruits, vegetables, spices and plantation crops.
- Determination of physiological loss in weight and respiration rate in fruits and vegetables.
- Determination of chemical constituents like sugar, starch, pigments, vitamin C, carotenes, acidity during maturation and ripening in fruits/ vegetables.
- Protective skin coating with organic wax emulsion to extend the shelf life of fruits and vegetables.
- Study of effect of precooling on shelf-life and quality of fresh fruits, vegetables and flowers.
- Study of packages-bulk and consumer packs for different fruits, vegetables, flowers and spices.
- Study of construction and working of zero energy cool chamber. Study of storage behaviour of different fruits and vegetables in zero energy cool chamber.
- Preparation and preservation of fruit-based beverages and blended products from fruits and vegetables.
- HACCP analysis, residue analysis in organic products. Visit to packaging centres, local markets, cooperative organisations, super markets dealing with marketing of organic perishables.

VII. Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B. Singh. Jain Brothers.

I. Course Title : Farming Systems Concepts and Practices for Organic Farming

II. Course Code : OF 506

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on practices of organic farming

V. Theory

Unit I: Introduction

Farming systems: Definition, importance, classification and scope, Classification of farming systems according to type of rotation, intensity of rotation, degree of commercialization, water supply, enterprises, Concept of sustainability in farming systems, role of integrated farming systems in agriculture, approaches

Unit II: Agro-ecology

Concepts and practices, Agro-ecology and the design of Sustainable Agro-ecosystems, Ecological processes to optimize in agro-ecosystems, Sustainable Agriculture: Basic Definitions and Concepts, Alternative Sustainable Farming Systems, Low external input sustainable agriculture

Unit III: Enterprises selection and Integration

Natural Farming Systems, Intentional Integrated Farming Systems, Pre-dominant farming systems in various regions, Eco-physiological approaches component selection and integration, Complementary and competitive interaction, Primary, Secondary, Complimentary and Supplementary enterprises for organic farming, livestock based systems, vertical farming, Principles and Practices of organic livestock production, Principles of organic aquaculture, Organic fruit and vegetable production practices, Models of integrated farming systems for irrigated ecosystems and rainfed ecosystems

Unit IV: Modeling of farming systems

Simulation models for intercropping, farming system design using farm design for various resource conditions, Linear programming, Multi-objective criteria decision making, Fuzzy logic analysis, Artificial Neural Network (ANN) based modeling, DSSAT, Infocrop, Cropsyst, Livesim

Unit V: Integrated Organic Farming Systems

Concepts, Principles, Strategies, Diversity plantations, Diversified cropping systems, crop rotations, soil fertility management, Selection of seeds, varieties and planting material, nutrient management, weed and pest management, integration of livestock, breeds and allied activities, *In-situ* recycling of Organic Wastes, Products and processes of composting, Component optimization, Market input chain, family employment generation, case studies, supplementary, Complimentary and substitution effects under dry-land, irrigated, wetland and hill-zone eco systems

Unit VI: Soil-crop-livestock-human chain

Bio-nutrition concepts, design of farming systems for nutrition, Household level production of food, feed, fodder, fertilizer, fuel and fibre from farming systems

Unit VII: Secondary Agriculture

Product diversification, Process diversification, processing of marketable surplus produces, packaging, branding and marketing

Unit VIII: Contract Farming

Farming system based cluster formation, production, processing and marketing, legal aspects of contract farming

Unit IX: Specialized farming systems

Protected cultivation, high value crops based systems, water based farming systems, region specific integrated farming systems, medicinal herb based systems

Unit X: Farming System diversification

Existing scenario of farming systems, need for diversification, methods of diversification, horizontal and vertical diversification

Unit XI: Four P Model of organic farming system

4P (Planning, Production, Processing and Promotion) model of organic farming systems

Unit XII: Ecological Engineering

Principles and Practices, Ecological engineering approach of soil fertility and pest management, examples of ecological engineering in traditional farming systems, case studies

VI. Practical

- Agro-ecosystem analysis: Field study of farming systems in the context of production flows, energy flows and pest dynamics using quantitative tools
- Farming System typology analysis and clustering of group of farmers
- Synthesis of organic farming system model for a given region using primary and secondary data
- Estimation of ecological, economic, social and sustainable livelihood indicators for a given farming system
- Design of alternative farming systems using Farm Design and other available modelling tools
- Experiential learning on different enterprises
- Documentation of farming system case studies

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion
Learning outcome: leadership development for an organic entrepreneur

VIII. Suggested Reading

- *Basics of Organic Farming:* by Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B.Singh. Jain Brothers.
- *Principles of Organic Farming:* S.R. Reddy. Kalyani Publisher.

I. **Course Title : Organic Certification, Standards and Regulations**

II. **Course Code : OF 507**

III. **Credit Hours : 2+1**

IV. **Aim of the course**

To provide knowledge Organic Certification, Standards and Regulations

V. **Theory**

Unit I

National and international regulations on quality assurance and certification

National Programme for Organic Production (NPOP), National Standards for Organic Production (NSOP), USDA NOP Programme and standards, EU Organic standards, Codex Alimentarius, Canada Organic regulation and important differences between NPOP and international standards. FSS Act 2006 for organic food, basic requirements, enforcement, standard operating procedures and verification in value chain

Unit II

ISO systems for quality assurance (ISO 17065, ISO 17011, ISO 19011 etc) and accreditation processes

What is ISO, salient features and functions of ISO, ISO systems for auditing, ISO 17065 for auditing and certification agencies, ISO 19011 Inspection protocols, ISO17011 Accreditation requirements, ISO 17025 Accreditation of quality analysis laboratories. Accreditation procedure and policies under NPOP, Essential requirements and competence for making an organic certification body, Conflict of interest management

Unit III

Types of certification systems (NPOP and PGS), standards and procedures

NPOP - A third party certification systems, Certification bodies operational policies and functions, National standards for crop production, livestock, Aquaculture, Processing and handling and other miscellaneous systems. Tracenet the online data management tool and traceability management

PGS – Participatory Guarantee Systems – Evolution of PGS Systems, Guiding principles, PGS Standards, International scenario on PGS development Procedure for organic guarantee under PGS systems, PGS-India programme, operation of PGS-India programme, institutional structure, PGS-India Data management platform, management of traceability.

Unit IV

On-field management of standard compliance and documentation

Issues for implementation of standards on field such as conversion period, contamination control, fertility management, living condition requirement for livestock, management of integrity in processing and handling, Fundamental policy for inspections, step-by-step inspection protocols, Development of inspection formats and inspection checklists. Documentation requirements such as organic system plan, field operation register, input and cultural practices record, processing record, purchase and sales records and product flow in processing.

Unit V

Individual and grower group certification management

Basic requirements for certification management by (a) Individual producer and (b) Grower/ producer groups. Applicability and types of systems covered

Unit VI

Inspection (under NPOP) and peer review (under PGS) systems

Fundamental principles of inspection, checklists and inspection parameters, general policy frame work

NPOP – Third party inspection procedure, risk assessment, documentation and record keeping review, physical verification of facilities, fields and stables, production facilities, estimated yield/production assessment, tracking the product flow throughout the process, chain of custody. Review of inspection forms and checklists and certification decisions.

PGS-India – Peer review principles, making of peer review committees and peer review checklists, analysis of peer review checklists and certification decisions. Submission of summary sheets to Regional councils and assessment and endorsement of certification decisions.

Unit VII

Certification of crop, livestock, aquaculture and other systems

Standards, their implementation in production systems, measures for contamination control, integrity management, sanitation and hygiene, input evaluation procedures, development of process tracking checklists

Unit VIII

Certification of processing, handling, trading and management of traceability

Standards, their implementation in production/ processing and handling systems, measures for contamination control, integrity management, sanitation and hygiene, packaging and labelling, development of process tracking checklists

Unit IX

Internal control system management in large farmer groupsunder NPOP

Large farmer groups, essential requirements, internal control systems, development of ICS operating manual, management of ICS, internal inspections, risk assessment, assessment of internal inspections and certification decisions, additional documentation for groups, produce/ output management and sale record management

Unit X

PGS Group development and PGS certification management

Essential requirements for local groups, development of local group operating manuals, requirements of group meetings and trainings, decision making by farmers, operational policies for Regional Councils, developing operating manual for Regional councils, assessment of summary sheets and decisions of local groups, procedure for decision endorsement and certification granting

VI. Practical

- Documentation of certification procedures, acquaintance with record keeping, handling, labeling and preparation of farmers IDs for developing ICS.
- Visit to certification bodies, certified farms, certified processing and handling operations
- Development of organic system plan for specific production system
- Development of inspection format and checklists for specific production system
- Development of operating procedures on specific aspects
- Risk assessment on organic farms and possible mitigating measures
- Running of audit trails in certified operations
- Mock inspections of different production systems
- Exercise on inspection report/ peer evaluation checklist review and certification decision
- Exercise on methods of yield assessment

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

Educating to become a real organic grower

IX. Suggested Reading

- *Basics of Organic Farming:* Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B.Singh. Jain Brothers.
- *Principles of Organic Farming:* S.R. Reddy. Kalyani Publisher.

I. Course Title : Value Chain Management
II. Course Code : OF 508
III. Credit Hours : 2+2

IV. Aim of the course

To provide knowledge on value chain for optimization of crop yield due to organic farming

V. Theory

Unit I: Introduction

What is value chain? Defining value chain and its finance (Internal value chain finance, External value chain finance, Interest around value chain finance in agriculture, interest in value chain finance in agriculture); Overview of value chain management.

Unit II: Understanding agricultural value chain finance

Context, the concept of agricultural value chain finance, Agricultural value chain finance as an approach, Enabling environment (standards and certification, regulation and enforcement, macro-economic and social context), and Value chains and diversified livelihoods.

Unit III: Value chain business models

Producer-driven value chain models, Buyer-driven value chain models, Facilitated value chain models, and Integrated value chain models. Case Study 1. On commercial village approach.

Unit IV: Agricultural value chain finance instruments

Product overview, Product financing (trader credit, input supplier credit, marketing company credit, lead firm financing), Receivables financing (Trade receivables finance, factoring and forfeiting), Physical asset collateralization (warehouse receipts, repurchase agreements, financial lease), Risk mitigation products (crop/ weather insurance, forward contracting, futures), Financial enhancements (securitization, loan guarantees, joint ventures). Case Study 2. Producer-driven financing of farm inputs: informal inventory credit; Case Study 3. Integrated financial instruments and value chain services.

Unit V: Innovations

Value chain innovations, Financial innovations, Technological innovations (management systems, networks and exchanges, mobile phones and mobile banking), Infrastructural innovations, Policy and public sector innovations. Case Study 4. Technological innovations; Case Study 5. Avenues for sustainable agricultural development.

Unit VI: Leadership Approaches for Successful Food Value Chains

Values-Based Leadership, Values-Based Leadership in Practice, Leadership in succession.

Unit VII: Organic food value chain management

VI. Practicals

- Collection, aggregation and value addition
- Maintain quality and integrity of the product - practices and procedures, monitoring practices and procedures followed, record keeping systems, management practices and separation measures, handling and processing of organic products
- Pest control - Treatments with pest regulating agents – permitted [physical barriers, sound, ultra-sound, light and UV-light, traps (incl. pheromone traps and static bait traps), temperature control, controlled atmosphere and diatomaceousearth] and prohibited
- Ingredients - approved and prohibited ingredients (microorganisms, minerals, gases)
- Processingmethods - permitted and prohibited mechanical, physical and biological
- Packaging - permissible biodegradable, recyclable, reusable systems and eco-friendly packaging
- Labeling - labeling requirements for agricultural commodities and processed food
- Storage and Transport - permitted conditions of storage to maintain productintegrity
- Food additives including carriers for use in production of processed organic food
- Processing aids and other products for use for processing of ingredients of agricultural origin from organic production flavouring agents, Preparations of Micro-organisms, Ingredients
- Approved products for packaging of organic foodstuffs incl. Permissible packaging material for aquaculture

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VIII. Learning outcome

High value in organic products

IX. Suggested Reading

- *Basics of Organic Farming:* Mamta Bansal. Kindle Edition.
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B. Singh. Jain Brothers.
- *Principles of Organic Farming:* S.R. Reddy. Kalyani Publisher.

I. Course Title : Marketing

II. Course Code : OF 509

III. Credit Hours : 2+0

IV. Aim of the course

To provide knowledge on marketing of organic produce for economic profit of the grower

V. Theory

Unit I: What is Marketing?

Facets of marketing, Facilitating functions of a market, What's special about agricultural markets? Pricing policy and Role of prices.

Unit II: Basics of Supply and Demand–

Demand, Aggregate demand, Supply and Aggregate supply.

Unit III: Food Marketing Channel–

Understanding the food marketing channel, Scenario Analysis.

Unit IV: Market intelligence–

Marketresearch, Production cost assessment, Projecting Revenues, Accounting, Market Selection.

Unit V

Organic production and domestic market size, Institutional context and regulations (such as NPOP, NSOP, APGMC Act, PGS, FSSAI, Jaivik Bharat).

Unit VI: Organic Food Distribution System–

Domestic market structures, and classification framework, urban organic retail models, Organic specialty stores, markets and health food stores. Direct marketing and Community Supported Agriculture.

Unit VII: Market Potential for Organic Foods–

Consumer preferences and perceptions (organic sensitivity, building awareness on organic foods and consumer needs, shopping Behavior, factors influencing purchases of new foods), general trade and organized retail.

Unit VIII: e-Marketing and e-Consumer Perceptions and Behaviour–

Why organic food, source and perception of organic foods, uses of organic food, resistance to use organic products, source of awareness, organic food-is it a fad?, On-line retail and home delivery services, role of advertising and choice of media, understanding the role of quality in marketing, perception of health benefits and assurance/certification.

Unit IX

Accessibility of organic foods, premiums and willingness to pay premiums, role of retailer

Unit X

Efficient supply chains and retail channels, sustainability of supply chain.

Unit XI: Consumer purchase Behavior and habits–

Shopping Behavior, role of influencer in decision making, concern over adulteration, chemicals, loss of nutrients and vitamins during processing and manufacturing and its impact on marketing and sale.

Unit XII: Challenges and success stories–

Success stories in organic marketing, organizational models, their advantages, challenges, limitations and legal context.

VI. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion

VII. Learning outcome

Basic knowledge on marketing to get higher prices in organic produces.

VIII. Suggested Reading

- *Basics of Organic Farming:* Mamta Bansal. Kindle Edition
- *The Complete book of Organic farming and products of organic compost:* NPCS Board of consultants and Engineers.
- *ABC of Organic Farming:* Amitava Rakshit and H.B. Singh. Jain Brothers
- *Principles of Organic Farming:* S.R. Reddy. Kalyani Publisher.

I. Course Title : Research Methodology and Biostatistics

II. Course Code : OF 510

III. Credit Hours : 2 + 1

IV. Theory

Unit I

Experimental techniques: Research design, sampling, data collection, On-station experimentation, On-Farm experimentation, tabulation, Statistical tools and analysis techniques for interpretation of data.

Unit II

Geo-referenced characterization: Questionnaire design principles, Questionnaire design for consumers of organic products, Questionnaire design for farmers and producers of organic products, Questionnaire design for processors/ traders/ exporters, Geo-spatial analysis and mapping of organic farms/ producers/ traders/ consumers.

Unit III

Meta data analysis: Concepts, statistical methods, clustering research results, Holism, Positivism, Objectivism, Reductionism, Constructivism, Subjectivism, data source, Variable coding and analysis, interpretation.

Unit IV

Niche area and crops for organic farming: Parameters for niche area and crop, Different scales of niche area, Tools and steps in Niche area and crop identification, Parameterization and classification based on macro, regional and micro level.

Unit V

Climate resilience of organic farming: Methodology for identification of climate resilient production systems, GHG's estimation using IPCC, GHG's measurement using instrumentation, Global Warming Potential, Energy & Carbon budgeting.

Unit VI

Breeding for organic production system: Conventional breeding strategies for organic production, participatory plant breeding, Marker aided selection, Stability analysis, Molecular characterization of indigenous organic inputs, Bio-chemical and molecular signature of organic produces.

Unit VII

Commercial Project Formulation on Organic Farming: Internal rate of return, Pay Back period, B: C ratio, Net Present Value, Model project formulation for organic farming, Impact analysis tools and methods.

Unit VIII

Farming System model development: Synthesis of IFS models using primary and secondary data, classification, validation of farming systems.

Unit IX

Notations in statistics: Basics of statistical notation, Algebric rules, designing a variable, standard notation for statistics.

Unit X

Descriptive statistics: Measures of central tendency, measures of variability, relative scores, measures of relationship, skewness, kurtosis.

Unit XI

Introduction to statistical inference and testing of hypothesis: Statistical model, point estimation, confidence intervals, hypothesis testing, t-test, non-parametric alternative sign test.

V. Practical

- Synthesis of farming system model
- Estimation of GHG emission from IPCC tool
- Meta data analysis using published papers
- Identification and niche area and crops for a district or block
- Identification of Climate resilient production system using long term meteorological data
- Commercial project formulation
- Geo-spatial analysis using GIS platform
- Carbon and energy budgeting of an organic farm

I. Course Title : Organic Input Management and Production Technologies

II. Course Code : OF 511

III. Credit Hours : 2+1

IV. Aim of the course

To provide knowledge on various organic inputs, their production technologies, quality control and commercialization aspects

V. Theory

Unit I: Introduction

Need for on-farm and off-farm (external) organic inputs, types of organic inputs allowed under organic farming, regulatory scenarios and standards. Status of organic and biological input industry in the country.

Unit II: On-farm inputs soil fertility and nutrient management

Types of on-farm inputs for soil fertility and nutrient management, their need assessment under specific cropping systems *vis-à-vis* soil test reports, methodologies for recycling of on-farm biomass and crop residue, innovative traditional inputs such as jivamrit, beejamrit, panchgavya etc. their microbial profiling and nutrient mobilization potential and standardized production methods, Oil cakes and their applications.

Unit III: On-farm inputs, plant health management and pest control

Types of plant protection inputs and intervention approaches, use of biological and ecological approaches, preventive practices, Types of plants used in plant protection and their biological characterization for pest control, basic methodologies for active ingredient extraction and on-farm formulations.

Unit IV: Composts and their value added products

Types of composts, their characters, nutrient potential, composting methodologies (aerobic, anaerobic, NADEP, *etc*), value added composts, quality control parameters, commercial production methodologies for city waste compost, Phosphate Rich Organic manure (PROM), bio-organic manure, technologies for product formulations such as enrichment and granulations, *etc.*

Unit V: Biofertilizers

Types of biofertilizers, standards for commercial products, testing methodologies, characterization and efficiency parameters, management of microorganisms in laboratory, production methodologies such as mother culture development, mass production through fermentation and fermentation parameters, mass scale culture techniques, product formulations, carrier-based inoculants, liquid inoculants and lyophilized inoculants.

Unit VI: Microbial Biopesticides

Types of biopesticides, standards for commercial products, testing methodologies, characterization and efficiency parameters, management of microorganisms in laboratory, production methodologies such as mother culture development, mass production through fermentation and fermentation parameters, mass scale culture techniques, product formulations, carrier based inoculants, liquid inoculants and lyophilized inoculants. Types of polyhedrosis and granulosis viruses and their production methodologies.

Unit VII: Mass rearing of beneficial insects

Introduction to beneficial insects such as pest predators and parasites, classification and identification, mass rearing technologies including rearing of host insects, Production of egg cards of beneficial insects and their release in the field.

Unit VIII: Botanical pesticides and other non-chemical pest protectants

Type of non-chemical plant protection options, importance of soaps and oils, important plants having pesticidal properties, plant parts having pesticidal active ingredient and their extraction methodologies, product formulation and stabilization for increased shelf life, field assessment of efficacy. Regulatory scenario and quality parameters.

VI. Practical

- Getting familiarized with on-farm soil fertility management inputs (such as beejamrit, jivamrit, panchgavyaetc), ingredients needed and production methodology. Preparation and quality assessment
- Application of such inputs in small plots on selected crops and observation on growth
- Production of different composts including vermicompost
- Quality analysis of composts for nutrients and heavy metals
- Biofertilizer organisms, their laboratory characterization, sub-culturing and mother culture development
- Fermentation technology demonstration, production of bacterial broth in pilot scale fermenters
- Biofertilizer product formulations and quality analysis methods
- Study biopesticide organisms, laboratory culturing, mass cultivation using solid state fermentation, liquid fermentation and spore harvesting methods and product formulations
- Visit to beneficial insect rearing laboratory and handling of insects including demonstration on tricho-cards production
- Extraction of neem seed kernel extracts and neem oil. Production of botanical extracts and product formulation using emulsifiers
- Study effect of various botanical extracts on insect pests
- Preparation of Bordeaux mixtures and copper fungicides

VII. Teaching methods/activities

Classroom teaching with AV aids, group discussion, assignment and class discussion. Practical in the laboratory, visit to production sites and demonstration of production protocols through industry visits, practical on analysis protocols

VIII. Learning outcome

Basic knowledge on marketing to get higher prices in organic produces.

IX. Suggested Reading

- *The Complete Technology Book on Vermiculture and Vermicompost*, NPCS Board of consultants and Engineers, Asia Pacific Business Press
- *Training material on Composting and Vermicomposting*, Published by Ecosan Services Foundation
- *Biofertilizers and Biopesticides*, A, Channabasava and H.C. Lakshman
- *Handbook of Biofertilizers and Biopesticides*, by AM Deshmukh, RM Khobrgade and PP Dixit
- *Mass Production of Beneficial Organisms*, by J. Morales-Ramos, M. Guadalupe and DS Ilan, Academic Press, 2013.

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 2

Social Sciences

- Agricultural Economics
- Agricultural Extension Education
- Agri-Business Management

Contents

Acknowledgements

The disciplines of Social Sciences deal with the study of society and the relationship among individuals within society. It includes study of business, sociology, commerce, demography, and allied areas. Research in Social science research provides authentic and scientifically validated information to the end users. The importance of social research is reflected in its ability to provide fact-checked and well-validated answers to questions involving human interactions. Hence, while technology can serve the purpose of taking agricultural sciences across society for bettering profits and livelihoods and also become food and nutritional-secure, social science research can enhance the social unity by providing solutions at the doorstep of the end-users with a societal acceptance. It is most important that Agricultural Universities develop their curriculum integrating the technology developing sciences into the social sciences and catalyse trained social science professionals. Deployment of technologies-be it cost-intensive cutting-edge agricultural technologies or simple local innovations is crucial for augmenting agricultural production for our country and social science professionals have a crucial role to play in the dissemination to the end-users.

Against this responsibility to develop such trained professionals, this committee of BSMA has done 360 degree evaluation of the current curriculum of three disciplines namely, Agricultural Extension, Agricultural Economics and Agri-Business Management adopting a multi-pronged approach. Hence, stakeholder interaction, expert consultation and analysis of curriculum of global-level agricultural universities formed the basis to match the needs as per the national vision. Specifically, the committee has also explored the essence of National Educational Policy (NEP) into the curriculum planning processes. The Fifth Dean Committee report and the earlier under-graduate curricula in three disciplines also formed an important base for the committee to ensure continuity with UG and PG curriculum. We would like to put on record our sincere thanks to Dr T. Mohopatra, Secretary, DARE and Director General (DG), ICAR; Dr N.S. Rathore, Former Deputy Director General (Education), and Dr R.C. Agrawal, Deputy Director General (Education), ICAR, New Delhi for constituting this committee. We are highly indebted to Dr Arvind Kumar, Vice Chancellor, RLBCAU and Chairman of National Core Group for PG/ PHD course revision for his patience and constant support. The role of Dr G.Venkateshwarlu, Former ADG (EQR) as Member Secretary, NCG has been extremely supportive and crucial during the two years of this activity for this committee. The committee puts on record with appreciation his constant support to it.

Our sincere gratitude and thanks to all the members of this BSMA Committee for Social Sciences namely Dr Rakesh Singh , Professor, Dept. of Agricultural Economics, IAS, BHU, Varanasi, Dr S. Mahapatra, Professor and Head, Agri Business Management, OUAT, Bhubaneswar, and Dr Aditi Mathur, Professor, Institute of Agri Business Management, Swami Keshwanand Rajasthan Agricultural University, Bikaner for their continuous support, encouragement and suggestive nature throughout the journey of final draft preparation.

Lipi Das	**R.Kalpana Sastry**
Convenor	Chairperson
BSMA for Social Sciences	BSMA for Social Sciences

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Social Sciences
– Agricultural Economics

Acknowledgements

Agricultural sector plays an important role in Indian Economy. Changes in agricultural sector are taking place at a faster rate and this sector is integrated globally and therefore facing global challenges. In the era of Information and Communication Technology, the knowledge which we gain becomes obsolete within few years therefore it is important to update/ reform our curriculum in line with the recent changes taking place. The major challenges faced by agricultural sector currently is related to distribution/ supply chain rather than production side. We are largest producer of food grain, horticultural products milk and livestock products but we are the host of large no of poor people and mal nutrition people. Farmers' distress has become the major cause of concern for policy makers, on the other hand climate change is posing many challenges.

The sub-committee on Agricultural Economics constituted by ICAR (under the ICAR Broad Subject Matter Area (BSMA) for Social Sciences) has kept all these challenges and development in view while revising the PG and PhD Curricula in Agricultural Economics. We reviewed the under-graduate, PG and Ph.D curricula. Moreover, student's prior knowledge is critical for learning any discipline and so we had to review and propose a new curriculum for Agricultural Economics at all levels. To do these, we identified first the core competencies that are required at the different levels and worked backwards based on the areas and organising them into courses.

We are also recommending internship at the Master's level for 5 credits and Teaching Assistantship at the Ph.D. level for 5 credits. We believe this will help the students to have more relevant practical experience and this will boost their job prospects. The committee also discussed about the need for organizing exposure visit for PG/Ph.D. students to universities abroad (student exchange).

The committee organized three national level stakeholders meeting and consultation with Agril Economics professionals representing different universities, ICAR institutions involved in teaching and research in Agricultural Economics first at PJTSAU, Hyderabad on 12 July 2018, second meeting at Institute of Agri Business Management, Swami Keshwanand Rajasthan Agril University, Bikaner during September 17-18, 2018 and third BSMA (Social Sciences) meeting on 28-01-2019 at Institute of Agricultural Sciences, BHU, Varanasi for reviewing the final drafts of three disciplines of Social Sciences.

Our sincere thanks to Prof. Suhasini, Head, Dr (Mrs) Vijayakumari and faculty members, research scholars of Dept of Agril Economics, PJTSAU, Hyderabad; Prof. Smita Sirohi, Head Agril Economics, NDRI, Karnal (Haryana); Prof. RL Shiyani, Junagarh Agril. University Gujarat; Prof. Sanjay Kumar Srivastava, GBPUA&T, Pantanagar, Prof. Rajesh Sharma, HOD and Prof. Madhu Sharma, SKRAU Bikaner; Prof. PS Badal, Prof Chandra Sen, Prof. HP Singh, Dr O.P. Singh, Dr Prashant Kumar Singh, Dr Manish Kumar Yadav, Dr Neeraj Singh and research scholar ofrom the Department of Agril Economics, Institute of Agril Sciences BHU, Dr Ranjit HOD ABM, NAARM Hyderabad for their participation and valuable inputs/ suggestion in the development of course curriculum of Aril Economics. We extend our gratitude to Prof. Jyoti Kacharoo, HOD Agril Economics, SKUAST, Jammu; Prof. Wani, HOD, SKUAST, Srinagar, Prof. HN Singh, HOD, GBPUAT, Prof. Alka Singh, IARI, New Delhi, Prof. Ram Singh, HOD, CAU, Barapani, Prof. KK Datta, CAU, Barapani, Shillong for their critical inputs and suggestion. We thank to Prof. Rakesh Bhatnagar, Vice-Chancellor, BHU, Prof. Ramesh Chand, Director, Institute of Agril. Sciences, Prof. AP Singh, Dean, Prof. PS Badal, Head for their support to organize the BSMA meeting at BHU Varanasi.

Our sincere gratitude and thanks to all the members of BSMA Committee for Social Sciences, namely, Prof. I Sreenivasa Rao, Professor, Dept. of Extension, PJTSAU, Hyderabad; Dr S Mahapatra, Professor and Head, Agri Business Management, OUAT, Bhubaneswar, and Dr Aditi Mathur, Professor, Institute of Agri Business Management, Swami Keshwanand Rajasthan Agricultural University, Bikaner for their continuous support, encouragement and suggestive nature throughout the journey of final draft preparation.

Finally, we thank profusely Dr NS Rathore, Former Deputy Director General (Education), ICAR, New Delhi, Dr Venkateswarlu, Former ADG (EQR), ICAR for constituting the BSMA for undertaking curricula revision of PG and Ph.D. and their valuable guidance and support in this regard.

Prof. Rakesh Singh (Member, BSMA, Agricultural Economics)
Dr Lipi Das (Convener, BSMA, Social Sciences)
Dr Kalpana Sastry (Chairperson, BSMA, Social Sciences)

Course Title with Credit load
M.Sc. (Ag) in Agricultural Economics

Major Courses: 20 credits

Course Code	Course Title	Credit Hours
AEC-501*	Micro Economic Theory And Applications	3 (3+0)
AEC-502*	Agricultural Production Economics	2 (1+1)
AEC-503*	Agricultural Marketing and Price Analysis	3 (2+1)
AEC-504*	Macro Economics And Policy	2 (2+0)
AEC-505*	Econometrics	3 (2+1)
AEC- 506	Agricultural Development and Policy Analysis	2 (2+0)
AEC-507*	Agricultural Finance and Project Management	3 (2+1)
AEC-508*	Linear Programming	2 (1+1)
AEC-509*	Research Methodology for Social Sciences	2 (1+1)
AEC-510	Indian Economy: History and Contemporary Issues	2 (2+0)
AEC-511	International Economics	2 (1+1)

*courses to be taken compulsorily

Minor Courses: 08 credits

a. It is suggested the student may choose at least two out of three courses listed above as part of minor courses as these are related to policy advocacy and aim to build larger understanding of the subject.
b. Further, it is suggested that the student may also opt to choose the remaining Courses from any other discipline including the disciplines of Agrl. Extensions/ ABM and are related to the research problem selected by the student.
c. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/ HOD.

Course Code	Course Title	Credit Hours
AEC-512	Institutional Economics	1(1+0)
AEC-513	Natural Resource and Environmental Economics	2 (1+1)
AEC-514	Commodity Future Trading	2 (2+0)
AEC-515	Development Economics	2 (2+0)
AEC-516	Rural Marketing	2 (2+0)
AEC-517	Evolution of Economic Thought	1 (1+0)

Minor courses may be taken from above list or subjects closely related to a student's major subject.

Supporting Courses: 6 credits

STAT-501	Statistical Methods For Applied/ Social Sciences	3 (2+1)
STAT-502	Mathematics For Applied Sciences/ Agricultural Economics	3 (2+1)
STAT/COMP	Computer Applications For Agri-Business & Economics	3 (2+1)

Common Courses: 05 credits

1. Technical Writing and Communications Skills
2. Intellectual Property and its management in Agriculture
3. Agricultural Research, Research Ethics and Rural Development Programmes

Further, the subcommittee attempted to oversee the design of the entire course is such a way that students may opt to take extra courses to compete with MA Economics stream and Universities may consider to issue a certificate that the degree of M.Sc.(Ag) Agricultural Economics with special mention of extra credits in core Economics.

Course Contents
M.Sc. (Ag) in Agricultural Economics

I. Course Title : Micro Economic Theory and Applications
II. Course Code : AEC-501
III. Credit Hours : 3+0

IV. Why this course?

Markets form an integral part of the economy. They are governed by demand and supply mechanism with profit making its ultimate goal. Thus, it is imperative to expose the students towards how the markets function, their types and how the buyers and sellers behave. That will help them make correct decision when it comes to price setting and choice of product.

V. Aim of the course

The course envisages the concepts and principles embodying micro-economics. The economic problems, functioning of price mechanism, theory of household behaviour and consumer's demand function. Theory of firm, supply determinants, determination of price under different market structures and factor pricing (micro economic components).

VI. Organisation of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to micro-economics	1. Basic Concepts: A review
2.	Insight of consumer, production and cost involved	1. Consumer Choice 2. Production and Cost
3.	Overview of market	1. Market Forms 2. Factor Markets

VII. Theory

Block 1: Introduction to micro-economics

Unit 1: Basic Concepts: A review

Scarcity and Choice; Production possibility frontier, Positive and normative economics; concepts of opportunity cost, Demand and Supply: determinants of individual demand/supply; demand/ supply schedule and demand/ supply curve; market versus individual demand/ supply; shifts in the demand/ supply curve

Block 2- Insight of consumer, production and cost involved

Unit 1: Consumer Choice

Cardinal Utility Approach – Ordinal Utility Approach -Budget sets and Preferences under different situations – Hicks and Slutsky income and substitution effects –

Applications of Indifference curve approach – Revealed Preference Hypothesis – Consumer surplus – Derivation of Demand curve – Elasticity of demand – Demand and supply together; how prices allocate resources; controls on prices – price floor and price ceiling – applications in agriculture.

Unit 2: Production and Cost

Production functions: single variable - average and marginal product, variable proportions, stages of production. Two variables - isoquants, returns to scale and to a factor; factor prices; Technical progress; cost minimization and output maximization; Elasticity of substitution. Expansion path and the cost function Concept of economic cost; Short run and long run cost curves; increasing and decreasing cost industries; envelope curve; L-shaped cost curves; economies of scale; revenue and expenditure, elasticity and marginal revenue; Firm equilibrium and profit.

Block 3: Overview of market

Unit 1: Market Forms

Behaviour of profit maximizing firms and the production process- Perfect competition: Equilibrium of the market. Long run industry supply, applications: effects of taxes and subsidies; Monopoly: Equilibrium; supply; multiplant firm; monopoly power; deadweight loss; price discrimination; Monopolistic Competition: Product differentiation; equilibrium of the firm in the industry-with entry of new firms and with price competition. Comparison with pure competition. Duoploy: Cournot model and reaction curves; Stackelberg's model, Bertrand model; Oligopoly.

Unit 2: Factor Markets

Labour and land markets - basic concepts (derived demand, productivity of an input, marginal productivity of labour, marginal revenue product); demand for labour; input demand curves; shifts in input demand curves; competitive labour markets; Economic rent and quasi rent.

VIII. Teaching Methods/ Activities

- Lectures
- Case studies
- Assignments (Group/individual)
- Group Discussions on practises done by firms.
- Power point presentations by students.
- Exploring the agricultural market and identification of industries and their type.

IX. Learning outcome

After completion of the course the student will be able to:

- Get acquainted with the basic concepts of market functions.
- Build up vision towards how consumers makes choices and market reaches the equilibrium.
- Develop decision making skill for firms about product selections and scale of production to ensure maximum profit.
- Understand about different types of markets existing in the real world, their principles and whereabouts.

X. Suggested Reading

- Koutsoyiannis A. *Modern Micro Economics*. Macmillan Press Ltd

- Ferguson and Gould. *Micro Economic Theory*. Richard D Erwin Inc., USA
- Richard A. Bilas, *Micro Economic Theory*.
- Leftwich Richard H. *The Price System and Resources Allocation*
- Allen CL. *A Frame Work of Price Theory*.

I. Course Title : Agricultural Production Economics

II. Course Code : AEC-502

III. Credit Hours : 1+1

IV. Why this course?

Production in agriculture is the outcome of the input factors involved. In this competitive and uncertain market, it is important that the farmers take the right decision about the combination of inputs that will result in higher income. Thus, as an economist it is a pre-requisite that the students understand the interaction between output and input. And work out the most effective production plan.

V. Aim of the course

To expose the students to develop the concept, significance and uses of production economics. To understand the relationships between factors and output. To learn how to decide the combination of inputs to be used as per the resources available. Ensure that the production process works efficiently.

VI. Organization of the course

The course is organised as follows-

No	Block	Unit
1.	Introduction to production economics	1. Concepts of production economics
2.	Factors and costs	1. Factors and theory of production 2. Concepts of costs
3.	Assessment	1. Dynamics of assessment

VII. Theory

Block 1: Introduction to Production Economics

Unit 1: Concepts of production economics

Nature, scope and significance of agricultural production economics- Agricultural Production processes, character and dimensions-spatial, temporal - Centrality of production functions, assumptions of production functions, commonly used forms - Properties, limitations, specification, estimation and interpretation of commonly used production functions.

Block 2: Factors and costs

Unit 1: Factors and theory of production

Factors of production, classification, interdependence, and factor substitution -Determination of optimal levels of production and factor application -Optimal factor combination and least cost combination of production - Theory of product choice; selection of optimal product combination.

Unit 2: Concepts of cost

Cost functions and cost curves, components, and cost minimization -Duality theory

– cost and production functions and its applications -Derivation of firm's input demand and output supply functions -Economies and diseconomies of scale.

Block 3: Assessment

Unit 1: Dynamics of economic assessment

Technology in agricultural production, nature and effects and measurement - Measuring efficiency in agricultural production; technical, allocative and economic efficiencies - Yield gap analysis-concepts-types and measurement - Nature and sources of risk, modeling and coping strategies.

VIII. Practical

- Different forms of production functions
- Specification, estimation and interpretation of production functions
- Returns to scale, factor shares, elasticity of production
- Physical optima-economic optima
- Least cost combination
- Optimal product choice
- Cost function estimation, interpretation
- Estimation of yield gap
- Incorporation of technology in production functions
- Measuring returns to scale-risk analysis.

IX. Teaching Methods/ Activities

- Lectures
- Assignments (Group/individual)
- Group Discussions on working out
- Power point presentations by students
- Exploring the agricultural market and identification of industries and their type.

X. Learning outcome

After the successful completion of the course the student will be able to— Understand how the factors and output interact with each other. - Work out whether the production system is working efficiently and point out the loop holes.- Apply the knowledge of costs and profits to work out the demand and supply functions. This will result into more efficient decision making.

XI. Suggested Reading

- EO Heady. *Economics of Agricultural Production and resources use.*
- John P Doll and Frank Orazem. *Production Economics: Theory with application*
- Heady EO & Dillon JL. 1961. *Agricultural Production functions.* Kalyani Publishers, Ludhiana, India. 667 p.
- Baumol WG. 1973. *Economic theory and operations analysis*. Practice Hall of India Private Limited, New Dehli.626 p.
- Gardner BL & Rausser GC. 2001. *Handbook of Agricultural Economics* Vol. I Agricultural Production. Elsevier.

I. Course Title : Agricultural Marketing and Price Analysis

II. Course Code : AEC 503

III. Credit Hours : 2+1

IV. Why this course?

The ultimate aim of production process is to sell the produce in the market and generate income. Markets serves as platform where this exchange takes place. Agriculture markets are different from other markets due to the nature of the commodity. Thus, it is important to develop a strong foundation of agricultural marketing, its components and issues. The student needs to know about the multi-pronged ways of marketing the produce, agencies involved. In this modern era, it is important to understand how technology is transforming this sector.

V. Aim of the course

The course is designed to acquaint the students about the basics of dynamics of agricultural marketing. The content includes supply, demand and marketing of farm production, marketing functions and channels, marketing costs, margins and efficiency, agricultural prices, New marketing formats like e-marketing, e-NAM future trading, supply chain management, market intelligence etc.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to agricultural marketing	1. Introduction to agricultural marketing
2.	Agricultural markets	1. Aspects of agricultural marketing 2. Future marketing and government
3.	Advances in agricultural marketing	1. Use of information technology 2. Dynamics of price

VII. Theory

Block 1: Introduction to Agricultural Marketing

Unit 1: Introduction to agricultural marketing

New Concepts in Agricultural Marketing - Characteristic of Agricultural product and Production – Problems in Agricultural Marketing from Demand and Supply and Institutions sides. Market intermediaries and their role - Need for regulation in the present context - Marketable & Marketed surplus estimation. Marketing Efficiency - Structure Conduct and Performance analysis - Vertical and Horizontal integration - Integration over space, time and form-Vertical co-ordination.

Block 2: Agricultural Markets

Unit 1: Aspects of agricultural marketing

Different Forms of marketing: Co-operatives Marketing – APMC Regulated Marketing - Direct marketing, Farmer Producer Companies, e-NAM and marketing under e-NAM, e-marketing Contract farming and Retailing, Organized retailing - Supply Chain Management - State trading, Warehousing and other Government agencies -Performance and Strategies -Market infrastructure needs, performance and Government role - Value Chain Finance.

Unit 2: Future marketing and government

Introduction to Commodities markets and future trading - Basics of commodity futures - Operation Mechanism of Commodity markets – Price discovery - Hedging and Basis - Fundamental analysis - Technical Analysis – Role of Government/SEBI in promoting commodity trading and regulatory measures.

Block 3: Advances in Agricultural Marketing

Unit 1: Use of Information Technology

Role of Information Technology and Market Intelligence in marketing of agricultural commodities, -electronic auctions (e-bay), e-Chaupals, Agmarknet and Domestic and Export market Intelligence Cell (DEMIC).

Unit 2: Dynamics of price

Price forecasting – time series analysis – time series models – spectral analysis. Price policy and economic development – non-price instruments.

VIII. Practical

- Supply and demand elasticities in relation to problems in agricultural marketing.
- Price spread and marketing efficiency analysis.
- Marketing structure analysis through concentration ratios.
- Performance analysis of Regulated market and marketing societies. Analysis on contract farming and supply chain management of different agricultural commodities, milk and poultry products.
- Supply Chain Analysis - quantitative estimation of supply chain efficiency.
- Market Intelligence – Characters, Accessibility, and Availability Price forecasting.
- Online searches for market information sources and interpretation of market intelligence reports – commodity outlook.
- Technical Analysis for important agricultural commodities.
- Fundamental Analysis for important agricultural commodities.
- Presentation of the survey results and wrap-up discussion.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on price volatility and control measures prevailing.
- Power point presentations by students on government schemes.
- Visit to eNAM mandies, Warehouses, etc.

X. Learning outcome

After the completion of this course the student will be able to–

- Understand the whereabouts of agricultural marketing.
- The different forms of marketing existing in this sector.
- Gain expertise in market intelligence and price forecasting.

XI. Suggested Reading

- Acharya SS & Agarawal NL. 2004. *Agricultural Marketing in India*. Oxford and IBH Publishing company Pvt. Ltd. New Delhi.
- Acharya SS & Agarawal NL. 1994. *Agricultural Prices-Analysis and Policy*. Oxford and IBH Publishing company Pvt. Ltd. New Delhi.
- Richard H Kohls and Joseph N. Uhl: *Marketing of Agricultural products* by Collier MacMillan International.

I. Course Title : Macro Economics and Policy

II. Course Code : AEC-504

III. Credit Hours : 2+0

IV. Why this course?

The economy of the nation is governed by certain rules, regulation and principles. The students has to gain knowledge of the mechanism through which the large economies are controlled and ensure that welfare prevails. They are entitled to know the transactions between different markets and policies framed to keep value of money under control.

V. Aim of the course

The course envisages the concepts and principles of macroeconomics from classical to Keynesian theories. The other component deals with the monetary system-money, credit and banking system, value of money and economic activities, national income accounting and approaches to estimate national income theory of income and employment determination and inflation.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Conceptualising Macro economics	1. Introduction: Measurement and Concepts
2.	Theories of macroeconomics	1. Classical Macroeconomics 2. Income and spending: Keynesian Framework
3	Money, Consumption and Inflation	1. Money, Interest and Income 2. Theories of Aggregate Consumption and Investment 3. Inflation and Unemployment

VII. Theory

Block 1: Conceptualising Macro Economics

Unit 1: Introduction: Measurement and Concepts

Basic concepts and scope of Macro-economics, National Income Accounting: Methods of measurement of key macro-economic aggregates, relationship of national income and other aggregates (with numerical exercises), real and nominal income

Block 2: Theories of macroeconomics

Unit 1: Classical Macroeconomics

Say's Law, Quantity Theory of Money, aggregate labour supply and demand of labour, Classical theory of determining output, wages and prices.

Unit 2. Income And Spending: Keynesian Framework

Simple Keynesian model of income determination; Keynesian Multiplier- aggregate spending, taxation, transfer payments, foreign spending, balanced budget; budget surplus (with numerical exercises).

Block 3- Money, Consumption and Inflation

Unit 1: Money, Interest and Income

Goods market equilibrium-IS curve; Demand for Money, the Liquidity Preference

Theory – Liquidity Trap; asset market equilibrium- LM curve; simultaneous equilibrium in goods and asset market- effect of fiscal and monetary policy

Unit 2: Theories of Aggregarte Consumption and Investment

Absolute Income Hypothesis, Relative Income Hypothesis, Fisher's Inter-temporal Choice Model, Life-Cycle and Permanent Income Hypotheses; Profits and Accelerator Theory.

Unit 3: Inflation and Unemployment

Inflation: Nature, Effects and control; Types of inflation – demand pull, cost push-stagflation, core inflation, hyperinflation; Phillips curve.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on inflation.

IX. Learning outcome

After the completion of the course the student will be able to-Understand the concepts of national income, theories build up to understand macroeconomics. Understand better about the policies and government steps taken to control the economic transaction of the nation. Workout how the investment acts as a catalyst in national development.

X. Suggested Reading

- Stonier & Hegue. *A Text Book of Economic Theory*
- Samuelson PA. 1948. *Foundation of Economic Analysis*. Harvard University Press
- MC Vaish Allid. 1983. *Macro–Economics Theory*
- Gardner Ackley. 1961. *Macro–Economics Theory*: Macmillan, New York.
- TF Dernburg & DM Mcdougali-*Macro Economics*
- G. Sirkin – *Introduction to Macro–Economics Theory*
- RL Heibroker-*Understanding Macro–Economics*
- JK Mehta –*Macro Economics*
- Michael R Edgemand – *Macro-Economics: Theory & Policy*
- David' W Pearce –*The dictionary of modern Economics*

I. Course Title : Econometrics

II. Course Code : AEC 505

III. Credit Hours : 2+1

IV. Why this course?

Development of analytical skills is imperative to make students proficient in conducting quality research work. The knowledge of variables, their models, and problems encountered when dealing with variables will build up a compatibility with the analytical aspects.

V. Aim of the course

The course provides knowledge of the econometric methods like time series analysis, linear regression models and their application in economic analysis. The course provides an insight into the econometric problems in analyzing time series and cross section data.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to econometrics	1. Introduction
2.	Classical Regression	1. Classical Linear Regression 2. Breaking down of Classical assumptions
3.	Qualitative Variables	1. Qualitative variables and simultaneous equation models

VII. Theory

Block 1: Introduction to Econometrics

Unit 1: Introduction

Relationship between economic theory, mathematical economics, models and econometrics, methodology of econometrics-regression analysis.

Block 2: Classical Regression

Unit 1: Classical Linear Regression

Basic two variable regression – assumptions estimation and interpretation approaches to estimation – OLS and their properties – extensions to multi-variable models-multiple regression estimation and interpretation.

Unit 2: Breaking down of Classical assumptions

Violation of assumptions – identification, consequences and remedies for Multicollinearity, heteroscedasticity, autocorrelation – data problems and remedial approaches – model misspecification.

Block 3: Qualitative Variables

Unit 1: Qualitative variables and simultaneous equation models

Use of dummy variables- Introduction to simultaneous equations- identification problem

VIII. Practical

- Single equation two variable model specification and estimation
- Hypothesis testing transformations of functional forms and OLS application
- Estimation of multiple regression model
- Testing and correcting specification errors
- Testing and managing Multicollinearity
- Estimation of regressions with dummy variables

IX. Teaching Methods/ Activities

- Lectures.
- Assignments (Group/individual).

X. Learning outcome

After the completion of the course, the student will be able to-Understand the variables and the properties of regression models. Identify the problems in variables and remove them before conducting the analysis and avoid biased results.

XI. Suggested Reading

- Dorfman R. 1996. *Linear Programming and Economic Analysis*. McGraw Hill.
- Greene WH. 2002. *Econometric Analysis*. Pearson Education.
- Johnston J and Dinardo J. 2000. *Econometric Methods*. Mc Graw-Hill.
- Koutseyianis, A. 1997. *Theory of Econometrics*. Barner & Noble.
- Maddala GS. 2002. *Econometrics*. Mc Graw-Hill.
- Pinndyck RS and Rubinfeld DL. 1990. *Econometric Models and Econometric Forecasts*. McGraw Hill.

I. Course Title : Agricultural Development and Policy Analysis

II. Course Code : AEC-506

III. Credit Hours : 2+0

IV. Why this course?

The ultimate aim of the economies is to attain a satisfactory level of development. Development ensures that there is not only increase in income but also the distribution is such that lesser inequalities exist. The students need to know what is development and its related concepts. All the policies framed are with one sole objective of increasing the welfare. Thus, once concept of development is build up, students can better understand policies and their genesis.

V. Aim of the course

Concept of economic development and policy, theories of development, performance of Indian agriculture. The process and implementation of policies over a period of time.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Basic concepts	1. Introduction
2.	Theoretical Concepts	1. Theories of Agricultural Development
3.	Performance and policies	1. Performance of Indian Agriculture
		2. Agricultural Policy: Process and Implementation

VII. Theory

Block 1: Introduction

Unit 1: Introduction

Role of agriculture in economic/ rural development – Evolution of thinking on agriculture and development; Agricultural development – meaning, stages and determinants – Population and food supply – need for sound agricultural policies

Block 2: Theoretical Concepts

Unit 1: Theories of Agricultural Development

Resource exploitation model- Conservation model- Location (Urban impact) model- Diffusion model- High pay-off input model-Induced Innovation Model- Agricultural R&D and Linkages

Block 3: Performance and policies

Unit 1: Performance of Indian Agriculture

Agrarian structure and land relations; trends in performance and productivity; agrarian structure and technology; credit, commerce and technology; capital formation; subsidies; pricing and procurement; Post Green Revolution agriculture; Production and productivity crisis in agriculture; Regional differences; Food Security, PDS system and Malnutrition.

Unit 2: Agricultural Policy: Process and Implementation

Instruments of Agricultural Policy; Process of agricultural policy formulation, implementation, Monitoring and Evaluation in India; Global experiences in participatory approach to Agricultural policy process; critical review of various elements of Indian agricultural policy-resource policies – credit policies – input and product marketing policies – price policies; WTO – Agreement on Agriculture; Planning models. Planning for utilization of resources and Indian Five Year Plans.

VIII. Teaching Methods/ Activities

- Lectures.
- Assignments (Group/individual).
- Group Discussions on evolution of Indian Agriculture and Development indices.
- Power point presentation by students on policies and their relevance.

IX. Learning outcome

After the completion of the course the student will be able to-Understand the concept of development and its preference over growth. Visualize how the agriculture sector is performing in this aspect. Understand the motive behind the policies and their implementation.

X. Suggested Reading

- Albert O. Hirschman 1958. *Strategy of Economic Development.* New Man Yale University
- Simon Kuznets 1965. *Economic Growth and Structures.* Oxford New Delhi.
- Das Gupta AK. 1965. *Planning and Economic Growth.* George Allen and Unwin London
- Robert E. Baldwin 1966. *Economic Development and Growth.* John Willey, New York

I. Course Title : Agricultural Finance and Project Management

II. Course Code : AEC 507

III. Credit Hours : 2+1

IV. Why this course?

Money is the fuel of driving all the economic activities. India is a land of small and marginal farmers. The financial conditions of the farmers is not so strong that they can finance themselves. They require credit to meet the requirements of inputs. Thus, the student should know the sources, principles involved and types of credit available. The institutions involved and on what grounds the finance is given to the farmer. What are the risks involved and how to overcome them.

V. Aim of the course

This course is designed with an objective to deliver knowledge of the principles, procedures, problems and policies relating to financing agricultural firms. In addition to this the students are also given knowledge about the research developments in the subject. The approach is analytic.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1	Introduction to Agricultural Finance	1. Basic Concepts: A review
2.	Credit and financial analysis	1. Credit and its aspects 2. Financial analysis
3	Project and risk management	1. Project Overview 2. Risk and its Management

VII. Theory

Block 1: Introduction to Agricultural Finance

Unit 1: Basic concepts: A Review

Role and Importance of Agricultural Finance. Financial Institutions and credit flow to rural/priority sector. Agricultural lending – Direct and Indirect Financing - Financing through Co-operatives, NABARD and Commercial Banks and RRBs. District Credit Plan and lending to agriculture/priority sector. Micro-Financing and Role of MFI's - NGO's, and SHG's.

Block 2: Credit and Financial Analysis

Unit 1: Credit and its aspects

Lending to farmers – The concept of 3 C's, 7 P's and 3 R's of credit. Estimation of Technical feasibility, Economic viability and repaying capacity of borrowers and appraisal of credit proposals. Understanding lenders and developing better working relationship and supervisory credit system. Credit inclusions – credit widening and credit deepening.

Unit 2: Financial analysis

Financial Decisions – Investment, Financing, Liquidity and Solvency. Preparation of financial statements - Balance Sheet, Cash Flow Statement and Profit and Loss Account. Ratio Analysis and Assessing the performance of farm/ firm.

Block 3- Project and Risk Management

Unit 1: Project Overview

Project Approach in financing agriculture. Financial, economic and environmental appraisal of investment projects. Identification, preparation, appraisal, financing and implementation of projects. Project Appraisal techniques – Undiscounted measures. Time value of money – Use of discounted measures - B-C ratio, NPV and IRR. Agreements, supervision, monitoring and evaluation phases in appraising agricultural investment projects. Net work Techniques – PERT and CPM.

Unit 2: Risk and its Management

Risks in financing agriculture. Risk management strategies and coping mechanism. Crop Insurance programmes – review of different crop insurance schemes - yield loss and weather based insurance and their applications.

VIII. Practical

- Development of Rural Institutional Lending;

- Branch expansion, demand and supply of institutional agricultural credit and Over dues and Loan waiving;
- An overview, Rural Lending Programmes of Commercial Banks, Lead Bank Scheme;
- Preparation of District Credit Plan, Rural Lending Programmes of Co-operative Lending Institutions;
- Preparation of financial statements using farm/firm level data, Farm credit appraisal techniques and farm financial analysis through financial statements;
- Performance of Micro Financing Institutions;
- NGO's and Self-Help Groups, Identification and formulation of investment projects;
- Project appraisal techniques – Undiscounted Measures and their limitations;
- Project appraisal techniques – Discounted Measures;
- Network techniques – PERT and CPM for project management;
- Case Study Analysis of an Agricultural project;
- Financial Risk and risk management strategies – crop insurance schemes;
- Financial instruments and methods – E banking, Kisan Cards and core banking.

IX. Teaching Methods/ Activities

- Lectures
- Case studies
- Assignments (Group/individual)
- Group Discussions on inflation

X. Learning outcome

After the completion of the course the student will be able to-Understand the key issues of finance in Agriculture. Learn the techniques of assessing the worth of a project.

XI. Suggested Reading

- E Die Sollem H and Heady EO. (Ed.). *Capital and Credit Needs in Changing Agriculture*, Bauman.
- Hopkins A Barry, Peter Jo and Baker CB. *Financial Management in Agriculture*.
- Murray WG and Nelson AG. 1960. *Agricultural Finance*. Iowa State University
- Chanona C. 1969. *Agricultural Finance in India: Role of Commercial Banks*. Marketing and Economics Research Bureau, New Delhi.
- Gittinger JP. 1972. *Economic analysis of agricultural projects*, John Hopkins Univ. Press, Baltimore.
- Little IMD and JA Mirrless. 1974, *Project appraisal and planning for developing countries*, Oxford and IBH publishing Co. New Delhi.
- Arnold CH. 1972. *Project Evaluation, collected papers*, Macmillan.

I. Course Title : Linear Programming

II. Course Code : AEC-508

III. Credit Hours : 1+1

IV. Theory

Unit I

Decision Making- Concepts of decision making, introduction to quantitative tools, introduction to linear programming, uses of LP in different fields, graphic solution to problems, formulation of problems.

Unit II

Simplex Method: Concept of simplex Method, solving profit maximization and cost minimizations problems. Formulation of farms and non farm problems as linear programming models and solutions.

Unit III

Extension of Linear Programming models: Variable resource and price programming, transportation problems, recursive programming, dynamic programming.

Unit IV

Game Theory- Concepts of game theory, two person constant sum, zero sum game, saddle point, solution to mixed strategies, the rectangular game as Linear Programming.

V. Practical

- Graphical and algebraic formulation of linear programming models.
- Solving of maximization and minimization problems by simplex method.
- Formulation of the simplex matrices for typical farm situations.

I. Course Title : Research Methodology for Social Sciences

II. Course Code : AEC 509

III. Credit Hours : 1+1

IV. Why this course

Planning of research is very crucial to conduct a successful research. There is need to give an insight to the student about how to conduct a research, right from data collection to analysis and finally writing the references.

V. Aim of the course

The course deals with scientific methods of research, the initiation of an inquiry, formulation of research problems and hypotheses, the role of induction and deduction in research, collection and analysis of date and interpretation of results

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to research methodology	1. Concepts of research methodology
2.	Building up hypothesis and sample selection	1. Hypothesis: Framing and Testing 2. Sampling
3.	Data collection and analysis	1. Data collection 2. Data Analysis

VII. Theory

Block 1: Concepts of research methodology

Unit 1: Concepts of research methodology

Importance and scope of research in agricultural economics. Types of research – Fundamental vs. Applied. Concept of researchable problem – research prioritization – selection of research problem. Approach to research – research process.

Block 2- Building up hypothesis and sample selection

Unit 1: Hypothesis: Framing and Testing

Hypothesis – meaning – characteristics – types of hypothesis – review of literature – setting of Course Objective and hypotheses – testing of hypothesis.

Unit 2: Sampling

Sampling theory and sampling design – sampling error - methods of sampling – probability and non-probability sampling methods - criteria to choose. Project proposals – contents and scope – different types of projects to meet different needs – trade-off between scope and cost of the study. Research design and techniques – Types of research design.

Block 3- Data Collection and Analysis

Unit 1: Data Collection

Data collection – assessment of data needs – sources of data collection – discussion of different situations. Mailed questionnaire and interview schedule – structured, unstructured, open ended and closed-ended questions. Scaling Techniques. Preparation of schedule – problems in measurement of variables in agriculture. Interviewing techniques and field problems - methods of conducting survey – Reconnaissance survey and Pre testing.

Unit 2: Data Analysis

Data coding, tabulation, cleaning. –Multivariate analysis –factor analysis' PCA' cluster analysis. Universal procedures for preparation of bibliography – writing of research articles.

VIII. Practical

- Exercises in problem identification.
- Project proposals – contents and scope.
- Formulation of Objective and hypotheses.
- Assessment of data needs – sources of data – methods of collection of data.
- Methods of sampling – criteria to choose – discussion on sampling under different situations.
- Scaling Techniques – measurement of scales.
- Preparation of interview schedule.
- Field testing. Method of conducting survey.
- Exercise on coding, editing, tabulation and validation of data.
- Preparing for data entry into computer.
- Hypothesis testing – Parametric and Non-Parametric Tests.
- Exercises on format for Thesis/ Report writing.
- Presentation of the results.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Learning outcome

After the successful completion of this course, student will be able to-Understand fundamentals of research. How to carefully plan out the research work and conduct it.

XI. Suggested Reading

- Baker CB. *Research Methodology in Agricultural Economics*
- Cohen MR and Nagel R. *An Introduction to Logic and Scientific Method*
- Devey J Logic. *The Theory of Enquiry*
- Dhondhyal SP. *Social Science Research and Thesis Writing*
- Ezekiel M. *Correlation Analysis*
- Heady EO. *Linear Programming Methods*
- Willson ER. *An Introduction to Scientific Research*
- Kumar A. 2008. *Research Methodology: A Survey*. Alts, New Delhi,

I. Course Title : Indian Economy: History and Contemporary Issues Credit

II. Course Code : AEC-510

III. Credit Hours : 2+0

IV. Why this course?

India is a developing economy. The evolution of the Indian economy will enlighten the student with how an economy develops. Students will understand how the policies and measures taken shape up the economy of the country.

V. Aim of the course

To introduce the students to the economic history over a period of time. It also highlights the contemporary issues of Indian economy.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	History of Indian Economy	1. India from Independence to Liberalization 2. India since 1980's (Liberalization and Beyond): Overview 3. Macro Trends Since 1990
2.	Contemporary Issues	1. Contemporary Issues

VII. Theory

Block 1- History of Indian Economy

Unit 1: India from Independence to Liberalization

An overview of the economic developments during the period 1947-1980; Objectives and strategies of planned economic development and the role of the State; Sectoral growth performance; savings and investment; Demographic trends and issues; education; health and malnutrition; Trends and policies in poverty; inequality and unemployment.

Unit 2: India Since 1980's (Liberalization And Beyond): Overview

Policy Changes since 1980s. The 1990 Crisis. Causes and Effects of liberalization. Regional differences: infrastructure, primary, secondary and tertiary sector.

Unit 3: Macro Trends Since 1990

Growth; Savings and Investment, Employment; productivity; diversification; Agro-based industries; competition policy; foreign investment, Regional differences.

Block 2- Contemporary Issues

Unit 1: Contemporary Issues

Monetary and Financial trends- areas of government spending in India, Capital expenditure, revenue expenditure, plan expenditure, non plan expenditure, Deficits (fiscal, primary, revenue), impact of fiscal deficit on economy, Capital receipts, revenue receipts, tax and non tax revenue, direct and indirect taxes, need to rationalize tax structure. Goods and Services Tax (GST). Union Budget, Zero base budgeting, Gender budgeting, Fiscal devolution and centre state financial relations in India, WPI, CPI implicit deflators. Foreign Trade policy.

VIII. Teaching Methods/ Activities

- Lectures
- Power point presentation by students on monetary and fiscal policy in past and present.
- Assignments (Group/individual).
- Group Discussions on Tax and its reforms.

IX. Learning outcome

After the completion of the course the student will be able to-Visualize how the Indian economy has evolved. Get acquainted with the basic steps involved in the working of the national economy.

X. Suggested Reading

- Dutt and Sundaram. *Indian Economy*

I. Course Title : International Economics

II. Course Code : AEC 511

III. Credit Hours : 2+1

IV. Why this course?

The era of Globalisation, liberalization and privatization has unified the whole world. There is trade across national boundaries and one economy has effect on the other. Getting familiar with national economy is not sufficient to understand the mechanism of trade and economic aspects. Thus, this course is designed to teach student about the trade as international level.

V. Aim of the course

The major objective of this course is to give an insight of the interactions between national economies. What are the theories governing the trade across national boundaries. The methods involved to regulate the international trade and institutions involved.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction	1. Concepts of International Economics
2.	Models, Rate and terms of trade	1. Barriers to trade
		2. Models of trade
		3. Rates and Terms of trade
3	Institutions	1. Trades Institutions

VII. Theory

Block 1- Introduction

Unit 1: Concepts of International Economics

Scope and Significance of International Economics – The role of trade- General Equilibrium in a Closed Economy (Autarky Equilibrium) – Equilibrium in a Simple Open Economy - Possibility of World Trade - Trade gains and Trade Equilibrium.

Block 2- Models, Rate and Terms of Trade

Unit 1: Barriers to trade

Tariff, Producer Subsidy, Export Subsidy, Import Quota and Export Voluntary Restraints- The Case of Small Country and Large Country Case.

Unit 2: Models of trade

Ricardian Model of Trade- Specific Factors Model- Heckscher - Ohlin Model - Trade Creation and Trade Diversion – Offer Curve - Export Supply Elasticity and Import Demand Elasticity – Comparative Advantage and Absolute Advantage.

Unit 3: Rates and Terms of trade

Official Exchange Rate and Shadow Exchange Rate - Walra's Law and Terms of Trade – Trade Blocks.

Block 3- Institutions

Unit 1: Trades Institutions

IMF, World Bank, IDA, IFC, ADB – International Trade agreements – Uruguay Round – GATT – WTO.

VIII. Practical

- Producer's Surplus, Consumer's Surplus, National Welfare under Autarky and Free Trade Equilibrium with small and large country assumption.
- Estimation of Trade Gains
- Estimation of competitive and comparative measures like NPC, EPC, ERP and DRC
- Estimation of Offer Curve Elasticity
- Estimation of Effect of Tariff, Export Subsidy, Producer Subsidy, Import Quota and Export Voluntary Restraints on National Welfare
- Estimation of Ricardian Model
- Estimation of Effect of Trade under Specific Factor Model
- Estimation of trade Equilibrium under Heckscher -Ohlin model

- Trade Creation and Diversion.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Power point presentation on International Trade in current scenario.

X. Learning outcome

After successful completion of the course the student will be able to –Understand how trade take place between nations. Be able to work out strategies to maintain a favourable trade balance. Understand how the institutions play role in regulating the cross country trade and deal with the issues.

XI. Suggested Reading

- Kindelberger and Joshi PK. 2016. *International Economics* AITBS Delhi-110051
- Brouwer F. *International Trade and Food Security*. LEI - Wageningen UR, The Netherlands.

I. Course Title : Institutional Economics

II. Course Code : AEC 512

III. Credit Hours : 1+0

IV. Why this course?

Institutions are involved in framing of economic development. The human behavior is governed by the institutions working in their environment. Thus, the student need to understand the institutions and their working.

V. Aim of the course

To develop critical and informed understanding about institutions, their role in the working of economy. Exposure of issues, policies & regulations and its application in agricultural system

VI. Organization of the course

The course is organised as follows–

No	Block	Unit
1	Introduction	1. Basics of Institutional Economics
2.	Approaches	1. Institutional changes & Resource allocation 2. Group and collective Approach
3.	Law Protection and Institutions	1. Property rights 2. Agrarian Institutions

VII. Theory

Block 1: Introduction

Unit 1: Basics of Institutional Economics

Old and New Institutional Economics – Institutional Economics vs Neo-classical Economics. Definition of institutions – Distinction between institutions and organizations – Institutional evolution.

Block 2: Approaches

Unit 1: Institutional changes & Resource allocation

Institutional change and economic performance - national and international economic institutions. Transaction cost economics – Transaction costs and the allocation of resources. Transaction costs and efficiency. Asymmetric information - Moral hazard and Principal-Agent problem.

Unit 2: Group and collective Approach

Free rider problem – path dependency – Interlinked transactions. Collective action and the elimination of free-rider problem - The logic of collective action and its role in reducing free rider problem – theory of Groups. Rent seeking – interest groups and policy formulation.

Block 3: Law Protection and Institutions

Unit 1: Property rights

Economic analysis of property rights- property rights regimes – private property – State Property - Common property Resources (CPRs) – public goods and club goods.

Unit 2: Agrarian Institutions

Special features of institutional arrangements in agriculture – Transaction costs in agriculture - Case Studies - Theories of agrarian institutions - tenancy institutions.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on Property rights

IX. Learning outcome

After successful completion of this course the student will be able to-Understand institutions and their roles in economic development. Know about the policies and their issues in an institutions.

X. Suggested Reading

- Pearce DW –*The dictionary of modern Economics*

I. Course Title : Natural Resource and Environmental Economics

II. Course Code : AEC 513

III. Credit Hours : 1+1

IV. Why this course?

Sustainable development is the need of the hour. The economic activities affect not only the society but also the environment. Every activity has its social cost. The students, hence will be taught about the economic aspect of environment.

V. Aim of the course

To understand about economics of environment and social costs incurred due to economic development. Work out methods to maintain environment quality and reduce social costs

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to natural resource and environmental economics	1. Basic Foundation
2.	Insight of the subject	1. Theories and economics of natural resources 2. Functioning of Market
3	Dealing with Issues and sustainability	1. Environmental Issues 2. Regulations 3. Sustainability aspects

VII. Theory

Block 1- Introduction to natural resource and environmental economics

Unit 1: Basic Foundation

Concepts, Classification and Problems of Natural Resource Economics – Economy Environment interaction – The Material Balance principle, Entropy law-Resources Scarcity - Limits to Growth - Measuring and mitigating natural resource scarcity – Malthusian and Recardian scarcity – scarcity indices - Resource Scarcity and Technical Change.

Block 2- Insights of the subject

Unit 1: Theories and economics of natural resources

Theory of optimal extraction renewable resources –economic models of oil extraction-efficiency - time path of prices and extraction - Hotelling's rule, Solow-Harwick's Rule. Theory of optimal extraction exhaustible resources – economic models of forestry and fishery.

Unit 2: Functioning of Market

Efficiency and markets – market failures - externalities – types - property rights – transaction costs – Coase's theorem and its critique - public goods - common property and open access resource management - Collective action.

Block 3- Dealing with the issues and sustainability

Unit 1: Environmental Issues

Environmental perspectives - biocentrism, sustainability, anthropocentrism - Environmental problems and quality of environment - Sources and types of pollution -air, water, solid waste, land degradation – environmental and economic impacts - Economics of pollution control - efficient reduction in environmental pollution.

Unit 2: Regulations

Environmental regulation – economic instruments - pollution charges – Pigovian tax - tradable permits – indirect instruments – environmental legislations in India.

Unit 3: Sustainability aspects

Concept of sustainable development – Economic Perspective – Indicators of sustainability Relation between development and environment stress-Environmental Kuznet's curve Environmental Accounting – resource accounting methods –

International Environmental Issues – climate change – likely impacts – mitigation efforts and international treaties.

VIII. Practical

- Exhaustible resource management – optimum rate of oil extraction.
- Renewable resource management – optimum harvest of Forestry/fishery.
- Exercise on pollution abatement-I.
- Exercise on pollution abatement-II.
- Concepts in valuing the environment.
- Taxonomy of valuation techniques.
- Productivity change method – substitute cost method – Hedonic price method – Travel cost method – Contingent valuation methods.
- Discount rate in natural resource management.
- Environment impact assessment
- Visit to Pollution Control Board.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).

X. Learning outcome

After successful completion of this course, the student will be able to-Work out the plan for extraction / use of natural resource in most economical way. Understand the environment and its pollution. Learn how markets are affected if environment is not taken into consideration. Gain proficiency in rules and regulation governing economic aspect of environment.

XI. Suggested Reading

- Pearce DW and Turner RK. *Economics of Natural Resource and Environment*
- Kwak J. *Economism: Bad Economics and the Rise of Inequality*
- Tietenberg T and Lewis L. *Environmental and Natural Resource Economics*
- Schwarz PM. *Energy Economics*

I. Course Title : Commodity Future Trading Credits

II. Course Code : AEC 514

III. Credit Hours : 2+0

IV. Why this course?

Risk is involved in marketing. Price fluctuation is a very common phenomenon in agriculture marketing. In such situation selling of commodity in future market serves as a resort to insulate from this uncertainty. Thus, knowledge of futures market is helpful in ...

V. Aim of the course

To disseminate the knowledge about risk mitigating measures especially future trading. The future trading in agricultural commodities is increasing day by day therefore the role of SEBI, functioning of commodity exchanges are discussed.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to commodity market	1. Concepts of commodity future trading
2.	Techniques and risks in commodity market	1. Technical aspects 2. Risk and its Management
3.	Commodity exchange and market analysis	1. Commodity Exchange–A review 2. Analysis of commodity market

Theory

Block 1- Introduction to commodity market

Unit 1: Concepts of commodity future trading

History and Evolution of commodity markets – Terms and concepts: spot, forward and futures Markets – factors influencing spot and future markets. Speculatory mechanism in commodity futures.

Block 2- Techniques and Risks in Commodity Market

Unit 1: Technical aspects

Transaction and settlement – delivery mechanism - role of different agents - trading strategies -potential impact of interest rate, Foreign Exchange, FDI in Commodity Markets.

Unit 2: Risk and its Management

Risk in commodity trading, importance and need for risk management measures - managing market price risk: hedging, speculation, arbitrage, swaps - pricing and their features.

Block 3- Commodity exchange and market analysis

Unit 1: Commodity Exchange – A review

Important global and Indian commodity exchanges - contracts traded – special features -Regulation of Indian commodity exchanges - FMC and its role.

Unit 2: Analysis of commodity market

Fundamental Vs Technical analysis – construction and interpretation of charts and chart patterns for analyzing the market trend – Market indicators – back testing. Introduction to technical analysis software – analyzing trading pattern of different commodity groups.

VII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions.
- Power point presentations by students.

VIII. Learning outcome

After successful completion of this course, the student will be able to-The basic concepts of commodity markets. The national and international commodity markets.

IX. Suggested Reading

- Kaufman PJ. *The Concise Handbook of Futures Markets*: Jhon Wiley & Sons
- Purcell WD. *Agricultural Futures and Options: Principles and Strategies*: MacMillan Publications
- Wasendorf RR & McCaffery *All About Commodities from the Inside Out*. McGraw Hill

I. Course Title : Development Economics Credit

II. Course Code : AEC-515

III. Credit Hours : 2+0

IV. Why this course?

Development is more important than growth. The development of a nation ensures that condition of welfare prevails. The students has to understand different measures of development. How to measure them and relevant theories.

V. Aim of the course

To develop concept of growth and development. Methods and theories of measuring development. Study of different developed economies will give exposure towards measures to create economic upliftment.

VI. Learning outcome

After successful completion of this course, the student will be able to-Measure the development using different methods. Understand the theories of development and relate it to real world.

VII. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction to development economics	1. Conceptions of Development
2.	Theories and comparison	1. Theories of Economic growth and development 2. Comparative Economic Development

VIII. Theory

Block 1- Introduction to Development Economics

Unit 1: Conceptions of Development

Development Economics – Scope and Importance - Economic development and economic growth - divergence in concept and approach - Indicators and Measurement of Economic Development –GNP as a measure of economic growth – New Measures of Welfare – NEW and MEW – PQLI – HDI – Green GNP - Criteria for under development – Obstacles to economic development –Economic and Non-Economic factors of economic growth- Development issues, poverty, inequality, unemployment and environmental degradation.

Block 2- Theories and comparison

Unit 1: Theories of Economic growth and development

Classical theories- Adam smith - Ricardo- Malthus, Marx's theory of economic development; Schumpeter's theory, Approaches to development- low income equilibrium trap - critical minimum effort- The Strategy of economic development- Balanced vs. Unbalanced growth, choice of technique, investment criteria, big push theory, Rostow's stages of Economic Growth, unlimited supply of labour; social and technological dualisms; roles of capital accumulation, human capital and technological change in economic development, Models of economic growth Harrod-Domar, Kaldor, Mahalanobis, Lewis, FeiRanis, Input-Output, multisectoral models.

Unit 2: Comparative Economic Development

Countries selected for case studies -USA, Japan, China and India; Overview of economic development is selected countries; agrarian surplus and the role of the peasantry in economic development; industrial revolution; division of labour, organisation of work and industrial production, the role of the State in developmental transition

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions on inflation

X. Suggested Reading

- Blaug M. 1986. *Economic History and the History of Economic Thought*
- Chenery HB and TN Srinivasan. *Handbook of Development Economics*
- Baldwin RE. *Economic Development and Growth*. John Willey, New York

I. Course Title : Mathematics for Agricultural Economics

II. Course Code : STAT/AEC

III. Credit Hours : 3+0

IV. Why this course?

Knowledge of calculus is basic requirement for carrying out simple calculations.

V. Aim of the course

To solve various mathematical problems in economic research. Calculations are integral part of research analysis therefore it has wide application in economic studies.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Introduction	1. Preliminaries
2.	Variables and functions	1. Variables and functions 2. Differentiation of functions
3.	Overview of linear algebra	1. Linear Algebra 2. Optimization of functions 3. Integration of functions

VII. Theory

Block 1- Introduction

Unit 1: Preliminaries

Logic and proof techniques; sets and set operations; relations; functions and their properties; number systems

Block 2- Variables and functions

Unit 1: Variables and functions

Specific functions is economic theory. Elementary analytical geometry-gradient and equation of straight line. Standard equations and simple properties of circle, parabola and rectangular hyperbola.

Unit 2: Differentiation of functions

Limit and continuity. Differentiation, theorems of differentiation, differentiation of logarithmic and exponential functions, function of a function, derivative of higher order, partial derivatives. Application of derivatives to determine average and marginal values in economic analysis; determination of elasticities; points of inflexion; linear homogenous production functions; derivation of average and marginal curves.

Block 3- Overview of Linear Algebra

Unit 1: Linear Algebra

Determinants, evaluation and properties of determinants, Vectors and vector spaces, Matrices, notations and operations, laws of matrix algebra; transpose and inverse of matrix; Solution of linear and quadratic equations involving one variable, simultaneous equations, application of determinants and matrices in solution of equation for economic analysis.

Unit 2: Optimization of functions

Optimization- unconstrained, maxima and minima, constrained optimization, Lagrange multiplier and their economic applications for optimization problems of cost, production, demand and supply.

Unit 3: Integration of functions

Integration as a reverse process of differentiation, methods of integration, reduction formulae, definite integral, use of integration to determine relation between average and marginal value. Capitalization over time, estimation of returns from capital goods over time. Pareto distribution.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Power point presentations

IX. Learning outcome

After successful completion of this course, the student will be able to-Develop expertise in calculus operations.

Course Title with Credit Load
Ph.D. in Agricultural Economics

Major Courses: 12 credits

Course Code	Course Title	Credit Hours
AEC-601	Advanced Micro Economic Analysis	2 (1+1)
AEC-602	Advanced Macro Economic Analysis	2 (2+0)
AEC-603	Advanced Econometrics	3 (2+1)
AEC-604	Advanced Production Economics	3 (2+1)
Common	Research and Publication Ethics	2(2+0)

Minor Courses: 06 credits

a. It is suggested the student may choose at least one out of three courses listed below as part of minor courses as these are related to policy advocacy and bring in global perspectives with an aim to build a larger understanding of the subject to the student.
b. Further, it is suggested that the student may choose the remaining Courses from any other discipline including the disciplines of Agril. Economics/ ABM and are related to the research problem selected by the student.
c. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/ HoD.

AEC-606	Advanced Agricultural Marketing and Price Analysis	3 (2+1)
AEC-607	Quantitative Development Policy Analysis	2 (1+1)
AEC-608	Natural Resource Management	3 (2+1)
AEC-609	Environmental Economics	3(2+1)

Minor courses may be taken from above list or subjects closely related to a student's major subject

Supporting Courses: 05 credits

AEC-605	Operations Research	3 (2+1)

One course of 600 series of 2 credits from Statistics or computer discipline may be taken depending upon availability.

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

- It is also suggested that the student may choose the Supporting Courses other than the listed courses, provided the opted courses are related to the research problem selected by the student and be mandatorily approved by the Student Advisory committee/HoD".

AEC-660	Doctoral Seminar -I	1(1+0)
AEC-661	Doctoral Seminar -II	1(1+0)
	RESEARCH	75
	Total	100

There will be two Doctoral Seminar and a research scholar has to published one review paper as output of these seminar. At Ph.D. level, Research Plan Proposal (RPP) be delivered by the end of SEM II

Course Contents
Ph.D. in Agricultural Economics

I. Course Title : Advanced Micro Economic Analysis

II. Course Code : AEC 601

III. Credit Hours : 1+1

IV. Why this course?

This course is required to upscale the knowledge of students about micro economics. So that they can get a deeper and better understanding of the subject.

V. Aim of the course

To gain fundamental understanding of consumer behavior, producer's strategy, market structure through which transactions take place and human and firms interact. Develop foundation of scarce resource allocation for optimum results.

VI. Organization of the course

The course is organised as follows–

No	Block	Unit
1.	Consumer Theory	1. Consumer Theory
2.	Market and General quilibrium	1. Market 2. General Equilibrium
3.	Market failure and welfare	1. Market Failure 2. Welfare Economics

VII. Theory

Block 1- Consumer Theory

Unit 1: Consumer Theory

Theory of consumer behavior – Duality in consumer theory - expenditure function and indirect utility function - Measurement of Income Effect and Substitution Effect. Measurement of Changes in Consumers' Welfare – Consumer's Surplus, Compensating Variation and Equivalent Variation - Dynamic versions of demand functions – Integrability of demand functions. Demand Models – Linear Expenditure System, Almost Ideal Demand System. Applications of consumer theory – Household model and time allocation – Labour supply decisions by households.

Block 2- Market and General Equilibrium

Unit 1: Market

Perfect competition – Monopoly, monopolistic competition and oligopoly. Oligopoly models – collusive and non-collusive models of oligopoly - Cournot model, Chamberlin model, Stackleberg solution.

Unit 2: General Equilibrium

General equilibrium theory – Conceptual overview - General equilibrium conditions with Production and Consumption. Existence, Uniqueness and Stability of general competitive equilibrium. Walrasian general equilibrium – Mathematical derivation of conditions for general equilibrium.

Block 3- Market Failure and Welfare

Unit 1: Market failure

Market failure - Incomplete markets - Asymmetric information – Principal-Agent problem, adverse selection and moral hazard. Externalities – Network externalities, Public goods – Optimal provision of public goods.

Unit 2: Welfare Economics

Welfare Economics - Concepts, problems, approaches and limitations of Welfare Economics, Pareto conditions of maximum welfare – Criteria for social welfare - Social Welfare functions, Social versus Private costs and benefits.

VIII. Practical

- Problems in consumer utility maximization
- Estimation of income and substitution effects;
- Estimation and comparison of Consumer's surplus, equivalent variation and compensating variation.
- Estimation of demand models – Derivation and estimation of labour supply equations from household models comparative static analysis in consumption.
- Advanced problem solving in price determination under perfect competition, monopoly, oligopoly and monopolistic competition.
- Game theory models.
- Problems solving in General Equilibrium Theory and Welfare Economics.
- Problems in public goods provision.

IX. Teaching Methods/ Activities

- Lectures
- Case studies
- Assignments (Group/individual)
- Group Discussions

X. Learning outcome

After successful completion of the course, the student will be able to-Understand the different market competition. Work out strategies for attaining equilibrium in the market.

XI. Suggested Reading

- Henderson JM and Quandt RE. *Microeconomic Theory: A Mathematical Approach* Tata McGraw Hill Publishing Co Ltd
- Koutsoyiannis A. *Modern Micro Economics*. Macmillan Press Ltd
- Ferguson and Gould. *Micro Economic Theory*. Richard D Erwin Inc USA

I. Course Title : Advanced Macro Economics

II. Course Code : AEC-602

III. Credit Hours : 2+0

IV. Why this course?

A deeper understanding of the conceptual and structural framework is imperative to develop vision of a student about how the knowledge of various macroeconomic models is applied in real economy.

V. Aim of the course

To understand the functioning of national economy, its history and models. The policies governing the modern economic system and concerned institutions.

VI. Organization of the course

The course is organised as follows–

No	Block	Unit
1.	Introduction	1. Overview
2.	Economic Models	1. Open Economy Models 2. Dynamic Macroeconomic Models
3.	Business cycle and pollicies	1. Business Cycles 2. Macroeconomic Polices

VII. Theory

Block 1- Introduction

Unit 1: Overview

Conceptual framework - Classical, Keynesian, Neo-Classical, and Neo-Keynesian macroeconomics; Review of Keynes-Classical Synthesis; Aggregate Demand and Supply in the closed economy with fixed and variable price level- determination of wage, prices, output and employment

Block 2- Economic Models

Unit 1: Open Economy Models

Exchange rate determination; purchasing power parity; asset market approach; Short-run open economy models; Mundell-Fleming model- exchange rate regime: perfect capital mobility under fixed and flexible exchange rate; effectiveness of fiscal policy and monetary policy; Dornbusch's overshooting model; monetary approach to balance of payments; international financial markets

Unit 2: Dynamic Macroeconomic Models

Introduction to dynamic macroeconomic Models; Dynamic aggregate demand and supply – short and long term equilibrium- rational expectations approach

Block 3: Business Cycle and Policies

Unit 1: Business Cycles

Business cycle and its alternative equilibrium model, Stability analysis Economics of Great Events-Depression, Hyperinflation and Deficits; Advances in Business Cycle Theory; Real Business Cycles & Neo-Keynesian Economics

Unit 2: Macroeconomic Polices

Monetary policy - Design of Monetary Policy; Inflation Targeting, Fiscal Policy - Government Budget Constraint: The Arithmetic of Deficits and Debt, Current versus Future Taxes, the Evolution of Debt-to-GDP Ratio; Public Borrowing-Internal and external aid, Deficit financing, Development Financing; BOP & Adjustment Policies - Foreign Exchange Policy -International macro-economic policies, IMF, IBRD, UNCTAD.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

IX. Learning outcome

After successful completion of this course the student will be able to-Figure out how policies are framed to safe guard the national economy. Understand the rationale behind the working of different economy.

X. Suggested Reading

- Heibroker RL. *Understanding Macro Economics.*
- Mehta JK. *Macro Economics.*
- Edgemand MR. *Macro-Economics: Theory & Policy.*
- David' W Pearce. *The dictionary of modern Economics.*
- Allen RGD. 1968. *Macro–Economic Theory: A Mathematical Treatment*. London: Macmillan.
- Stanlake GF. *Macro–Economics: An Introduction*. Longman, London.
- Mithai DM. 1981. *Macro–Economics: Analysis and Policy*. Oxford and IBH, New Delhi.
- Hicks JR *Critical Essays in Monetary Theory.*
- Nawiyn WT. *Theory of Money.*

I. Course Title : Advanced Econometrics

II. Course Code : AEC 603

III. Credit Hours : 2+1

IV. Why this course?

The heart of any research is carrying out the analysis with the most appropriate model. The results obtained are crucial for the researchers. Thus, this course acts as the centre point of building up analytical framework of research. The students need to learn building up of models that will be used to test the hypothesis framed. Use different analysis depending upon the requirement and type of data.

V. Aim of the course

The course aims at providing the knowledge and command over analysis of data collected to get the desired result. Train the student in use of econometric models.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Concepts	1. Review
2.	Least squares and dummy variables	1. Concept of Least Squares 2. Dummy Variable
3.	Econometric models	1. Models and their extensions 2. Simultaneous equation modles

VII. Theory

Block 1: Concepts

Unit 1: Review

Review of classical regression model – review of hypothesis testing – restrictions on parameters – single equation techniques.

Block 2: Least Squares and Dummy Variables

Unit 1: Concept of least squares

Ordinary least squares – weighted least squares - generalized least squares – method of principal components – instrumental variables method - maximum likelihood method - errors in variables, non-linearity and specification tests – non spherical error terms.

Unit 2: Dummy Variable

Dummy variables - Qualitative and truncated dependent variables - limited dependent variables –LPM, probit and logit models, their multinomial extensions.

Block 3: Econometric Models

Unit 1: Models and their extensions

Autoregressive distributed lag models – panel data fixed and random effects models and their extensions.

Unit 2: Simultaneous equation models

Simultaneous equation methods –identification – estimation by indirect least squares 2SLS, PIML, SURE, 3SLS

VIII. Practical

Estimation of multiple regression model - GLS estimation methods - testing misspecification errors – Testing and Managing multicollinearity, heteroscedasticity and autocorrelation - estimation of LPM, Logit and Probit models - comparing two regressions - Chow test - estimation of distributed lag models – panel data random and fixed effects models - Indirect least squares 2SLS, SURE, 3SLS, estimation of simultaneous equation models.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/ individual).
- Group Discussions

X. Learning outcome

After successful completion of the course, the student will be able to–

- Analyse the data collected for testing the framed hypothesis.
- Get expertise in analytical framework.

XI. Suggested Reading

- Greene WH. 2002. *Econometric Analysis*. Pearson Education.
- Johnston J and Dinardo J. 2000. *Econometric Methods*. Mc Graw-Hill.
- Koutseyianis A. 1997. *Theory of Econometrics*. Barner & Noble.

I. Course Title : Advanced Production Economics

II. Course Code : AEC 604

III. Credit Hours : 2+1

IV. Why this course?

There is requirement of getting acquainted with decision making process in case of factors and products. The researcher needs to understand about working on production process and work out suitable suggestions to improve it.

V. Aim of the course

The course deals with the concept of advanced production economics. The exposition would be mathematically oriented. The course would also cover the analysis of production functions, its interpretation, decision making with multiple input use, factor sharing and decision making under risk and uncertainty.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Consumer Theory	**1.** Production Process
2.	Market and General quilibrium	1. Production Functions and characteristics
3.	Market failure and welfare	1. Decision Making in Production 2. Technology, Efficiency and Risk Management 3. Programming

VII. Theory

Block 1: Production process

Unit 1: Production Process

Agricultural Production process – Relationship between farm planning and production economics-scope of agricultural production and planning-methods/ procedures in agro-economic research and planning.

Block 2: Production Function

Unit 1: Production Functions and characteristics

Production functions, components, assumptions, properties and their economic interpretation - Concepts of homogeneity, homotheticity,, APP, MPP, elasticities of substitution and their economic relevance – Production relations – optimality- Commonly used functional forms, nature, properties, limitations, estimation and interpretation - linear, Spillman - Cobb Douglas, quadratic, multiplicative (power) functional forms - Translog, and transcendental functional forms - CES, production functional forms-Conceptual and empirical issues in specification, estimation and application of production functions- Analytical approaches to economic optimum - Economic optimum – determination of economic optimum with constant and varying input and output prices - Economic optimum with production function analysis - input use behaviour.

Block 3: Dynamics of production process

Unit 1: Decision Making in Production

Decision making with multiple inputs and outputs – MRT and product relationship- cost of production and adjustment in output prices-single input and multiple product decisions- Multi input, and multi product production decisions - Decision making with no risk -Cost of wrong decisions - Cost curves – Principles and importance of duality theory - Correspondence of production, cost, and profit functions - Principles and derivation of demand and supply functions

Unit 2: Technology, Efficiency and Risk Management

Technology, input use and factor shares -effect of technology on input use-decomposition analysis-factor shares-estimation methods- Economic efficiency in agricultural production – technical, allocative and economic efficiency – measurement -Yield gaps analysis – concepts and measurement - Risk and uncertainty in agriculture – incorporation of risk and uncertainty in decision making – risk and uncertainty and input use level-risk programming.

Unit 3: Programming

Simulation and programming techniques in agricultural production-Multiple Objective Programming (MOP) – Goal programming, Weighted sum and Compromise programming – applications.

VIII. Practical

Estimation of different forms of production functions- Optimal input and product choice from estimated functions-Derivation of demand and supply functions and estimation-Estimation of cost function and interpretations-Optimal product and input choice under multi input and output system-Estimation of factor shares from empirical functions estimated-Estimating production functions incorporating technology changes: Decomposition analysis and incorporation of technology-Estimation of efficiency measures – Stochastic, probabilistic and deterministic frontier production functions-Risk programming – MOTAD-Quadratic programming-Simulation models for agricultural production decisions-Goal programming – Weighted, lexicographic and fuzzy goal programming-Compromise programming.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Learning outcome

After successful complétion of the course, the student will be able to-Get familiar with different production function and use them in practise and come out with useful decision. Work out the efficiency of the production process and use models for finding the optimum solution.

XI. Suggested Reading

- Baumol WG. 1973. *Economic theory and operations analysis*. Practice Hall of India Private Limited, New Dehli. 626 p.
- Gardner BL and Rausser GC. 2001. *Handbook of Agricultural Economics* Vol. I Agricultural Production. Elsevier.
- Heady EO. 1952. *Economics of Agricultural Production and resources use*. Practice Hall of India.
- Heady EO and Dillon JL. 1961. *Agricultural Production functions*. Kalyani Publishers, Ludhiana, India. 667 p.

I. Course Title : Operations Research

II. Course Code : AEC-605

III. Credit Hours : 2+1

IV. Why this course?

In sphere of management it is important, to take correct decision of assigning tasks and roles to individuals. The business is full of uncertainity and in this situation the manager has to take decision. It becomes imperative to gain knowledge of models used for finding this solution of performing well.

V. Aim of the course

To gain elementary knowledge of solving problems and decision making for managing farming and organisation in resource constraint in order to achieve the objective.

VI. Organization of the course

The course is organised as follows–

No	Block	Unit
1	Concepts	1. Concepts
2	Inventory and models	1. Inventory- A Review 2. Models
3	Decision making	1. Decision making 2. Game theory

VII. Theory

Block 1: Concepts

Unit 1: Concepts

Elementary concepts and objectives of Operations Research, Review of Linear programming - Assumptions & Methods, Non-linear programming problem - Quadratic programming, Multi Objective Programming (MOP)

Block 2: Inventory and Models

Unit 1: Inventory- A Review

Inventory control models, costs involved in Inventory management, types of inventory, Economic order quantity model, Waiting line models: Waiting line problem, Characteristics of a waiting line system, Single channel model,

Unit 2: Modles

Markov Chains, Sequencing, Replacement models, Transportation and Assignment problems.

Block 3: Decision Making

Unit 1: Decision Making

Decision making under risk and uncertainties, decision problem, maximax criterion, maximin criterion, minimax regret criterion, Laplace criterion, Pay off tables, Decision trees, Expected value of perfect information.

Unit 2: Game Theory

Game Theory – Two-person Zero sum game, Simulation, Network Analysis- PERT & CPM.

VIII. Practical

- Linear and Non-linear programming problem,
- Quadratic programming, Multi-Objective Programming- Goal Programming,
- Lexicographic, Weighted Sum, Determining economic order quantity, reorder levels of EOQ model.

- Waiting line problem, Problems on Markov Chains, Sequencing and Replacement models.
- Formulating and solving transportation type problems, Assignment problems as a special type of transportation problem.
- Solving deterministic and probabilistic queuing models Structuring and solving decision trees for optimal decisions Game theory, Simulation, Developing network (PERT/CPM) diagrams and determining the critical path.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Learning outcome

After successful completion of this course, the student will be able to-
Gain expertise in formulating problems of management into mathematical form and work out the optimum solutions.
Apply the knowledge of different models in better decision making and controlling of the firm.

XI. Suggested Reading

- Taha HA. *Operations Research: An Introduction*.
- Veerabhadrappa H. *An Introduction to Operations Research*.
- Gupta PK and Hira DS. *Operations Research*.
- Sharma R. *Operations Research*.
- Sharma JK. *Operation Research*.
- Greene WH. 2002. *Econometric Analysis*. Pearson Education.
- Johnston J and Dinardo J. 2000. *Econometric Methods*. Mc Graw-Hill.
- Koutseyianis A. 1997. *Theory of Econometrics*. Barner & Noble.

I. Course Title : Advanced Agricultural Marketing And Price Analysis
II. Course Code : AEC 606
III. Credit Hours : 2+1
IV. Why this course?

Efficient markets, connectivity in markets, facilities of transport and storage ensure that there is growth in marketing of the produce as well as the industries based on those produce. The decision of selling the produce at the right time, and at a higher price is crucial to ensure remunerative returns to the farmer. Thus, this course is required to enhance the knowledge to students in agricultural markets and price analysis.

V. Aim of the course

To impact adequate knowledge and analytical skills in the field of agricultural marketing and enhance expertise in improving the performance of the marketing institutions and the players in marketing of agricultural commodities. Learning outcome: After successful completion of this course, the student will be able to-Gain the knowledge of marketing and agricultural prices. Work out the interaction between different markets and analyse their working. Gain expertise in forecasting of price and build up market intelligence.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Concepts	1. Agricultural Marketing- Insights
2.	Marketing Institutions and Dynamics	1. Institutions and their functions 2. Market Dynamics
3.	Techniques	1. Commodity marketing 2. Models for Analysis

VII. Theory

Block 1: Concepts

Unit 1: Agricultural Marketing-

Insights Importance of market analysis in the agricultural system - types of marketing-advantages and disadvantages - quantitative estimation -the distinguishing characteristics and role of agricultural prices -data sources for agricultural products and prices - softwares used in market analysis.

Block 2: Marketing Institutions and Dynamics

Unit 1: Institutions and their functions

Role of various formal institutions in agricultural marketing - and functions - measuring their efficiency - public - private partnership - institutional arrangements. Successful case studies.

Unit 2: Market Dynamics

Multi market estimation, supply response models. Market integration and price transmission - supply / value chain management. GAP analysis. Current trends in information in the changing agrifood system.

Block 3: Techniques

Unit 1: Commodity Marketing

Agricultural commodity marketing -spot and futures- marketing of derivatives-speculation, hedging, swap, arbitrage etc. commodity exchanges - price discovery and risk management in commodity markets-Regulatory mechanism of futures trading.

Unit 2: Models for Analysis

Lag operators and difference equations; stationary and stochastic processes; Unit roots and cointegration; conditional heteroscedasticity: ARCH and GARCH models -forecast evaluation; methods of forecasting. price indices and econometric estimation and simulation.

VIII. Practical

- Estimation of demand/ supply forecasting,
- Supply chain/ value chain analysis for different commodities
- Commodity models- multi market estimation- time series analysis
- Market integration studies- price discovery price volatility estimation
- Commodity price forecasting using econometric softwares.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Suggested Reading

- Acharya SS and Agarawal NL. 1994. *Agricultural Prices-Analysis and Policy*. Oxford and IBH Publishing company Pvt. Ltd, New Delhi.
- Acharya SS and Agarawal NL. 2004. *Agricultural Marketing in India*. Oxford and IBH Publishing company Pvt. Ltd, New Delhi.
- Kohls RH and Joseph N. Uhl: *Marketing of Agricultural products* by Collier MacMillan International.
- Rhodes VJ. 1978. *The Agricultural Marketing System*. Grid Pub. Ohio.

I. Course Title : Quantitative Development Policy Analysis

II. Course Code : AEC 607

III. Credit Hours : 1+1

IV. Why this course?

Policy reforms are inevitable. They are continuously required to deal with the loop holes of previous policy and control the present situation in a better manner. Reforms take place in both microeconomic and macroeconomic polies. The analysis of these policies help us to develop a framework for designing and implementing the policies.

V. Aim of the course

To develop expertise in understanding the rationale behind development of policies. Conceptualization of equilibrium and working out the economic implications of development policy. Learning outcome: After the completion of the course, the student will be able to-Conceptualize policy framework. Get acquainted with analysisng the policy and work out corrective solutions.

VI. Organization of the course

The course is organised as follows

No	Block	Unit
1.	Concepts	1. Policy Framework
2.	Demand-supply and household behaviour	1. Demand- Supply Analysis 2. Household Behaviour and models
3.	Approaches to review policy and welfare	1. Multi-Pronged approach to policy review 2. General equilibrium and programming

Theory

Block 1: Concepts

Unit 1: Policy Framework

olicy framework – goals, value, beliefs and welfare maximization. Market – Policy and State – State vs. Market – Failure of Policy – Failure of Markets - Rationale for Government Intervention. Role of Quantitative Policy Analysis.

Block 2: Demand-supply and household behaviour

Unit 1: Demand- Supply Analysis

Demand analysis for policymaking – Alternative approaches to demand analysis – Policy implications. Supply response – Alternative approaches to measurement of supply response – Nerlovian models of supply response – Policy implications.

Unit 2: Household Behaviour and models

Household behaviour and policy analysis – Household models.

Block 3: Approaches to review policy and welfare

Unit 1: Multi-Pronged approach to policy review

Partial equilibrium analysis – Concept of reference prices – Price distortions – indicators and impact. Transaction costs – Implications for efficiency and productivity – Institutional solutions - Multi market approach to policy analysis.

Unit 2: General equilibrium and programming

Social Accounting Matrices and multipliers -– Computable General Equilibrium models to assess economy wide impact of policy changes. fuzzy goal programming-Compromise programming.

VII. Practical

- Review of criteria for policy evaluation
- Estimation of price elasticities
- Review of estimation of complete demand systems
- Estimation of Nerlovian supply Response model
- Review of Household models
- Specification and estimation of household models
- Partial equilibrium analysis
- Input–output table
- Social Accounting Matrix
- Construction of a SAM
- Computation of Multipliers
- Multi Market Analysis
- Review of Computable General Equilibrium Models.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

I. Course Title : Natural Resource Management

II. Course Code : AEC 608

III. Credit Hours : 1+1

IV. Why this course?

The environment envisages the whole living creatures' within it. There are resources we obtain from the nature and at the same time spoil the environment by exploiting the resources. Thus, it is necessary for the student to develop environment friendly plans to utilize the scarce resources.

V. Aim of the course

Concept building on natural resources. Gaining expertise in economic aspect of natural resources and maintain a balance between economic gains and environment conservation. Learning outcome-After the completion of the course, the student will be able to-Understand the natural resources and methodolies to develop plans for their optimal use. Work out the economics of forest, fisheries and ground water. Be able to deal with the legal matters of the natural resourses.

VI. Organization of the course

The course is organised as follows:

No	Block		Unit
1.	Concepts	1.	Concepts
2.	Models and Management	1.	Models for economic view of natural resources
		2.	Management of water resources
3.	Regulations and planning	1.	Property Rights
		2.	Dynamics of resource economics

VII. Theory

Block 1: Concepts

Unit 1: Concepts

Natural resources - definition - characteristics and classification. Stock dynamics of renewable and non-renewable resources. Equation of motion for renewable and non-renewable resources. Fundamental equation of renewable resources.

Block 2: Models and Management

Unit 1: Models for economic view of natural resources

Growth curves of fishery and forest resources. The role of time preference in natural resource use. Simple two-period model of optimal use of renewable and non-renewable resources. Advanced models of optimal resource use – Static Vs. dynamic efficiency in natural resource use Applications of dynamic programming and optimal control.

Unit 2: Management of water resources

Economics of groundwater use - optimal extraction of groundwater. Analytical and numerical solutions for optimal inter-temporal allocation of natural resources. Optimal harvesting of single rotation and multiple rotation forests. Optimal management of fishery.

Block 3: Regulations and planning

Unit 1: Property Rights

Property rights in natural resources and their implication for conservation and management of natural resources. Management of common property natural resources – Institutional arrangements for conservation and management of common pool fishery, groundwater and forestry resource.

Unit 2: Dynamics of resource economics

Resource scarcity – Natural resource degradation – Poverty and resource degradation

– Natural resource accounting - Pricing and valuation of natural resources – Natural resources policy. Practical Derivation of the fundamental equation of renewable resources-Estimation of growth curves and stock dynamics for fishery and forestry resources. Simple two period problem of optimal resource use – Numerical solution for simple two-period model of dynamic efficiency in natural resource extraction. Multi-period dynamic efficiency – Using Excel Solver in solving dynamic natural resource harvesting problems. Using analytical solution procedures for solving natural resource management problems – Optimal control.

VIII. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

IX. Suggested Reading

- Hackett SC. 2001. *Environmental and Natural Resource Economics: Theory, Policy and the Sustainable Society*. M.E. Sharpe, Armonk, NY.
- Hartwick JM and Olewiler ND. 1998. *The Economics of Natural Resource Use*. 2nd Ed. Addison-Wesley Educational Publ.
- Kerr JM, Marothia DK, Katar Singh, Ramasamy C and Bentley WR. 1997. *Natural Resource Economics: Theory and Applications in India*. Oxford & IBH.
- Pearce DW and Turner K. 1990. *Economics of Natural Resources and the Environment*. John Hopkins Univ. Press.
- Prato T. 1998. *Natural Resource and Environmental Economics*. Iowa State Univ. Press.
- Sengupta R. 2000. *Ecology and Economy, an Indian Perspective*. Oxford Univ. Press.
- Tietenberg T. 2003. *Environment and Natural Resource Economics*. 6th Ed. Addison Wesley.

I. Course Title : Environmental Economics

II. Course Code : AEC 609

III. Credit Hours : 2+1

IV. Why this course?

Economics not only deals with transaction taking place between human beings within and across national boundaries. Each economic activity has a price to pay to the environment. The activity causes loss to the environment in various ways. Thus, as a student of economics it is necessary to work out the costs and returns in terms of losses to environment while carrying out these development/production activities.

V. Aim of the course

To understand the economic outcomes of environmental degradation. Make students proficient in decision making regarding environment protection, resource use, and conservation policy.

VI. Organization of the course

The course is organised as follows:

No	Block	Unit
1.	Overview	1. Overview of Environmental Economics
2.	Assessment and Development Dynamics	1. Economic assessment 2. Developmental Aspects

No	Block	Unit
3.	Regulations and Issues	1. Accounting, Policies and Regulations 2. Environmental Issues

VII. Theory

Block 1: Overview

Unit 1: Overview of Environmental Economics

Environmental pollution as a consequence of market failure - Causes and consequences of market failure - Externalities - Public goods and externalities -Economics of pollution – Private vs. Social cost of environmental pollution – Property rights, environment and development – Theory of environmental policy.

Block 2: Assessment and Development Dynamics

Unit 1: Economic assessment

Environmental cost benefit analysis - Environmental impact assessment techniques Non-market valuation of environmental resources (WTP / WTA) - Environment, market and social welfare.

Unit 2: Developmental aspects

Economic growth and environmental cost - Growth oriented economic policies and their environmental impacts - Population and environmental quality - poverty and environmental degradation – Sustainable development – Indicators of sustainable development – Issues in sustainable development.

Block 3: Regulations and Issues

Unit 1: Accounting, Policies and Regulation

Environment, ecology and environmental accounting - Environmental pollution with respect to water and air - Land and forest resources related environmental pollution - Coastal externalities - Urbanization and environment - Basic approaches to environmental policy (Tax, subsidy, pollution permits, *etc.*) Green taxes - Political economy of environmental regulation and management.

Unit 2: Environmental Issues

Transboundary environmental problems - Economics of global warming, climate change and emission trading - Environment, international trade and development.

VIII. Practical

- Contemporary global environmental global environmental issues, movement, policies, programmes, laws and other regulatory mechanisms
- Criteria for evaluating the environment related projects and review of Environmental Impact Assessment (EIA) techniques
- Recreation demand models of environmental valuation
- Contingent valuation techniques
- Environmental Resource Accounting Techniques
- Discussion on the techniques dealing with air pollution and review of case studies on air pollution and its impacts - forest environment and wild life conservation
- Green GDP and Green house insurance
- Practical considerations and comparison of instruments of environmental policy

- Non-point source pollution control methodologies
- Environment in macroeconomic modeling
- Meta-analysis, economic valuation and environmental economics
- Multi-criteria methods for quantitative, qualitative and fuzzy evaluation problems related to environment
- Input output analysis, technology and the environment
- Computable general equilibrium models for environmental economics and policy analysis.

IX. Teaching Methods/ Activities

- Lectures.
- Case studies.
- Assignments (Group/individual).
- Group Discussions

X. Learning outcome

After the successful completion of the course, the student will be able to-Understand the concept of pollution and externalities caused by economic activity. Work out the economics of productions activities in terms of losses to environment. Learn about accounting of environmental costs and other issues related.

XI. Suggested Reading

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Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Social Sciences
– Agricultural Extension Education

Acknowledgements

Curriculum reform essentially means bringing about changes to the subject content, delivery, and assessment of a curriculum. In the field of agricultural extension, curriculum reforms are important for several reasons. Firstly, farmers face several new challenges related to changing climate, uncertain markets and deteriorating and declining natural resource which sustain agriculture. These challenges mean that extension today needs to tackle an increased diversity of objectives that not only include but also go beyond transfer of new technology and increasing production. While some of these roles still continue to be important, extension services are required to play an increasingly important intermediation and facilitation role to support application of new knowledge.

Agriculture extension is no longer only a public sector phenomenon. It now involves a more complex range of actors providing a wide range of services, together bracketed as EAS. These include organizations in the private sector dealing with agriculture inputs, agribusiness, and financial services; non-governmental organizations (NGOs) (international as well as local); producer groups, cooperatives and associations; consultants (independent as well as associated with or employed by agri-business/ producer associations) and information and communication technology (ICT)-based services. The job market for extension professionals has thus changed and now demands quite different competencies than what the current curricula tries to provide.

Moreover, the theory and practice of extension has evolved considerably in the recent past based on new research in the area of diffusion, innovation and communication studies. These new insights are important tools in any effort to reinvent extension to meet the evolving needs of stakeholders in the Agricultural Innovation Systems (AIS).

The sub-committee on Agricultural Extension constituted by ICAR (under the ICAR Broad Subject Matter Area (BSMA) for Social Sciences) has kept above development in view while revising the PG and Ph.D. Curricula in Agricultural Extension. We also addressed the issue of repetitions of content at different levels and in this process, and considered the Fifth Dean Committee report and the earlier under-graduate curricula in extension. Moreover, student's prior knowledge is critical for learning any discipline and therefore identified first the core competencies that are required at the different levels and worked backwards based on the areas and organizing them into courses.

We are also recommending internship at the Master's level for 5 credits and Teaching Assistantship at the Ph.D. level for 5 credits. We believe this will help the students to have more relevant practical experience and this will boost their job prospects. The committee also discussed about the need for organizing exposure visit for PG/Ph.D. students to universities abroad (student exchange).

We have organized the curricula under different block and units and each course has an introduction explicitly stating the purpose of this course (why this course?), aim of the course (what it tries to provide?) and learning outcomes. Several new and relevant references including appropriate web links to different resources are also provided at the end of each course. The committee strongly proposes training programmes in collaboration with the concerned organizations for the teachers of Agrl Extension of all SAUs to gear them up for dealing the new revised courses effectively.

The report is based on several rounds of stakeholders meeting and consultation with extension professionals representing different universities, ICAR institutions, NGOs etc. involved in teaching and training in extension . The first such workshop was at Hyderabad on 12 July 2018. Our sincere thanks to Dr R.K. Samantha, Former VC, BCKV, Mohanpur, West Bengal; Dr Raji Reddy, Director of Extension, PJTSAU, Hyderbabad; Dr Biswanath Sadangi, Former Head, ICAR-CIWA, Bhubaneswar; Dr Mahesh Chander, Head, Division of Extension Education, ICAR-IVRI, Izatnagar; Dr Debabrata Basu, Porfessor and HoD, BCKV, Nadia; Dr R.N. Padaria, Principal Scientist (Extension) IARI, New Delhi; Dr K. Ponnusamy, Principal Scientist, NDRI, Karnal; Dr Sreenath Dixit, Head, ICRISAT; Dr Basavaprabhu Jirli, Professor (Extension), I.A.S, BHU, Varanasi; Dr D. Sandhya Shenoy, Principal Scientist (Extension), ICAR-NAARM, Hyderbabad; Dr Bharat S. Sontaki, Principal Scientist, ICAR-NAARM, Hyderbabad; Dr Rasheed Sulaiman, Director, CRISP, Hyderbabad; Dr Sarvanan Raj, Director (Agriculture Extension), MANAGE, Hyderbabad; Dr P.V.K. Sasidhar, Professor and Director, SOEDS, IGNOU, New Delhi; Dr P. Amala Kumari, Professor (Retd.), College of Home Science, Hyderbabad; Dr Srinivas Surisetti, Professor, TISS, Hyderbabad; Dr V. Sudha Rani, Professor and Head, Dr G. Samuel, Professor, Dr A. Sailaja, Professor, Dr M. Sreenivasulu, Professor, Ms Aruna, Assistant Professor from the Department of Agricultural Extension, College of Agriculture, Hyderbabad; Prof. K. Madhu Babu, Director, Prof. B. Jamuna, Prof. S. Chandra Shekar, Prof. R. Vasantha. Prof. M.Preethi, Prof. M. Prasuna, Extension Education Institute, Hyderbabad; Prof. Ch. Venugopal Reddy, PAIO; Dr V. Ravinder Naik, Senior Scientist, Agricultural Information and Communication Centre, PJTSAU, Hyderbabad; Dr P. Prashanth, Scientist, Electronic wing, PJTSAU, Hyderbabad; Dr B. Savitha, Assistant Director of Extension, PJTSAU, Hyderbabad; Dr P. Archana, Scientist (ToT), DAATTC, Mahboobnagar, Dr K. Madan Mohan Reddy, Scientist (ToT), DAATTC, Karimnagar, Dr R. Vishwatej, S.M.S (Agriculture Extension), KVK, Bhadradri, Kothagudem for their valuable inputs which paved way for right direction to identify the lacunae in the existing curricula and to prepare the revised curricula.

The committee also interacted closely with the Sub-Committee constituted by the National Institute of Agricultural Extension Management (MANAGE) for development of Extension curricula and this joint effort of two committees represents a much wider number of extension professionals.

Our special thanks to Ms V. Usha Rani, IAS, Director General, MANAGE and all the sub-committee members of MANAGE Sub-Committte on Extension Curricula Reforms (Dr Saravanan Raj, MANAGE, Dr Rasheed Sulaiman, CRISP-AESA, Dr P.S. Sivakumar, ICAR-CTCRI, Dr Mahesh Chander, ICAR-IVRI, Dr M. Chandragowda, ICAR-ATARI, Dr M.A. Ansari, GBPUAT, Dr P.V.K. Sasidhar, IGNOU, Dr P.S. Ananthan, ICAR-CIFE, Dr Ritu Chakravarty, ICAR-NDRI, Dr Sagar Wadkar, VAMNICOM and Dr Souvik Ghosh, Visva Bharati University) for their specific contributions to development of this revised curricula. The two days joint consultation and brain storming on each of the courses, the two committees organized together at Hyderabad on 28-29 September 2018 helped us in development of this final output. Our special thanks to Dr Onima, V.T., Research Officer, Centre for Research on Innovation and Science Policy (CRISP) for supporting this exercise both intellectually and operationally.

The committee organized third BSMA (Social Sciences) meeting on 28-01-2019 at Institute of Agricultural Sciences, BHU, Varanasi for reviewing the final drafts of three

disciplines of social Sciences. Our sincere thanks to Dr Basavaprabhu Jirli, Professor and Head, Prof. A.K. Singh and Prof. Kalyan Ghadee from the Department of Extension Education, I.A.S, BHU, Varanasi for their critical comments and suggestions with regard to revised curricula.

The suggestions at National Core Group review on April 24, 2019 were valuable and incorporated in the report. The detailed insights and advice from Dr N.S. Rathore as Chairman of the Special Meeting of BSMA on May 10, 2019 were crucial in shaping of final report.

Our sincere gratitude and thanks to all the members of BSMA Committee for Social Sciences namely Dr Rakesh Singh, Professor, Dept. of Agricultural Economics, IAS, BHU, Varanasi, Dr S. Mahapatra, Professor and Head, Agri Business Management, OUAT, Bhubaneswar, and Dr Aditi Mathur, Professor, Institute of Agri Business Management, Swami Keshwanand Rajasthan Agricultural University, Bikaner for their continuous support, encouragement and suggestive nature throughout the journey of final draft preparation.

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Finally, we thank profusely Dr N.S. Rathore, Former Deputy Director General (Education), and Dr R.C. Agrawal, Current Deputy Director General (Education) ICAR, New Delhi for constituting the BSMA for undertaking curricula revision of PG and Ph.D. in Social Sciences and for their valuable guidance and support in this regard.

I. Sreenivasa Rao
(Member, BSMA, Agricultural Extension)
Dr Lipi Das
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Dr Kalpana Sastry
(Chairperson, BSMA, Social Sciences)

September, 2020

Preamble

Justification for modification of Present Courses and recommendation of New Courses
Innovativeness in the present curricula development:

- The developed curricula is the result of sincere and coordinated effort of multi-stakeholders and experts in the discipline of Extension Education with a aim to enhance the value of the discipline, relevance to field and develop the graduates with multi core competencies to face the challenges in TOT.
- The content of the courses are perfectly related to the present changes and scenario in the Ecosystem of Extension Education at National and Global level.
- The practical content coverage will give multiple opportunities to the graduates to have hands on experience and demonstrate what they learn in variety of contexts i.e. various extension teaching methods, Big data, IOTs, project development and evaluation, organizations of groups/FPOs, etc.
- The recommended curricula is perfect match and having high relevancy to the developments and innovations in the field.
- The curricula is developed by benchmarking the core competencies that are expected from the Extension graduates, thus the approach is bottom-up.
- The recommended Extension Research methodology courses will help the students to identify the contemporary problems and their solving could lead to develop quality extension models for effective TOT and policy making.
- The recommended Internships and Teaching assistantships will help the students to have more relevant practical experience and this will boost their job prospects.

Course Title with Credit Load
M.Sc. in Agricultural Extension Education

Major Courses 20

Course Code	Course Title	Credit Hours
EXT-501*	Extension Landscape	2(2+0)
EXT-502*	Applied Behaviour Change	3(2+1)
EXT-503*	Organisational Behaviour and Development	3(2+1)
EXT-504*	Research Methodology in Extension	3(2+1)
EXT-505*	Capacity Development	3(2+1)
EXT-506*	ICTs for Agricultural Extension and Advisory Services	3(2+1)
EXT-507*	Evaluation and Impact Assessment	3(2+1)

Minor Courses 08

a. It is suggested the student may choose at least two out of three courses listed below as part of minor courses as these are related to policy advocacy and aim to build larger understanding of the subject.
b. Further, it is suggested that the student may choose the remaining Courses from any other discipline including the disciplines of Agrl. Economics/ABM and are related to the research problem selected by the student.
c. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/HoD.

EXT-508	Managing Extension Organisations	3(2+1)
EXT-509	Enabling Innovation	2(1+1)
EXT-510	Gender Mainstreaming	3(2+1)

Supporting Courses 06

STAT	Statistical Methods for Applied/ Social Sciences	3(2+1)
STAT/COMP	Computer Applications for Agricultural Extension Research	3(2+1)

It is suggested that the student may choose the Supporting Courses other than the listed courses, provided the opted courses are related to the research problem selected by the student and be mandatorily approved by the Student Advisory committee/HoD”.

Common Courses 05

1. Technical Writing and Communications Skills
2. Intellectual Property and its management in Agriculture
3. Agricultural Research, Research Ethics and Rural Development Programmes

Some of these courses are already in the form of e-courses/ MOOCs. The students may be allowed to register these courses/ similar courses on these aspects, if available online on

SWAYAM or any other platform. If a student has already completed any of these courses during UG, he/ she may be permitted to register for other related courses with the prior approval of the HoD/BoS.

EXT-591	Master's Seminar	**01**
	Thesis/Research	30
	Total	70

Course Contents
M.Sc. in Agricultural Extension Education

I. Course Title : Extension Landscape

II. Course Code : EXT 501

III. Credit Hours : 2+0

IV. Why this course?

Extension and advisory services (EAS) need to support farmers to deal with several new challenges they face currently. To effectively support farmers, EAS should perform several new functions and it should have capacities to perform these functions. EAS have evolved considerably especially during the last 3 decades. Several new approaches have emerged and many new funding and delivery models emerged in response to reforms (economic policies and new governance structure) implemented in several countries. Apart from these, new insights from communication and innovation studies have also started to influence the practice of extension. There is a lot of interest globally in strengthening pluralistic EAS and enhancing its contribution towards development of an effective Agricultural Innovation System (AIS). Keeping these in view, there is a need to orient students of extension on how extension is shaped globally and the policy level challenges it faces so that the extension students fit well to the global demand for competent extension professionals who can appreciate and understand this changing context.

V. Aim of the course

The aim of this course is to introduce the new challenges before extension and how extension is evolving globally. It presents the new capacities that are needed by EAS providers to provide a much wider support to farmers and it orient students to the new insights from communication and innovation studies that are influencing the practice of extension globally. The course also help students to appreciate the process and the impact of extension reforms implemented in many countries, the new approaches that are evolving globally in different regions and the policy challenges in managing a pluralistic extension system.

The course is organized as follows:

No	Blocks	Units
1	Globally, What is new in Extension?	1. Challenges Before Extension and Advisory Services 2. New Functions and New Capacities 3. Pluralism in EAS
2.	Insights from Communication & Innovation Studies & New Extension Approaches	1. From the Linear Paradigm To Systems Paradigm 2. Evolving Extension Approaches
3	Extension Reforms And Policy Challenges	1. Changes In Governance, Funding and Delivery of EAS 2. Challenges In Managing Pluralistic EAS

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Appreciate the changing global extension landscape
- Broaden their understanding on the role of EAS in agricultural innovation system
- Critically evaluate the reforms in extension and the evolving approaches in extension
- Analyse the policy level challenges in extension funding and delivery

Block 1: Globally, What Is New In Extension?

Unit 1: Challenges before Extension and Advisory Services (EAS)

Extension and Advisory Services (EAS)- Meaning (embracing pluralism and new functions) New Challenges before farmers and extension professionals: Natural Resource Management-Supporting farmers to manage the declining/deteriorating water and soil for farming; Gender Mainstreaming- How extension can enhance access to new knowledge among women farmers; Nutrition- Role of extension in supporting communities with growing nutritious crop and eating healthy food; Linking farmers to markets- Value chain extension including organizing farmers, strengthen value chain and supporting farmers to respond to new standards and regulations in agri-food systems; Adaptation to climate changes-How extension can contribute to up-scaling Climate Smart Agriculture; Supporting family farms- strengthening the capacities of family farms; Migration-Advising farmers to better respond to opportunities that emerge from increasing mobility and also supporting migrants in enhancing their knowledge and skills; Attracting and Retaining Youth in Agriculture including promotion of agripreneurship and agri-tourism; Urban and peri-urban farming- How to support and address issues associated with urban and peri-urban agriculture; Farmer distress, suicides- Supporting farmers in tackling farm distress.

Unit 2: New Functions and New Capacities

Beyond transfer of technology: Performing new functions to deal with new challenges; Organising producers into groups-dealing with problems that need collective decision making such as Natural Resource Management (NRM) and access to markets; Mediating conflicts and building consensus to strengthen collective decision making; Facilitating access to credit, inputs and services-including development of service providers; Influencing policies to promote new knowledge at a scale Networking and partnership development including convening multi-stakeholder platforms/ innovation platforms.

New Capacities needed by extension and advisory services at different levels –at the individual (lower, middle management and senior management levels), organizational and enabling environment levels; –Core competencies at the individual level; Varied mechanisms for capacity development (beyond training).

Unit 3: Pluralism in EAS

Pluralism in Extension Delivery: Role of private sector (input firms, agri-business companies, consultant firms and individual consultants)- Trends in the development of private extension and advisory services in India and other countries; challenges faced by private extension providers; Role of Non-Governmental Organizations (National/international)/ Civil Society Organizations (CSOs) in providing extension- Experiences from India and other countries; Producer Organizations- Role in strengthening demand and supply of extension services; their strength and weaknesses-experiences from different sectors; Role of Media and ICT advisory service providers; global experiences with use of media and ICTs in advisory services provision.

Block 2: Insights From Innovation Studies and New Extension Approaches

Unit 1: From the Linear Paradigm to Systems Paradigm

Diffusion of Innovations paradigm- strengths and limitations; multiple sources of innovation-farmer innovation, institutional innovation; farmer participation in technology generation and promotion; strength and limitations; Agricultural Knowledge and Information Systems (AKIS); strength and limitations; Agricultural Innovation Systems (AIS); Redefining Innovation- Role of Extension and Advisory Services in AIS-From information delivery to intermediation across multiple nodes; Role of brokering; Innovation Platforms, Innovation Management; Strength and weaknesses of AIS. Rethinking Communication in the Innovation Process – Network building, support social learning, dealing with dynamics of power and conflict.

Unit 2: Evolving Extension Approaches

Evolution and features of extension approaches: Transfer of technology approach; educational approach, farmer participatory extension approach, demand-driven extension, market led extension (value chain extension), extension for climate smart agriculture, gender sensitive extension, extension for entrepreneurship Extension systems in different regions: Asia-Pacific, Europe, Latin America, Australia, North America Networking for Strengthening EAS: GFRAS (Global Forum for Rural Advisory Services) and its regional networks.

Block 3: Extension Reforms and Policy Challenges

Unit 1: Changes in Governance, Funding and Delivery

Reduction in public funding: public withdrawal from extension provision (partial/ full); Examples/Cases; Privatization: Public funding and private delivery; cost sharing and cost recovery; Examples/Cases; Decentralisation of extension services; Examples/ Cases; Lessons from extension reforms in different countries; Extension and Sustainable Development Goals (SDGs).

Unit 2: Challenges in Managing Pluralistic Extension Systems

Pluralism: Managing pluralism and Co-ordination of pluralistic extension provision; Public private partnerships in extension (including the role of local governments/ panchayats and producer organisations); Examples, challenges in co-ordination; Achieving convergence in extension planning and delivery, Financing Extension: Mobilising resources for extension: public investments, donor support (grants/loans); Monitoring and Evaluation of Extension: Generating appropriate data for Assessment and Evaluation of pluralistic extension; Strengthening extension policy interface; generating evidence on impact of extension and policy relevant communication.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Book Review by students
- Student presentation
- Group Work

VIII. Suggested Reading

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https://openknowledge.worldbank.org/handle/10986/7184

Websites

- **AESA**- Agricultural Extension in South Asia http://www.aesanetwork.org/
- **FAO**- Food and Agricultural Organisation (Research and Extension) http://www.fao.org/research-and-extension/en/
- **GFRAS**- Global Forum for Rural Advisory Services http://www.g-fras.org/en/
- **INGENEAS**- Integrating Gender and Nutrition within Agricultural Extension Services https://ingenaes.illinois.edu/
- **IFPRI**- International Food Policy Research Institute (Extension) http://www.ifpri.org/topic/agricultural-extension
- **KIT**- Royal Tropical Institute (KIT)-Sustainable Economic Development https://www.kit.nl/sed/
- **WUR**- Wageningen University and Research Research (Knowledge, Technology and Innovation Group (KTI)) https://www.wur.nl/en/Research-Results/Chair-groups/Social-Sciences/KnowledgeTechnology-and-Innovation-Group.htm

I. Course Title : Applied Behaviour Change

II. Course Code : EXT 502

III. Credit Hours : 2+1

IV. Why this course?

The behavioural change of the stakeholders is the key objective in extension profession, which is reflected through their enhanced capacity, attitude change, modification of perceptions and beliefs, improved understanding of a system, adoption of improved technologies, empowerment, and resilience to adverse phenomenon and improved decision-making. Irrespective of their role and profession, all the key stakeholders in agriculture like farmers, extension agents, scientists/ academicians, development managers and policy makers are human beings, whose behaviour is the product of internal psychological processes influenced by external environment. Since human behaviour is a psychological phenomenon, expressed through interaction of internal psychological processes, social systems and external environment, there is an essential need to understand how these psychological processes guide the behavioural change. These psychological processes may be expressed at individual, group, community and organisational level involving human learning, choices, judgement and decisions about an extension intervention.

V. Aim of the course

This course aims to build capacities of students to understand the fundamental psychological processes which guide human behaviour at individual, group and community levels in specific contexts, to develop sound extension strategies.

The course is organized as follows:

No	Blocks	Units
1	Foundations of Behaviour Change	1. Foundations of Human Behaviour
2	Cognitive Processes and Learning	1. Cognitive Processes affecting Human Behaviour 2. Information Processing 3. Learning 4. Judgement, Choice and Decision-making
3	Human Behaviour in the Society	1. Attitudes and Influence 2. Social Judgement, Social Identity and Inter-Group Relations

VI. Theory

Block 1: Foundations of Behaviour Change

Unit 1: Foundations of Human Behaviour

Human behaviour – Meaning, importance and factors influencing human behaviour; Biological bases of human behaviour – Nervous system, brain, endocrine system and genes; Individual variations – intelligence, ability and creativity– foundations and theories, personality and temperament - foundations, approaches, theories of personality, measuring personality (traits, locus of control, self-efficacy; Personal, social and moral development – meaning, concepts – self-concept, self-esteem and self-worth and theories. Motivation – foundations, approaches, theories, managing human needs and motivations; perceiving others – impression, attitude, opinions; Emotions - foundations, types and functions, measuring emotional intelligence.

Block 2: Cognitive Processes And Learning

Unit 1: Cognitive Processes affecting Human Behaviour

Sensory organs and their role cognition; Cognitive processes – Attention, perception, remembering and forgetting, knowledge and expertise – foundations and theories; Principles and processes of perception; Consciousness – meaning, types, sleep and dreams; Learning and Memory – Memory - meaning, types and mechanisms of storage and retrieval of memories in the Human brain; Complex cognitive processes - Concept formation, Thinking, Problem solving and transfer – foundations, theories and approaches.

Unit 2: Information Processing

Information processing – meaning, principles; Models of information processing - Waugh and Norman model of primary and secondary memory; Atkinson and Shiffrin's stage model of memory; other models including blooms taxonomy and Sternberg's Information Processing Approach; Attention and perception – meaning, types, theories and models; Consciousness.

Unit 3: Learning

Learning – foundations, approaches and theories; Cognitive approaches of learning – meaning, principles theories and models; Memory – foundations, types; Behavioural approaches of learning – foundations and theories - classical conditioning, operant conditioning, applied behaviour analysis; Social cognitive and constructivist approaches to learning – foundations and theories – social cognitive theory, Self-regulated learning; learning styles – meaning, types and applications in learning.

Unit 4: Judgement, Choice and Decision-making

Human judgement – meaning, nature, randomness of situations, theories and models; Choice – meaning, criteria for evaluating options; theories and models of human choice; Choice architecture; Decision-making – Meaning, problem analysis; steps and techniques of decision-making under different contexts.

Block 3: Human Behaviour in the Society

Unit 1: Attitudes and Influence

Attitudes - meaning, assumptions, types, theories and models of attitude formation; methods of changing attitudes, Relating to others - liking, attraction, helping behaviour, prejudice, discrimination and aggression; Liking/ affect – meaning, types and theories; Attraction – meaning, types and theories; Persuasion – meaning, theories and techniques; Social influence and groups – conformity, compliance and obedience.

Unit 2: Social Judgement, Social Identity and Inter-Group Relations

Social judgement – meaning, frame of reference, stereotyping; The judgement of attitude models; Attribution – meaning, theories; Rational decision making; Social identify – meaning, types; assessment; Groups – meaning, types, group processes; sustainability of groups; Inter group processes and theories social learning.

VII. Practicals

- Understanding perception – Attentional Blink and Repetition Blindness exercise
- Understanding attention - Testing selective attention capacity and skills and processing speed ability through Stroop test
- Hands-on experience in the techniques for assessing creative thinking – divergent and convergent thinking
- Lab exercise in applying Maslow's need hierarchy to assess motivation
- Learning - Classical conditioning and operant conditioning
- Assessing learning styles through Barsch and Kolb inventories
- Practical experience in building self-esteem
- Assessment of emotional intelligence

- Exercises in problem solving
- Exercises in visual perception
- Measuring self-concept using psychometric tools
- Experiment on factors influencing information processing
- Assessment of attitudes
- Hands on experience in methods of persuasion
- Field experience in assessing social judgement
- Simulation exercise to understand decision-making under different situations
- Exercise in rational decision-making.

Teaching methods/activities

- Lecture cum discussion
- Class exercises
- Group Presentation

Learning outcome

The students should:

- Understand the biological and cognitive processes determining human behaviour
- Understand the process of learning under different context
- Develop competencies in influencing the human decision process in various contexts
- Design effective strategies to influence attitude and behaviour

Suggested Reading

Eiser J, Richard. 2011. *Social Psychology: Attitudes, Cognition and Social Behaviour*. Cambridge: Cambridge University Press.(First Edition, 1986))

Eysenck MW and Keane M T. 2010. *Cognitive psychology: A student's handbook*. Sixth Edition, Hove: Psychology Press.

Feldman RS. 2008. *Essentials of understanding psychology* (7th ed.). Boston: McGraw-Hill.

Gilovich T, Keltner D, and Nisbett RE. 2011. *Social psychology*. New York: W.W. Norton & Co.

Moreno R. 2010. *Educational Psychology*. Hoboken, NJ: John Wiley & Sons Inc.

Nevid JS. 2012. *Essentials of psychology: Concepts and applications* Belmont, CA: Wadsworth, Cengage Learning.

Rachlin H. 1989. *Judgment, decision, and choice: A cognitive/behavioral synthesis*. New York: W.H. Freeman.

I. Course Title : Organisational Behavior and Development

II. Course Code : EXT 503

III. Credit Hours : 2+1

IV. Why this course?

In changing and competitive world, the survival of any organization is dependent on its ability to adjust to the new challenges, adapt its structure and develop the competencies needed among its staff. This course is designed to understand the theory and practice relating to the processes of organizational behavior, development and change. It attempts to bring about change in the different levels of the organization (the individual, group and organization) using a wide variety of interventions.

V. Aim of the course

- To understand the theory and practice relating to the processes of organizational behavior, development and change.
- To develop insight and competence in diagnostic and intervention processes and

skills for initiating and facilitating change in organizations.
- To gain necessary self-insight, skills in facilitation, organizational development (OD) skills, group process and techniques, to become an effective change agents and OD consultants.
- To understand the behavior of individuals and small groups in organization with special focus on beliefs, attitudes and values, human inference - attribution, self-concept, motivation, active listening, interpersonal communication, conflicts management.

The course is organized as follows:

No	Blocks	Units
1.	Organisational Behaviour	1. Basics of Organisation 2. Basics of Organisational Behaviour 3. Individual Behaviour in Organizations 4. Group Behaviour in Organizations 5. Productive Behaviour and Occupational Stress 6. Organisational Systems
2.	Organisational Development	1. Overview of Organisational Development 2. Managing the Organisational Development Process 3. Organisational Development Interventions 4. Organisational Development Practitioner or Consultant

VI. Theory

Block 1: Organizational Behavior

Unit 1: Basics of Organization

Introduction to organizations-concept and characteristics of organizations; Typology of organizations; Theories of organizations: nature of organizational theory, Classical theories, Modern management theories, System Theory - Criticisms and lessons learnt/ analysis.

Unit 2: Basics of Organizational Behaviour

Concepts of Organisational Behaviour, Scope, Importance, Models of OB.

Unit 3: Individual Behaviour in Organizations

Introduction, Self-awareness, Perception and Attribution, Learning, Systems approach to studying organization needs and motives – attitude, values and ethical behavior, Personality, **Motivation**-Concept & Theories, Managing motivation in organizations.

Unit 4: Group Behaviour in Organization

Foundations of group, group behaviour and group dynamics, Group Development and Cohesiveness, Group Performance and Decision Making, Intergroup Relations; Teams in Organizations-Team building experiential exercises, Interpersonal Communication and Group; Leadership: Meaning, types, Theories and Perspectives on Effective Leadership, Power and Influence, managing Conflict and Negotiation skills, Job/ stress management, decision-making, problem-solving techniques.

Unit 5: Productive Behaviour and Occupational Stress

Productive behaviour - Meaning, dimension; Job analysis and Job performance – meaning, dimensions, determinants and measurement; Job satisfaction and organizational commitment - meaning, dimensions and measures roles and role clarity; Occupational stress – meaning, sources, theories and models, effects, coping mechanism, effects and management; Occupational stress in farming, farmer groups/ organizations, research and extension organizations.

Unit 6: Organizational System

Organizations Structure- Need and Types, Line & staff, functional, committee, project structure organizations, centralization &decentralization, Different stages of growth and designing the organizational structure; Organizational Design-Parameters of Organizational Design, Organization and Environment, Organizational Strategy, Organization and Technology, Power and Conflicts in Organizations, Organizational Decision-Making; Organizational Culture vs Climate; Organizational Change; Organizational Learning and Transformation.

Block 2: Organisational Development

Unit 1: Overview of Organizational Development

Concept of OD, Importance and Characteristics, Objectives of OD, History and Evolution of OD, Implications of OD Values.

Unit 2: Managing the Organizational Development Process

Basic Component of OD Program-Diagnosis-contracting and diagnosing the problem, Diagnostic models, open systems, individual level group level and organizational level diagnosis; Action-collection and analysis for diagnostic information, feeding back the diagnosed information and interventions; Program Management- entering OD relationship, contracting, diagnosis, feedback, planned change, intervention, evaluation.

Unit 3: Organizational Development Interventions

Meaning, Importance, Characteristics of Organization development Interventions, Classification of OD Interventions-Interpersonal interventions, Team Interventions, Structural Interventions, Comprehensive Interventions.

Unit 4: Organizational Development Practitioner or Consultant

Who is OD consultant? Types of OD consultants and their advantages, qualifications, Comparison of traditional consultants Vs. OD consultants, Organizational Development process by the practitioners skills and activities.

VII. Practicals

- Case Analysis of organization in terms of process – attitudes and values, motivation, leadership.
- Simulation exercises on problem-solving – study of organizational climate in different organizations.
- Study of organizational structure of development departments, study of departmentalization, span of control, delegation of authority, decision-making patterns.
- Study of individual and group behaviour at work in an organization.
- Conflicts and their management in an organization.

- Comparative study of functional and nonfunctional organizations and drawing factors for organizational effectiveness.
- Exercise on OD interventions (Interpersonal, Team, Structural, Comprehensive) with its procedure to conduct in an organization

VIII. Teaching methods/activities

- Lecture cum discussion
- Cases
- Class exercises
- Group Presentation

IX. Learning outcome

This course will equip the students to become potential change agents and OD practitioners. They should be able to learn how to improve individual, group/team and organizational performance through the use of OD techniques or interventions.

X. Suggested Reading

Bhattacharyya DK. 2011. *Organizational Change and Development*, Oxford University Press.

Hellriegel D, Sloccum JW and Woodman. 2001. **Organizational Behaviour.** Cincinnati, Ohio: South-Western College Pub.

Luthans F. 2002. *Organizational Behaviour*. Tata McGraw-Hill, New York

Newstrom JW and Davis K. 2002. *Organizational Behaviour: Human behaviour at Work*. Tata-McGraw Hill, New Delhi.

Peter MS. 1998. *The Fifth Discipline: The Art and Practice of Learning Organization*. Random House, London.

Pradip NK. 1992. *Organizational Designs for Excellence.* Tata McGraw Hill, New Delhi.

Shukla, Madhukar. 1996. *Understanding Organizations*. Prentice Hall of India, New Delhi.

Stephens PR and Timothy AJ. 2006. *Organizational Behaviour*, 12th Edition. Prentice Hall Pub.

Thomas GC and Christopher GW. 2013. *Organizational development and change*, 10th edition, South-Western college publishing.

Wendell LF and Cecil HB. 1999. *Organizational Development: Behavioural science interventions for organization improvement*, Pearson. 368 pp.

I. Course Title : Research Methodology in Extension

II. Course Code : EXT 504

III. Credit Hours : 2+1

IV. Why this course?

Growth of any discipline is directly proportional to the creation of knowledge in that discipline. Extension research is the backbone of extension discipline. Extension research is a unique social science inquiry where research ideas are gathered from the field problems and put through a systematic cycle of objective investigations that result in significant solutions. Apart from developing theories and models that advance scientific knowledge, extension research should also provide new insights for improving extension policy and practice. As extension is a field oriented discipline seeking to improve the welfare of its stakeholders, the extension professionals require critical competencies in conducting empirical research for developing sound extension models, methods and tools.

V. Aim of the course

This course aimed to create a workforce which has sound fundamental knowledge and critical competencies in planning, conducting and applying behavioural research for developing quality extension models, methods and tools.

The course is organized as follows:

No.	Blocks	Units
1.	Introduction to behavioural research	1. Nature of Behavioural Research 2. The Behavioural Research Process
2.	Steps in behavioural research process	1. Formulating a Research Problem 2. Reviewing the Literature 3. Identifying Variables and Hypotheses 4. Formulating Research Designs, Methods and Tools 5. Selecting Sample 6. Collecting Data 7. Analysing and Interpreting the Data 8. Reporting and Evaluating Research

VI. Theory

Block 1: Introduction To Behavioural Research

Unit 1: Nature of Behavioural Research

Methods of knowing; Science and scientific method; Behavioural research – Concept, aim, goals and objectives; Characteristics and Paradigms of research; Types of behavioural research based on applications, objectives and inquiry; Types of knowledge generated through research – historical, axiological, theoretical and conceptual knowledge, prior research studies, reviews and academic debate; Role of behavioural research in extension; Careers in behavioural research.

Unit 2: The Behavioural Research Process

Basic steps in behavioural research – Formulating a Research Problem; Reviewing the Literature; Identifying the variables and hypotheses; Formulating research designs, methods and tools; Selecting sample; Collecting data; Analyzing and Interpreting the Data; Reporting and Evaluating Research; Skills needed to design and conduct research; Writing research proposals.

Block 2: Steps in Behavioural Research Process

Unit 1: Formulating a Research Problem

The research problem and research topic - definitions; Importance of formulating a research problem; Sources of research problems; Characteristics of a good research problem; Research problems in quantitative and qualitative research; Steps in formulating a research problem; Strategies for writing research problem statement; Research purpose statement; Research questions – Types, Criteria for selecting research questions, techniques for narrowing a problem into a research question; Objectives - Meaning, types and criteria for judging the objectives.

Unit 2: Reviewing the Literature

Review-meaning and importance; Types of literature review – Context, Historical, Integrative, methodological, self-study and theoretical; Literature review for quantitative and qualitative studies; Steps in conducting literature review – Identify key terms, locate literature, critical evaluation and selection; organising literature and writing literature review.

Unit 3: Identifying Variables and Hypotheses

Developing theoretical, conceptual, empirical frameworks; Approaches for identifying concepts, constructs and variables; Role of theory in behavioural research; Steps in identifying variables – Domain, Concepts, Constructs, Dimensions; Indicators; Variables, Definitions, premises, propositions and hypotheses; Techniques of identifying concepts, constructs and variables - Types of concepts; Types of variables –causal relationship, the study design; and the unit of measurement; Types of definitions-Types of propositions and hypotheses. Characteristics of good hypotheses; Measurement – Meaning, levels of measurement – nominal, ordinal, interval and ratio; Criteria for choosing measurement levels for variables.

Unit 4: Formulating Research Designs, Methods and Tools

Research designs – Definition, purpose and functions; Research Design as Variance Control - MAXMINCON Principle; Criteria for selecting a suitable Research Design; Classification of research designs: Quantitative designs - experimental, descriptive, comparative, correlational, survey, ex-post facto and secondary data analysis; Qualitative designs - ethnographic, grounded theory, phenomenological and Narrative research; Mixed method designs – Action research design; Translational research; Elements of research design - Research strategies, Extent of researcher interference, Study setting, Unit of analysis and Time horizon. Sources of errors while specifying research designs. Internal and external validity; Choosing right research design; Triangulation - Importance in behavioural research, Types of triangulation. Research methods: Designing research Instruments – questionnaires, interview schedules; tests – knowledge tests, behaviour performance tests; scales – scales and indexes, checklists, focus groups; Steps in developing and using research methods and tools; participatory rural appraisal.

Unit 5: Selecting Sample

Sampling - population, element, sample, sampling unit, and subject; Sampling strategies for quantitative and qualitative research; Principles of sampling; Factors affecting the inferences drawn from a sample; Types of sampling, Methods of drawing a random sample, Sampling with or without replacement, Types of sampling - Probability Sampling - Simple random sampling, Cluster sampling, Systematic sampling, Stratified random sampling and Unequal probability Sampling; Non-probability Sampling - Reliance of available subjects, Purposive or judgmental sampling, accidental sampling, expert sampling, Snowball sampling, and Quota sampling; Sample size requirements for quantitative and qualitative studies. Methods for estimating sample size; Generalisation – Importance, Types of generalisations.

Unit 6: Collecting Data

The process of collecting data – Selection, training, supervision, and evaluation of field investigators; Online data collection; Errors and biases during data collection. Testing goodness of measures through item analysis - Reliability and validity; Types of validity – Content validity: Face and content validity, Criterion-related validity: concurrent and predictive validity, Construct validity: convergent, and discriminant validity, factorial validity, and nomological validity; Types of reliability – Test-Retest, Parallel forms, Inter-item consistency reliability, Split-half reliability.

Factors affecting the validity and reliability of research instruments, Strategies for enhancing validity and reliability of measures. Validity and reliability in qualitative research.

Unit 7: Analyzing and Interpreting the Data

Data coding, exploration and editing; Methods of data processing in quantitative and qualitative studies; Quantitative data analysis - parametric and non-parametric statistical analyses; Parametric analysis – Descriptive and inferential statistics, Hypothesis testing - Type I and Type II errors. Concepts in hypothesis testing - Effect Size, á, â, and Power, P Value; Multivariate data analysis – regression, factor analysis, cluster analysis, logistic regression and structural equation modelling. Guidelines for choosing appropriate statistical analysis; Statistical packages for data analysis; Methods of interpreting data and drawing inferences - The Ladder of Inference; Methods of communicating and displaying analysed data.

Unit 8: Reporting and Evaluating Research

Writing reports and research publications; Evaluation Methodology

VII. Practicals

- Selecting a research problem and writing problem statement
- Narrowing down research problem to purpose, research questions and objectives
- Choosing, evaluating and reviewing research literature
- Selection of variables through construct conceptualisation and defining variables
- Choosing research design based on research problem
- Choosing right sampling method and estimating sample size
- Developing research methods and tools – questionnaires, interview schedule, check lists and focus group guides
- Writing a research proposal
- Field data collection using research methods and tools
- Testing reliability and validity of research instruments
- Hands on experience in using SPSS for coding, data exploration, editing, analysis and interpretation Formulation of secondary tables based on objectives of research
- Writing report, writing of thesis and research articles
- Presentation of reports

VIII. Teaching methods/activities

– Lecture cum discussion
– Class exercises
– Assignment(Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group Work
– Research Report

IX. Learning outcome

– Understand the concepts, paradigms, approaches and strategies of behavioural research
– Enable to choose research design, methods and tools suitable for the research problem
– Design research instruments skilfully and conduct research in an objective and unbiased way

– Analyse the data through appropriate analytical methods and tools and derive meaningful interpretations

X. Suggested Reading

Babbie E. 2008. *The basics of social research*. 4th ed. Belmont, CA, USA; Thompson Wordsworth.

Creswell JW. 2009. *Research design: Qualitative, quantitative, and mixed methods approaches*. Third edition. Thousand Oaks: Sage Publications.

Creswell JW. 2012. *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. Fourth edition. Boston, MA: Pearson.

Kerlinger FN and Lee HB. 2000. *Foundations of Behavioral Research*. Orlando, FL: Harcourt College Publishers.

Kumar R. 2014. *Research Methodology: A Step- by- Step Guide for Beginners*. Fourth. Edition. Thousand Oaks, California: Sage Publications.

Malhotra NK. 2010. *Marketing research: An applied orientation*. Sixth Edition. Upper Saddle River, NJ: Prentice Hall.

NeumanWL. 2006. *Social Research Methods: Qualitative and Quantitative Approaches*. Toronto: Pearson.

Sekaran U and Bougie R. 2013. *Research Methods for Business A Skill-Building Approach*. 6th Edition, Wiley, New York.

Sendhil R, Kumar A, Singh S, Verma A, Venkatesh K and Gupta V. 2017. *Data Analysis Tools and Approaches (DATA) in Agricultural Sciences*. e-Compendium of Training-cum-Workshop organised at the ICAR-IIWBR during March 22-24, 2017. pp 1-126.

Sivakumar PS, Sontakki BS, Sulaiman RV, Saravanan R and Mittal N. (eds). 2017. *Good Practices in Agricultural extension Research*. Manual on Good Practices in Extension Research and Evaluation. Agricultural Extension in South Asia. Centre for Research on Innovation and Science and Policy (CRISP), Hyderabad. India.

Sivakumar PS and Sulaiman RV. 2015. *Extension Research in India-Current Status and Future Strategies*. AESA Working Paper 2. Agricultural Extension in South Asia.http://www.aesanetwork.org/aesa-working-paper-2-on-extension-research-in-india-current-status-and-future-strategies-p-sethurman-sivakumar-and-rasheed-sulaiman-v-december-2015/

I. Course Title : Capacity Development

II. Course Code : EXT 505

III. Credit Hours : 2+1

IV. Why this course?

Competent and skilful extension professionals are not naturally born. Their capacities need to be improved primarily at three different levels:

1. Pre-service capacity development – Under graduation and post-graduation studies
2. Induction capacity development – Just before job entry
3. In-service capacity development – During job

If undergone appropriately, pre-service studies help extension professionals to mainly acquire knowledge related to development. However, they are not fully ready for development work with required attitude and skills needed by an organisation. Properly planned and organized induction / in-service capacity building programmes help them to use development concepts, apply methods, exhibit attitude and skills required for development work at different levels. In short, the essence of this course is to make you understand these notions and help you to think up, manage, put into practice and evaluate capacity development programmes.

V. Aim of the course

- To understand the concepts of training, capacity building, capacity development and human resource development in the context of roles and responsibilities of extension professionals
- To discuss capacity development- approaches, strategies, needs assessment and methods / tolls
- To help you devise, organize, implement and evaluate capacity development programmes

The course is organized as follows:

No	Blocks	Units
1.	Introduction to Capacity Development	1. Capacity Development - An Overview 2. Capacity Development - Approaches and Strategies 3. Planning and Organization of Capacity Development Programmes
2.	Capacity Development Needs Assessment	1. Capacity Development Needs Assessment - An Overview 2. Capacity Development Needs Assessment Methods
3.	Capacity Development Institutions and Management	1. Capacity Development Institutions 2. Capacity Development Project Formulation
4.	Capacity Development Process and HRD	1. Capacity Development Methods and Tools 2. Evaluation 3. Impact Assessment 4. Human Resource Development

VI. Theory

Block 1: Introduction to Capacity Development

Unit 1: Capacity Development–An Overview

Training, capacity building, capacity development and HRD-Meaning and differences; Need and principles of capacity development; Types and levels of capacities - Institutional capacities (include the rules, regulations and practices that set the overarching contextual environment), Organisational capacities (how various actors come together to perform given tasks), Individual capacities (technical, functional and leadership skills). Types of capacity building - Based on structure (structured, semi-structured &unstructured), Based on context (orientation, induction and refresher), and other categories (online, Webinar, distance etc.). Components of capacity development; Capacity development cycle.

Unit 2: Capacity Development- Approaches and Strategies

Capacity Development Dilemma- Theory versus Practice, Trainee versus Task, Structured versus Unstructured, Generic and Specific; Approaches in Capacity Development -Informative approach, Participatory approach, Experimental approach/ Experiential, Performance based approach; Capacity Development Strategies - Academic strategy, Laboratory strategy, Activity strategy, Action strategy, Personal development strategy, Organizational development strategy.

Unit 3: Planning and Organization of Capacity Development Programmes

Steps in Designing and Planning of Capacity Development- Step 1. Select the participants, Step 2. Determine the participants' needs, Step 3. Formulate goal and objectives, Step 4. Outline the content, Step 5. Develop instructional activities, Step 6. Prepare the design, Step 7. Prepare evaluation form, Step 8. Determine follow-up activities; Organising capacity development programme; Operational arrangements at different stages- Before the programme, During the programme, Middle of the programme, At the end of the programme, After the programme, Follow up; Stakeholders' responsibilities.

Block 2: Capacity Development Needs Assessment

Unit 1: Planning and Organization of Capacity Development Programmes

Concept of Need Assessment; Approaches in Need Analysis- Performance Analysis, Task Analysis, Competency Study; Needs Survey.

Unit 2: Capacity Development Needs Assessment Methods

Data Collection Methods in Identifying Needs - Rational Methods (Observation, Informal talks, Complaints, Comparison, Analysis of report, Opinion poll, Buzz session, Analysis of the new programme), Empirical Methods (Job analysis, Performance evaluation, Checklist or Questionnaire Method, Tests, Critical Incident Technique, Card Sort Method, Focus Group Discussion, Interview, SWOT Analysis); Information and Skills required in Need Analysis; Identification of Needs through Task Analysis - Task identification, Task Analysis, Gap Analysis.

Block 3: Capacity Development Institutions and Management

Unit 1: Capacity Development Institutions

Capacity Developer (Trainer): Meaning and concept; Types of Capacity Developers (regular, *ad-hoc*, part time, guest and consultants); Roles of Capacity Developer (explainer, clarifier, supporter, confronter, role model, linker, motivator, translator/ interpreter, change agent); Good Capacity Developer – Qualities, skills and roles Qualities, Skills (Intrapersonal & Inter personal), Roles (Manager, Strategist, Task Analyst, Media Specialist, Instructional Writer, Marketer, Facilitator, Instructor, Counsellor, Transfer Agent, Evaluator); Capacity Development Centres and Locations; Organisation's Role in Capacity Development.

Unit 2: Capacity Development Project Formulation

Project Proposal: Concept and Meaning; Steps in Project Formulation- Review of past proposals, Consulting experts, consultants, and previous organizers, Review past project evaluation reports, Interact with the prospective beneficiaries; Format for Writing Project Proposal (LFA).

Block 4: Capacity Development Process and HRD

Unit 1: Capacity Development Methods and Tools

Capacity Development Methods –Lecture, Discussion, Syndicate, Seminars, Conference, Symposium, Role Play, Case study, Programmed Instruction, T - group/ Laboratory methods; Factors Determining Selection of Methods - Capacity development objectives, subject matter, categories of participants, and the available resources like time, location, budget; Capacity Development Aids.

Unit 2: Evaluation

Capacity Development Programme Evaluation - Meaning & Importance; Purpose of Evaluation; Principles of Evaluation; Types of Evaluation – Formative, Summative, Kirkpatrick's four levels of evaluation; Process of Evaluation- Evaluation at the beginning, Evaluation during the programme, Evaluation at the end; Use of evaluation findings; Statistical Tools for evaluation.

Unit 3: Impact Assessment

Impact Assessment- Meaning, Need, Features, Benefits, Concepts; Indicators for Impact Assessment - Direct indicators, Indirect or proxy indicators, Quantitative indicators, Qualitative indicators, Result chain / hierarchy of indicators; Methods of Impact Evaluation- Learning retention of participants (KOSA), Impact on the job performance, Impact on organizational effectiveness, Impact on stakeholder's competency.

Unit 4: Human Resource Development

HRD: Meaning, Importance and Benefits; Types of HRD Systems & Sub-systems Career system (Manpower planning, Recruitment, Career planning, Succession planning, Retention), Work system (Role analysis, Role efficacy, Performance plan, Performance feedback and guidance, Performance appraisal, Promotion, Job rotation, Reward), Development system (Induction, Training, Job enrichment, Self-learning mechanisms, Potential appraisal, Succession development, Counselling, Mentor system), Self-renewal system (Survey, Action research, Organisational development interventions), Culture system (Vision, mission and goals, Values, Communication, Get together and celebrations, Task force, Small groups); Components of HRD System - Performance Appraisal, Potential Appraisal, Task System, Development System, Socialisation System, Governance; Functions of HRD-Organisational Development, Career Development, Capacity Development.

VII. Practicals

- Capacity development needs assessment exercise
- Capacity development project formulation exercise
- Planning organizing and conducting an extension capacity development programme
- Designing a programme
- Writing learning objectives
- Developing objectives into curriculum
- Training plan
- Organizing capacity development workshop
- Evaluation with pre- and post-training tests
- Training methods – Practicing each method mentioned in contents as group exercise

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group work
– Case Analysis
– Guest Lectures
– Review of training manuals and training evaluation studies
– Short attachments to a nearby training institute.

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Differentiate between training, capacity building, capacity development and human resource development
- Explain different levels of capacities, needs assessment approaches & methods, capacity development methods and tools
- Formulate, implement and evaluate need based capacity development programmes

X. Suggested Reading

ADB. 2009. *Training Needs Assessment and Strategic Training Plan.*

Bentaya GM, and Hoffmann V (Eds). 2011. *Rural Extension* Volume 3 -Training Concepts and Tools. Margraf Publishers GmbH, Scientific books, KanalstraBe 21; D-97990, Weikersheim, 191 pp.

DFID .2003. *Promoting Institutional and Organisational Development. A Source Book of Tools and Techniques,* Department for International Development, United Kingdom

DoPT.2014. *Civil Services Competency Dictionary: Strengthening Human Resource Management of Civil Service.* Department of Personnel and Training, Government of India

FAO .2010. *FAO Capacity Assessment Approach and Supporting Tools - Discussion Draft*, Food and Agriculture Organisation of the United Nations

FAO .2012. *Capacity Development: Learning Module 2.* FAO Approaches to Capacity Development inProgramming. Processes and Tools, Food and Agriculture Organisation of the United Nations

FAO .2012. *Corporate Strategy on Capacity Development.*

FAO .2013. *Capacity Development: Learning Module 4.* Organization Analysis and Development Food and Agriculture Organisation of the United Nations

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FAO–FAO Capacity Development– http://www.fao.org/capacity-development/en/
GFRAS–Global Forum for Rural Advisory Services– http://www.g-fras.org/en/
AESA–Agricultural Extension in South Asia– http://www.aesanetwork.org/

I. Course Title : ICTs for Agricultural Extension and Advisory Services
II. Course Code : EXT 506
III. Credit Hours : 2+1

IV. Why this course?

Information and Communication Technologies (ICTs) are continuously evolving. More ICT applications having better relevance to extension and advisory services (EAS) are currently available considering the human and other resource constrains faced by EAS, ICTs can supplement and complement EAS extension efforts in a cost-effective way. Extension professionals should have sound knowledge of ICTs and comprehensive understanding on its various applications for effectively deploying these in EAS provision. This course will provide knowledge and hands-on-experience on ICT applications relevant for EAS.

V. Aim of the course

- To discuss different ICT initiatives, knowledge management process and application aspects

- To orient students on advances in smart/ disruptive technologies and data analytics
- Hands on experience in navigating ICTs

The course is organized as follows:

No	Blocks	Units
1.	Introduction to Information and Communication Technologies (ICTS) and e-Extension	1. ICTs- Concepts and Status 2. ICTs in Knowledge Management 3. e-Extension initiatives in Agriculture and allied sectors
2.	Application of ICTs in Extension and advisory services	1. ICT Applications 2. ICT Expert Systems 3. ICT Networks
3.	Knowledge management and Standards	1. Policies in Knowledge Management 2. Web Standards 3. Social Media Applications to engage audience
4.	Smart and disruptive Technologies and advanced analytics for agricultural extension	1. Smart Technologies 2. Human Computer Interactions

VI. Theory

Block 1: Introduction to Information and Communication Technologies (ICTs) and E-extension

Unit 1: ICTs- Concepts and Status

ICTs- meaning, concepts, basics of ICTs, global and national status, types and functions of ICTs, innovations, meaning of e-Governance, e-learning, mLearning, advantages and limitations of ICTs.

Unit 2: ICTs in Knowledge Management

Knowledge management-meaning, approaches and tools. Role of ICTs in Agricultural Knowledge Management.

Unit 3: e-Extension initiatives in Agriculture and allied sectors

e-Extension, overview on Global and national e-extension initiatives, Inventory of e-Extension initiatives in Agriculture and allied sectors from Central and State governments, ICAR, SAUs, private sector and NGO initiatives in India.

Block 2: Application of ICTs in Extension and Advisory Services

Unit 1: ICT Applications

Knowledge centres (tele centres), digital kiosks, websites and web portals, community radio, farmers call centres, mobile phone based advisory services and mobile applications (mExtension, mLearning), Self-learning CDs on Package of practices, social media, digital videos, Market Intelligence and Information Systems- ICT enabled Supply-Chains and Value-Chains/ e-Marketing (e-NAM, Agmarknet, *etc.*).

Unit 2: ICT Expert Systems

Expert System/ Decision Support System/ Management Information Systems, Farm Health Management & Intelligence System for Plant Health, Animal Health, Soil Health, Fishery, Water, Weather, etc.

Unit 3: ICT Networks

Global and regional knowledge networks, international information management systems, e-Learning platforms (MOOCS, Course CCRA, EduEx, *etc*), e-Governance Systems; digital networks among extension personnel, Farmer Producers Organisations (FPOs)/ SHGs/ Farmers Groups.

Block 3: Knowledge Management and Standards

Unit 1: Policies in Knowledge Management

Global policy/ Standards on e-Governance, National policy on e-governance, Open Data / Open Gov Standards and Open Source etc; Language Technology Applications; National e-Agriculture policy/ Strategies/ guidelines.

Unit 2: Web Standards

Web standards, creating and writing for webportals, development of mobile applications, developing digital videos- story board- video recording- video editing, types of blogs and writing guidelines.

Unit 3: Social Media Applications to engage audience

Video conference, live streaming and webinars, types and functions of social media applications, guidelines for preparing social media content, engaging audience and data-analytics.

Block 4: Smart and Disruptive Technologies and Advanced Analytics for Agricultural Extension

Unit 1: Smart Technologies

Open technology computing facilities, System for data analytics/ mining/ modelling/ Development of Agricultural simulations; Remote Sensing, GIS, GPS, Information Utility (AIU); disruptive technologies- Analysis; Internet of Things (IoTs), Drones, Artificial intelligence (AI), block chain technology, social media and Big Data analytics for extension.

Unit 2: Human Computer Interactions

Human Centered Learning/Ergonomics/ Human Computer Interactions-Meaning; Theories of multimedia learning - Sweller's cognitive load theory, Mayer's cognitive theory of multimedia learning, Schnotz's integrative model of text and picture comprehension, van Merriënboer's four-component instructional design model for multimedia learning; Basic Principles of Multimedia Learning - Split-attention, Modality, Redundancy, Coherence, Signaling, segmenting, pre-training, personalisation, voice embodiment; Advanced principles - Guided discovery, worked examples, Self-explanation, drawing, feedback, multiple representation, Learner control, animation, collaboration, prior knowledge, and working memory. Designing ICT gadgets based on human interaction principles - Interactive design-Meaning, importance; Approaches of interactive design - user-centered design, activity-centered design, systems design, and genius design; Methods of interactive design - Usability testing methods.

VII. Practicals

- Content and client engagement analysis
- Designing extension content for ICTs
- Creating and designing web portals, blogs, social media pages
- Developing digital videos

- Live streaming extension programmes and organising webinars
- Working with Farmers call centres
- Engaging with professional digital networks
- Writing for digital media

VIII. Teaching methods/activities

- Lecture
- Guest Lectures
- Assignment (Reading/Writing/ developing mApps/ media management/Social media initiatives)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Student's interview of ICT practitioners/ champions
- Documenting good practices and case studies
- Review of ICT policy documents and guidelines/ standards
- Short internship with ICT projects

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the importance of the ICTs in EAS
- Understand the ICT application aspects
- Critically evaluate ICT initiatives and smart/disruptive technologies
- To execute extension functions by applying ICTs and
- Engage stakeholders in knowledge management process

X. Suggested Reading

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GFRAS–Global Forum for Rural Advisory Services–
http://www.g-fras.org/en/

AESA–Agricultural Extension in South Asia–
http://www.aesanetwork.org/

I. Course Title : Evaluation and Impact Assessment

II. Course Code : EXT 507

III. Credit Hours : 2+1

IV. Why this course?

Many organizations now look for experts to evaluate development projects and developmental interventions. It is now required that impact be assessed whenever any development programme is implemented. Thus, the extension professionals need to have good understanding of the theory and practice of programme evaluation and impact assessment. This course, thus, has been designed to help students develop as extension professionals who can plan and conduct systematic assessments of the results and impacts of extension programmes.

V. Aim of the course

- To orient students on the importance of evaluation and impact assessment
- To develop capacities for evaluation and impact assessment
- Discuss ways of conducting evaluations and impact assessment

The course is organized as follows:

No	Blocks	Units
1.	Programme Evaluation	1. Introduction to Evaluation 2. Evaluation Theories
2.	Evaluation Process	1. How to Conduct Evaluation 2. Evaluating the Evaluation

No	Blocks	Units
3.	Programme Management Techniques	1. SWOT Analysis and Bar Charts 2. Networks
4.	Programme Evaluation Tools	1. Bennett's Hierarchy of Evaluation 2. Logic Framework Approach
5.	Impact Assessment	1. Introduction to Impact Assessment 2. Impact Assessment Indicators 3. Approaches to Impact Assessment 4. Environment Impact Assessment

VI. Theory

Block 1: Programme Evaluation

Unit 1: Introduction to Evaluation

Concept of Evaluation: Meaning and concept in different contexts; Why Evaluation is Done and When? Programme planning, analyse programme effectiveness, decision making, accountability, impact assessment, policy advocacy; Objectives, types, criteria and approaches of programme evaluation, evaluation principles; the context of program evaluation in agricultural extension; Role and Credibility of Evaluator: Role as educator, facilitator, consultant, interpreter, mediator and change agent. Competency and credibility of evaluator.

Unit 2: Evaluation Theories

Evaluation theory vs. practice – synergistic role between practice and theory in evaluation; Evaluation theories - Three broad categories of theories that evaluators use in their works - programme theory, social science theory, and evaluation theory (other theories/ approaches - Utilization-Focused Evaluation & Utilization-Focused Evaluation (U-FE) Checklist, Values Engaged Evaluation, Empowerment Evaluation, Theory-Driven Evaluation). Integration between theory and practice of evaluation: –evaluation forums, workshops, conferences and apprenticeship/ internship.

Block 2: Evaluation Process

Unit 1: How to Conduct Evaluation

Ten Steps in programme evaluation: (1) Identify and describe programme you want to evaluate (2) Identify the phase of the programme(design, start-up, on-going, wrap-up, follow-up) and type of evaluation study needed (needs assessment, baseline, formative, summative, follow-up) (3) Assess the feasibility of implementing an evaluation (4) Identify and consult key stakeholders (5) Identify approaches to data collection (quantitative, qualitative, mixed) (6) Select data collection techniques (survey interviews and questionnaires with different types) (7) Identify population and select sample (sampling for evaluation, sample size, errors, sampling techniques (8) Collect, analyse and interpret data (qualitative and quantitative evaluation data analysis) (9) Communicate findings (reporting plan, evaluation report types, reporting results, reporting tips, reporting negative findings (10) Apply and use findings (programme continuation/ discontinuation, improve on-going programme, plan future programmes and inform programme stakeholders).

Unit 2: Evaluating the Evaluation

Evaluating the Evaluation - 10 Steps as above with focus on conceptual clarity, representation of programme components and stakeholders, sensitivity, representativeness of needs, sample and data, technical adequacy, methods used for data collection and analysis, costs, recommendations and reports.

Block 3: Programme Management Techniques

Unit 1: SWOT Analysis and Bar Charts

SWOT Analysis – Concept, origin and evolution; SWOT As a Programme Management Tool; Conducting SWOT Analysis - Common Questions in SWOT Analysis; Advantages and Disadvantages of SWOT; Bar Charts (Gantt Charts and Milestone Charts) - Characteristics, advantages and limitations.

Unit 2: Networks

Networks – Introduction, origin and widely used networks (Programme Evaluation and Review Technique (PERT) and Critical Path Method (CPM), differences between PERT and CPM, advantages and disadvantages. Networks Terminology – Activity, Dummy activity, Event (predecessor event, successor event, burst event, merge event, critical event), Earliest Start Time (EST), Latest Start Time (LST), Critical Path, Critical Activity, Optimistic time (T_o), Pessimistic time (P_o), Most likely time (T_M), Expected time (T_E), Float or Slack, Event Slack, Lead time, Lag time, Fast tracking, Crashing critical path, Acclivity Table, Danglers, Normal Time. Rules for Preparation of Networks and Steps in Network Preparation with example.

Block 4: Programme Evaluation Tools

Unit 1: Bennett's Hierarchy of Evaluation

Introduction to Bennett's hierarchy – Background and description; Relation between programme objectives & outcomes at 7 levels of Bennett's hierarchy – Inputs, activities, participation, reactions, KASA changes, practice and behaviour changes, end results. Advantages and Disadvantages of Bennett's hierarchy

Unit 2: Logic Framework Approach (LFA)

Introduction to LFA – Background and description; Variations of LFA - Goal Oriented Project Planning (GOPP) or Objectives Oriented Project Planning (OOPP); LFA Four-by-Four Grid – Rows from bottom to top (Activities, Outputs, Purpose and Goal & Columns representing types of information about the events (Narrative description, Objectively Verifiable Indicators (OVIs) of these events taking place, Means of Verification (MoV) where information will be available on the OVIs, and Assumptions). Advantages and Disadvantages of LFA.

Block 5: Impact Assessment

Unit 1: Introduction to Impact Assessment

Concept of Impact Assessment: Meaning, concept and purpose in different contexts; Impact Assessment Framework: Meaning of inputs, outputs, outcomes, impacts and their relation with monitoring, evaluation and impact assessment.

Unit 2: Impact Assessment Indicators

Indicators for impact assessment – meaning and concept; Selecting impact indicators; Types of impact indicators for technology and extension advisory services - social and behavioral indicators, socio-cultural indicators, technology level indicators, environmental impact assessment indicators and institutional impact assessment indicators.

Unit 3: Approaches for Impact Assessment

Impact assessment approaches – Quantitative, qualitative, participatory and mixed methods with their advantages and disadvantages; Quantitative Impact Assessment Types – Based on Time of Assessment (Ex-ante and ex-post), Based on Research Design (Experimental, quasi experimental, Non-experimental). Econometric Impact Assessment: - (Partial Budgeting Technique, Net Present Value, Benefit Cost Ratio, Internal Rate of Return, Adoption Quotient, *etc*). Qualitative and Participatory Impact Assessment Methods.

Unit 4: Environment Impact Assessment (EIA)

Concept of EIA – Introduction, What it is? Who does it? Why it is conducted? How it is done?; Benefits and important aspects of EIA-risk assessment, environmental management and post product monitoring. Environmental Components of EIA – air, noise, water, biological, land; Composition of the expert committees and Steps in EIA process - screening, scoping, collection of baseline data, impact prediction, mitigation measures and EIA report, public hearing, decision making, monitoring and implementation of environmental management plan, assessment of alternatives, delineation of mitigation measures and EIA report; Salient Features of 2006 Amendment to EIA Notification - Environmental Clearance/Rejection, participants of EIA; Shortcomings of EIA and How to improve EIA process?

VII. Practicals

- Search the literature using web / printed resources and identify evaluation indicators for the following:
  - Utilization-Focused Evaluation
  - Values Engaged Evaluation
  - Empowerment Evaluation
  - Theory-Driven Evaluation
- Visit Directorate of Extension in your university and enquire about extension programmes being implemented / coordinated by Directorate. Develop an evaluation proposal of any one programme using 'Ten Steps in Programme Evaluation' discussed in the theory class.
- Review any comprehensive programme evaluation report from published sources. Evaluate the report and write your observations following the 'Evaluating the Evaluation' approach.
- Identify at least four agriculture development programmes and their objectives being implemented in your state. Write two attributes each on Strengths, Weaknesses, Opportunities and Threats related to the identified programme objectives in the SWOT grid.
- Identify an on-going development programme and make-out 6 activities from the programme.
- Draw a Gantt chart for 12 months programme activities.
- Write a report on evaluation hierarchy levels and indicators as per Bennett's hierarchy of evaluation for any development programme or project.
- Develop LFA four-by-four grid for any development programme or project with activities, outputs, purpose and goal and objectively verifiable indicators, means of verification & assumptions.
- Visit a nearby KVKs / ATIC. Select any agriculture technology with package of practices and extension advisory services promoted by KVK / ATIC. Identify impact assessment indicators for social and behavioral indicators, socio-cultural indicators,

technology level indicators, environmental impact assessment indicators and institutional impact assessment indicators.
- Refer any Environment Impact Assessment report and analyse steps in EIA. Write your observations.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to: Develop competencies in the areas of evaluation planning, indicator development, conducting evaluation and impact assessment and writing reports.

X. Suggested Reading

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I. Course Title : Managing Extension Organizations
II. Course Code : EXT 508
III. Credit Hours : 2+1

IV. Why this course?

Organizations need to follow management principles, objectives and organizational processes. The extension organizations including management of agricultural extension services need to be managed for effectiveness and efficiency. This calls for key business management skills to be learnt by the students so that they can run extension organizations, and extension and advisory services efficiently using the principles, practices, knowledge and skills required for effective management.

V. Aim of the course

- To orient students on the importance of knowledge and skills on various management functions, as applicable to extension organizations
- Discuss ways of running extension services as managers of agri-ventures
- To develop capacities for becoming effective managers of agri-ventures

The course is organized as follows:

No	Blocks	Units
1.	Basics of Management	1. Management- An Over view
2.	Management in different types of Extension organizations	1. Extension Management in public, private sector and other sectors 2. Concepts in Management
3	Motivation and Organizational Communication	1. Motivation and Communication 2. Supervision and Control

VI. Theory

Block 1: Basics of Management

Unit 1: Management- An Over view

Management and Extension management – Meaning, concept, nature and importance;
and theories of management. Management, administration and supervision - meaning, definition and scope; Approaches to management, Principles, functions and levels of management; Qualities and skills of a manager; Interpersonal relations in the organization; Reporting and budgeting

Block 2: Management in different types of Extension Organizations

Unit 1: Extension Management in public, private sector and other sectors

Extension management (POSDCORB) in public sector, Department of Agriculture, Agricultural Technology Management Agency (ATMA), Krishi Vigyan Kendra (KVK), SAUs, ICAR Institutes, Private sector, Cooperatives, NGOs, FPOs etc. Organisational Structure, Relations between different units- Challenges in management

Unit 2: Concepts in Management

Decision making – Concept, Types of decisions, Styles and techniques of decision making, Steps in DM Process, Guidelines for making effective decisions; Human Resource Management: Manpower planning, Recruitment, Selection, Placement and Orientation, Training and Development; Dealing with fund and staff shortages in different extension organizations (KVK, ATMA etc.); Leadership – Concept, Characteristics, Functions, Approaches to leadership, Leadership styles; Authority and responsibility, Delegation and decentralization, line and staff relations; Challenges of co-ordination in extension organizations; Managing interdepartmental coordination and convergence between KVK, ATMA and line departments; Coordinating pluralism in extension services; Challenges in managing public-private partnerships (PPPs) at different levels in agricultural development in general and extension in particular; Performance appraisal – Meaning, Concept, Methods.

Block 3: Motivation and Organizational Communication

Unit 1: Motivation and Communication

Managing work motivation – Concept, Motivation and Performance, Approaches to motivation, team building; Organizational Communication – Concept, Process, Types, Networks, Barriers to Communication; Mentoring, Time management, Team work and team-building strategies; Modernization of information handling

Unit 2: Supervision and Control

Supervision – Meaning, Responsibilities, Qualities and functions of supervision, Essentials of effective supervision; Managerial Control – Nature, Process, Types, Techniques of Control, Observation, PERT and CPM, Management Information Systems (MIS): Concept, tools and techniques, MIS in extension organizations.

VII. Practicals

- Simulated exercises on techniques of decision making
- Study the structure and function of agro-enterprises, Designing organizational structure/ organograms.
- Group activity on leadership development skills
- Simulated exercise to understand management processes
- Field visit to extension organizations (ATARI, KVKs, NGOs), FPOs, dairy cooperatives to understand the functions of management
- Practical exercises on PERT & CPM
- Group exercise on development of short term and long term plans for agro-enterprises
- Developing model agriculture-based projects including feasibility study, financial planning and cost-benefit analysis

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Student's interview of officers engaged in EAS
- Short attachments

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Turn good managers of extension and advisory services including agri-ventures, FPOs, cooperatives etc.
- understand the key business skills needed for managing agribusinesses and managing the value chains
- critically evaluate the Management functions to make extension systems efficient by applying management principles and good practices of effective management
- engage in management of extension organizations

X. Suggested Reading

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I. Course Title : Enabling Innovation

II. Course code : EXT 509

III. Credit Hours : 1+1

IV. Why this course?

An effective process of agricultural innovation is a pre-condition for meeting the global challenge of feeding the growing world population and reducing poverty. Ideas about innovation have evolved considerably over the past 4 decades. A frequently used term in the discussions around innovation in agriculture is 'Agricultural Innovation Systems' (AIS). The AIS is increasingly recognized as a useful framework to diagnose innovation capacity, design investment and organise scaling up interventions. Extension and Advisory Services (EAS) are integral to AIS. Extension professionals should have sound knowledge on how to scale up new knowledge and thereby enabling innovation and impact and their roles in strengthening AIS. This course aims to provide these perspectives.

V. Aim of the course

The aim of this course is to introduce the new perspectives related to "innovation" and help learners to apply the AIS framework especially in dealing with scaling up knowledge. It discusses the different ways to explore AIS including the roles of different actors and the enabling environment (including institutions and policies) in enabling innovation. The course also aims to broaden the understanding of students in scaling up knowledge and orient students to varied tools and approaches to scaling up

The course is organized as follows:

No	Blocks	Units
1	Agricultural Innovation Systems	1. Agricultural Innovation Systems: Concepts and Elements
		2. Enabling Innovation
2	Scaling Up Knowledge for Innovation	1. Scaling Up: Tools, Approaches and Pathways

VI. Theory

Block 1: Agricultural Innovation Systems

Unit 1: Agricultural Innovation Systems: Concepts and Elements

Origins of the innovation systems concept-Innovation vs Invention; Agricultural Innovation System (AIS) -ToT, FSR, AKIS and AIS compared, Key insights from AIS: How Innovation takes place; Role of different actors in AIS; Importance of interaction and knowledge flows among different actors, Role of Communication in Innovation Process; Role of Extension in AIS, Different views to analyze AIS: structural view, functional view, process view and capacity view.

Unit 2: Enabling Innovation

Role of enabling environment: Policies and institutions in enabling innovation; Role of Government-Innovation Policy: Achieving coordination and policy coherence;

Innovation Platforms; Role of Innovation Brokers, Methodologies for AIS Diagnosis: Typologies of existing methodologies-strengths and limitations; Assessing Extension and Advisory Services within AIS; Capacity Development in AIS: Strengthening capacities to innovate.

Block 2: Scaling Up Knowledge for Innovation

Unit 1: Scaling Up: Tools, Approaches and Pathways

Scaling Up: Definitions; Changing views on scaling up: Approaches to Scaling Up: Push, pull, plant, probe: Scaling up pathways: Drivers and spaces for scaling up; Framework and Tools for Scaling up: Planning and implementing a scaling up pathways; Scalability assessment tools; Role of policies in scaling up: Influencing policies for scaling up; Innovation Management for scaling up knowledge and implications for Extension and Advisory Services.

VII. Practical

- Identify one crop/commodity sector and use AIS framework to diagnose actors and their roles, patterns of interaction, institutions determining interaction and the enabling policy environment and develop a AIS Diagnosis Report (Review and Key informant interviews)
- Undertake a case study on a successful case of scaling up knowledge and identify factors that contributed to its success
- Identify one specific knowledge (a technology, an approach) that has been recently introduced and develop an Up scaling Strategy

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group Work

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:
– Appreciate and apply AIS framework in different contexts
– Enhance their knowledge and skills related to enabling innovation
– Diagnose AIS and design interventions for improvement and
– Design scaling up strategies to achieve innovation and impact

X. Suggested Reading

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FAO- Food and Agricultural Organisation (Research and Extension)– http://www.fao.org/research-and-extension/en/

GFRAS- Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

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I. Course Title : Gender Mainstreaming

II. Course Code : EXT 510

III. Credit Hours : 2+1

IV. Why this course?

Gender as a concept has gained well deserved attention globally. Development planners and policy makers have realized that gender implications need to be considered while planning and implementing programmes and projects for their desired impacts. Conversely, the impacts of programmes on men and women also vary due to their different socially ascribed roles and responsibilities. Extension professionals need to understand the concept of gender and its implications on agricultural and rural development and their skills need to be built for critically identifying and analysing gender implications. This course is designed to meet these requirements.

V. Aim of the course

- To orient students on the importance of "Gender mainstreaming" as well as the other concepts related to gender. The students will be able to understand the gender roles and responsibilities and how in the present times, the roles may be shifting
- To discuss ways and various techniques for conducting gender analysis theoretically and practically as well as the prerequisites for gender analysis
- To develop capacities for identifying and addressing gender implications in all development programmes related to agriculture and allied sectors, climate change adaptation and livelihood security, as well as addressing gender issues through application of extension methods including PRA and PLA

The course is organized as follows:

No	Blocks	Units
1.	Why Gender Matters	1. Historical Perspective of Gender 2. Agrarian Importance of Gender
2.	Gender Related Concepts, Analysis, Gender and Technology	1. Gender Related Concepts and Divides 2. Gender Analysis 3. Gender and Technology
3.	Gender Mainstreaming and Women Empowerment	1. Gender Mainstreaming 2. Women Empowerment 3. Global Best Practices, Policies and Frameworks 4. Entrepreneurship Development for Women

VI. Theory

Block 1: Why Gender Matters?

Unit 1: Historical Perspective of Gender

Historical perspective of gender: Feminism and emergence of gender as a concept, Scope of gender studies in agriculture and rural development

Unit 2: Agrarian Importance of Gender

Agrarian Importance of Gender: Understanding the importance of gender in national and global agriculture-Key gender issues and challenges in agriculture - Gender and value chain- Global actions to address gender-needs and strategies to address gender and women empowerment.

Block 2: Gender Related Concepts, Analysis, Gender and Technology

Unit 1: Gender Related Concepts and Divides

Gender related concepts and divides: Understanding of the concepts of gender, gender equality and equity, gender balance, gender blindness, gender relations, gender neutrality, gender bias and discrimination, gender rights, gender roles and responsibilities. Gender budgeting, Gender divides and their implications such as gender digital divide, gender access to resources and inputs divide, gender mobility divide, gender wage divide, Gender needs: practical and strategic.

Unit 2: Gender Analysis

Gender analysis: Importance, usage, prerequisites, techniques of gender analysis-Tools for gender analysis.

Unit 3: Gender and Technology

Gender and technology: How gender and technology impact each other, Gender neutral technology, Gender sensitive technology, Gender supportive assistance in technology adoption-Gender in agricultural research and extension.

Block 3: Gender Mainstreaming and Women Empowerment

Unit 1: Gender Mainstreaming

Gender mainstreaming: Importance of gender mainstreaming in agriculture, Extension strategies to address gender issues such as gender and health, nutrition, gender in agricultural value chains, gender and climate change adaptation, gender and globalization& liberalization for mainstreaming gender concerns into the national programmes and policies.

Unit 2: Women Empowerment

Women Empowerment: Importance of women empowerment, Current national women empowerment and gender indices. Women empowerment approaches (technological, organizational, political, financial, social, legal and psychological), Case studies based on experiences and learning from various development and rural development programmes.

Unit 3: Global Best Practices, Policies and Frameworks

Global Best Practices, Policies and Frameworks: Global best practices, women empowerment and gender mainstreaming models and frameworks for addressing gender concerns in agriculture, approaches of various organizations: gender mainstreaming and special women focused programmes in agriculture and rural development.

Unit 4: Entrepreneurship Development for Women

Entrepreneurship development for women: Women entrepreneurship development in agriculture and agro processing: current status, women led enterprises, supporting organizations and schemes, Govt. policies, entrepreneurship development programme and process for women in agriculture.

VII. Practicals

- Visit to a village for understanding rural gender roles and responsibilities as groups, followed by class presentation by groups
- Exercise for capturing shifts in gender roles and responsibilities
- Conducting gender analysis in a village using gender analysis techniques
- Visit to agencies supporting women empowerment followed by report presentation. Each student to visit a different organization such as State Rural Livelihood Mission, Women Development Corporation, Department of Agriculture, Important NGOs working for women empowerment
- Exercise for identification and prioritization of issues affecting/needs for women empowerment
- Interaction with a successful women entrepreneur/ SHG

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review
– Student presentation
– Group Work
– Student's interview of key policy makers
– Case Analysis
– Guest Lectures
– Review of policy documents
– Short attachments

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Appreciate the importance of addressing agrarian gender concerns in the context of sustainable livelihoods and national development
– Understand the various concepts related to gender and the application of these concepts for women empowerment and gender mainstreaming
– Critically evaluate the various agricultural development, rural development programmes, schemes, policies and strategies for women empowerment within the context of achieving gender equity
– How to engage in gender analysis and collect and analyse sex-disaggregated data for developing strategies for women empowerment and gender mainstreaming

X. Suggested Reading

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JAEE (Editorial article). 2013. *Gender Inequality and Agricultural Extension.* The Journal of Agricultural Educatiion and Extension Vol 19 (5) 433-436.

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Jessica F. 2015. *Integrating Nutrition into Rural Advisory Services and Extension.* Global Forum for Rural Advisory Services, Switzerland. https://www.g-fras.org/en/download.html?download=344: ggp-note-9-integrating-nutrition-into-rural-advisory-services-and-extension

Liz P. 2018. *Implementing Gender Transformative Approaches (GTAs) in Agricultural Initiatives.* IGENAES and USAID. https://ingenaes.illinois.edu/wp-content/uploads/ING-DP-2018_06-Gender-Transformative-Approaches-in-Agricultural-Initiatives-Poulsen.pdf

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Sinha K. 2000. *Empowerment of Women in South Asia*. Association of Management Development Institute in South Asia, Hyderabad.

Websites

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RRW- Reaching Rural Women– http://www.reachingruralwomen.org/
UN WOMEN– http://www.unwomen.org/en

Course Title with Credit Load
Ph.D. in Agricultural Extension Education

Major Courses 12

Course Code	Title of Course	Credit Hours
EXT-601*	Policy Engagement and Extension	2+1
EXT-602*	Methodologies for Social and Behavioural Sciences	2+1
EXT-603*	Technology Commercialization and Incubation	2+1
EXT-604*	Educational Technology and Instructional Design	2+1

Minor Courses 06

a. It is suggested the student may choose at least one out of three courses listed below as part of minor courses as these are related to policy advocacy and bring in global perspectives with an aim to build a larger understanding of the subject to the student.
b. Further, it is suggested that the student may choose the remaining Courses from any other discipline including the disciplines of Agrl. Economics/ABM and are related to the research problem selected by the student.
c. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/HOD.

EXT-605	Risk Management and Climate Change Adaptation	2+1
EXT-606	Livelihood Development	1+1
EXT-607	Facilitation for People centric Development	2+1

Supporting Courses 05

STAT	Multivariate Statistical Methods for Extension Research	2+1
COM	Multimedia and Applications	1+1

It is suggested that the student may choose the Supporting Courses other than the listed courses, provided the opted courses are related to the research problem selected by the student and be mandatorily approved by the Student Advisory committee/HOD".

Seminars 2

EXT-691	Doctoral Seminar-I	1+0
EXT-692	Doctoral Seminar-II	1+0
	ii. Thesis / Research	75
	Total	100

Course Contents
Ph.D. in Agricultural Extension Education

I. Course Title : Policy Engagement and Extension

II. Course Code : EXT 601

III. Credit Hours : 2+1

IV. Why this course?

Extension's performance in any country to a large extent is dependent on the wider policy and institutional context prevailing at the national level. At the organizational level, extension should have capacities to influence policies that affect their performance. To effectively influence policies, extension professionals need to generate not only sound evidence of its impact, but also capacities to engage with policy relevant actors especially at various levels. While few countries have developed specific extension policies, there has been very limited success in translating these policies into programmes and operational guidelines. Lack of policy relevant research to generate evidence on extension's impact; poor documentation of successful initiatives, and lack of training on engaging with policy relevant actors have all contributed to this. Extension professionals, often encounter situations where existing policy constraints development interventions or where new policies could better support development. This course is aimed at developing these capacities to successfully engage with policy actors and bringing about desirable policy changes to strengthen extension.

V. Aim of the course

- To orient students on the importance of policies in shaping extension's performance
- To discuss ways of generating policy relevant evidence to influence policies
- To develop capacities to engage with policy actors and the policy development process

The course is organized as follows:

No	Blocks	Units
1.	Why policies matter?	1. Understanding Policy 2. Policy Advocacy and Tools 3. Policy Analysis 4. Policy Development Process
2.	Using evidence to influence Policy Change	1. Influencing Policy Change 2. Global Experience with Extension Policy

VI. Theory

Block 1: Why Policies Matter?

Unit 1: Understanding Policy

Why policies are important for extension? Role in providing structure, ensure funding and framework for providing functions-examples; Policy: definitions and types: Is policy a product or a process or both? Policies and institutions-How these influence defining organisational roles and performance in extension organizations-Role of policies in upscaling knowledge-Role of extension in influencing policies to enable innovation.

Unit 2: Policy Advocacy and Tools

Definition of advocacy, Approaches to policy advocacy-Advising, Media campaigning, Lobbying, Activism, Information Education Communication (IEC) and Behavior Change Communication (BCC); Advocacy for Rural Advisory Services (RAS); Policy advocacy strategy

Unit 3: Policy Analysis

Explain the meaning and use of policy analysis in decision- making; Describe different types of policy analysis- empirical, evaluative or normative policy analysis, retrospective/ prospective policy analysis, predictive/prescriptive/descriptive policy analysis; How to do policy analysis? - understand the process of policy analysis, highlight the different methods and techniques used in policy analysis, doing ethical policy analysis; Tools for policy impact- research tools, context assessment tools, communication tools, policy influence tools

Unit 4: Policy Development Process

Policy development process: Who drives policy change?: National Governments, Donors, Civil Society-varied experiences: Understanding the environment and key actors in policy space- problem identification-policy adoption, implementation and evaluation; stakeholder mapping, identifying opportunities and barriers, mobilising financial resources; Dealing with policy incoherence: identifying contradictions and challenges in policy implementation

Block 2: Using Evidence to Influence Policy Change

Unit 1: Influencing Policy Change

Generating evidence: Role of policy research; analyzing the usefulness and appropriateness of the evidence; Using evidence in policy advocacy; Understanding your audience: analyzing channels of influence; creating alliances; identifying policy champions; Defining goals and objectives; Developing advocacy messages: Policy papers, Policy briefs, good practice notes, *etc*.: Good practices in influencing policies Organising policy dialogues: Policy engagement strategy-Engaging with policy makers: GO and NGO experiences; Policy working groups; advisory panels; use of committees: Use of media including ICTs and social media for influencing policies.

Unit 2: Global Experience with Extension Policy

Extension policy in different countries: Explicit extension policy Vs extension as part of Agriculture Policy, Challenges in policy implementation: lack of capacities, financial resources, ownership, lack of stakeholder consultations: Strengthening capacities in extension to influence policies: Global Forum for Rural Advisory Services (GFRAS)'s efforts in strengthening extension policy advocacy: policy compendium, training modules, training for strengthening capacities to influence policies.

VII. Practicals

- Analysis of country/state level agricultural/extension policy to understand the policy intentions from strengthening EAS

- Analysis of extension policy of other countries: policy intentions, processes adopted in development of the policy and mechanisms of policy implementation
- Interview key policy actors in EAS arena at the state/national level (eg: Director of Agriculture, Director of Extension in SAU, Chairman/Managing Director of Commodity Board. Member Agriculture, State Planning Board) to explore policy level challenges in EAS
- Identify what evidence policy makers look for from extension research? Is the evidence available? If so what form? (Reports, Briefs etc), If not, develop a plan
- Explore how different stakeholders influence policies (eg: policy advocacy of prominent NGOs, private sector and public sector) -What mechanisms and tools they use
- Identify policy level bottlenecks that constrain effective EAS delivery at the district level- Eg: Issues around linkages between KVK and ATMA; inter-departmental collaboration; public private partnerships; joint action etc.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Student's interview of key policy makers
- Case Analysis
- Guest Lectures
- Review of policy documents
- Short attachments

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the role of policies in shaping performance of extension
- Understand how to generate and communicate policy relevant evidence
- Critically evaluate extension policies in different countries
- How to engage in policy advocacy.

X. Suggested Reading

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https://www.cbd.int/doc/pa/tools/Tracking%20the%20Impact%20of%20Policy%20Strategies% 20in%20Conservation%20Work%20.pdf

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http://planningcommission.gov.in/aboutus/committee/wrkgrp12/agri/wg_ agriextn.pdf

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The Policy Project. 1999. *Networking for Policy Change An Advocacy Training Manual.* The Futures Group International, Research Triangle Institute (RTI) and The Centre for Development and Population Activities (CEDPA). http://www.policyproject.com/pubs/AdvocacyManual.pdf

I. Course Title : Methodologies for Social and Behavioural Research

II. Course Code : EXT 602

III. Credit Hours : 2+1

IV. Why this course?

In general, social and behavioural science research plays a crucial role in the professional development in a subject domain, through advancing knowledge and developing working modalities and standards. Precisely, the empirical research helps to develop robust and outcome focused working strategies, processes and models to enable the professionals to maximise their efficiency. This course on advanced social science research caters to the need to equipping the scholars with essential skills in conducting high quality research which helps them to design working strategies, processes and models for professional development.

V. Aim of the course

This course aims to equip the doctoral students to conduct outcome-oriented social and behavioural science research and to develop sound field focused extension strategies and models with adequate replicability, while advancing knowledge on processes governing success of those strategies. The focus of the course is on equipping the scholars with advanced capacities in conducting systematic, objective and outcome oriented research by applying state-of-art methods and tools at every stage of research from planning to publishing.

The course is organized as follows:

No	Blocks	Units
1.	Advanced methods for improving quality of research data	1. Measurement Properties of Research Instruments 2. Threats to Data Quality
2.	Scales, indexes and tests	1. Scales, Indexes and Tests-1 2. Scales, Indexes and Tests-2

No	Blocks	Units
3.	Emerging research approaches and designs	1. Qualitative Research Methods 2. Emerging Approaches
4.	Utilising research outputs	1. Publishing Research 2. Ethics in Extension Research

VI. Theory

Block 1: Advanced Methods for Improving Quality of Research Data

Unit 1: Measurement Properties of Research Instruments

Measurement properties – Dimensionality, reliability and validity; Dimensionality – Unidimensionality and multidimensionality, Methods of assessing dimensionality, Formative and reflective constructs; Validity - Importance, Internal validity - face validity; content validity, Substantive Validity, Structural Validity; External validity - Convergent and Discriminant Validity, known-group validity, Criterion-Related Validity, Consequential Validity, nomological validity; Methods of assessing various forms of validities – Judges rating, Lawshe's Content Validity Ratio, Item-objective congruence index; latent variable method; Reliability - Internal consistency reliability – Split-Half, Cronbach alpha; Temporal Stability reliability - test-retest method; Interrater Consistency and Consensus – inter rater reliability and interrater agreement; Alternative Forms or parallel forms reliability – Reliability of difference - Factors Affecting the Validity and Reliability of Test Scores; Generalizability Theory

Unit 2: Threats to Data Quality

Errors and biases; Errors – Meaning and sources; Types - Sampling error, Non-sampling or measurement error and Processing error – Meaning, causes; Effects of errors and biases on data quality; Bias in behavioural research – Meaning, causes, Types – Respondent and researcher biases; Methods of reducing errors and biases in surveys, questionnaires, personal interviews, focus groups and online methods

Block 2: Scales, Indexes and Tests

Unit 1: Scales, Indexes and Tests-1

Approaches to measurement and scale development - Classical test theory. Formative or index models, The C–OAR–SE approach and Item Response Theory; Item analysis in Classical test theory – item difficulty and item discrimination; Scoring performance in scales and tests – meaning, types and methods; Scale development strategies – deductive and empirical; Stimulus-centred scales – method of equally appearing intervals, paired comparison, Person scaling – Q methodology; Subject-centre scales – The Likert scale and Semantic Differential

Unit 2: Scales, Indexes and Tests-2

Steps in constructing a multi-dimensional scale using confirmatory factor analysis,; Response scales - Guttman's scalogram analysis and The Rasch method; Indexes –Meaning, types, importance; Similarities and differences with scales, Methods of constructing indexes; Common indexes used in extension. Measurement invariance –Meaning, types, methods of assessing measurement invariance. Tests – meaning, types, importance; steps in conducting various tests – knowledge test

Block 3: Emerging Research Approaches and Designs

Unit 1: Qualitative Research Methods

Qualitative methods – Meaning; Types – Ethnography, Grounded theory, Phenomenology, Ecological psychology, Discourse Analysis; Observational research; Case study research – Sampling and sample size; Data collection methods - In-depth interviews, Focus groups, Direct observation, Record review; Content analysis; Unobtrusive Measures; Projective and semi-projective techniques; Selecting right qualitative method – Strengths and limitations of qualitative research; Analysis and interpretation of qualitative research data; Research synthesis – meaning, importance, methods; Systematic reviews and meta analysis – meaning, steps, and applications; Policy research

Unit 2: Emerging Approaches

Mixed methods research – meaning, purpose, types and applications; Participatory research – Meaning, importance, types, methods and tools and applications; Action research – Meaning, importance, Principles, Types, Steps in conducting action research, application in behavioural sciences. Social Network Analysis – Meaning, importance, types, steps in social network analysis, applications; Advanced methods of measuring perception and beliefs. Multi criteria decision making, analytical hierarchy approach

Block 4: Utilising Research Outputs

Unit 1: Publishing Research

Scholarly communication process; Research reports – Meaning, types, contents; Presentations – Meaning, types, principles of good presentation - Tell 'Em" and KISS 'Em" principles; Research publications – meaning, importance, types; Guidelines for preparing research papers - Peer review process, citation styles; Open access publishing; Publishing in social media. Software in academic writing

Unit 2: Ethics in Extension Research

Ethics in conducting behavioural research; Human subject research – Meaning, history, and ethical guidelines; Ethical aspects of collecting and using Indigenous knowledge and farmers technologies; Ethical practices in publishing; Plagiarism – meaning, sources, Identifying and correcting plagiarism in a research paper using anti-plagiarism software

VII. Practicals

- Practice in developing research instruments
- Methods of assessing measurement properties of research instruments - dimensionality, reliability and validity
- Hands-on exercise in minimising errors and biases
- Hands-on experience in constructing tests, scale and indexes
- Practice in summated scale development using confirmatory factor analysis
- Hands on experience in assessing measurement invariance
- Practicing and collecting data using participatory tools and techniques, analyzing and interpreting qualitative data
- Hands-on experience in writing systematic review using meta-analysis
- Field practice in conducting action research
- Practical experience in writing research paper
- Hands on exercises using software for qualitative data analysis
- Practice in detecting and correcting plagiarism using software

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group Work
- Guest Lectures
- Research Report (Writing)

IX. Learning outcome

- The scholars should develop critical skills in conducting systematic and objective research by using robust methods while minimising biases and errors
- The students should intelligently choose and apply advanced methods and tools at every stage of research and execute them in a objective way by managing the actors and processes effectively
- The students should develop expertise in designing tests, scales and indexes along with other tools to measure the socio-psychological processes at individual, group and community levels

X. Suggested Reading

Berg B. 2009. *Qualitative Research. Methods for the Social Sciences.* Boston: Allyn& Bacon.

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Rao, C.R. and Sinharay S. 2007. *Handbook of Statistics, Vol. 26: Psychometrics,* The Netherlands; Elsevier Science B.V.

Raykov T and Marcoulides GA. 2010. *Introduction to Psychometric Theory.* New York, NY: Taylor & Francis

Scott J and Carrington PJ. 2011. *The SAGE handbook of social network analysis.* London: SAGE.

Sekaran U and Bougie R. 2013. *Research Methods for Business A Skill-Building Approach.* 6th Edition, Wiley, New York.

Sivakumar PS, Sontakki BS, Sulaiman RV, Saravanan R and Mittal N. (eds). 2017. *Good Practices in Agricultural extension Research. Manual on Good Practices in Extension Research and Evaluation.* Agricultural Extension in South Asia. Centre for research on innovation and science and policy (CRISP), Hyderabad. India. http://www.aesanetwork.org/wp-content/uploads/2018/07/6.pdf

I. Course Title : Technology Commercialisation And Incubation

II. Course Code : EXT 603

III. Credit Hours : 2+1

IV. Why this course?

The technology commercialisation and incubation is an emerging area which links technology development, transfer and commercialisation processes with entrepreneurship development. Technology commercialisation aims to realize the value of agricultural technologies developed at the research establishments, by maximising their utility to stakeholders. With the increasing awareness of protecting and commercialising the Intellectual Property Resources (IPR) in the free market economy, there is a need to understand the organic relationship between protection and commercialisation IPR, and entrepreneurship development.

V. Aim of the course

This course is aimed to develop a critical understanding among extension students about how the technology commercialisation process is linked to IPR management and entrepreneurship development.

The course is organized as follows:

No	Blocks	Units
1.	Technology commercialisation and the modern context	1. Basics of Technology Commercialisation 2. Nature of Agricultural Technology 3. Basics of Technology Transfer and Commercialisation
2.	Intellectual Property Resources (IPR) Management	1. Overview of Intellectual Property Resources 2. Systems for protecting IP 3. Management of IPR 4. Protection and Management of Biological Resources 5. Protection, Management and Commercialisation of Grass root and Farmers Innovations, Traditional and Indigenous Knowledge 6. Geographical Indications (GI) and Appellation of Origin 7. Genetically Modified Organisms (GMO), Agriculture and Biosafety
3.	Technology commercialisation	1. Technology Assessment and Refinement 2. Technology Valuation 3. Technology Commercialisation Strategies 4. Scaling up of Technologies 5. Technology Licensing 6. Technology Takers and Entrepreneurship 7. Policy Support for Technology Commercialisation and Entrepreneurship Development
4.	Technology Incubation	1. Basics of Technology Incubation 2. Technology Incubation in India
5.	Technology promotion and essential skills for technology commercialisation	1. Technology Promotion 2. Dealing with Entrepreneurs, Agripreneurs and Other Stakeholders
6.	Emerging approaches in technology commercialisation and incubation	1. Technology Scouting

VI. Theory

Block 1: Technology Commercialisation and the Modern Context

Unit 1: Basics of technology commercialisation

Technology - Definition, functions, process of technological advancement – invention, discovery, innovation and technology; types of innovation - Basic research, Breakthrough innovation, Disruptive Innovation and Sustaining Innovation; Technology transfer and commercialisation

Unit 2: Nature of Agricultural Technology

Agricultural technology – meaning, types; technology generation system; technology life cycle

Unit 3: Basics of Technology transfer and commercialisation

Technology transfer Vs Commercialisation; Technology commercialisation process – elements, models, systems and processes; Technology transfer model – research, disclosure, development and commercialisation

Block 2: Intellectual Property Resources (Ipr) Management

Unit 1: Overview of Intellectual Property Resources

Introduction to IPR; Overview & Importance; Genesis; IPR in India and IPR abroad; Patents, copyrights, trademarks & trade secrets, geographical indication, industrial design; Emergence of IPR Regimes and Governance Frameworks - Trade-Related Aspects of Intellectual Property Rights (TRIPS), Convention on Biological Diversity (CBD), Cartagena Protocol, International Union for Protection of New Plant Varieties (UPOV), and BIMSTEC.

Unit 2: Systems for Protecting IP

IPR protection laws and systems – National IPR Policy; and IPR laws; procedures for filing IP protection; Systems of IP protection and management in agricultural universities and research institutions and also by stakeholders

Unit 3: Management of IPR

Mechanisms of IPR Management – Institutional arrangement, IP Management processes – invention disclosure; IP portfolio management; Infringement management

Unit 4: Protection and Management of Biological Resources

Introduction; National Biodiversity Act (2002); Protection of Plant Varieties and Farmers Rights Act (2001); Guidelines for registration and transfer of biological resources; Farmers rights; Mechanisms of documenting/ collecting, protecting and commercialising farmers varieties and other biological resources; National Biodiversity Authority, PPVFRA and other agencies involved in management of biological resources in India. Access to Genetic Resources and Sharing of Benefits

Unit 5: Protection, Management and Commercialisation of Grassrootand Farmers Innovations, Traditional and Indigenous Knowledge

Traditional and Indigenous Knowledge, Grassroot and Farmers Innovations – Meaning, forms and importance; Systems of documentation, registration, protection and commercialisation. Documentation of traditional indigenous knowledge - Traditional Knowledge Digital Library (TKDL), Community Biodiversity Registers

(CBRs), People's Biodiversity Registers (PBRs), Plant Biodiversity Register, and Honeybee Network.

Unit 6: Geographical Indications (GI) and Appellation of Origin

Geographical indications and appellation of origin – meaning, origin; Geographical Indications of Goods (Registration and Protection) Act (1999); Documentation, registration and commercialisation of GI protected materials and processes.

Unit 7: Genetically Modified Organisms (GMO), Agriculture and Biosafety

The Global Concerns on Use of Genetically Modified Organisms in Food and Agriculture; The Cartagena Protocol on Bio-safety; Regulation of GMO in India - Recombinant DNA Advisory Committee (RDAC), Institutional Bio-safety Committee (IBSC), Review Committee on Genetic Manipulation (RCGM), Genetic Engineering Approval Committee (GEAC), State Bio-safety Coordination Committee (SBCC) and District Level Committee (DLC). Laws and Acts for regulation of GMO - Guidelines for Research in Transgenic Plants, 1998; Seed Policy, 2002; Plant Quarantine Order, 2003; Regulation for Import of GM Products Under Foreign Trade Policy, 2006; National Environment Policy, 2006

Block 3: Technology Commercialisation

Unit 1: Technology Assessment and Refinement

Meaning; Importance; Approaches and methods of assessment and refinement of various technologies – stakeholder oriented approaches including participatory technology assessment and refinement; assessment and refinement of traditional and indigenous knowledge and grassroot innovations

Unit 2: Technology Valuation

Returns to investment; IP Valuation-Oxford context, IP Valuation methods - Cost approach; Income approach - Discounted Cash Flow, Risk-Adjusted Net Present Value, Net Present Value with Monte Carlo Simulation and Real Options Theory; Market approach - Industry Standards Method, Rating/Ranking Method, Rules of Thumb Approach and Auction Method; Hybrid approaches; Royalty rate method

Unit 3: Technology Commercialisation Strategies

Meaning- approaches for technology commercialisation – technology scaling up, technology licensing, handholding, agripreneur development, technology business incubation

Unit 4: Scaling up of Technologies

Meaning, types and stages of technology scaling up; mechanisms

Unit 5: Technology Licensing

Meaning and types - Procedures of licensing, preparing licensing documents; Management of technology licensing process

Unit 6: Technology Takers and Entrepreneurship

Meaning; types of technology takers; Technology Taking as a Strategy; Types of entrepreneurship – agripreneurs, startups, small businesses, Producer Organizations, Self Help Groups, Clusters and other forms of entrepreneurship

Unit 7: Policy support for Technology Commercialisation and Entrepreneurship Development

Policy support for entrepreneurship development in India - National Policy on Skill

Development and Entrepreneurship and other polices; Government of India Support for Innovation and Entrepreneurship – Startup India, Make in India, Digital India, Atal Innovation Mission and others; Entrepreneurship policy and schemes at different states of India; Organisations promoting entrepreneurship in India

Block 4: Technology Incubation

Unit 1: Basics of Technology Incubation

Meaning, functions and types; stakeholder oriented incubation process – Livelihood incubation, village incubators

Unit 2: Technology Incubation in India

System of technology incubation- incubation process; its effectiveness; Managing profit oriented and non-profit incubators; Schemes for promoting incubators in India

Block 5: Technology Promotion And Essential Skills For Technology Commercialisation

Unit 1: Technology Promotion

Technology promotion – meaning, types, business meetings, scientist-industry/ entrepreneur meets, technology conclave, business plan competition, farmers fairs, technology shows

Unit 2: Dealing with Entrepreneurs, Agripreneurs and Other Stakeholders

Business communication; Business Etiquette; business networking

Block 6: Emerging Approaches in Technology Commercialisation and Incubation

Unit 1: Technology Scouting

Technology Scouting and Innovations in technology incubation

VII. Practicals

- Understanding the technology commercialisation process – Visit to Technology Commercialisation Unit of ICAR Institute/ Agricultural University
- Understanding the IPR protection practices – Visit to Patent Attorney office
- Hands-on experience in drafting IPR application – Patent/Copyright/ Trademark
- Understanding protection of biological resources including plant varieties – Visit to PPVFRA Branch office/ ICAR Institute or Agricultural University involved in plant variety protection
- Documenting Traditional and indigenous knowledge – Field experience in using various protocols of using traditional and indigenous knowledge
- Protecting unique local goods through Geographical Indications – Hands on experiences in documenting and registering Geographical indications
- Technology assessment/ validation of traditional and indigenous knowledge – QuIK and other methods
- Hands on experience in technology valuation
- Hands on experience in technology licensing process including drafting agreements
- Understanding the Technology Business Incubation – Visit to Agri Business Incubator or Technology Business incubator
- Hands on experience in planning and organising technology promotion events

- Hands on experience in various techniques in business communication and Business etiquette

VIII. Teaching methods/activities

- Lecture cum discussion
- Cases
- Class exercises
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Group Presentation

IX. Learning outcome

At the end of the course the students are expected to develop competencies in:

- Enabling stakeholders to protect and manage their IPR
- Managing IPR to maximise their value realisation through commercialisation, and
- Providing mentoring and handholding support to agripreneurs, rural entrepreneurs, start-ups, Farmer Organisations and other forms of entrepreneurs through incubation

X. Suggested Reading

Bandopadhyay D. 2018. *Securing Our Natural Wealth: A Policy Agenda for Sustainable Development in India and for Its Neighbouring Countries*. Singapore; Springer.

Ghosh, S. and Joshi, A. 2017. *Handbook for Non-Profit Incubator Managers*. New Delhi: Deutsche Gesellschaftfür Internationale.

Gupta AK. 2016. *Grassroots Innovation: Minds on the margin are not marginal minds*. Gurgaon: Penguin Books.

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Stevens AJ. 2016. *Intellectual property valuation manual for academic institutions* (Report No. CDIP/17/INF/4). Geneva: Committee on Development and Intellectual Property (CDIP).

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I. Course Title : Educational Technology and Instructional Design

II. Course Code : EXT 604

III. Credit Hours : 2+1

IV. Why this course?

Technology, digital media and mobile access have drastically changed how people learn. And the field of education is rapidly becoming a dynamic opportunity for interactive instruction. Today's curriculum developers and instruction designers, especially in the extension and RAS ecosystem, need to equip themselves with the continuous developments in both theory and practice of instructional design so as to create satisfying learning experiences. Similarly, knowledge and skilful use of social media and disruptive technologies like internet of things (IOT), augmented reality, artificial intelligence, etc. makes this course essential for extension professionals who are expected to act as harbingers of change.

V. Aim of the course

The aim is to develop knowledgeable, responsive and effective teachers committed to educating diverse group of learners in a dynamic extension landscape. This course will help the learners to appreciate the role of technology in learning and how it can be integrated into instructional design to create engaging learning experience in both classroom and online learning environment. The course also aims to prepare the students as competent professionals employable in the extension and RAS providers both as specialised researchers as well as designers.

The course is organized as follows:

No	Blocks	Units
1.	Educational Technology	1. The Landscape of Educational Technology and Instructional Design 2. Theories of learning 3. Technology Enabled Learning
2	Instructional Design	1. Theories of Instruction 2. Creating Instruction 3. Instructional Strategies 4. Evaluating Instruction 5. Trends in Instructional Design

VI. Theory

Block 1: Educational Technology

Unit 1: The Landscape of Educational Technology and Instructional Design

Understanding various terms - educational technology, instructional design, instructional systems design, curriculum design, pedagogy, andragogy; Brief overview of the origin and evolution of ET and ID as theory and practice; what is the relevance of ET and ID relevant in extension and rural advisory services? Extensional professionals as instructional designers and architects of the learning experience

Unit 2: Theories of Learning

What is learning? Critical overview of Behaviorism, Cognitivism, Constructivism and Complex learning theories; instructional designers and learning theories; Types of learning or learning domains- Bloom's taxonomy of the cognitive domain, Krathwohl and Bloom's affective domain and Simpson's psychomotor domain

Unit 3: Technology Enabled Learning

What is the role of technology in education? Digital media, new tools and technology; Open and distance Learning (ODL); Online Education - Synchronous and Asynchronous learning models; eLearning, Massive Open Online Courses - SWAYAM, Open Education Resources (OERs), Course CERA, EduEx, CoL, RLOs; digital education and its applications in higher agricultural education; Smart classrooms and Campuses, Web-based remote laboratory (WBRL); Integrating media and digital tools into ID; types and implications of disruptive technologies for higher education and extension; Augmented learning; Adaptive learning; meaning, features and good practices in using open source Learning Management Systems (Moodle); Quality assurance and certification in e-learning.

Block 2: Instructional Design

Unit 1: Theories and Models of Instruction

Howard Gardner's Theory of Multiple Intelligences, David Kolb's Experiential Learning Cycle, Albert Bandura's Social Learning Theory, Rand Spiro's Cognitive Flexibility Theory and Its Application In eLearning, Wlodkowski's Motivational Framework for Culturally Responsive Adult Learning; ADDIE Model, Dick and Carey Model, SAM Model, Bloom's Taxonomy; integrating the theories of instruction into the practice of ID in extension and RAS ecosystem.

Unit 2: Creating Instruction

Overview of planning, designing and implementing the curricula and learning experiences; Needs Analysis - meaning, approaches and steps; Task and content analysis - meaning, approaches, steps and techniques (topic analysis, procedural analysis, and the critical incident method); Learner analysis – meaning, importance and approaches, relevance of Maslow's Hierarchy of Needs and learning styles, Captive Audience vs. Willing Volunteers, Universal vs. user-centered design, Learner Analysis Procedures; Writing learning objectives: Meaning of Learning Goal and Learning Objectives; ABCDs of well-stated objectives; Setting goals, translating goals into objectives; Contextualising ADDIE process within the Extension learning environment

Unit 3: Instructional Strategies

Organizing content and learning activities - scope and sequence of instruction; Posner's levels of organizing (Macro, Micro, Vertical, and Horizontal) and structures of organizing (content vs. media) instruction, Gagne's events of instruction, Edgar Dale's Cone of Experience; Methods of Delivery- classroom teaching, programmed instruction, synchronous and asynchronous modes of distance education; Changing role of a teacher in classroom and teaching competencies

Unit 4: Evaluating Instruction

Meaning of Assessment, Measurement and Evaluation; Developing learner evaluations and their reliability & validity; assessment techniques for measuring change in knowledge, skill and attitude of learners - Objective Test Items, Constructed-Response Tests, Direct Testing, Performance Ratings, Observations and Anecdotal Records, Rubrics, Portfolios, Surveys and Questionnaires, Self-Reporting Inventories, Interviews; Conducting learner evaluation pre-, during and post-instruction; Formative and Summative Evaluation- meaning, approaches and steps; Evaluating Learner Achievement and the Instructional Design Process; Evaluating the success of instruction; Performance appraisal of teachers

Unit 5: Trends in Instructional Design

Alternatives to ADDIE model - Rapid prototyping and constructivist ID, reflections on instructional design as science and as an art; Relating ID models and process in extension learning environment; political economy of higher education in developed and developing countries; University assessment and rating methods, returns from agricultural higher education; research in education and instructional design.

VII. Practicals

- Exercises on preparation of the Analysis Report that includes the task/content

analysis and learner analysis and the Design Plan includes learning objectives and corresponding instructional strategies and assessment items
- Prepare course outline and lesson plan with an appreciation for diverse learning styles based on temperament, gender, and cultural/ethnic differences and deliver a lecture for UG/PG students
- Assessing learning styles through Barsch and Kolb inventories
- Development and testing of survey instruments for evaluating learning outcomes/ competencies of students
- Development and testing of survey instruments for performance appraisal / competency assessment of teachers.
- Design an online e-learning module on a topic of interest as a capstone project - integrate and apply the knowledge and skills gained from the course for creating an effective learning experience for a target audience
- Designing and developing a theme based knowledge portals
- Exercises on designing an online course using open source LMS like moodle or EdX
- Select and evaluate or design for social al media
- Prepare a short research paper on recent theories and models of instructional design
- Interview an instructional designer of your choice and prepare a synthesis report about what job roles he/she perform, What ID processes does he or she use, challenges faced
- Develop a prototype for one of the lessons in your design plan using PowerPoint or a website builder such as Weebly to create the screens integrating multimedia content and various functionalities
- Field visit to a virtual learning / augmented learning labs, e-learning labs, distance learning centres, etc.
- Hands-on practice with video-editing software, web conferencing and video conferencing solutions

VIII. Teaching methods/activities

– Lectures & Videos
– Individual and group assignments
– Group discussion and debating
– Enactive learning exercises
– Case studies / Case analysis
– Storyboarding
– Guest Lectures
– Field Visits
– Capstone Project
– Prototype development

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Develop a critical understanding of concepts of learning and education within the context of agricultural development
– Relate and apply learning theories and models to the development, design and evaluation of courses utilizing educational technology and instructional design
– Hone their skills to take up research work in analysing and evaluating different

learning systems, teaching-learning environments, competencies and learning outcomes
- Find placement opportunities in the industry for job profiles such as e-learning specialist, training officer, curriculum developer, instructional designer, education consultant, etc.

X. Suggested Reading

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Allen M. 2013. *Leaving ADDIE for SAM: An Agile Model for Developing the Best Learning Experiences*
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https://ikhsanaira.files.wordpress.com/2016/05/the-essential-of-instructional-design.pdf

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Duffy TM and Cunningham DJ. 1996. *Constructivism: Implications for the design and delivery of instruction.* In Jonassen D (Ed.), Handbook of Research for Educational Communications and Technology (pp. 170-198). New York: Simon & Schuster Macmillan Edward T. 2013. Power Point Is Evil.
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Parrish PE. 2007. *Aesthetic principles for instructional design,* Education Technology Research and Development, DOI 10.1007/s11423-007-9060-7

Parrish PE. 2005. *Embracing the aesthetics of instructional design.* Educational Technology, 45(2), 16–25.

Reiser RA, Mackal M, and Sachs SG . 2005. *Textbooks used in graduate programs in instructional design and technology: Changes over the past twelve years.* Educational Technology, 45(5), 53-61.

Reiser RA. 2001. *A History of Instructional Design and Technology: Part I: A History of Instructional Media.* Educational Technology Research and Development, 49 (1), 53-64.

Reiser RA. 2001. *A History of Instructional Design and Technology: Part II: A History of Instructional Design.* Educational Technology Research and Development, 49 (2), 57-67.

Spector JM, Merrill MD, Elen J and Bishop MJ. (Eds.), 2014. *Handbook of research on educational communications and technology* (4th ed.). New York: Springer.

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e-Learning Industry– https://elearningindustry.com/
Instructional Design Central– https://www.instructionaldesigncentral.com/
Instructional Design– http://www.instructionaldesign.org/theories/
International Society for Educational Technology– https://www.isfet.org/courses/
Educational Technology– https://educationaltechnology.net/
AESA-Agricultural Extension in South Asia– http://www.aesanetwork.org/
GFRAS-Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

I. Course Title : Risk Management and Climate Change Adaptation

II. Course Code : EXT 605

III. Credit Hours : 2+1

IV. Why this course?

Present agriculture and allied sectors India face tremendous challenges on multiple fronts. Agrarian distress and the climate change impacts together pose grave dangers to food, nutritional and ecological security. As change agents, extensional professionals in particular and agricultural graduates in general need to quip themselves with knowledge and skill sets required to navigate the climate change scenario so as to help reduce risk and vulnerability. Hence, this customised course.

V. Aim of the course

The course is designed to provide both basic and applied knowledge on the subjects of risks management and climate change adaptation with reference to Indian agriculture. This course will approach the subjects from a multidisciplinary

perspective - technical, socio-economic, political, financial, and regulatory. It aims to equip students to identify, evaluate and evolve ways to address (mitigate and manage) risks and climate change.
The course is organized as follows:

No	Blocks	Units
1	Risk Management in Agriculture	1. Understanding Risk and Distress 2. Managing Risk and Distress in Agriculture 3. Extension Professionals and Risk management
2	Adapting to Climate Change	1. Introduction to Climate Change Science 2. Introduction to Climate Change Adaptation and Mitigation 3. Climate Smart Agriculture and Extension Advisory Services

VI. Thory

Block 1: Risk Management in Agriculture

Unit 1: Understanding Risk and Distress

Introduction to risk, risk management, uncertainty, sensitivity and distress, General risk theory, Risk analysis methods, Risk perception and decision making, Indicators of risk and distress in agriculture – identification, selection and assessment, Understanding the agrarian distress in Indian agriculture, Sources of distress in Indian farming -changing farm size, land use, cropping patterns, pricing policy, markets and terms of trade, Typology of crisis in agriculture; Droughts, floods and Indian agriculture, Distress and farmer suicides - causes and socio-economic consequences

Unit 2: Managing Risk and Distress

Ways to reducing/managing risk and distress in Indian agriculture; crop and life insurance; Developing support systems; Planning, implementation and evaluation of risk/distress management programs; Institutional frameworks for risk and disaster management - NDMA & SDMAs; Developing District Agriculture Contingency Plans; Risk management by diversification; Good practices and lessons from other countries; Responses of government, non-government and extension system to agrarian crisis; National Farmers Policy.

Unit 3: Extension Professionals and Risk management

Understanding social-psychological and behavioural dimensions of farmers under risk/distress; Risk perception and communication; Helping farmers manage farm level risks - mobilising resources, linking with markets, strengthening capacities; Working with village level risk management committees; Operational skills for preparing contingency and disaster management plans; Institutional and extension innovations in managing risk and distress; Policy and technological preferences for dealing with drought and flood.

Block 2: Adapting to Climate Change

Unit 1: Introduction to Climate Change Science

Basic concepts of and terms in climate change science; impacts of climate change;

anthropogenic drivers of climate change, Climate change and Indian agriculture; climate adaptation vs. disaster risk reduction; anticipated costs of adaptation; climate change and poor; Overview of UNFCCC framework and institutions, Kyoto Protocol and beyond; India's National Action Plan on Climate Change and National Mission on Strategic Knowledge on Climate Change; National Coastal Mission, Institutional arrangements for managing climate change agenda.

Unit 2: Introduction to Climate Change Adaptation and Mitigation

Introduction to Climate Change Adaptation, Conducting a vulnerability assessment (CVI and SEVI frameworks), Identifying and selecting adaptation options; Global, national and state level initiatives and plans to support climate change adaptation, private sector and civil society initiatives and activities; Mainstreaming climate change adaptation into development planning, Financing climate adaptation and budgetary allocations for programmes, Gender and climate change adaptation, Agricultural development programmes and strategies towards climate change adaptation and mitigation, Community based and Ecosystem based adaptation strategies, preparing evidence based intervention plans for vulnerability reduction at micro and macro-levels.

Unit3: Climate Smart Agriculture (CSA) and Extension &Advisory Services

Climate smart agriculture; Developing climate smart and climate resilient villages; Stakeholders and determinants involved in climate smart agriculture; Climate smart agriculture and EAS; Innovative extension approaches used in CSA; Climate information services, Farmers perceptions about climate change; Farm and household level manifestations and adaptation strategies; Barriers and limits to adaptation; Farmers feedback on performance of extension methods; Skills, competencies and tools required for extension professionals at different levels and development departments in up scaling CSA.

VII. Practicals

- Hands-on practice in using risk assessment/analysis tools
- Case studies on risk / distress assessment in agriculture -Indian and global
- Lessons / Experiences from NICRA Project in agriculture and allied sectors
- Developing criteria, indicators and indices for assessment of risk, vulnerability and resilience
- Hands on practice on use of vulnerability and risk assessment tools and techniques
- Case studies on success stories of climate change adaptation and community based initiatives
- Developing district and village level intervention plans for climate change adaptation
- Field Visits to State Disaster Management Authority
- Case studies on climate smart agriculture / villages from India and world
- Case studies on impact assessment of crop insurance programs, disaster management programs
- Capstone project on documenting ITKs and local practices related to reducing risk / climate resilience agriculture

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student's Book/Publication Review

- Student presentation
- Group Work
- Student's interview of key policy makers
- Case Analysis and case studies Guest Lectures
- Review of policy documents

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the scientific foundation of risk management and climate change science and relate the key learning to the job of an extension professional
- Utilise methods and tools for risk and climate related vulnerability assessments and adaptation strategies in the context of Indian agriculture / farming scenario
- Utilise material in scientific publications relevant for risk management and climate change adaptation and critically reflect on their benefits and limitations for decision making

X. Suggested Reading

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GFRAS-Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

AESA-Agricultural Extension in South Asia– http://www.aesanetwork.org/

NICRA-National Innovations in Climate Resilient Agriculture–
http://www.nicra-icar.in/nicrarevised/

CRIDA-Central Research Institute for Dryland Agriculture– http://www.crida.in/

UNCC: Learn- UN Climate Change Learning Partnership– https://www.uncclearn.org/

DST- Department of Science and Technology- Climate Change Programme, GoI–
http://www.dst.gov.in/climate-change-programme

I. Course Title : Livelihood Development

II. Course Code : EXT 606

III. Credit Hours : 1+1

IV. Why this course?

One of the aims of extension work is to enhance and expand the sustainable livelihood opportunities for individuals in a society. For this a thorough understanding of the different aspects of livelihood and its interface with nature becomes imperative. Resource poor farmers and the socially and politically weaker sections of the society currently face several challenges in expanding their livelihoods. Keeping these in view, the course has been designed to provide a theoretical framework for understanding of the basic concepts, definitions and approaches related to 'livelihood', 'vulnerability' 'institutional processes', and 'development and policies' pertaining to livelihood development in India.

V. Aim of the course

- To develop an understanding on the concept of livelihood and its various forms
- To acquaint the students regarding the various alternative approaches that has been adopted to support livelihoods
- To familiarize the students to some of the methods, tools and techniques they can utilize to design livelihood interventions
- To expose the students to the context, especially the economic models and policy environment that guides the livelihood choices
- To equip students to work in multidisciplinary teams and engage at multiple levels on livelihood issues

The course is organized as follows:

No	Blocks	Units
1.	Understanding of Livelihood	1. Concept of Livelihoods 2. Livelihood Challenges
2.	Livelihood Analysis	1. Livelihood Frameworks 2. Designing Livelihood Intervention and Promotion
3.	Livelihood Augmentation	1. Pathways for LA

VI. Theory

Block 1: Understanding of Livelihood

Unit 1: Concept of Livelihoods

Basic concepts of livelihood and Development, Types of development-Immanent/ inherent and interventionist/ intentional; Why promote livelihood; Livelihood intervention: definition, types-Spatial, segmental, sector –sub-sector; Systemic view of Livelihoods, Understanding Rural Livelihoods-Farm, Non-Farm, and off farm; Linkages with Farm and Off-farm Livelihoods; Economic Models

Unit 2: Livelihood Challenges

Livelihood Challenge- Political economy of Livelihoods, Issues of access to farm and non-farm livelihoods; Livelihoods from a Gender Perspective-Feminization of agriculture/ poverty, women in the unorganized sector, the issue of unpaid and informal work; Livelihood Coping Mechanism- Climate Change and Livelihoods; Livelihoods and Disasters

Block 2: Livelihood Analysis

Unit 1: Livelihood Frameworks

Sustainable Livelihoods Approaches (SLAs)-Definition and origins of SLA; Assets or capitals and capabilities in SLA and its linkage to the other capitals: Physical, Social, Economic, Human, Natural; Vulnerability Assessment- Shocks, trends, seasonality; Policies, institutional context and processes; Conceptual Frameworks- DFID, CARE, UNDP, OXFAM, BASIX livelihood triad, Nine square Mandala or Rural Livelihood System's Framework, etc.; Past, Present and possibilities for the future of the SLA, critiques of the approach

Unit 2: Designing Livelihood Intervention and Promotion

Designing a suitable livelihood intervention-Observing and Understanding the Local Economy; Selecting livelihood activities suitable for the poor in the area; Deciding on the interventions. Livelihood promotion approaches-Poverty and livelihood: Approaches and programs in India; Livelihood and a Rights Based Approach-MGNREGA and its critique; Livelihood and a Social Capital based approach: NRLM

Block 3: Livelihood Augmentation (LA)

Unit 1: Pathways for LA

Basic concepts; Pathways: a) Entrepreneurial strategies for LA; b) NRM based intervention; c) Market based interventions including Value-chain analysis; d) ICT based interventions; e) Livelihood and allied agriculture (dairy, poultry, Goatery, etc.) based livelihood; f) Forest based Livelihoods vis a vis Livelihood Protection and Promotion: Contribution of NTFP in supporting rural livelihoods
Note: Block 'A' and 'B' is theoretical; Block 'C' should be covered in the form practical's supported by few classroom discussion through cases

VII. Practicals

- Village stays to understand the livelihood pattern of villagers and how the other socio-economic factors affect the livelihood of people
- Visit to institutes/ universities adopted and/or nearby villages to experience the life and natural resources in rural communities-understanding of village culture, evolution, social structure, livelihood pattern, trends, governance arrangements, and the natural context (landscape layout, land use, vegetation types etc)
- Application of participatory rural appraisal skills for understanding village context; Engagement of working with rural communities and their grass-root institutions, understanding dynamics of working in a group
- Visit to different agri-business models as mentioned in the Block 'C'. Group assignments may be given to document the field experience in the form of case study of an enterprise/ entrepreneur/ members and other related stakeholders

VIII. Teaching methods/activities

- Interactive Lectures – by sharing in advance a reading material
- Analysis of case studies
- Audio-visual of successful/ failure models of agribusiness firms
- Guest session by field practitioners, if possible

– Group presentations by the students
– Field visit and field based individual or group assignments

IX. Learning outcome

This course will equip students with perspectives, knowledge and skills to develop a comprehensive understanding of the livelihood concepts, various forms, approaches, tools and techniques to analyze existing livelihood pattern and strategies the sustainable livelihood intervention in the rural areas.

X. Suggested Reading

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I. Course Title : Facilitation for People Centric Development

II. Course Code : EXT 607

III. Credit Hours : 2+1

IV. Why this course?

The prime aim of the agricultural extension professionals is to influence development change among the stakeholders with whom they work. In the Agricultural Innovation Systems (AIS) context, this change will happen when good relationships, networks and partnerships are formed. A new extension approach that aims at participatory and group learning as well as networking, where the extensionist acts as a facilitator is needed. It is important to inculcate the good facilitation skills by the extension professional to increase the effectiveness and impact among the agricultural extension and advisory services stakeholders.

V. Aim of the course

- To orient students on the importance facilitation
- To inspires students to understand facilitation tools to influence change at the individual, group and organisational levels
- To develop capacities in multi-stakeholder engagement, facilitation and networking

The course is organized as follows:

No	Blocks	Units
1.	Introduction to Facilitation for Development	1. Facilitation for Development in the AIS 2. Principles, Attributes and Skills for Facilitation for Development
2.	Facilitating change in individuals, groups and organizations	1. Realise Potential- Self-Discovery 2. Group Dynamics and Working Together 3. Organizational Change Process
3.	Facilitating operational level multi-stakeholder engagements	1. Multi-Stakeholder Interactions 2. Innovation and Policy Engagement Platforms
4.	Brokering strategic partnerships, networking and facilitation	1. Linkages, Partnerships, Alliances and Networking 2. Facilitating Capacity Development

VI. Theory

Block 1: Introduction to Facilitation for Development

Unit 1: Facilitation for development in the AIS

Facilitation for development in the AIS; Understanding facilitation for development; Importance of facilitation as a core function of extension within the Agricultural Innovation Systems (AIS)

Unit 2: Principles, Attributes and Skills for Facilitation for Development

Basic principles of facilitation for development; Desired attributes of facilitator for development- Cognitive attributes, Emotional attributes (Emotional intelligence), Social, behavioural and attitudinal attributes; Technical skills of a facilitator for development- Design processes, Facilitation techniques and tools, the art of questioning and probing, Process observation and documentation, Visualisation

Block 2: Facilitating Change in Individuals, Groups and Organisations

Unit 1: Realise Potential- Self-Discovery

Self-discovery to realise our potentials, Tools for self-discovery, formulating a personal vision, Taking responsibility for your own development

Unit 2: Group Dynamics and Working Together

Understanding the dynamics of human interaction, Group dynamics and power relations, Managing relationships, Shared vision and collective action, Tools for team building

Unit 3: Organizational Change Process

Organizational change process, Organizational learning to adapt to changing environments, Enhancing performance of organizations, Leadership development, Tools for organizational change

Block 3: Facilitating Operational Level Multi-stakeholder Engagements

Unit 1: Multi-Stakeholder Interactions

Defining stakeholders, Development of collective and shared goals, Building trust and accountability, Tools for stakeholder identification and visioning

Unit 2: Innovation and Policy engagement Platforms

Visualising innovation platforms (IPs), Why are IPs important?, Different models of IPs for multi-stakeholder engagement, policy engagement platforms, Generating issues and evidence for policy action, Advocacy for responsive policy processes

Block 4: Brokering Strategic Partnerships, Networking And Facilitation

Unit 1: Linkages, Partnerships, Alliances and Networking

Brokering linkages and strategic partnerships, Identification of critical links, Knowledge brokering, Creating linkages with markets, Learning alliances and networking, Coordination of pluralistic service provision within the AIS, The concept of action learning and reflective practitioners, Networking

Unit 2: Facilitating Capacity Development

Facilitating Capacity Development-Facilitate participation and learning in development programs and projects. Virtual platforms- skills for strengthening dialogue, collaboration, shared commitment amongst diverse actors and stakeholders

VII. Practicals

- Practicing facilitation techniques,
- Self discovery exercises,
- Working together and interaction (task based),
- Arrangement for multi-stakeholder interactions,
- Understanding organisational change process tools and techniques,
- Case analysis on organisational change process,
- Participating with innovation platforms,
- Policy engagement platforms,
- Stakeholder analysis mapping,
- Exercise on networking skills,
- Facilitating capacity building programmes
- Facilitating virtual platforms
- Filed visit to multi-stakeholder partnership projects

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Facilitation Manual/Publication Review
- Student presentation
- Group Work
- Student's interview with facilitators
- Case Analysis
- Guest Lectures
- Review of facilitation methodologies
- Short internships

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the importance of facilitation skills and tools
- Understand facilitation and networking techniques
- Critically evaluate strategic partnerships and linkages
- How to manage group dynamics and engage multi-stakeholders and virtual platforms

X. Suggested Reading

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Websites

- **MSU**–Michigan State University Extension Facilitation– https://www.canr.msu.edu/facilitation/
- **TAPipedia**– Tropical Agriculture Platform– https://www.tapipedia.org/
- **CGSpace**- A Repository of Agricultural Research Outputs by CGIAR– https://cgspace.cgiar.org/handle/10568/33667
- **UMaine**– The University of Maine– https://extension.umaine.edu/community/strengthening-your-facilitation-skills/
- **GFRAS**– Global Forum for Rural Advisory Services– http://www.g-fras.org/en/

I. Course Title : Multivariate Statistical Methods For Extension Research

II. Course Code : STAT

III. Credit Hours : 2+1

IV. Why this course?

With increasing complexity in agricultural systems, research problems in extension are becoming multi-dimensional and often influenced by the composite of biological, social and economical factors. Such complex problems require advanced analytical methods and tools derived from statistical and other decision sciences.

V. Aim of the course

This course aims to equip the students with critical skills in choosing appropriate analytical tools and interpreting the results for solving complex and multidimensional extension research problems.

The course is organized as follows:

No	Blocks	Units
1.	Overview of Multivariate Statistical Methods	1. Basics of Multivariate Statistical Methods (MVSM) 2. Classification and Types of MVSM 3. Selecting Appropriate MVSM 4. A structured Approach for Building Multivariate Statistical Models 5. Basic Econometric Methods-1 6. Basic Econometric Methods-2
2.	Data preparation and cleaning	1. Missing Data Analysis and Outlier Management 2. Testing Assumptions of MVSM and Data Transformation
3.	Methods for assessing human choice/ preferences and decision-making	1. Assessing Human Preference Structures Using Conjoint Analysis 2. Assessment of Adoption of Agricultural Technologies Using Limited Dependent Variable Models 3. Multidimensional Scaling 4. Multi-criteria Decision-making
4.	Methods of assessing association and causality	1. Multiple Correlation and Multiple Regression 2. Discriminant Analysis
5	Methods of grouping objects/ variables based on latent variables	1. Principal Component Analysis (PCA) and Common Factor Analysis 2. Structural Equation Modeling (SEM)–Two units 3. Cluster Analysis
6	Emerging MV statistical methods	1. Emerging MV Statistical Methods

VI. Learning outcome

At the end of this course, the students will be able – To choose appropriate multivariate statistical methods based on research problem/ situation – To design, implement and interpret in a skilful way using SPSS

VII. Theory

Block 1: Overview of Multivariate Statistical Methods

Unit 1: Basics of Multivariate Statistical Methods (MVSM)

What is multivariate data analysis; Basic concepts in MV – variate, measurement error; Power analysis and effect size; SPSS software

Unit 2: Classification and Types of MVSM

Independence and dependence techniques; Factor analysis – principal component, exploratory factor analysis; Multiple correlation and multiple regression; Discriminant analysis; Logistic regression; Cluster analysis; Conjoint analysis; Multi Dimensional Scaling/ Perceptual mapping; Correspondence analysis; Structural equation model

Unit 3: Selecting Appropriate MVSM

Selection based on purpose - Dimension reduction, identifying latent variables, strength of relationship among multiple dependent/ independent variables, identifying choice and estimating their utility; etc and type of variables – metric and non-metric

Unit 4: A Structured Approach for Building Multivariate Statistical Models

Steps in planning and conducing MVSM

Unit 5: Basic Econometric Methods-1

Nature of regression analysis; Two variable and multivariable regression models; Linear and non-linear regression models; Estimation methods

Unit 6: Basic Econometric Methods-2

Simultaneous-equation models; Panel data models; **Forecasting** - Time series and other models

Block 2: Data Preparation and Cleaning

Unit 1: Missing Data Analysis and Outlier Management

Missing data - Meaning, types, methods of missing data processing, advantages and limitations, **Outliers-** Meaning, types, methods for identifying and managing outliers

Unit 2: Testing Assumptions of MVSM and Data Transformation

Testing assumption of parametric analyses – normality, linearity, multicollinearity; Data transformation methods

Block 3: Methods for Assessing Human Choice/ Preferences and Decision-making

Unit 1: Assessing Human Preference Structures Using Conjoint Analysis

Meaning- Importance, guidelines for selecting variables, steps in designing a conjoint experiment – objectives, design, data collection and analysis. Applications in extension

Unit 2: Assessment of Adoption of Agricultural Technologies Using Limited Dependent Variable Models

Meaning, importance, types – logit, probit and tobit and their variations; steps in analysis and interpretation of results, applications in extension

Unit 3: Multidimensional Scaling

Meaning, importance and types, steps and applications in extension

Unit 4: Multi-criteria decision-making

Meaning, importance, methods – analytical hierarchy process, Applications in extension

Block 4: Methods of Assessing Association and Causality

Unit 1: Multiple Correlations and Multiple Regressions

Meaning, importance, types, methods of estimation, analysis and interpretation of results, application sin extension

Unit 2: Discriminant Analysis

Meaning, types, steps in conducting discriminant analysis, Applications in extension

Block 5: Methods Of Grouping Objects/ Variables Based On Latent Variables

Unit 1: Principal Component Analysis (PCA) and Common Factor Analysis

Meaning, importance, types of factor analysis, difference between types, steps in conducting PCA/ Common Factor Analysis, applications in extension

Unit 2: Structural Equation Modelling (SEM) – Two units

Meaning, importance, types – confirmatory factor analysis and structural model; steps in conducting SEM, Applications in extension

Unit 3: Cluster Analysis

Meaning, importance, types – Steps; Applications in extension

Block 6: Emerging MV Statistical Methods

Unit 1: Emerging MV Statistical Methods

Canonical correlation, partial least square (PLS)

VIII. Practicals

- Hands on experience of following methods using SPSS/ AMOS software
- Selecting appropriate MVSM
- Missing data analysis and outlier management
- Testing assumptions of MVSM and data transformation
- Assessing human preference structures using conjoint analysis
- Assessment of adoption of agricultural technologies using limited dependent variable models – logit, probit and tobit.
- Multidimensional scaling
- Multiple correlation and multiple regression
- Discriminant analysis
- Principal Component Analysis (PCA) and Common Factor Analysis
- Structural Equation Modeling (SEM)
- Cluster analysis

IX. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Group Work
– Guest Lectures

X. Suggested Reading

Agresti, A. 2002. *Categorical data analysis*. Second edition. New York, NY: John Wiley & Sons.

Belsley, D. A. 1991. *Conditioning diagnostics: Collinearity and weak data in regression*. New York, NY: Wiley.

Bollen, K.A. 1989. *Structural equations with latent variables*. New York: John Wiley and Sons.

Burnham, K. P. and Anderson, D. R. 2002. *Model selection and multimodel inference*. New York, NY: Springer.

Byrne BM. 2010. *Structural equation modeling with AMOS: Basic concepts, applications, and programming*. New York: Routledge.

Chambers, J., Cleveland, W., Kleiner, B., and Tukey, P. 1983. *Graphical methods for data analysis*. Wadsworth.

Field A. 2013. *Discovering statistics using IBM SPSS Statistics*, 4th edition. Sage, London.

Greene, W. 2000. *Econometric Analysis* Fourth edition. New York, NY: Wiley.

Hair JJF, Black WC, Babin BJ and Anderson RE. 2010. *Multivariate Data Analysis: A Global Perspective*. 7th Edition, Pearson.

Hosmer, D. W. and Lemeshow, S. 2000. *Applied logistic regression*. Second edition. New York, NY: John Wiley & Sons

Kelloway, K. E. 1998. *Using LISREL for structural equation modeling: A researcher's guide*. Thousand Oaks: Sage

Long, J. S. 1997. *Regression models of categorical and limited dependent variables*. Thousand Oaks, CA: Sage

Ray, S. 2016. *A comprehensive guide to data exploration*. https://www.analyticsvidhya.com/blog/2016/01/guide-data-exploration/

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Stokes, M. E., Davis, C. S., and Koch, G. G. 2000. *Categorical data analysis using the SAS system*. Cary, NC: SAS Institute Inc

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Social Sciences
– Agri-Business Management

Preface

Rapid advancement in agriculture has resulted in increased demand for qualified managers to manage this sector. Indian agriculture is facing numerous challenges with a rapidly changing business environment, pace of technological change, globalisation, competitive environment and changing role of government. These challenges will place unparalleled demands on the capabilities of tomorrow's managers. Agribusiness Management has enormous potential to address key national and global challenges of inclusive growth, and food and nutritional security. With increasing incomes, the demand for value added agricultural products will also increase, driving the demand for Agribusiness Managers. Increasing integration of World food markets and the expansion of organized retail also imply that the scope of agribusiness is becoming increasingly global. The Agribusiness Management Education System in India is uniquely placed to meet the demand for professional agribusiness managers across the globe.

Agri business management is a specialized two-year MBA programme which focuses on business aspect of agriculture production and its international trade. The postgraduate course aims to craft professional business leaders and entrepreneurs in food, agriculture and allied sectors. The course is offered in premier business schools in and State Agricultural Universities in India and across the globe and focuses on managerial skill development in the agricultural sector. Students learn how to make sustainable business decisions and minimize risk while working in the agricultural sector. The course curriculum is designed to build and enhance a global perspective among students. The course also needs to create awareness among students about the environmental forces that impact managerial decisions.

In light of the above mentioned issues and concerns, courses and programmes in the field of agri-business management must also be reformed to increase the employability and entrepreneurship opportunities for the Post Graduates and Doctoral participants at the same time prepare them for handling global competitiveness without compromising farmers' and farming community needs and demands.

The sub-committee on Agri Business Management constituted by ICAR (under the ICAR Broad Subject Matter Area (BSMA) for Social Sciences) has kept above development in view while revising the PG and PhD Curricula in Agri Business Management. We also addressed the issue of repetitions of content, updating them with the recent trends in the industry, under-graduate curricula in agriculture. To do these, we identified first the core competencies that are required at the different levels and worked backwards based on the areas and organising them into courses.

We are also recommending summer internship-2 at the Master's level (each for 4-6 weeks with agri based organisations) and we propose a credit load of 10 and 4 for each of these internships/ attachments at PG level. We believe this will help the students to have more relevant practical experience and this will boost their job prospects.

We have organised the curriculum under different block and units and each course has an introduction explicitly stating the purpose of this course (why this course), aim of the course (what it tries to provide) and learning outcomes. Several new reading references are also provided at the end of each course. The committee recognised the need for organising training of teachers to impart some of the new courses and this could be further elaborated in consultation with ICAR and other organisations that can support or even lead this exercise.

The committee organised a stakeholders meeting with agri based industry executives, academicians from reputed institutions, alumni from different ABM programmes of the SAUs, teachers involved in ABM teaching in selected SAUs at Bikaner on September 17, 2018 for development of curricula.

Our heartfelt gratitude to all the core committee members and stakeholders for their specific contributions to development of this revised curricula especially Mr Kamal Kumar, Advisor, Dhanuka Agritech Ltd; Dr Vikram Singh, Dean, NIAM, Jaipur; Dr Ranjit Singh, Professor, NAARM; Dr Seema Nath, Associate Dean, College of Agriculture, PJTSAU; Dr Radhika, Associate Professor, PJTSAU; Dr Madhu Sharma, Professor, SKRAU, Bikaner, Dr Swati Sharma, Assistant Professor, Navsari Agricultural University, Navsari; Dr Dinesh Jain, Associate Professor, RAJUVAS, Bikaner and Dr Amita Sharma, Assistant Professor, IABM, Bikaner.

Finally, we thank Dr NS Rathore, Deputy Director General (Education), ICAR for organising the BSMA for undertaking curricula revision and for his valuable guidance and support in this regard.

Dr Samarendra Mahapatra, Member
Dr Aditi Mathur, Member
Dr Lipi Das, Convener
Dr Kalpana Sastry, Chairperson

May 31, 2019

Course Title with Credit Load
MBA in Agri-Business Management

Major Courses 20 Credits

Course Code	Course Title	Credit Hours
ABM 501	Principles of Management and Organisational Behaviour	3
ABM 502	Managerial Accounting and Control	3
ABM 503	Applied Agribusiness Economics	2
ABM 504	Human Resource Management for Agricultural Organizations	2
ABM 505	Production and Operations Management	2
ABM 506	Agricultural and Food Marketing Management- I	2
ABM 507	Agricultural and Food Marketing Management- II	2
ABM 508	Agri Supply Chain Management	2
ABM 509	International Trade for Agricultural Products	2

Minor Courses 8 Credits

It is suggested the student may choose at least four courses out of the courses listed below as part of minor courses as these are related to specific areas of agri business and aim to build larger understanding of the subject. The final choice of the minor courses should be mandatorily approved by the Student Advisory committee/HoD.

Course Code	Course Title	Credit Hours
ABM 510	Food Technology and Processing Management	3
ABM 511	Rural Marketing	3
ABM 512	Fertiliser Technology and Management	3
ABM 513	Management of Agro-Chemical Industry	3
ABM 514	Seed Production Technology Management	3
ABM 515	Technology Management for Livestock Products	3
ABM 516	Fruit Production & Post Harvest Management	3
ABM 517	Farm Power & Machinery Management	2
ABM 518	Food Retail Management	2
ABM 519	Management of Agricultural Input Marketing	2
ABM 520	Feed Business Management	2
ABM 521	Management of Veterinary Hospitals	2
ABM 522	Poultry And Hatchery Management	2
ABM 523	Management Of Floriculture And Landscaping	2
ABM 524	Risk Management In Agri Business	2
ABM 525	Management Of Agri-Business Co-Operatives	2

Course Code	Course Title	Credit Hours
ABM 526	Business Analytics for Agriculture	2
ABM 527	Dairy Business Management	1
ABM 528	Agri Extension Management	1
ABM 529	Renewable Energy Sources Management	1
ABM 530	Quality Management for Agri Business	1
ABM 531	Advertising And Brand Management	1
ABM 532	Agri Infrastructure and Warehousing Management	1
ABM 533	Contract Farming	1
ABM 534	Human Resource Competence And CapacityBuilding Systems	1
ABM 535	Agri Commodity Markets And Futures Trading	1

Supporting Courses 6 Credits

Course Code	Course Title	Credit Hours
ABM 536	Strategic Management for Agri Business Enterprises	2
ABM 537	Operations Research	2
ABM 538	Financial Management in Agri Business	2

Common Courses 5 Credits

1. Technical Writing and Communications Skills
2. Intellectual Property and its management in Agriculture
3. Agricultural Research, Research Ethics and Rural Development Programmes

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

Master's Seminar 01 Credit

Course Code	Course Title	Credit Hours
	Research (Summer Internship + Research Project)	**30 (10+20)**
	Summer Internship/ Industrial Attachment	4
	Basic Courses mandatory for Summer Internship	6
ABM 539	Communication for Management and Agri Business	3
ABM 540	Research Methodology for Agri Business Mgmt	3
	Research Project	**20**
	Project work	**10**
	Basic courses mandatory for Project	10

Course Code	Course Title	Credit Hours
ABM 541	Computer Applications for Agri Business	3
ABM 542	Project Management and Agri Business Entrepreneurship	3
ABM 543	Agribusiness Environment and Policy	2
ABM 544	Agri Business Laws and Ethics	2

Course Contents
MBA in Agri-Business Management

I. Course Title : Principles of Management and Organizational Behaviour

II. Course Code : ABM 501

III. Credit Hours : 3+0

IV. Aim of the course

Provide students with opportunities to understand a wide variety of topics related to business management, focusing on fundamental management principles and concepts that apply to agribusiness, traditional management skills, and new competencies needed to succeed in a fast-paced environment that demands ongoing innovations.

The course is organized as follows:

No	Blocks	Units
1.	Basic Concepts of Management	1. Introduction to Management 2. Planning, Organising, Directing and Controlling
2.	Insights about Organisational Behaviour	1. Foundations of Individual behaviour 2. Group Dynamics
3.	Organisational Dynamics	1. Understanding and managing organisational culture 2. Concept of Organisational Development

V. Theory

Block 1: Basic Concepts of Management

Unit-I: Introduction to Management: Nature, Scope and Significance of Management, Evolution of Management Thought, Approaches to Management, functions and skills of a manager

Unit-II: Management functions: Planning – Types, Steps, Objective, Process, Strategies, Policies, MBO, Organizing – Structure & Process, Line, Staff, Authority & Responsibility, Staffing – Recruitment and Selection, Directing – Training, Communication & Motivation, Controlling- Significance, Process, Techniques, Standards & Benchmarks, Management Audit

Block 2: Insights About Organizational Behavior

Unit III: Nature, Scope and Significance of Organizational Behavior; Foundations ofIndividual behaviour – Emotions, Personality, Values, Attitudes, Perception, Learning and individual decision making, Motivation- Types of motivation, theories of motivation, motivational practices at workplace, managing stress and work life balance

Unit IV: Group dynamics- types of groups, group formation, Group decision making, teambuilding and developing collaboration, leadership styles and influence process;

leadership theories, leadership styles and effective leader

Block 3: Organisational Dynamics

Unit V: Understanding and managing organisational culture, power and political behavior inorganisations, conflict Management, negotiation, managing organizational change, concept of organisational development

VI. Teaching methods/activities

- Interactive Lectures
- Assignment (Reading/Writing)
- Student presentations
- Case study related to basics of management and organizational behaviour

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the basic concepts of management and organizational behaviour
– Develop a overall view about the various management functions, managerial skills and approaches
– Get insights about the fundamentals of individual and group behavior in the orgnisational setting
– Analyse the organisational level challenges in managing the resources optimally

VIII. Suggested Reading

- Robbins SP, Coulter M and Vohra N. 2010. *Management*. Pearson Edu.
- Weihrich H, Cannice MV and Koontz H. 2015*, Management, A Global, Innovative and Entrepreneurial Perspective,* 14th Edition, McGraw Hill Education Pvt Ltd.
- Beierlein JG, Schneeberger KC, Osburn DD. 2014. *Principles ofAgribusiness Management.* Fifth edition. Waveland Press
- Neck CP, Houghton JD and Murray EL. 2017, *Organizational behavior*, Sage Publication India Private Limited.
- Greenberg J. 2013, *Behavior in Organisations*, PHI Learning Private Limited, New Delhi.
- John A, Wagner III JA and Hollenbeck JR. 2015. *Organizational Behaviour*, Routledge Taylor & Francis Group, New York.
- Koontz H and Weighhrich K. 2010. *Essentials of Management*. Tata McGraw Hill

I. Course Title : Managerial Accounting and Control

II. Course Code : ABM 502

III. Credit Hours : 3+0

IV. Aim of the course

The objective of this course is to expose the learner to the concept and methods of financial and management accounting. Focus will be on understanding techniques, uses and applications of financial and management accounting.

No	Blocks	Units
1.	Financial Accounting	1. Introduction to financial accounting 2. Accounting standards 3. Double Entry system 4. Use of accounting softwares
2.	Managerial Accounting	1. Meaning of Managerial accounting 2. Analysis of financial statements 3. Cash flow and fund flow analysis

No	Blocks	Units
3.	Cost Accounting	1. Introduction to cost accounting 2. Standard costing 3. Variance Analysis 4. Budget and budgetary control

V. Theory

Block 1: Financial Accounting

Unit I: Financial Accounting- Meaning, Need, Accounting principles: Accounting Conceptsand Conventions; Branches of Accounting, Users of Accounting information, Advantages and Limitations of Financial Accounting, Accounting Standards

Unit II: The Double Entry System- Its Meaning and Scope, The Journal, Cash Book, Ledger, Trial Balance, Trading Account Profit and Loss Account, Balance Sheet, entries and adjustments of different heads in different Books and Accounts, Introduction of Company Accounts, Use of Accounting Software

Block 2: Managerial Accounting

Unit III: Management Accounting-Meaning, Functions, Scope, Utility, Limitations and Toolsof Management Accounting, Analysis of Financial Statements- Ratio, time series, common size and Du pont Analysis, Comparative and Common Size Statements, Cash Flow and Fund Flow Analysis

Block 3: Cost Accounting

Unit IV: Cost Accounting–Nature, Course, Significance of Cost Accounting; Classification ofCost, Costing for Material; Labour and overheads; Marginal Costing and cost volume profit Analysis- Its Significance, Uses and Limitations; Standard Costing – Its Meaning, Uses and Limitations, Determination of Standard Cost, Variance Analysis-Material, Labour and Overhead.

Unit V: Budget and Budgetary Control- Meaning, Uses and Limitations, Budgeting and Profitplanning, Different Types of Budgets and their Preparations: Sales Budget, Purchase Budget, Production Budget, Cash Budget, Flexible Budget, Master Budget, Zero Based Budgeting. Mergers and Acquisition, Tax System- GST

VI. Teaching methods/activities

- Lecture
- Case studies for making the participants get a clear idea about the real life budgeting and accounting practices
- Live project in the firms finance departments for getting the first hand experience

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Develop a clear understanding about the concepts of financial and managerial accounting
– Understand the basics of cost accounting through various tools and techniques available
– Get a insight about the budget and budgetary control methods

VIII. Suggested Reading

- Jain SP and Narang KL. 2014. *Financial Accounting*. 12th Edition. Kalyani publisher

- Sharma and Gupta. 2018. *Management Accounting* 13th Edition, Kalyani Publisher
- Maheshwari SN and Maheshwari SK. 2018. *Financial Accounting*. 6th Ed. Vikas Publ. House.

I. Course Title : Applied Agribusiness Economics
II. Course Code : ABM-503
III. Credit Hours : 2+0

IV. Aim of the course

This course applies basic economic tools and models to problems involving supply, demand, individual consumer and firm behavior, and market structure. Basic market structure models covered include perfect competition, monopolistic competition, oligopoly, and monopoly. Economic tools and models are related to business strategies throughout the course.

The course is organized as follows:

No	Blocks	Units
1.	Overview of Managerial Economics	1. Basic managerial economics principles 2. Mathematical concepts used in managerial economics 3. Introduction to behavioral economics
2.	Production, cost and supply analysis	1. Production Function 2. Cost Concepts 3. Determinants of price
3.	Macroeconomics	1. The national income 2. Flow of money in the market and economy 3. Business decisions under certain and uncertain situations

V. Theory

Block 1: Overview of Managerial Economics

Unit I: Scope of managerial economics, objective of the firm and basic economic principles; mathematical concepts used in managerial economics. Introduction to behavioral economics

Unit II: Indifference curves and budget sets - Demand analysis - meaning, types and determinants of demand; demand function; demand elasticity; demand forecasting-need and techniques.

Block 2: Production, Cost and Supply Analysis

Unit III: Production, cost and supply analysis- production function, Multi period productionand cost least-cost input combination, factor productivities and returns to scale, cost concepts, cost-output relationship, short and long-run supply functions.

Unit IV: Pricing-determinants of price - pricing under different market structures, pricing ofjoint products, pricing methods in practice, government policies and pricing. Price discrimination (First, Second and Third level)

Block 3: Macroeconomics

Unit V: The national income; circular flow of income: consumption, investment and saving: money-functions, factors influencing demand for money & supply of money; inflation; economic growth; business cycles and business policies; business decisions under certain and uncertain situations

VI. Teaching methods/activities

- Interactive Lectures
- Assignment (Reading and Writing)
- Cases on recent developments in economic environment
- Live projects to understand the principles of economics for an organisation
- Group analysis of newspapers covering national level economic trends

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the concepts of managerial economics and its implications on the agri business environment
– Develop a clearer overview on the macroeconomic environment that exists for a agri business enterprise to understand and adapt for optimizing the output

VIII. Suggested Reading

- Dwivedi DN. 2015. *Managerial Economics*. 8th Edition, Vikash Publishing
- Gupta GS. 2015. *Managerial Economics*. Tata McGraw Hill
- Savatore D. Srivastav R. 2012. *Managerial Economics*. 7th Edition, Oxford University Press
- Suma Damodaran. 2010. *Managerial Economics*. Oxford

I. Course Title : Human Resource Management for Agricultural Organisations

II. Course Code : ABM 504

III. Credit Hours : 2+0

IV. Aim of the course

The objective of this course is to expose the learner to the field of human resource management. The focus will be on human resource practices and their utility for managers in agri based organizations.

The course is organized as follows:

No	Blocks	Units
1	Overview of Human Resource Management	1. Meaning and scope of Human Resource Management 2. Human Resource Planning 3. Recruitment, Selection and Training 4. Performance Appraisal 5. Compensation Management
2	Industrial Relations	1. Trade Union 2. Grievance Management 3. Health and Safety of HR
3	Ethical and Global issues in HRM	1. Global HRM 2. HR Metrics, HRIS and workplace analystics

V. Theory

Block 1: Introduction to Human Resource Management

Unit I: Strategic Human Resource Management, Human Resource Planning-Nature andSignificance, Job Analysis and talent management process, Job Description, job Specification, Job enlargement, Job enrichment, Job rotation

Unit II: Recruitment and Selection Process, Induction, Training and Human Resource Development-Nature, Significance, Process and Techniques, e- recruitment, use of Big Data for recruitment, use of Artificial Intelligence and machine learning tools in recruitment practices Career planning and Development Internal mobility including Transfers, Promotions, employee separation.

Unit III: Performance Appraisal–Significance and methods, Compensation management, Strategic pay plans, Job Evaluation, Wage and Salary Administration; Wage Fixation; Fringe Benefits, Incentive Payment, bonus, and Profit Sharing

Block 2: Industrial Relations

Unit IV: Role and Status of Trade Unions; Collective Bargaining; Worker's Participation inManagement, employee retention. Quality of work life, employee welfare measure, work life balance, Disputes and Grievance Handling Procedures; Arbitration and Adjudication; Health and Safety of Human Resources;

Block 3: Ethical And Global Issues In Hrm

Unit V: Ethical issues in HRM**,** Managing Global Human Resources, Managing Human Resources in Small and Entrepreneurial firms, Human Resources accounting, Human Resources outsourcing. HR Information System, Human Resource Metrics and Workforce Analytics, Future trends in workforce technologies.

VI. Teaching methods/activities

- Lectures
- Videos showing trends and practices of innovative human resource management
- Live project for understanding the application of concepts in the real life situation
- Interaction with the HR managers of the agri based organsiations to understand the intricacies involved in the managing the human resource
- Group tasks to study the policy framework and regulatory environment that exists in India and globally to manage human resource

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the basic concept of HRM and SHRM
– Develop an insight into important human resource management functions like job analysis, job planning, recruitment, selection, performance appraisal, training, development, compensation management etc with major reference to the agri based organisations
– Get a clearer view about the status of employee – employer relationship in Indian agri enterprises and global agri based organizations
– Understand the ethical and recent trends in managing human resource effectively

VIII. Suggested Reading

- Gary Dessler & Biju Varkkey 2016, *Human Resource Management*, XIV Edition, Pearson India
- VSP Rao. 2010, *Human Resource Management, Text and Cases,* 3rd Edition, Excel Books
- Ashwathapa K. 2016. *Human Resource Management, Text and Caes*. Tata McGraw Hill
- Michael J. Kavanagh, Mohan Thite & Richard D. Johnson. 2016, *Human ResourceInformation Systems*, Sage Publications
- Subba Rao P. 2004. *Essentials of Human Resource Management and Industrial Relations*. Himalaya Publ. House.

I. Course Title : Production and Operations Management

II. Course Code : ABM 505

III. Credit Hours : 2+0

IV. Aim of the course

The objective of this course is to expose the learner to the field of production and operations management. The focus will be on imparting knowledge of the basic concepts, tools, and functions of production management.
The course is organized as follows:

No	Blocks	Units
1	Introduction to Production and Operations Management	1. Concept and scope of production and operations management 2. Operations strategy 3. Productivity variables and measurement
2	Inventory management	1. Determination of material requirement 2. Industrial safety 3. Cloud operations management
3	Overview of Quality Management	1. Statistical process control 2. Reengineering and Value engineering

V. Theory

Block 1: Introduction to Production and Operations Management

Unit I: Nature Concept and Scope of Production and Operations Management; FactorsAffecting System; Facility location, Types of Manufacturing Systems and Layouts, Process Selection and Facility Layout, Layout Planning and Analysis, Forecasting

Unit II: Operations Strategy: Operations Strategy, Competitive Capabilities and CoreCompetencies, Operations Strategy as a Competitive Weapon, Linkage Between Corporate, Business, and Operations Strategy, Developing Operations Strategy, Elements or Components of Operations Strategy, Competitive Priorities, Manufacturing Strategies, Service Strategies, Global Strategies and Role of Operations Strategy.

Unit III: Productivity Variables and Productivity Measurement, Production Planning andControl, Mass Production, Batch Production, Job Order Manufacturing, Product Selection, Product Design and Development, Process Selection, Capacity planning.

Block 2: Inventory Management

Unit IV: An Overview of Inventory Management Fundamentals, Determination of MaterialRequirement, Safety Management Scheduling, Maintenance Management Concepts, Work Study, Method Study, Work Measurement, Work Sampling, Work Environment, Production Planning and Control (PPC) Industrial Safety, human-machine interface, types of interface designs. Cloud operations management

Block 3: Quality Management

Unit V: Quality Assurance, Accepting Sampling, Statistical Process Control, Total QualityManagement, ISO standards and their Importance, Introduction to re-engineering, value engineering, check sheets, Pareto charts, Ishikawa charts, JIT Pre-requisites for implementation Six Sigma, Lean Management, Reliability

Engineering, Safety Engineering, Fault Tree Analysis.

VI. Teaching methods/activities

- Interactive sessions
- Live projects
- Assignments (reading and writing)
- Presentations of quality management practices by leading agri and food organizations

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the basic concepts of production and operations management including manufacturing systems, layout planning and analysis
- Develop a understanding about the operations strategy, productivity variables, and their measurement along with product design and development
- Get an insight about fundamentals of inventory management, safety management, quality assurance practices and techniques with major emphasis on agri and food based industries

VIII. Suggested Reading

- William J. Stevenson. 2014. *Operations Management*, 12th Edition, McGraw-Hill
- Panneerselvam K. 2012. *Production and Operations Management* 3rd Edition, Prentice Hall India Learning Private Limited
- S. N Chary, 2017. *Production and Operations Management*, McGraw Hill Education; 5 edition

I. Course Title : Agricultural And Food Marketing Management-I

II. Course Code : ABM 506

III. Credit Hours : 2+0

IV. Aim of the course

To develop the understanding the concept of marketing system with specific inputs of product, pricing, availability and promotional details

The course is organized as follows:

No	Blocks	Units
1.	Marketing concept	1. Overview of Marketing Management 2. Developing the product mix 3. Branding decisions 4. Packaging technology
2	Pricing decisions	1. Pricing Objectives 2. Types of pricing
3	Channel Management and Physical Distribution	1. Distribution channels 2. Warehouse management, Inventory management 3. Transport management
4	Marketing Communications	1. Marketing communications mix 2. Digital Marketing, Mobile Marketing, Social Marketing and Social Media Marketing 3. Marketing efficiency and effectiveness

V. Theory

Block 1: Overview Of Marketing Management

Unit 1: Introduction and Concept/ philosophies of Marketing Management; Product Management: The product, The product mix, Product line extensions, Product linedeletions, Branding products, The advantages and disadvantages of branding, Branding decisions Brand loyalty models, Homogenous first-order markov models, Higher-order markov models Packaging, The functions of packaging, Packaging technology, Recent developments in packaging

Block 2: Pricing Decisions

Unit 2: Pricing objectives, The laws of supply and demand, Elasticity of demand Cross-price elasticity of demand, Practical problems of price theory, Cost - revenue - supply relationships, The meaning of price to consumers, Price as an indicator of quality, Pricing strategies, Cost-plus methods of price determination, Breakeven analysis, Market-oriented pricing, Psychological pricing, Geographical pricing, Administered pricing

Block 3: Channel Management and Physical Distribution

Unit 3: Channel decisions in relation to marketing strategy, The value of middlemen, Key decisions in channel management, Types of distribution system, Marketing to middlemen, Power and conflict in distribution channels, Physical distribution, Customer service levels, Developing a customer service policy, The total distribution concept, Warehouse management, Inventory management, Calculating the economic order quantity, Transport management, Technological advances in physical distribution, Vehicle scheduling and routing, Fixed and variable routing systems, Vehicle scheduling tools, Vehicle scheduling models, Computer-based vehicle scheduling

Block 4: Marketing Communications

Unit 4: The nature of marketing communications, Setting marketing communication objectives, Factors influencing the communications mix, The marketing communications mix, Advertising, Sales promotion, Public relations, Personal selling, Digital Marketing, Mobile Marketing, Social Marketing and Social Media Marketing, Training the sales force, Change agents, Selecting the media, Establishing the promotional budget, Monitoring the effectiveness of marketing communications

Unit 5: Marketing Costs And Margins: Assessing the performance of a marketing system, Marketing efficiency and effectiveness, Operational efficiency, Pricing efficiency, Identifying marketing costs and margins, The reference products concept, Handling costs, Packaging costs, Transport costs, Storage costs, Processing costs, Capital costs

VI. Teaching methods/activities

- Lectures
- Cases studies from recent marketing trends from the agri and food organisations
- Assignments (Group/ Individual)
- Live project based upon marketing practices adopted by various organizations
- Group discussions on contemporary marketing practices

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the basics of marketing with specific emphasis on managing the product details
– Get detailed insight on the pricing techniques and managing the demand and supply relationship profitably
– Develop the understanding about the marketing channels and intermediaries involved
– Understand the promotional strategies and communication development tools and methods

VIII. Suggested Reading

- Kotler P, Keller K, Koshy A and Jha M. 2013. *Marketing Management–Analysis, Planning, Implementation and Control*. Pearson Education.
- Ramaswamy VS. 2017. *Marketing Management: A Strategic Decision Making Approach*
- McGraw Hill Education
- Saxena R. 2009. *Marketing Management*. Mc Graw Hill.4th Edition
- William Perreault Jr., Mccarthy E. Jerome., 2006, *Basic Marketing: A Global Marketing Approach,* Tata McGraw Hill
- Gay R, Cjarlesworth A, Esen R. 2014, *Online Marketing*, Oxford University Press
- Mohammed, Fisher, Jaworski and Cahill: *Internet Marketing – Building Advantage in a networked economy* Tata McGraw-Hill
- Strauss J and Frost R. 2013. *E-Marketing*, Prentice-Hall
- Roberts M. 2018. *Internet Marketing*, Cengage Learning
- Vassos: *Strategic Internet Marketing – Practical e-commerce and branding Tactics*, Que Books
- Chaffey, Meyer, Johnston and Ellis – Chadwick. 2009. *Internet Marketing*, Prentice-Hall/ Financial Times

I. Course Title : Agricultural and Food Marketing Management-II

II. Course Code : ABM 507

III. Credit Hours : 2+0

IV. Aim of the course

To develop learning about the basic concept of marketing with major emphasis on agri and food marketing by equipping the students with the understanding of ecosystem in which the agri organization functions to meet the requirements of the customer profitably

The course is organized as follows:

No	Blocks	Units
1.	Agricultural and Food Marketing	1. Marketing concept and marketing systems 2. Market Liberalisation
2.	Marketing Strategy, Planning and Control	1. Marketing planning 2. New Product Development:
3.	Commodity Marketing	1. Grain marketing, 2. Livestock and meat marketing, 3. Poultry and eggs marketing, marketing of fresh milk

V. Theory

Block 1: Agricultural and Food Marketing

Unit 1: The importance of agricultural and food marketing to developing countries,

the marketing concept and marketing systems, Marketing sub-systems
Marketing functions, Links between agriculture and the food industry, Agricultural and food marketing enterprises, Marketing boards in developing countries, Co-operatives in the agriculture and food sectors, Control and management of secondary co-operatives, The weaknesses of co-operatives, Selling arrangements between co-operatives and their members

Unit 2: Market Liberalisation: Economic structural adjustment programmes, Macro-economicstabilisation, The role of the state in liberalised markets, Strategies for reforming agricultural marketing, Obstacles to be overcome in commercialisation and Privatisation of agricultural marketing, Dealing with accumulated deficits, Encouraging private sector involvement in agricultural marketing, Impediments to private sector participation in agricultural markets, impact of the macro-economic environment on private traders, Government action to improve private sector performance

Block 2: Marketing Strategy, Planning and Control

Unit 3: Marketing Strategy, Planning and Control: Strategy, policy and planning, Strategic businessunits, The need for marketing planning, The process of marketing planning, Contents of the marketing plan, Monitoring, evaluating and controlling the marketing planning, Marketing controls, Marketing plan control, Efficiency control

Unit 4: New Product Development: The impetus to innovation, New product development process
The adoption process, The effect of products characteristics on the rate of adoption, Buyer behavior: The influences on buyer behaviour, Exogenous influences on buyer behaviour Endogenous influences on buyer behaviour, The consumer buying decision process, Buyer behaviour and market segmentation, Lifestyle segmentation, Organisational markets Industrial markets, Industrial buyer characteristics

Block 3: Commodity Marketing

Unit 5: Stages in a commodity marketing system, Grain marketing, Challenges for grain marketing systems, fruits and vegetables, Livestock and meat marketing, Poultry and eggs marketing, marketing of fresh milk

VI. Teaching methods/activities

- Lectures
- Cases studies from recent marketing trends from the agri and food organisations
- Assignments (Group/ Individual)
- Live project based upon marketing practices adopted by various organizations
- Group discussions on contemporary marketing practices

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the agricultural and food marketing concepts and systems
- Get an insight about the marketing planning and strategies for developing products for meeting the specific needs of the final customers
- Develop a clear view about the commodity marketing practices in India and in International markets

VIII. Suggested Reading

- Acharya SS and Agarwal NL. 2011. *Agricultural Marketing in India*. 4th Ed. Oxford and IBH.

- Kohls RL and Uhj JN. 2005. *Marketing of Agricultural Products*. 9th Ed. Prentice Hall.
- Mohan J. *Agri-Marketing Strategies in India*, NIPA
- Sharma Premjit. 2010. *Agri-Marketing Management*, Daya Publishing House

I. Course Title : Agri Supply Chain Management

II. Course Code : ABM 508

III. Credit Hours : 2+0

IV. Aim of the course

To introduce the students to the concepts, processes and framework of agricultural supply chain management.

The course is organized as follows:

No	Blocks	Units
1	Overview of Supply Chain Management	1. Introduction to Agri Supply Chain Management 2. Demand Management in Supply Chain 3. Manufacturing Management
2	Procurement Management	1. Purchasing Cycle 2. Material Requirement Planning
3	Logistics Management	1. Distribution Strategies and Management 2. Warehouse Management 3. IT application in ASCM

V. Theory

Block 1: Overview Of Supply Chain Management

Unit I: Supply Chain: Changing Business Environment; SCM: Present Need; ConceptualModel of Supply Chain Management; Evolution of SCM; SCM Approach; Traditional Agri. Supply Chain Management Approach; Modern Supply Chain Management Approach; Elements in SCM. Innovations in Global Agri-SCM

Unit II: Demand Management in Supply Chain: Types of Demand, Demand Planning andForecasting; Operations Management in Supply Chain, Basic Principles of Manufacturing Management. SCM Metrics/Drivers and Obstacles.

Block 2: Procurement Management in Agri. Supply Chain

Unit III: Purchasing Cycle, Types of Purchases, Contract/Corporate Farming, Classification ofPurchases Goods or Services, Traditional Inventory Management, Material Requirements Planning, Just in Time (JIT), Vendor Managed Inventory (VMI).

Block 3: Logistics Management

Unit IV: History and Evolution of Logistics; Elements of Logistics; Management; Distribution Management, Distribution Strategies; Pool Distribution; Transportation Management; Fleet Management; Service Innovation; Warehousing; Packaging for Logistics, Third-Party Logistics (TPL/3PL); GPS Technology.

Unit V: Concept of Information Technology: IT Application in SCM; Advanced Planning andScheduling; SCM in Electronic Business; Role of Knowledge in SCM; Performance Measurement and Controls in Agri. Supply Chain Management-Benchmarking: introduction, concept and forms of Benchmarking. Case Studies on the following: (a) Green Supply Chains (b) Global Supply Chains (c) Coordination in a SC. Value of and distortion of information: Bullwhip effect (d) Sourcing and contracts in SC (e) Product availability with uncertain demand (f) Inventory planning with known/ unknown demand (g) Cases from FAO/IFPRI, etc.

VI. Teaching methods/activities

- Lectures
- Case study on the real life situations regarding the supply chain management practices
- Assignments (Group and individual)
- Live projects
- Newspaper analysis
- Presentations of best practices in the industry
- Videos and guest lectures by the eminent and successful organizations

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the various elements involved in managing agri supply chain from farm to fork
– Relate well with the issues and challenges involved in managing and forecasting the demand of the products
– Develop insights on the techniques of procurement management and handling inventory
– Assess the importance of managing logistics along with adequate handling and packaging intricacies
– Get a overall clarity about the use of information technology to make the agri supply chain more efficient and rewarding

VIII. Suggested Reading

- Acharya SS and Agarwal NL. 2011. *Agricultural marketing in India*. Oxford and IBH.
- Altekar RV. 2006, *Supply Chain Management: Concepts and Cases*. PHI
- Chopra S, Meindl P and Kalra DV. 2016. *Supply chain management: Strategy, Planning, and Operation*, Pearson Education India
- Mohanty RP. 2010. *Indian Case studies in Supply Chain Management & other Learning Resources*. Oxford.
- Chandrasekaran N. 2010. *Supply Chain Management: Process, system & Practice*. Oxford.
- Singh S. 2004. *Organic Produce Supply Chains in India-Organisation and governance*. Allied Publ.

I. Course Title : International Trade in Agricultural Products

II. Course Code : ABM 509

III. Credit Hours : 2+0

IV. Aim of the course

To impart knowledge to the students about international trade in agriculture and various provisions under WTO in the new trade regime.

The course is organized as follows:

No	Blocks	Units
1.	Introduction to International Trade	1. Basic concepts of International Trade 2. WTO and its implications for Indian agri business sector 3. International trade restrictions and support systems
2.	Regulations and policy measures for International trade	1. India's foreign trade policy framework 2. Market entry methods 3. Export procedures & documentations

V. Theory

Block 1: Introduction To International Trade

Unit I: International trade–basic concepts, WTO and its implications for Indian economy ingeneral and agriculture sector in particular.

Unit II: TRIPS, TRIMS quotas, anti dumping duties, quantitative and qualitative restrictions, tariff and non-tariff measures, trade liberalization, subsidies, green and red boxes, issues for negotiations in future in WTO; CDMs and carbon trade.

Unit III: Importance of foreign trade for developing economy; absolute and comparativeadvantage, foreign trade of India. Cases on agri business commodity trade practices

Block 2: Regulations and Policy Measures for International TRADE

Unit IV: India's balance of payments; inter regional Vs international trade; tariffs andtradecontrol; exchange rate; the foreign trade multiplier.

Unit V: Foreign demand, supply side analysis, opportunity cost, trade and factor prices, implications for developing countries, market entry methods, export procedures & documentations.

VI. Teaching methods/activities

- Lectures
- Cases on contemporary issues
- Group assignments
- Live projects
- Policy discussions
- Guest lectures
- Industrial visits to firms exporting agri commodities

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand the basic concepts of International trade with reference to WTO and International agreements on Agriculture
- Assess the practices of trade of agri business commodities
- Develop a clear understanding about the significant regulations and policy measures for International Trade

VIII. Suggested Reading

- Study materials by the Center for WTO Studies, ITPO, New Delhi, *The Future of Indian Agriculture*

• Brouwer F and Joshi PK. 2016. *International Trade and Food Security*, LEI - Wageningen UR, The Netherlands.

I. Course Title : Food Technology and Processing Management
II. Course Code : ABM 510
III. Credit Hours : 3+0

IV. Why this course?

As a discipline, Food Technology is the combination of engineering, food science, hotel management, and home science. It is an advanced study of the technology and processing methods used to develop, research, manufacture, produce, preserve and process food with related substances.

V. Aim of the course

Food Technology is the application of food science to the selection, preservation, processing, packaging, distribution and use of safe, wholesome and nutritious food. The food processing industry covers a range of food products.

The Course is organized as follows:

No	Blocks	Units
1.	Food Technology	1. Food Industry in India
2.	Processing Management	1. Basics of Food Processing 2. Food Safety and Costs Analysis 3. Case studies on project formulation in various types of food industries

VI. Theory

Block 1: Food Technology

Unit 1: Food Industry in India: Present status of food industry in India; Organization in food industry; Introduction to operations of food industry; Deteriorative factors and hazards during processing, storage, handling and distribution.

Block 2: Processing Management

Unit 2: Basics of Food Processing: Basic principles of food processing and food preservation through technology interventions; Application of energy, radiations, chemicals and other agents for food preservation; aseptic modes of processing-freezing, quick, cryogenic, high pressure, membrane technology; Packaging of foods, labelling techniques, advanced technologies for packaging.

Unit 3: Food Safety and Costs Analysis: Analysis of costs; risk management; Laws and regulations w.r.t to food industry including production, processing and marketing; Food Safety and Quality Standards-AGMARK, BIS/ISO, FPO, FSSAI, TQM, HACCP etc.

Unit 4: Case studies on project formulation in various types of foodindustries: Discussion sessions and analysis of Case studies related to dairy, cereal milling, sugarcane production; baking/confectionary, vegetable storage, handling, egg processing, fish and meat products; Cases related HACCP.

VII. Learning outcome

After completion of this course, the students are expected to be able to acquaint the students with different food processing techniques and their management.

VIII. Suggested Reading

- Acharya SS and Aggarwal NL. 2004. *Agricultural Marketing in India*. Oxford & IBH.
- Early R. 1995. *Guide to Quality Management Systems for Food Industries*. Springer
- Jelen P. 1985. *Introduction to Food Processing*. Reston Publishing.
- Potly VH and Mulky MJ. 1993. *Food Processing*. Oxford & IBH
- Fellows PJ. 2016. *Food Processing Technology Principles and Practice,* Woodhead Publishing, 4th Edition
- Potter NN. 2018. *Food science*. McGraw-Hill Education, 6th Edition
- Singh RP, Heldman DR. 2013. *Introduction to Food Engineering.* Elsevier Inc., 5th Edition
- Smith JS, Hui YH. 2013. *Food Processing: Principles and Applications*, Wiley

I. Course Title : Rural Marketing

II. Course Code : ABM 511

III. Credit Hours : 3+0

IV. Aim of the course

To explore the possibilities and potential of the rural market. It aims at critically analysing the market opportunities, consumer trends and patterns and development of better marketing strategies for the rural areas.

The Course is organized as follows:

No	Blocks	Units
1	Rural MarketingEnvironment	1. Rural Market Concept & Scope 2. Environmental factors 3. Rural finance 4. Rural consumer's behavior
2	Rural Marketing Strategy	1. Rural Product strategy 2. Pricing for rural markets 3. Promotion and communication strategy

V. Theory

Block 1: Rural Marketing Environment

Unit 1: Rural Market Concept & Scope: Concept, Definition and Scope of rural marketing, nature and characteristics of rural markets, potential of rural markets in India, rural V/S urban market.

Unit 2: Environmental factors: Socio-cultural, economic, demographic, technological and other environmental factors affecting rural marketing.

Unit 3: Rural finance: Concept, demand, banking model; Finance Schemes of NABARD, Other Schemes of State Govt, Central Govt.

Unit 4: Rural consumer's behavior: Behavior of rural consumers and farmers; buyer characteristics and buying behavior; customer relationship management, rural market research.

Block 2: Rural Marketing Strategy

Unit 1: Rural Product strategy: Marketing of consumer durable and non-durable goods and services in the rural markets with special reference toproduct planning; marketing mix, product mix.

Unit 2: Pricing for rural markets: Pricing policy and pricing strategy, distribution strategy, Rural retailing and modern store formats in rural areas.

Unit 3: Promotion and communication strategy: Media Planning, Distribution channels, personal selling strategies in rural markets, innovations in rural marketing

Teaching methods/activities

- Lectures
- Discussion
- Case Studies
- Student-led presentations

V. Learning outcome

After completion of this course, the students are expected to be able to develop understanding regarding issues in rural markets like marketing environment, consumer behaviour, distribution channels, marketing strategies, etc.

VI. Suggested Reading

- Krishnamacharyulu and Ramakrishnan. 2010. *Rural Marketing: Text and Cases*: Pearson Education. 2nd edition
- Singh S. 2004. *Rural Marketing: Focus on Agricultural Inputs,* Vikas Publishing
- Kashyap P. 2011. *Rural Marketing*. Pearson Education
- Kumar D and Gupta P. 2017. *Rural Marketing: Challenges andOpportunities*. Sage Publications.

I. Course Title : Fertilizer Technology and Management

II. Course Code : ABM 512

III. Credit Hours : 3+0

IV. Why this course?

Provide exposure to most recent Nitrogenous and Complex fertilizer production technologies. Improve participants' technical knowledge over a varied range of fertilizer production techniques

V. Aim of the course

Enhance the participants' analytical and trouble-shooting skills by generating awareness to identify and resolve operational inefficiencies, if any, of their facilities. The Course is organized as follows:

No	Blocks	Units
1	Fertilizer Production	1. Fertilizer development 2. Raw material 3. Production efficiency
2	Testing and Field Trials	1. Testing 2. Field trials

VI. Theory

Block 1: Fertilizer Production

Unit 1: Fertilizer development: Concept, scope, need, resource availability; import and export avenues for fertilizer; types of fertilizers, grading and chemical constituents, role of fertilizers in agricultural production, production and consumption of fertilizer in India.

Unit 2: Raw material Supply; Principles of manufacturing-potassic fertilizers, secondary and micro-nutrient formulations

Unit 3: Production efficiency: Production efficiency and capacity utilization; quality control and legal aspects fertilizer control order

Block 2: Testing and Field Trials

Unit 1: Testing facilities; constraints in fertilizer use; assessment of demand and supply of different fertilizers, fertilizer distribution, fertilizer storage.
Unit 2: Field trialsand demonstrations; environmental pollution due to fertilizers

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

Provide a platform to exchange ideas on a varied range of production topics, opportunity for active interaction with leading technology experts and to acquaint the students in latest advances in fertilizer technologymanagement.

IX. Suggested Reading

- Brady NC & Weil RR. 2002. *The Nature and Properties of Soils*. 13th Ed. Pearson Edu.
- *Fertilizer Control Order* (different years). Fertilizer Association of India, New Delhi.
- *Fertilizer Statistics* (different years). Fertilizer Association of India, New Delhi
- *Indian Journal of Fertilizers* (different years). Fertilizer Association of India, New Delhi.
- San Chilli V. 1960. *Chemistry and Technology of Fertilizers*. American Chemical Soc. Monograph Series. Reinhold Publ. Corp.
- Tisdale SL, Nelson WL, Beaton JD & Havlin JL. 2002. *Soil Fertility and Fertilizers*. 5th Ed. Prentice Hall

I. Course Title : Management of Agro Chemical Industry
II. Course Code : ABM 513
III. Credit Hours : 3+0

IV. Why this course?

The agrochemicals (pesticides, hydrogels, plant growth regulators etc.) have played a pivotal role in the past in increasing agricultural productivity and production, and in protecting and preserving the human and animal food, feed, health and the belongings.

V. Aim of the course

Plant protection chemicals have and will continue to play a crucial role in meeting the food, feed and fiber needs of the mankind.
The Course is organized as follows:

No	Blocks	Units
1.	Agro Chemicals	1. Agro Chemicals 2. Insecticides 3. Fungicides
2.	Insecticide Act and Plant Protection	1. Insecticide Act. 2. Plant Protection

VI. Theory

Block 1: Agro Chemicals

Unit 1: Introduction: Agro-chemicals: Definition and classification; Basic knowledge of agro- chemicals; role andstatus of agro-chemical industry in India; Pesticides – Classification and Introduction, knowledge of different pesticides.

Unit 2: Insecticides: Insecticides – Definition and classification based on (a)Mode of Entry (b) Mode of Action and(c) ChemicalStructure with example; Insecticidal formulation; preliminary knowledge of mode of action of insecticides; knowledge of plant protection equipments.

Unit 3: Fungicides: Fungicides – Classification and preliminary knowledge of commonly used fungicides; Biomagnifications ofpesticides and pesticidal pollution.

Block 2: Insecticide Act and Plant Protection

Unit 1: Insecticide Act: Introductory knowledge about development of agro-chemicals; Insecticidal poisoning, symptoms and treatment; Main features of Insecticide Act.

Unit 2: Plant Protection: Directorate of Plant Protection, Quarantine and Storage– A brief account of its organizational set up and functions; IPM Concept – Bio-pesticides – Plant products.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To familiarize the students with the agrochemicals, their structure, classification and development and management of agro-chemical industry.

IX. Suggested Reading

- Dhaliwal GS, Singh R and Chhillar BS. 2014. *Essentials of Agricultural Entomology*. Kalyani Publishers.
- Hayes WT and Laws ET. 1991. *Hand Book of Pesticides*. Academic Press.
- Matsumura F. 1985. *Toxicology of Insecticides*. 2nd Ed. Plenum Publ.
- Rajeev K and Mukherjee RC. 1996. *Role of Plant Quarantine in IPM*. Aditya Books.

I. Course Title : Seed Production Technology Management

II. Course code : ABM 514

III. Credit Hours : 3+0

IV. Aim of the course

The course covers a wide range of seed science and technology issues related to production of high quality seeds, processing, testing, certification, quality control, seed policies and regulations, variety release and registration, seed quality management in *seed* multiplication systems, seed storage, marketing.

The Course is organized as follows:

No	Blocks	Units
1.	Seed Technology	1. Seed Technology
2.	Seed Management Programmes	1. Development and Management of Seed

No	Blocks	Units
		2. Maintenance of genetic purity 3. Management of seed processing plant 4. Seed Marketing

V. Theory

Block 1: Seed Technology

Unit 1: Seed Technology: Role of Seed Technology, its Course Objective and goal, Seed Industry in India, National Seed Corporation – Tarai Seed Development, Corporation, State Seed Corporations, National Seed Project and State Farms and their role.

Block 2: Seed Management

Unit 1: Development and Management of Seed Programmes: Seed Village Concept, Basic Strategy of Seed Production and Planning and Organization of Seed Programme; Types of Seed Programme–Nucleus seed, Breeders seed, Foundation seed and Certified seed etc.

Unit 2: Maintenance of genetic purity: Minimum seed certification standard and Management of breeders & Nucleus seed; Management of seed testing laboratory and research and development.

Unit 3: Management of seed processing plant seed storage management; seed packaging and handling.

Unit 4: Seed Marketing: GM Crop seed, IPR, PBR, Patents and related issues and their impact on developing countries; Statutory intervention in the seed industry; Seed legislation and seed law enforcement, Seed act; Orientation and visit to seed production farms, seed processing Units, NSC, RSSC, RSSCA and seed testing laboratories.

VI. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VII. Learning outcome

To apprise students regarding principles and efficient management of seed production technology.

VIII. Suggested Reading

- Agrawal RL. 2017. *Seed Technology*. Oxford & IBH.
- Desai BB, Katecha PM and Salunkhe DK. 2009. *Seed Handbook: Biology, Production, Processing and Storage*. Marcel Dekker.
- Kelly A. 1988. *Seed Production of Agricultural Crops*. Longman.
- McDonald MB Jr. and Copeland LO. 2012. *Seed Production: Principles and Practices.* Chapman & Hall.

I. Course Title : Technology Management for Livestock Products

II. Course code : ABM 515

III. Credit Hours : 3+0

IV. Why this course?

Students may study two major topics include meat technology and dairy technology.

They may also do research activities on product development, development of functional meat, an extension of shelf life, and development of milk products.

V. Aim of the course

The main aim of this course is to disseminating knowledge about hygienic milk production, hygienic slaughter, utilization of slaughterhouse by-products, preparation of value-added meat products, preparing of value-added indigenous as well as milk products, and dressing of food animals.

The Course is organized as follows:

No	Blocks	Units
1.	Livestock product & Technology	1. Status of livestock product and technology 2. Manufacturing technologies
2.	TQM and Marketing of Livestock Products	1. TQM in processing 2. Marketing livestock products

VI. Theory

Block 1: Livestock Product and Technology

Unit 1: Present status of livestock products industry in India: Dairy, meat, skin and hides, wool, etc; SWOT analysis of livestock product industry, importance of value addition of livestock products, Concept of organic milk and meat. New techniques of biotechnology for improving food value.

Unit 2: Manufacturing technologies: Dairy-Manufacturing technologies of various dairy products and byproduct utilization. Meat- Manufacturingtechnologies of meat and its products, industrial processing and utilization of wool and animal by-products, valueadded egg product development.

Unit 3: Milk and meat processing plant: Layout and designing of milk and meat processing plant, abattoir design, sanitation and basic slaughterhouse practices, Plant Management- Production, planning and control, packaging, preservation and storage system for livestock products; transportation system for domestic markets and international markets.

Block 2: TQM and Marketing of Livestock Products

Unit1: Total quality management in processingTotal quality management in processing of milk and its byproduct, meat and byproduct, value added eggduct and wool, Quality control measures during storage transit; extent of losses during storage and transport, management measures to minimize the loss.

Unit 2: Marketing livestock products

Milk, meat, wool, fish etc and its byproduct, Marketing and distribution system of animal products; National and international specifications and quality standards for various products; environmental and legal issues involved.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To impart knowledge about management of livestock products, product development, quality control, preservation and marketing strategies for livestock products.

IX. Suggested Reading

- Mandal PK and Biswas AK. 2014. *Animal Products Technology,* Studium Press India Pvt. Ltd.; 1st Edition
- Bishwas AK and Mandal PK. 2014. *Textbook of Poultry, Egg and FishProcessing Technology,* Studium Press (India) Pvt. Ltd.

I. Course Title : Fruit Production and Post-Harvest Management

II. Course Code : ABM 516

III. Credit Hours : 3+0

IV. Why this course?

Postharvest management of fruits and vegetable: A potential for reducing a minimum postharvest losses as well as can potentially reduce production cost .

V. Aim of the course

A dual purpose of preventing losses that occur due to harvest losses of fruits and vegetables vary from 25% to 40%, depending on the kind of produce and the pre and post-harvest practices they are put through. The Course is organized as follows:

No	Blocks	Units
1.	Fruit Production	1. Introduction 2. Management of horticultural crops
2.	Post-Harvest Management	1. Post harvest management in horticulture-procurement 2. Post harvest management in horticulture process 3. Marketing of fruits

VI. Theory

Block 1: Fruit Production

Unit 1: Introduction: Global and National Status of Horticultural production in India and emerging scenario

Unit 2: Management of horticultural crops: Establishing an orchard, basic cultural practices, regulation of flowering, fruiting and thinning, protection against insect-pest, weeds: Maturity indices, Harvesting and its relationship with quality, sorting and grading, pre-harvest crop management practices and their influence on quality during storage and marketing.

Block 2: **Post-Harvest Management**

Unit 1: Post-harvest management in horticulture-procurement: Procurement management, important factors for marketing, standardization and quality control, packaging. Physiology of ripening and senescence. Storage system: on-farm storage-evaporatively cooled stores, ventilated storage, pit storage etc. Refrigerated storage refrigeration cycle, controlled/modified atmosphere, hypobaric storage.

Unit 2: Post harvest management in horticulture process: Application of growth regulators for quality assurance, post-harvest treatments: pre cooling, heat treatments (hot water, hot air and vapor heat), fungicides & biologically safe chemicals, irradiation, curing, pulsing *etc*. Packingline operations, packaging of horticultural produce. Transportation rail, road, sea, air. Codex norms for export ofperishables. Development of fruit-based carbonated drinks, development of dehydrated products from someimportant fruits, storage of pulp in pouches, essential oils from fruit waste, dehydrated fruits. Market structure andexport potential of fruits.

Unit 3: Marketing of fruits: Problems in marketing of fruits, and government policy; quality standards for domestic and international trade.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To impart knowledge about management of horticultural crops and post-harvest technologies

IX. Suggested Reading

- Rathore NS, Mathur GK and Chasta SS. 2013. *Post-Harvest Management and Processing of Fruits and Vegetables*, ICAR.
- Chadha KL and Pareek OP. 1993. *Advances in Horticulture*. Vols. I-IV. Malhotra Publ. House.
- Kader AA. 1992. *Post-harvest Technology of Horticultural Crops*. Univ. of California. Div. of Agri. & Natural Resources.
- Jacob JP. 2012. Handbook on Post Harvest Management of Fruits and Vegetables, ASTRAL Publishing.
- NIIR Board of Consultants & Engineers. 2016. *The Complete Technology Book on Processing, Dehydration, Canning, Preservation of Fruits & Vegetables*, NIIR PROJECT CONSULTANCY SERVICES; 3rd Revised Edition
- Thompson K. 2003. *Fruit and Vegetables: Harvesting, Handling and Storage*, Wiley-Blackwell; 2nd Edition

I. Course Title : Farm Power and Machinery Management

II. Course Code : ABM 517

III. Credit Hours : 2+0

IV. Why this course?

The role of mechanization and its relationship to productivity, employment, social and technological change; performance and *power* analysis(Various sources of *farm power*, their availability and utilization) cost analysis of mechanized agriculture.

V. Aim of the course

Agricultural machinery management is the section of farm management that deals with the optimization ofthe equipment phases of agricultural production. It is concerned with the efficient selection, operation, repair and maintenance, and replacement of machinery.

The Course is organized as follows:

No	Blocks	Units
1.	Farm Power and Machinery	1. Farm power and tractors 2. Tillage and Tillage machinery 3. Sowing, Planting and Intercultural Equipment
2.	Agricultural equipments industry and Cost analysis of operations	1. Agricultural equipments industry 2. Cost analysis of operations

VI. Theory

Block 1: Farm Power And Machinery

Unit 1: Farm power and tractors: Farm power in India - sources, IC engines – working principles, two stoke and four stoke engines, IC engine terminology, different systems of IC engine. Tractors – types and utilities.

Unit 2: Tillage and Tillage machinery: Tillage – ploughing methods – primary tillage implements – mould board, disc plough and chisel plough – secondary tillage implements –cultivators, harrows and rotovators – wetland equipment – puddlers, tramplers and cage wheels.

Unit 3: Sowing, Planting and Intercultural Equipment: Sowing methods – seed drills, seed cum fertilizer drills – Paddy transplanters – nursery requirements – implements for intercultural operations – wet land, dry land and garden land intercultural tools. Plant Protection Gadgets, Harvesting Machinery and Horticulture tools: Plant protection equipment, tools for horticultural crops.

Block 2: Agricultural Equipments Industry and Cost Analysis Of Operations

Unit 1: Agricultural equipments industry: Agricultural equipments production, marketing and constraints; establishment of agricultural engineering enterprises (agro service centers, etc.). Equipment for land development and farm machinery selection: Equipment for land development and soil conservation.

Unit 2: Cost analysis of operations: Cost analysis ofoperations using different implements, economic performance of machines, optimization of tractor implements system and transport of farm produce. Cost of operation of farm machinery – Tractor and implement selection

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To equip the students with sufficient theoretical knowledge and practical skills about farm power and tractor power, implement resources used in agriculture, their cost of operation and selection.

IX. Suggested Reading

- Senthilkumar T, Kavitha R and Duraisamy VM. 2015. *A text book of farm machinery*, Thannambikkai Publications, Coimbatore.
- Jagadishwar S. 2010. *Elements of agricultural engineering.* Standard Publishers Distributors, New Delhi.

I. Course Title : Food Retail Management

II. Course Code : ABM 518

III. Credit Hours : 2+0

IV. Why this course?

Study a short *course* in *Retail Management* to learn how to run a retail store or department efficiently and to introduce you to key issues and concepts associated with the *retail* environment. Topics covered in the *course* typically include business administration, visual merchandising, and marketing.

V. Aim of the course

Identify the most dramatic change in food retailing today; Assess the variety and Define a target market; Explain why a retailer would want to meet the needs of a Customer. Describe the steps to recruiting top talent; Identify selection and training.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Introduction to Food market 2. Value Chain in Food Retailing
2.	Retail Marketing Strategy	1. Marketing Mix in Food Retail Management 2. Managing Retail Operations 3. Retail Sales Management

VI. Theory

Block 1: Introduction

Unit 1: Introduction to Food market: Introduction to International Food market, India's Competitive Position in World Food Trade, Foreign Investment in Global Food Industry, Retail management and Food Retailing, The Nature of Change in Retailing, Organized Retailing in India, E-tailing and Understanding food preference of Indian Consumer, Food consumption and Expenditure pattern, Demographic and Psychographic factors affecting Food Pattern of Indian Consumer.

Unit 2: Value Chain in Food Retailing: Value chain and value additions across the chain in food retail, Principal trends in food wholesaling and retailing, Competition and pricing in food retailing, various retailing formats, the changing nature of food stores, market implications of new retail developments, food service marketing.

Block 2: Retail Marketing Strategy

Unit 1: Marketing Mix in Food Retail Management: Merchandise Management, Pricing Strategies used in conventional and non-conventional food retailing, Public distribution system, Promotion mix for food retailing, Management of sales promotion and Publicity, Advertisement Strategies for food retailers & Brand Management in Retailing.

Unit 2: Managing Retail Operations: Managing Retailers' Finances, Merchandise buying and handling, Logistics, procurement of Food products and Handling Transportation of Food Products.

Unit 3: Retail Sales Management: Types of Retail Selling, Salesperson selection, Salesperson training, Evaluation and Monitoring, Customer Relationship Management, Managing Human Resources in retailing, Legal and Ethical issues in Retailing.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

It will equip the students with desired knowledge and skills for managing food retail operations.

IX. Suggested Reading

- Singh S. 2011. *Fresh food retails in India: Organisation and impacts,* Allied publishers Pvt. Ltd., New Delhi
- Mahapatra. S, *Food Retail Management*, Kalyani Publishers
- Zentes, Joachim, Morschett, Dirk, Schramm-Klein, Hanna 2017. *Strategic Retail Management: Text and International Cases,* Springer Gabler.
- Agrawal N and Smith SA. 2015. *Retail Supply chain Management: Quantitative Models and Empirical Studies,* Springer; 2nd revised edition.

I. Course Title : Management of Agricultrual Input Marketing

II. Course Code : ABM 519

III. Credit Hours : 2+0

IV. Why this course?

It will help in gaining a deeper understanding of the four P's of marketing as applied to agricultural input marketing and an exposure to social and ethical issues is oriented in the course.

V. Aim of the course

The present course aims at familiarizing the participants with various aspects of agricultural input marketing in India.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Market for agricultural inputs
2.	Marketing of Agricultural Inputs	1. Marketing of seeds 2. Marketing of fertilizers 3. Marketing of pesticides 4. Marketing of tractors

VI. Theory

Block 1: Introduction

Unit 1: Market for agricultural inputs: Nature of demand, promotional media, nature of competition, a framework for understanding the markets for inputs, agronomic potential, agro economic potential, effective demand, actual consumption.

Block 2: Marketing of Agricultural Inputs

Unit 1: Marketing of seeds: Government policy, product, trade practices in seed production, seed pricing, input costs, distribution system, management of seed distribution. proper storage of seeds, promotion, problems faced by seed industry, strategy for a seed enterprise, source of seeds, terms of transaction for seed procurements.

Unit 2: Marketing of fertilizers: Nature of Indian fertilizer market, product, fertilizer distribution, marketing cost and margins, credit, dealer selection and management, fertilizer promotion and extension, promotional program, advertising in fertilizers, emerging marketing mix in fertilizer, extension strategy for the future, marketing of biofertilizers, strategies for fertilizer marketing.

Unit 3: Marketing of pesticides: Market profile, structure of industry, farmer behaviour, problems of farmers in pesticide purchase and usage, marketing mix, bio pesticides market development and promotion activities, problems in marketing of bio pesticides. Integrated pest management.

Unit 4: Marketing of tractors: Segments in tractor market, market share, nature of demand, buyer behaviour, role of distribution, promotion, MNC's. Marketing of credit-Nature of market, market segment, market players, marketing mix, marketing options. Strategies for input marketing-Client and location specific promotion, joint promotion, interdependence of input markets, management of demands, developmental marketing, usp, extension services, ethics in business, sustainability.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To enhance the understanding and analytical capabilities with respect to products, market environment, and operational issues in marketing of agricultural inputs.

IX. Suggested Reading

- Mahapatra. S. *Management of Agricultural Inputs*, NIPA Publishers
- Seetharaman SP.: *Agricultural Input Marketing,* Oxford & IBH Pub. Co.
- Krishnamacharyulu CSG. : *Rural Marketing: Text and Cases*, Pearson Education India Venugopal P. 2014. *Agri-input Marketing in India,* SAGE Publication; 1st Edition.

I. Course Title : Feed Business Management

II. Course Code : ABM 520

III. Credit Hours : 2+0

IV. Why this course?

It will help in gaining a deeper understanding of the production, processing and marketing of cattle feed, poultry feed and fish feed.

V. Aim of the course

The present course aims at familiarizing the participants with various aspects feed for livestock and poultry.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Feed resources 2. Nutrients requirements of livestock and poultry
2.	Feed Preparation and Distribution	1. Feed preparation 2. Importance of mineral mixture 3. Feed Distribution

VI. Theory

Block 1: Introduction

Unit 1: Feed resources: Gap between demand and availability of nutrients; status of feed industry in India and world, constraints in the development of Indian feed industry.

Unit 2: Nutrients requirements of livestock and poultry: Knowledge about the quality of feed ingredients used in feed manufacturing. Procurement procedure of feed ingredients, scientific storage of feeds and feed ingredients. BIS, CLAFMA and all other commercial standards of all class of livestock and poultry feeds.

Block 2: Feed Preparation and Distribution

Unit 1: Feed preparation: Layout and design of feed plants, feed plant management; Basic principles of processing of feeds, Feed preparation for cattle and poultry and as specialty feeds for aqua and pet animals.

Unit 2: Importance of mineral mixture: Feed additives, supplements and pass feed, to know the new technology regarding improving the feeding value of poor quality roughages. To acquaint the concept of silage technology, complete feed block technology, hydroponics technology and UMMB technology.

Unit 3: Feed Distribution: Distribution channels, regulations relating to manufacture and sale of feed stuffs.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To acquaint the students with the role and importance of feed industry and the production of feed for livestock and poultry.

IX. Suggested Reading

- Morrison FB. 1961. *Feeds and Feeding*, Abridged, Morrison Publishing; 9th edition John.
- Moran. 2005. Tropical Dairy Farming: Feeding Management for Small Holder Dairy Farmers in the Humid Tropics, Csiro Publishing.
- Moran J and McDonald S. 2010. *Feedpads for Grazing Dairy Cows,* Csiro Publishing.
- Kellems RO and Church DC. 2009. *Livestock Feeds and Feeding*, Pearson; 6th Edition

I. Course Title : Managmement of Veterinary Hospitals

II. Course Code : ABM 521

III. Credit Hours : 2+0

IV. Aim of the course

It will help in gaining a deeper understanding of the Veterinary Science is the science of *treating* and curing the diverse types of Animals.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Feed resources 2. Nutrients requirements of livestock and poultry
2.	Feed Preparation and Distribution	1. Feed preparation 2. Importance of mineral mixture 3. Feed Distribution

V. Theory

Block 1: Veterinary Hospital Administration

Unit 1: Needs, aims and objectives: Objectives of Veterinary hospitals; the existing and simulated situations under which veterinary hospitals work or are to work.
Unit 2: Designing and planning an ideal hospital: Optimizing the use of resources - human, space, equipment, drugs, time, capital, etc.; Materials management and problems Normal purchase procedure. Receipt; storage and distribution of materials Cost reduction & scientific inventory control. Information system and materials management performance. Equipment maintenance, condemnation & disposal.
Unit 3: Authority, responsibility: Accountability of management for optimizing the use of skill, developing and upgrading skills and technology; efficient system of record keeping and accounting; Concept of quality & Total quality management (TQM) Introduction to Veterinary audit, Statistical quality control (SQC), Quality control Circle (QCC).

Block 2: Information System & Quality Control

Unit 1: Hospital information system: Hospital information system as an aid to efficient controlling and monitoring; need for financial resources - investment and working capital; Records: Types & Methodology, Reports and Reporting system. Contemporary and need-based methods of accounting; General consideration. Need based information system. Applicability in surveillance & monitoring; planning & policy making; cost control.
Unit 2: Quality control system: Economic functions and quality control system; Animal health Economics: An introduction Need for financial resources (type and need). Investment planning and working capital; Budgeting and cost cutting (cost control). legal aspects in the functioning of the hospital.

VI. Learning outcome

The objective of this course is to acquaint the students about the designing, planning, organizing, and controlling the veterinary hospitals for optimizing the use of space, capital, skill and other resources.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

I. Course Title : Poutlry and Hatchery Management
II. Course Code : ABM 522
III. Credit Hours : 2+0

IV. Why this course?

This course introduces about updated production standards achievable under field conditions and financial viability of poultry operations. This specialized course is designed to train persons in Incubation and Hatchery Management and is meant for those engaged in or scheduled to take up Hatchery operations.

V. Aim of the course

To give the opportunity for trainees to learn about raising chickens for their meat and eggs in order to manage a small-scale, commercial poultry enterprise that will be profitable

The Course is organized as follows:

No	Blocks	Units
1	Introduction	1. Poultry and hatchery Business 2. Poultry and hatchery unit
2	Hatcheries and Risk Management	1. Incubation and hatching 2. Franchise hatcheries management 3. Personal management and insurance

VI. Theory

Block 1: Introduction to Poultry and Hatchery Industry

Unit 1: Poultry and hatchery Business: Poultry and hatchery industry; Present scenario of Poultry industry, Integration in poultry farming, Scope and future perspective, role of management in poultry industry.

Unit 2: Poultry and hatchery unit: Planning and establishing a poultry and hatchery unit- location, size and construction; farm and hatchery equipments and physical facilities; organizing and managing a poultry farm and hatchery.

Block 2: Hatcheries and Risk Management

Unit 1: Incubation and hatching Production of quality chicks and eggs; factors affecting hatchability; bio-securityand hatchery sanitation; handling of hatching eggs; maintaining chick quality-chick grading, sexing, packing, dispatch, transportation and chick delivery.

Unit 2: Franchise hatcheries management: Custom hatching; brooding; growing and laying management; crisis management; industrial breeding, feeding, housing and disease management; waste management; Record management; cost accounting and budgetary control.

Unit 3: Personal management and insurance: Labour relations including wages and salaries, job evaluation and employee appraisal; marketing management direct sale and sale through franchisees/ agents, advertisement, sale and after sale services, other innovative sales strategies.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

The course provides an insight into the importance of management in poultry industry, managing a poultry and hatchery enterprise, planning production of poultry products, financial, personnel and marketing management.

IX. Suggested Reading

- Handbook of Poultry Science.
- Rathinam GK. 2015. *Manual of Hatchery Management: For Poultry Professionals* Hardcover.

I. Course Title : **Management of Floriculture and Landscaping**
II. Course Code : **ABM 523**
III. Credit Hours : **2+0**

IV. Why this course?

It deals with the cultivation of flowers and ornamental crops from the time of planting to the time of harvesting. It also includes production of planting materials through seeds, cuttings, budding, grafting, etc, up to the marketing of the flower and flower produce.

V. Aim of the course

The objective of this course is to expose the students with floriculture and landscaping technologies and their Agri-business implications including international trade.

The Course is organized as follows:

No	Blocks	Units
1.	Management of Floriculture	1. Introduction 2. Indoor and ornamental plants
2.	Landscaping and Trading	1. Introduction 2. Landscape gardening 3. Value-addition in floriculture

VI. Theory

Block 1: Management Offloriculture

Unit 1: Introduction: Introduction, importance and scope of floriculture industry and landscaping; Recent advances in floriculture industry.

Unit 2: Indoor and ornamental plants: Raising of foliage plants in pots, production technology of ornamental plants, commercial cultivation of flower crops (rose, jasmine gladiolus, tuberose, marigold, aster, carnation, gerbera, cilium chrysanthemum; special techniques for forcing of flowers for export.

Block 2: Landscaping and Trading

Unit 1: Introduction: Drying and dehydration of flowers; bonsai; scope of landscaping, response of flowering plants to environmental stresses;

Unit 2: Landscape gardening: Styles of gardening; modern and traditional garden planning; Socio-aesthetic planning; use of computers in designing gardens; planning towns

Unit 3: Value Addition in floriculture: Extraction, purification and storage of essential oils and perfumes; post-harvest storage changes; packing techniques of produce harvesting of flowers for export and home use, Export-Import trade in flowers and their specifications along major trading countries.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

Students are suitable for it working independently and apply the latest trends to their work. They should be able to understand about floriculture and landscaping.

IX. Suggested Reading

- Banker N. 2011. *Landscape gardening*, IBDC publishers, Lucknow
- Misra RL and Misra S. 2012. *Landscape gardening*, Westville Publishing House, New Delhi
- Chadha KL and Choudhary B. 2006, *Ornamental Horticulture in India*. ICAR. New Delhi
- Grindal EW. *Every Day Gardening in India*. DB Tarporevala Sons.
- Randhawa GS and Mukhopadhyay A. 1998, *Floriculture in India*. Allied Publ., New Delhi

I. Course Title : Risk Management in Agri Business

II. Course Code : ABM 524

III. Credit Hours : 2+0

IV. Why this course?

Risk and uncertainities is involved in food and Agribusiness industries. Government to formulate policy that will encourage investors adopt the highlighted risk keeping in view priority of food security for rising population. The focus is to foster profitability in agri-allied sector.

V. Aim of the course

Identification, mitigation and management of risk is unique to agriculture-production, markets, finance, Institutions and HR. Policy implications at local, regional, national as well as international level. Data analysis and research findings to help in decision making at firm and industry levels using history to guide future events/projection, Degree of risk varies in agri-business compared to other sectors.

The Course is organized as follows:

No	Blocks	Units
1.	Risk Management process	1. Financial intermediation 2. Strategic Issues in Bank Marketing 3. Credit policy in banks
2.	Introduction to banking Operations and Risk Management	1. Banking operations 2. Definition of Risk and risk management techniques

VI. Theory

Block 1: Risk Management Process

Unit 1. Financial Intermediation, Indian Financial system, Origin and Growth of Banking. RBI and its functions. Principles of Banking, Banking Law and Practice. Nationalization of Banks in India, Deposit Products, Lending Activities, Retail Banking, Wealth Management, Financing SMEs, Corporate Banking, Forex Management, Fee-Based & Subsidiary Services, Plastic Money, Role of Central Banks, Emerging Trends in Banking, Fundamentals of International Banking.

Unit 2: Strategic Issues in Bank Marketing, Positioning Bank Services in the Market, New Product Development, Pricing and Launching, New Distribution Channels for Bank Marketing, Communicating and Promoting Bank Services, Improving Quality and Productivity, Customer Relationship Management in Banks, Globalizing Bank Services, Opportunities and Challenges in Bank Marketing.

Unit 3: Credit Policy in Banks, Principles of Credit Management, Objectives of Credit Management, Credit Disbursal and Monitoring, Credit Deployment and

Types of Borrowers, Follow up and Recovery Management, Treasury Operations, Introduction to Risk Management in Banks, Rural Banking in India, Security Considerations, Control System in Banks, Corporate Governance in Banks, Annual Reports and Statutory Audit.

Block 2: Introduction to Banking Operations and Risk Management

Unit 1: Introduction to Banking Operations, Front Office and Back Office Operations, Operational Controls, Demand Forecasting and Resource Allocation, Policy Framing – Deposits, Advances and Investments, Services Design and Delivery Strategies in Banks, Service Quality Metrics, Work Measurement and Quality Assurance, Payment and Settlement Systems, RTGS and Clearing House, Cash Management Services, Facilities Planning, ERP in Banks, BPR in Banks, IT Enabled Supply Chain Management, Disaster and Recovery Management.

Unit 2. Introduction to Risk, Risk Management Essentials, Measurement of Risk, Loss Exposure, Risk Management – Non-insurance Techniques, Introduction to Insurance, Principles of Insurance, Insurance Industry, Insurance Market, Insurance as Risk Management Techniques, Selection and Implementation of Risk Management Techniques.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

Developing an understanding of the different types of risk in general to agriculture sector and with special reference to agriculture business.

IX. Suggested Reading

- Sethi J and Bhatia N. 2012. *Elements of Banking and Insurance*. PHI Learning
- Jian W and Rehman A. 2016. *Risk Management in Agriculture: Theories and Methods.* Science Publishing group
- Hardaker JB, Huirne RBM, Anderson JR and Lien G. 2004. *Coping With Risk in Agriculture,* CABI Publishing, 2nd Edition
- Rose PS and Hudgins SC. 2006. *Bank Management & Financial Services.* Mcgraw-Hill College; 7th edition

I. Course Title : Management of Agribusiness Cooperatives

II. Course Code : ABM 525

III. Credit Hours : 2+0

IV. Why this course?

Proper management enables cooperatives to offer high quality, efficient and effective services to their members. Moreover, well managed agricultural cooperatives can also contribute to wider development issues such as food security, sustainable use of natural resources and inclusive employment creation.

V. Aim of the course

These cooperatives were usually initiated by small scale farmers, as a response to their weak position in the market. By joining forces they could improve this position and obtain better prices and services for the purchase of inputs and the marketing of produce.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Cooperative administration 2. Cooperative management
2.	Cooperative Movement and Management	1. Cooperative Movement 2. Human resource management 3. Overview of agribusiness cooperative

VI. Theory

Block 1: Introduction

Unit 1: Cooperative administration: Global perspective, ecology of cooperative administration, cooperative sector and economic development.

Unit 2: Cooperative management: Nature, functions and purpose of cooperatives –procurement, storage, processing, marketing, process of cooperative formation, role of leadership in cooperative management.

Block 2: Cooperative Movement and Management

Unit 1: Cooperative Movement: The state and cooperative movement, effects of cooperative law in management, long range planning for cooperative expansion, policy making.

Unit 2: Human resource management: Placement and role of board of directors in cooperative management.

Unit 3: Overview of agribusiness cooperative: Credit cooperatives, cooperative marketing, dairy cooperative; financing agribusiness cooperative.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To provide the students an understanding about the agribusiness cooperative organizations and their management.

IX. Suggested Reading

- Kamat GS. 2011. *New Dimensions of Cooperative Management*. Himalaya Publ. House.
- Ansari AA. 1990. *Cooperative Management Patterns*. Anmol Publ.
- Ravichandran and Nakkiran. 2009. *Cooperation* (*Theory & Practice*) Neha Publishers & Distributors;
- Sah AK. 1984. *Professional Management for the Cooperatives*. Vikas Publ. House.
- Anwar SA. *HRM Practise in Cooperative Sector*. Idea Publishing.

I. Course Title : Business Analytics for Agriculture

II. Course Code : ABM 526

III. Credit Hours : 1+1

IV. Why this course?

Analytics can enble farmers to make data-based decisions like which crops to plant for their next harvest. Reality as actionable insights to make decisions on data and information to improve agronomic opportunities, such as timing of applications, product decisions, amounts of products, and profitability of decision making.

V. Aim of the course

To make the students understand the concepts of data science tools and techniques and develop the skills for using it strategically and for the developing of the agri business sector.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Introduction 2. Fundamentals of Research
2.	Machine and Deep Learning	1. Supervised machine learning-1 2. Supervised machine learning-2 3. Deep learning

VI. Theory

Block 1: Introduction

Unit 1: Introduction to data science, evolution of data science, work profile of a data scientist, career in data science, nature of data science, typical working day of a data scientist, importance of data science in agribusiness; defining algorithm, big data, business analytics, statistical learning, defining machine learning, defining artificial intelligence, data mining; difference between analysis and analytics, business intelligence and business analytics, typical process of business analytics cycle.

Unit 2: Fundamental of Research

Fundamentals of R and RStudio, fundamentals of packages of RStudio, data manipulations, data transformations, normalization, standardization, missing values imputation, dummy variables, data visualization (2D and 3D), basic architecture of machine learning analytical cycle, descriptive analytics-case study covering data manipulation, measures of central tendency, measures of dispersion, measures of distribution, measures of associations, t-test, f-test, ANOVA, Chi-square test, basic statistical modeling framework.

Block 2: Machine and Deep Learning

Unit 1: Supervised machine learning: Basic framework, regression models and classification models. Linear regression, nonlinear regression, multiple regression, polynomial regression, lasso regression, ridge regression, stepwise regression, quantile regression, logistic regression.

Unit 2: Supervised machine learning: Linear discriminant analysis, principal component analysis, factor analysis, support vector machines, naïve Bayes, nearest neighbors, decision trees, random forest, ensemble methods, *k*-fold cross validation, X gradient boosting. Unsupervised machine learning—basic framework, concept of clustering, k-means, c-means, hierarchical clustering, hidden markov models, forecasting models (AR, MA, ARMA and ARIMA).

Unit 3: Deep learning: Basic framework of neural nets, types of neural nets, computer vision, object detection and localization, gradient descent optimization for loss function, regularization L1 and L2, feed forward neural nets, back propagation, recurrent neural nets, convolutional neural nets, reinforcement neural net, concurrent net, introduction to IoT. All the illustrations used in the syllabus of Data Science in Agribusiness will be primarily from agribusiness domains and RStudio will be used for practical purposes.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To equip students of agribusiness with knowledge, skills and attitude for using data science tools and techniques so that agribusiness get competent professionals who can strategically and successfully implement data science applications.

IX. Suggested Reading

- *Deep Learning with R*. MEAP Edition, Manning Early Access Program. Version 1, © 2017, Manning Publication.
- James RG, Witten D, Hastie T and Tibshirani R. 2017. *An Introduction to Statistical Learning with Application*. Springer Publication
- Millstein F. 2018. *Machine Learning With Tensorflow: A Deeper Look At Machine Learning With Tensor Flow* Frank Millstein
- Stanton J. 2012. *Introduction to Data Science*. Version 3, SAGE Publications, Inc.

I. Course Title : Dairy Business Management

II. Course Code : ABM 527

III. Credit Hours : 1+0

IV. Why this course?

The main objective of dairy management course is to provide basic input to students about production, planning and management of dairy farms, entrepreneurship development in milk preservation, entrepreneurship development in dairy processing and management of dairy farm, co-operative and industry.

V. Aim of the course

To emphasize on the application of Principles of Management in dairy business with special emphasis on co-operative dairy units. The emphasis shall be on main functional areas like Finance, Marketing, Human Resources, Production and Information Technology.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Introduction to commodity derivatives 2. Dairy Plant Management System
2.	Dairy Business Strategy:	1. Marketing Management, Supply Chain and International Trade in Dairy sector 2. Strategic, HR Management and Entrepreneurship in Dairy Sector 3. Financial Management and Financial Analysis in dairy sector

VI. Theory

Block 1: Introduction

Unit 1: Dairy Development in India: Dairy organizations: functioning, Challenges and Opportunities, Anand pattern dairy Cooperatives: features and impact; Public sector dairy schemes, Dairy Development schemes, Dairy problems and policies, National Dairy Plan-I, Rise of Producer Companies. Policy Frameworks in context to dairying.

Unit 2: Dairy Plant Management System: Production Planning and control in dairy plants, milk procurement from the rural milk producer, milk processing and products manufacturing. Pricing and marketing of milk and milk products. Survey on milk production potential and marketed surplus of milk for setting up of milk plants, energy utilization, Conventional and nonconventional sources of energy used in dairy sector. Concept of Quality; TQM concept and Kaizen in Dairy Industry, new concepts in quality assurance (HACCP; ISO certification); patent laws, pollution control laws in relation to dairy plants. Guidelines for obtaining ISO/HACCP certification for dairy plants. SQC in dairy operations.

Block 2: Dairy Business Strategy:

Unit 1: Marketing Management, Supply Chain and International Trade in Dairy sector: Marketing- mix in relation to dairy sector, marketing environment,. Marketing Opportunities Analysis in Milk and Milk Products: Demand status of Milk and milk products in the country, growth rates, Marketing research and marketing information systems; Market measurement present and future demand; Market forecasting. Market segmentation, Product-mix; Promotion mix decisions. Advertising; Sales Promotion. Food and Dairy Products Marketing, Consumer Buying Behaviour; New product development processPrice determination and pricing policyInternational Marketing Marketing; Composition & direction of Indian exportsExports- Direct exports, indirect exports; WTO and its Implications; SPS/TBT; Supply chain Management in Dairy sectorLogistics Management: Primary and Secondary Markets; Distribution channels; chilling points

Unit 2: Strategic, HR Management and Entrepreneurship in Dairy Sector: PESTLE analysis, BCG matrix, Strategic Management in dairy industry, Governance Structure in Dairy Sector, Management control System. Organisational Performance parameters – Quantitative and Financial, Use of Balanced Score card and other strategy control tools. HR management practices in dairy sector, Promotions, transfers employee remuneration and other HR benefits and problems. Motivation, turnover, employee capacity building, Training and orientation etc. social and business economics; industrial relations and human values; labour laws; trade unionism Business Plan Preparation; TIDP plant setting; Compliances Systems in Dairy Industry

Unit 3: Financial Management and Financial Analysis in dairy sector: Nature and uses of financial analysis, Liquidity ratios, Leverage ratios, Activity ratios, Profitability ratios, Utility of Ratio analysis. Sources of long term capital in dairy Industry: Grants from NDDB, Grants from NABARD, Government and Other Schemes, cost of debt, debentures, preference share capital, equity share capital & retained earnings, overall cost of capital. Capital budgeting in dairy Industry. Various techniques: NPV, IRR, etc. Financial Planning and control in dairy Industry: Budgeting process, Problems and practices in Budgeting and evaluation. Cost Volume

– Profit analysis and operating leverage, Break-even analysis, Profit analysis and operating analysis, Utility of CVP analysis. Costing in Dairy sector: Costing Techniques and Costing of various dairy products – Milk costing based on Fat and SNF, Ice cream, milk, Paneer, etc. Essentials of sound costing system. Different methods of costing, elements of cost: Labour- recording of time, idle time, methods of remunerating labour, Premium & Bonus Plans, Materials, Overheads.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

- To understand the overall scenario of dairy and develop insights in managing dairy as a entrepreneurial venture.
- To enhance the Decision making, Critical thinking and the problem solving capabilities of the students.
- To bring out the hidden potential and entrepreneurship aptitude of the students and also to encourage team building activities.

IX. Suggested Reading

- Acharya R M and Kumar P. *Dairy Production & Business Management* EIRI, Dairy Darming
- Rao Venkateswara, *Dairy Farm Busines Management*
- Singh Umashankar, *Dairy Farming*

I. Course Title : Agri Extension Management

II. Course Code : ABM 528

III. Credit Hours : 1+0

IV. Why this course?

To enhance the techno-managerial competence of extension functionaries and to acquaint the extension functionaries on the latest developments in the field of agricultural extension

V. Aim of the course

To equip the extension functionaries in latest tools and techniques for participatory decision making and to develop an insight into various extension models to enrich the agri - value chain

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Approaches of Agricultural Extension 2. Cyber Extension
2.	Implications and contemporary issues	1. Implications of WTO 2. Extension and contemporary issues

VI. Theory

Block 1: Introduction

Unit 1: Approaches of Agricultural Extension: A critical analysis of different approaches of agricultural extension. Importance and relevance of indigenous knowledge system, identification and documentation of ITK, Integration of ITK system in research formulation, Concept of Agricultural Knowledge and Information System, Training of Stakeholders of AKIS.

Unit 2: Cyber Extension: Concept of cyber extension, national and international cases of extension projects using ICT and their impact of agricultural extension, alternative methods of financing agricultural extension - Scope, limitations and experience and cases. Research -Extension -Farmer - Market linkage: Importance, Scope, Implications etc., Market – Led Extension, Farmer - Led Extension, Concept of Farm Field School, Farm School, Public - Private Partnership: Meaning, Models, Identification of various areas for partnership. Stakeholder's analysis in Extension. Main streaming gender in Extension - Issues and Prospects

Block 2: Implications and Contemporary Issues

Unit 1: Implications of WTO: OA for extension services, re-orientation of extension services for agri-business and marketing activities, GOI- NGO collaboration to improve efficiency of extension.

Unit 2: Extension and contemporary issues: Extension and issues related to rural poverty. Privatization of Extension. Intellectual Property Rights (IPRs). Extension Reforms in India –Decentralized decision making, Bottom up planning, Farming System and Situation based Extension Delivery System, Extension delivery through Commodity Interest Groups. Organization innovations in Extension - ATIC, IVLP, Kisan Call Centres.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

By the end of the course student will be able to critically analyze different Agricultural Extension approaches, understand Agricultural Knowledge Information System (AKISs) ITK, Understand Advances in Extension - Cyber extension, ICT enabled extension services; Market Led Extension, Public Private Partnership, Mainstreaming gender in extension organizational Innovations.

IX. Suggested Reading

- Bagchi J. 2007. *Agriculture and WTO Opportunity for India*.
- Sanskruti Chambers R, Pacy A and Thrupp LA. 1989. *FarmersFirst*. Intermediate Technology Publ.
- Crouch BR and Chamala S. 1981. *Extension Education and Rural Development*. Macmillan.
- John KC, Sharma DK, Rajan CS and Singh C. 1997. *Farmers Participation in Agricultural Research and Extension Systems*. MANAGE, Concept Publ. Co.
- Khan PM. 2002. *Text Book of Extension Education*. Himanshu Publ.
- Narasaiah ML. 2005. *Agricultural Development and World Trade Organization*. Discovery Publ.
- Talwar S. 2007. *WTO Intellectual Property Rights*. Serials Publ.
- Van den Ban BW and Hawkins BS. 1998. *Agricultural Extension*. S.K. Jain Publ.
- Venkaiah S. 2001. *New Dimensions of Extension Education*. Anmol Publ.

I. Course Title : Renewable Energy Sources Management

II. Course Code : ABM 529

III. Credit Hours : 1+0

IV. Why this course?

Renewable Energy Management will contribute to the promotion of renewable energy sources in countries, especially developing nations.

V. Aim of the course

The course aims to provide fundamental clarity regarding various renewable&alternative energy sources/ technologies options available today, its usage potential & related aspects like cost, impact on environment, etc.

The Course is organized as follows:

No	Blocks	Units
1	Introduction	1. Introduction 2. Commercial application
2	Implications and contemporary issues	1. Institutional Framework 2. Devices for renewable energy development

VI. Theory

Block 1: Introduction

Unit 1: Introduction: Concept on alternate and non-conventional energy sources. Biofuels, Geothermal, Ocean, Hydropower, Biogas, Solar and Wind energy.

Unit 2: Commercial application: Commercial application of renewable energy sources and its benefits. Government Policy towards promoting renewable energy.

Block 2: Institutional Framework and Types

Unit 1: Institutional Framework: MNRE, CREDA-Renewable Energy Development Authority, State level Renewable Energy Development Agency, Society of Renewable Energy.

Unit 2: Devices for renewable energy development: Biogas plant, Wind Mills, Solar Cells – Solar Pumps, Solar Dryers, Solar water heating system, etc.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To provide an insight to the meaning and concepts of Renewable energy resources development and Institutional support as well as Government policy framework.

IX. Suggested Reading

- Sorensen B. 2010. *Renewable Energy: Physics, Engineering, Environmental Impacts, Economics and Planning*, Elsevier Publishing; 4th Edition
- Armaroli N, Balzani V and Serpone N. 2013. *Powering Planet Earth–Energy Solutions for the Future*, Wiley
- Boyle G. 2012. *Renewable Energy: Power for a Sustainable Future*, Oxford; 3rd Edition
- Twidell J, Weir T. 2013. *Renewable Energy Resources,* CRC Press; 3rd Edition
- Ahmed AI. *Renewable Energy Sources* by Jain Brothers

I. Course Title : Quality Management for Agribusienss

II. Course Code : ABM 530

III. Credit Hours : 1+0

IV. Why this course?

The focus of the process is to improve the quality of organizations outputs, including goods and services, through continual improvement of internal practices

V. Aim of the course

The course will help the students to have an understanding of the quality standards in agribusiness.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Basic concepts of quality management 2. TQM
2.	Quality grades, standards and Control	1. Quality grades and standards 2. Statistical to quality control 3. Food quality standards

VI. Theory

Block 1: Introduction

Unit 1: Basic concepts of quality management: importance of quality and the role of quality assurance in agribusiness.

Unit 2: Total Quality Manangement: TQM and business strategy. Quality control process and its relevance.

Block 2: Quality Grades, Standards And Control

Unit 1: Quality grades and standards: Overview and relevance, benefits to consumers, producers and food processors, food grades and standards for various food commodities; cereals, fruits and vegetables, meats, poultry products.

Unit 2: Statistical to quality control: Statistics relevant to quality control, quality control charts used in the food industry, process control to assure food quality, food processing.

Unit 3: Food quality standards: Food quality standards and world food trade. HACCP, ISO9000, auditing and certification.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

The course will help the students to have an understanding of the quality standards in agribusiness.

IX. Suggested Reading

- Luning PA, Marcelis WJ. 2009. *Food Quality Management: Technological and Managerial Principles and Practices*. Wageningen Academic Publishers
- Dale BG. 2004. *Managing Quality*. Blackwell Resources

I. Course Title : Advertising and Brand Management
II. Course Code : ABM 531
III. Credit Hours : 1+0

IV. Why this course?

To impart basic understanding among the candidates about the advertising along with detailed aspects of brand management practices and techniques.

V. Aim of the course

It aims to ensure consistency of message and the complementary use of media. ... measurable, persuasive brand communication programs with consumers.
The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Introduction to Advertising Management 2. Message Strategy 3. Consumer Promotions and Trade Promotions
2.	Branding Decision	1. Major Brand Concepts and branding Decision 2. Managing Brand Equity and Loyalty

VI. Theory

Block 1: Introduction

Unit 1: Introduction to Advertising Management: Integrated Marketing Communications, Setting Goals and Objectives, How advertising works: Segmentation and Positioning Assess the strengths, weaknesses, opportunities and threats (SWOT) of different kinds of promotional campaigns
Unit 2: Message Strategy: Attention and comprehension, Advertising appeals, Associating Feelings with the Brand, Brand Equity, Image and Personality and Group Influence and word of month advertising, Media Planning and Media Strategy, Media Strategy and Tactics, Legal, Ethical and Social concerns of Advertising.
Unit 3: Consumer Promotions and Trade Promotions: Their purpose and types How to plan and evaluate a successful promotion, The relationship between advertising and promotions, Introduction to Global Marketing, Advertising and sales promotion.

Block 2: Branding Decision

Unit 1: Major Brand Concepts and branding Decision: Identifying and selecting brand name Building brand personality, image and identity; Brand positioning and re-launch; Brand extension; Brand portfolio; communication for branding Enhancing brand image through sponsorship and even management.
Unit 2: Managing Brand Equity and Loyalty: Brand Building in Different Sectors - Customers, industrial, retail and service brands. Building brands through Internet, social Media. Building Indian brands for global markets.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

This course investigates various promotional tools used in the communication mix, such as advertising, sales promotion, and publicity, to sell products and services. Concepts include: advertising planning processes, determining advertising and promotional goals and objectives, control and evaluation of advertising and promotional programs, and regulatory issues. Students will develop a comprehensive advertising campaign for a real or imaginary product.

IX. Suggested Reading

- Keller KL. *Strategic Brand Management;* Pearson education, New Delhi Verma, Harsha*: Brand Management;* Excel Books; New Delhi
- Kapferer JN. *Strategic Brand Management;* Kogan Page; NewDelhi
- Kumar S. Ramesh; *Marketing and Branding–The Indian Scenario;* Pearson Education; New Delhi Kapoor, Jagdeep; *24 Brand Mantras*, Sage Publications; New Delhi
- Sengupta S. *Brand Positioning: Strategies for competitive advantage*; Tata McGrawHill; New Delhi.
- Clifton R and Simmons J. *Brands and Branding*; The Economist; Delhi

I. Course Title : Agri Infrastructure and Waregousing Management

II. Course Code : ABM 532

III. Credit Hours : 1+0

IV. Why this course?

To create a pool of Agricultural storage infrastructure, logistics and warehouse professionals with capacity to manage agri-warehouse operations efficiently includes the overall inventory turnover and working capital management.

V. Aim of the course

The course provides an introduction to the key principles and activities related to the warehousing function in a modern organization designed for receiving, shipping, picking, packing etc. It also includes cold chain project, logistics awareness & training programs.

The Course is organized as follows:

No	Blocks	Units
1.	Introduction	1. Agricultural Infrastructure in India 2. Warehouse Functions: 3. Warehouse Types, Characteristics
2.	Warehouse Management	1. IT for Warehouse Management (WM): 2. Agri-warehousing Management in India

VI. Theory

Block 1: Introduction

Unit 1: Agricultural Infrastructure in India: Incentive schemes, Agri-infra fund, Agri-market Infrastructure, Agri-technological infrastructure fund, Central Government policy on Infrastructure promotion for the development of primary sector such as Irrigation, Watershed development, Rural electrification, Connectivity, Communication and Markets in coordination with the Institutional framework.

Unit 2: Warehouse Functions: Meaning of Warehousing - Importance –Functions:

Receiving: Logistics support for Inward Transportation, Unloading, Inspection, Acceptance and Recording; Storing: Space allocation, Facilitation to stocking, Guarding &Recording; Risk bearing- Processing- Grading and branding – Disinfecting services -Issuing: Order preparation, Picking, Dispatching/ Delivery & Recording- Handling, Transportation & Storage of ISO Containers– Utility and Advantages of warehouses- Problems and issues in receiving processes.

Unit 3: Warehouse Types, Characteristics: Warehouse Types, Characteristics of ideal warehouses- Warehouse Layout-Principles and Facilities- Types, Internal Operations: Measures and metrics of warehouse operations, Logistics in the warehouse- Localization of materials in a warehouse, Identification and classification of Materials and products in the warehouse, Managing the material/products turns in warehouse (FIFO/LIFO) - Problems and issues in shipment processes. Warehousing Equipment, Inventory management.

Block 2: Warehouse Management

Unit 1: IT for Warehouse Management (WM): Warehouse documentation-Information flows in the warehouse- ERP-WMS - Bar code – RFID- Organization Data- Warehouse Structure- Warehouse Master Data - WM Material master view-Organization Data- Define Warehouse structure, Warehouse number - Storage type- Storage section - Storage Bin - Picking Area -Storage unit – Quantity- Creating Transfer requirement automatically/ manually – Creating Transfer requirement for storage.

Unit 2: Agri-warehousing Management in India: Agri-warehousing in India, capacity development and utilisation, Role and significance of Central Warehousing Corporation, State warehousing Corporation, Private sector in Agri-warehousing. Status of Warehousing Industry:

Agri-warehousing organisations in India, e-NAM to promote agri-warehouse.

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To study the status of development of Agricultural infrastructure as well as the role of Warehouses to boost Agricultural sector.

IX. Suggested Reading

- Study materials of NABARD as well as by the Ministry of Rural development
- Edward F. 2001. *World-Class Warehousing and Material Handling,* McGrraw Hill
- Jeroen P. Van Den Berg. 2009. *Integral Warehouse Management*, Management Outlook Max Muller. 2009. *Essentials of Inventory Management*. AMACOM
- Steven M. Bragg. 2011. *Inventory Best Practices*. Wiley

I. Course Title : Contract Farming

II. Course Code : ABM 533

III. Credit Hours : 1+0

IV. Why this course?

To assess the need of Contract farming arrangement . It relates to agricultural production carried out according to an agreement between a buyer and farmers, with set conditions for production and marketing of farm products.

V. Aim of the course

The course provides an agreement between a farmer and a buyer. At the same time, the buyer also needs to provide the farmer with the necessary inputs required for the farm like land preparation, technical aspects etc. It is an effective means to develop markets and bring about crop rotation.
The Course is organized as follows:

No	Blocks	Units
1	Introduction	1. Need for contract farming 2. Project formulation and management
2	Policies, prospects and global issues	1. Policies for promoting contract farming 2. Prospects of contract farming in India 3. Global issues

VI. Theory

Block 1: Introduction

Unit 1: Need for contract farming: objectives and its definition; contract farming framework, contract farming arrangement-centralized model, nucleus estate model, multipartite model, informal model, intermediary model.
Unit 2: Project formulation and management: Coordination, crop husbandry, human resource. Advantages of contract farming for farmers and sponsors and the problems faced by them.

Block 2: Policies, Prospects And Global Issues

Unit 1: Policies for promoting contract farming: Agreement for contract farming-parties, duration, produce and quality specification, delivery arrangements pricing, insurance, support services, etc.
Unit 2: Prospects of contract farming in India: Prospects of contract farming in India in view of interest for commercialization of agriculture. Active organizations in contract farming and their success stories.
Unit 3: Global issues: lobal issues in contract farming, Contract farming and WTO agreement

VII. Teaching methods/activities

- Lecture and Discussion
- Case Study
- PPT presentation

VIII. Learning outcome

To provide the students an understanding of concepts, policies, strategies and decisions relating to marketing that can be associated with agribusiness organizations. It involves agricultural production being carried out on the basis of an agreement between the buyer and farm producers. The farmer undertakes to supply agreed quantities of a crop or livestock product, based on the quality standards and delivery requirements of the purchaser.

IX. Suggested Reading

- Sharma P. 2007, C*ontract Farming*, Genetech Books

- Kuzilwa JA, Fold A, Henningsen A and Larsen MN. *Contractfarming and the development of smallholder* agricultural business. Routledge
- Kumaravel KS 2006. *Contract farming in India* - An Introduction.

I. Course Title : Human Resource Competence and Capacity Building Systems

II. Course Code : ABM 534

III. Credit Hours : 1+0

IV. Why this course?

Capacity development is the process by which individuals and organizations obtain, improve, and retain the skills, knowledge, tools, equipment and other resources needed for Human resource development.

V. Aim of the course

This course is designed to provide an in-depth understanding and enable the participants to manage capacity building processes and performance system for developing human resource.

The Course is organized as follows:

No	Blocks	Units
1	Introduction	1. Human Resource competence 2. Competency modelling and assessment
2	Capacity building	1. Competency based training and development 2. Performance Management System 3. Capacity building systems in agriculture and agri business

VI. Theory

Block 1: Introduction

Unit 1: Human Resource competence: Concept and rationale; processes, Organization and Management of competence and competency mapping.

Unit 2: Competency modelling and assessment: Approaches, tools and techniques, competency based human resource management applications.

Block 2: Capacity Building

Unit 1: Competency based training and development: Training methods compared with objectives, learning process and facilities, Developing Group and the Climate: the social process – indicators of group development, the training climate, Trainers And Training Style: Post training support for improved performance at work.

Unit 2: Performance Management System: Establishing and operationalising performance management system; measuring performance- results and behaviour; conducting performance review discussions; harnessing performance management system for performance improvement.

Unit 3: Capacity building systems in agriculture and agri business: Capacity building of farmers and agri stakeholders through e-learning, knowledge management for agri business.

VII. Teaching methods/activities

- Lecture and Discussion

- Case Study
- PPT presentation

VIII. Learning outcome

Proactive human resources management is essential to achieve the excellence through Capability Development and Planning. A Competence Profile for Staff Supporting the formal and informal training, job-rotation, traditional class-room courses, internal vs external training.

IX. Suggested Reading

- Kandula SR. 2013. *Competency Based Human Resource Management*. PHI
- Noe RA and Kodwani AD. 2012. *Employee Training and Development*. McGraw Hill Education. Fifth Edition
- Saks AM and Haccoun RR. 2013. *Managing Performance through Training and Development*. Cengage Learning. Sixth Edition

I. Course Title : Agri-Commodity Markets and Futures Trading

II. Course Code : ABM 535

III. Credit Hours : 1+0

IV. Aim of the course

To make the students understand the marketing procedure for commodity futures through commodity exchanges

The course is organized as follows:

No	Blocks	Units
1.	Overview of Commodity Market in India	i. Price risk management in agricultural markets ii. Global Specifications of futures contracts
2.	Mechanics of futurestrading	i. Option and forward transaction ii. Clearinghouse and margin system
3.	Market surveillance and risk control	i. trading in warehouse receipts ii. Regulation of futures and trading practices in leading national and regional exchanges in India

V. Theory

Block 1: Overview Of Commodity Market In India

Unit I: Introduction to commodity derivatives and price risk management in agriculturalmarkets; organizational setup of exchanges and specifications of futures contracts in world's leading commodity exchanges

Block 2: Mechanics of Futures Trading

Unit II: Futures trading; hedging price risk using futures contracts; option transaction andforward transaction – concept and mechanism, price discovery mechanism and market efficiency

Unit III: Clearinghouse and margin system; clearing, settlement and delivery of contracts

Block 3: Market Surveillance and Risk Control

Unit IV: Market surveillance and risk control; trading in warehouse receipts (WRs):

WRs andcollateralized commodity financing

Unit V: Regulation of futures and trading practices in leading national and regional exchangesin India.

VI. Teaching methods/activities

- Lectures
- Live projects
- Assignments (Individual and Group)
- Presentations about the ethical practices of the firms in India
- News paper analysis about the contemporary issues

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Get an overview about the commodity markets in India
– Understand the mechanics of futures trading practices
– Know about the risk and surveillance mechanism available for agri commodity trading in India

VIII. Suggested Reading

- Hull, John C. 2017. *Fundamentals of futures and options markets*, Boston, Pearson publication.
- Ram PV and Bala SD. 2016. *Strategic Financial Management*. Snow White Publ. 80.

I. Course Title : Strategic Management for Agri Business Enterprises

II. Course Code : ABM 536

III. Credit Hours : 2+0

IV. Aim of the course

The objective of this course is to provide students a strategic orientation in conduct of the business and to develop a holistic perspective of an organization and to enable the students to analyse the strategic situation strategies in general and functional management areas.

The course is organized as follows:

No	Blocks	Units
1.	Overview of Strategic Management	1. Strategic management process 2. Environment scanning and industry analysis 3. Value Chain Analysis
2.	Strategy Formulation and Choice	1. Strategy formulation 2. Types of strategies 3. Strategic analysis tools and techniques
3.	Strategy implementation and control	1. Strategy implementation and control 2. Entrepreneurial ventures and small businesses

V. Theory

Block 1: Overview Of Strategic Management

Unit I: Introduction - Concepts in Strategic Management, Strategic Management Process; Corporate Governance, Social Responsibility and Ethics in strategic management, Environment Scanning and Industry analysis

Block 2: Strategy Formulation And Choice

Unit II: Organization appraisal and strategy formulation: organizational dynamics andstructuring organizational appraisal, business models and Value chain analysis, Strategy formulation- corporate level strategies and business strategies, Generic Strategies- Types of Strategies, tools and techniques for strategic analysis.
Unit III: Turnaround and Diversification Strategies: Turnaround strategy - Management ofStrategic Change, Strategies for Mergers, Acquisitions, Takeovers and Joint Ventures - Diversification Strategy

Block 3: Strategy Implementation And Control

Unit IV: Strategy implementation and control: aspects, structures, design and change: behavioural implementation-leadership, culture, value and ethics, strategic evaluation and control-an overview and techniques of strategic evaluation and control.
Unit V: Strategic issues in managing technology & innovation, entrepreneurial ventures andsmall businesses, Cases in strategic management

VI. Teaching methods/activities

- Lectures
- Live projects
- Assignments (Individual and Group)
- Presentations about the ethical practices of the firms in India
- News paper analysis about the contemporary issues

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Define the strategic management process and scanning of internal and external environment
- Get a clear picture about value chain analysis
- Understand the different types of strategic choices available and the method of analysis to choose the best among them
- Learn the method of strategic implementation and evaluation for agr entrepreneurial ventures

VIII. Suggested Reading

- Wheelen TL and Hunger JD. 2012. *Strategic Management & Business Policy, towards Global Sustainability*, Pearson India Edn. Thirteenth Edition
- David FR and David FR. 2016. Strategic Management, Concept and Cases, Pearson India Edn, Fifteenth Edition
- Thompson Jr. AA, Peteraf M and Gamble JE. 2015. *Crafting and Executing Strategy*. McGraw Hill, Irwin.
- Stead JG and Stead EW. 2014, *Sustainable Strategic Management*. Routledge Taylor & Francis Group.
- Kazmi Azhar. 2015. Strategic Management. Mcgraw Higher Ed. 4th Edition
- Srinivasan R. 2014. Strategic Management. PHI Learning 5th Edition

I. Course Title : Operations Management
II. Course Code : ABM 537
III. Credit Hours : 2+0
IV. Aim of the course

To acquaint the students with the applications of important operations research

techniques for better understanding to solve business problems.
The course is organized as follows:

No	Blocks	Units
1.	Introduction to Linear Programming	1. Formulation of Linear Programming problem 2. Methods of solving linear programming problem 3. Transportation and Assignment problems
2.	Inventory control and waiting line models	1. Types of inventory and inventory costs
3.	Decision making under risk and uncertainty	1. Decision problem 2. Decision trees

V. Theory

Block 1: Introduction to Linear Programming

Unit I: Linear Programming: Objective, Assumptions, Formulation of Linear Programming Problem, Data Envelopment Analysis, Graphic Method, Simplex method, Introduction to Dynamic Programming, Transportation and Assignment Problems.

Block 2: Inventory Control And Waiting Line Models

Unit II: Inventory control Models: Costs Involved in Inventory Management, Types of Inventory, Economic Order Quantity (EOQ) Model, Continuous Review (Q) System, Periodic Review (P) System, and Hybrid System.

Unit III: Waiting Line Models: Waiting Line Problem, Characteristics of a Waiting-Line System, Single- Channel Model, Multiple-Channel Model, Constant-Service Time Model, Finite Population Model, Sequencing and Replacement models.

Block 3: Decisionmaking Under Risk and Uncertainty

Unit IV: Decision making under Risk and uncertainties, Decision problem, Maximax Criterion, Maximin Criterion, Minimax Regret Criterion, Laplace Criterion, Pay off Tables, Decision Trees, Expected Value of perfect Information, stochastic models, neural networks, Markov process.

Unit V: Game Theory - Two -Person Zero-Sum Game, Simulation, Network analysis– PERT& CPM. Financial Engineering

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Knowledge and understanding about the characteristics of different types of decision-making environments and the appropriate decision making approaches and tools to be used in each type.
– Develop cognitive skills (thinking and analysis) to build and solve Transportation Models and Assignment Models

VII. Suggested Reading

- Taha HA. 2007. *Operations Research - An Introduction*. Prentice Hall.
- Vohra ND. 2017. *Quantitative Techniques in Management*. 5th Edition McGraw Hill.
- Wagner HM. 2005. *Principles of Operation Research*. Prentice Hall.

I. Course Title : Financial Management in Agribusiness
II. Course Code : ABM 538
III. Credit Hours : 2+0

IV. Aim of the course

To impart trainings to the students regarding various aspects of sources of financing agribusiness.

The course is organized as follows:

No	Blocks	Units
1.	Financial management in India	1. Agribusiness Financing in India 2. Risk and return concept and analysis 3. Money and Capital Markets 4. International financial management
2.	Capital budgeting	1. Techniques of capital budgeting decision 2. Cost of Capital 3. Sources of Long and Short term finance
3.	Current assets management	1. Management of Working Capital 2. Perspectives and operational aspects of Micro finance

V. Theory

Block 1: Financial Management In India

Unit I: Meaning, importance, nature and scope of financing in India, agribusiness financing inIndia; classification and credit need in changing agriculture scenario; finance functions, investment financing, Risk and return concept & analysis

Unit –II: Business Financing System in India, Money and Capital Markets, Regional and All -India Financial Institutions; venture capital financing and its stages, International financial management.

Block 2: Capital Budgeting

Unit III: Features, types and Techniques of capital budgeting decision. Cost of Capital, Leverage analysis, Capital structure. Theory and Policy, Sources of Long and Short term finance, Dividend Theory, Dividend Policy.

Block 3: Current Assets Management

Unit IV: Management of Working Capital, Management of Receivables, Management of cash; Cash budget, Management of collections and disbursement, Investment of Surplus cash.

Unit V: Perspectives and operational aspects of Micro finance**:** Definition, Scope andimportance of Micro Finance, Evolution of Micro Finance in India, Micro Finance credit lending models: - Association model, Community Banking model, Credit union model, Co-operative model, SHG model, Village Banking model.

VI. Teaching methods/activities

- Lectures
- Live projects
- Assignments (Individual and Group)
- Presentations about the ethical practices of the firms in India
- News paper analysis about the contemporary issues

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:
– Understand the financial management practices in India
– Know about the concepts capital budgeting and cost of capital
– Understand the major sources of financing in India and their implications for a agri-based organization

VIII. Suggested Reading

- Nelson AG & Murrey WG. 1988. *Agricultural Finance*. Kalyani Publ.
- Gordon and Natarajan. 2016. *Financial Markets and Services*. Himalaya Publishing House; Tenth Edition
- Machiraju HR. 2010. *Indian Financial System*. Vikas Publishing House
- Pandey IM. 2015. *Essentials of Financial Management*, Vikas Publishing House
- Khan and Jain. 2014. *Financial Management*. McGraw Higher Education
- Srivastav and Misra. 2010. *Financial Management*, Oxford University Press; Second edition
- Reddy GS. 2010. Financial Management, Himalaya Publishing House

I. Course Title : Communication for Management and Business
II. Course Code : ABM 539
III. Credit Hours : 3+0

IV. Aim of the course

The course aims to make students proficient in written as well as in oral communication with focus on business related communication.
The course is organized as follows:

No	Blocks	Units
1.	Introduction to Business Communication	1. Communication process, barriers and methods 2. Types of business communication 3. Developing listening skills 4. Non verbal communication
2.	Reading and writing skills	1. Reading Comprehension and techniques 2. Business writing skills 3. Messages for electronic media
3.	Oral and visual communication Technical writing skills	1. Oral presentation skills 2. Public speaking skills
4.	Team and Interpersonal communication	1. Effective Interpersonal Communication 2. Business etiquettes 3. Problem solving skills 4. Case method of learning

V. Theory

Block 1: Introduction to Business Communication

Unit I: Communication process, barriers to communication, methods of communication, effective communication, assertive communication, types of organisational communication. Listening skills, active listening, barriers to effective listening, Non Verbal Communication

Block 2: Reading And Writing Skills

Unit II: Reading comprehension and techniques, rules of good writing, business letter writing, e-mail writing, crafting messages for electronic media, social media, business blogs, podcasts, employment messages

Block 3: Oral, Visual Communication and Technical Writing

Unit III: Visual presentation, oral presentation skills, conducting business meetings, brainstorming sessions and presentations, public speaking skills, Communicating across cultures, Various forms of scientific writings, theses, technical papers, reviews, manuals, research work, various parts of thesis and research communication Title page, authorship, contents, preface, introduction, review of literature, material and methods, experimental results and discussion, Technical Writing Style and Editing, Writing Introductions & Conclusions, Editing and Proof reading, Writing a review article and book summary

Block 4: Team And Interpersonal Communication

Unit IV: Developing interpersonal skills (transactional analysis), Business Etiquettes, essentials of business conversations. Business meeting agenda and minutes, circulars and sales letters, notices, overview of business proposals

Unit V: Developing self awareness (Johari Window), solving problems analytically andcreatively, introduction to case method of learning, case reading, approaches and analysis

VI. Teaching methods/activities

- Interactive sessions to make the participants practice communication skills
- Group and individual presentations followed by feedback
- Live projects to study the challenges faced in the organsiational communication setup
- Make the participants practice communicating on social media platforms to write blogs, make and upload videos
- Self awareness assessment based questionnaires
- Case studies to develop interest and understanding of solving real life situation analytically and creatively

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the concepts of business communication
– Practice listening, reading writing and presentation skills
– Develop clarity about the method of handling team and interpersonal communication effectively

VIII. Suggested Reading

- Cardon PW. 2015. *Business Communication, Developing leaders for a networkedworld* Mc Graw Hill Edication
- Chaturvedi PD and Chaturvedi M. 2017. *Business Communication, Skills, Concepts, Cases and Applications*, Pearson India Education
- Bovee CL, Thill JV and Chaterjee A. 2013. *Business Communication Today*, Pearson Education, Tenth Edition

I. Course Title : Research Methodology for Agri Business Management

II. Course Code : ABM 540

III. Credit Hours : 3+0

IV. Aim of the course

To develop an understanding of research methodology related to efficient agri business management

The course is organized as follows:

No	Blocks	Units
1.	Overview of research	1. Research methodology in management 2. Scales of measurement 3. Questionnaire designing
2.	Use of softwares for statistical analysis	1. Multivariate statistical analysis 2. Evaluation metrices 3. Forecasting Techniques
3.	Data science in agriculture	1. Introduction to data science in agriculture 2. Overview of deep learning and machine learning 3. Concept of cloud machine learning

V. Theory

Block 1: Overview of Research

Unit I: Meaning, Course Objective, types, and process of research; research methodology inmanagement- exploratory, descriptive, experimental, diagnostic, Problem formulation, setting of Course Objective, formulation of hypotheses, models, types of models, process of modeling.

Unit II: Scales of measurement - nominal, ordinal, interval, ratio, Likert scale and other scales; Primary and secondary data, sources of data, Questionnaire Designing, instruments of data collection, data editing, classification, coding, validation, tabulation, presentation, analysis, development process of scale, identification of variables, variable measurement, variable standardization and dummy variables.

Block 2: Use of Softwares for Statistical Analysis

Unit III: introduction to multivariate statistical analysis techniques, Multivariate linearregression models, principal component analysis, linear discriminant analysis, factor analysis, evaluation matrices and model diagnostics for regression models.

Unit IV: Logistic regression, decision trees, cluster analysis, random forest, GARCH, CARTmodels, support vector machines, Forecasting techniques (AR, MA, ARMA and ARIMA models)

Block 3: Introduction to Data Science

Unit V: Definition, scope and importance, machine learning, types of machine learning, linearand nonlinear models in machine learning, introduction to deep learning, basic differences in machine learning and deep learning, concept of cloud machine learning, Big data analysis.

VI. Teaching methods/activities

- Interactive lectures

- Group assignments
- Presentations
- Live projects for marketing research problems
- Case study on application of marketing research tools

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Understand research methodology concepts along with its application in marketing research
- Develop insights about the statistical analysis tools and techniques for better research outcomes
- Understand the concept of and usage of data science, big data analysis for agriculture

VIII. Suggested Reading

- Cooper DR and Schindler PS. 2006. *Marketing Research Concepts and Cases*. TMH
- Kumar R. 2014. *Research Methodology,* Sage publications, 4th Edition
- Glenn JC. 2010. *Hand book of Research Methods.* OXFORD.
- Kothari CR. 2018. *Research Methodology- Methods and Techniques.* New Age International Publishers; Fourth edition

I. Course Title : Computer Applications for Agri Business

II. Course Code : ABM 541

III. Credit Hours : 3+0

IV. Aim of the course

The course aims to instill the significance of computer applications in the organizations and handling recent trends in information technology and system for improved decision making

The course is organized as follows:

No	Blocks	Units
1.	Basics of computers	1. Concept of computers 2. System and application softwares 3. Data base management system
2.	Business value of internet	1. Cloud computing 2. Cyber security and ethical challenges
3.	Management Information System	1. Concept of MIS 2. Introduction to Artificial Intelligence 3. E-commerce agri business trends

V. Theory

Block 1: Basics Of Computers

Unit I: Concept of Computers- Brief History of Computers, Generation and Its Evolution, Characteristics of Computers, Main Areas of Computers and their Applications; Classification of Computers, Input-Output Devices, Memory Types (Cache, RAM, ROM), Memory Units,

Unit-II: System Software and Application Software, Open source software, introduction tocomputer languages, Introduction to Operating Systems – Functions, Features and Types., MS Windows and LINUX. Data Base Management System, MS Office (MS Word, MS Power Point, MS Excel, MS-Access and use of various management software Like SPSS, SAS etc.

Block 2: Business Value Of Internet

Unit III: The business value of internet, Intranet, extranet and Internet, Introduction to Web page design using HTML, Cloud Computing, Security and ethical challenges: Computer crime – Hacking, cyber theft, unauthorized use at work. Piracy – software and intellectual property. Health and Social Issues, Ergonomics and cyber terrorism.

Block 3: Management Information System

Unit IV: The concept of MIS–Definition, importance, Course Objective, pre-requisites, advantages and challenges; Information Needs of organization, MIS and Decision – Making. Types/Classification of Information System for organizations; Introduction to Artificial Intellignce (AI), Neural Networks, Fuzzy logical control systems.

Unit V: e-business/ e-commerce: e-business models, e-commerce processes, electronic paymentsystems, e-commerce trends with special reference to agri business. Applications of MIS in the areas of Human Resource Management, Financial Management, Production/Operations Management, Materials Management, Marketing Management.

VI. Teaching methods/activities

- Lectures
- Practicals
- Live project
- Assignments
- Presentations

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the fundamentals of computers
– Get a clearer idea about the application of Information technology in agri business management
– Use of e commerce, artificial intelligence and MIS for improved decision making in management

VIII. Suggested Reading

- Laudon KC and Laudon JP. 2016. *Management Information Systems- Managingthe digital Firm,* 14h Edition, Pearson India
- Turban, Volonino, Woods. Wali OP. 2015. *Information Technology for Management, Advancing Sustainable, Profitable Business Growth*, Wiley
- Jaiswal M and Mittal M. 2005. Management Information System, Oxford.

I. Course Title : Project Management and Agribusiness Entrepreneurship

II. Course Code : ABM 542

III. Credit Hours : 2+1

IV. Why this course?

This course aims at providing student an insight into the nature of small scale industry. They will be exposed to various aspects of establishment and management of a small business unit.

The course is organized as follows:

No	Blocks	Units
1.	Concept of Project Management	1. Introduction to project management 2. Project feasibility 3. Network methods and project scheduling
2.	Introduction to Agri Entrepreneurship	1. Concept of agri entrepreneurship 2. Creativity, Innovation and Agro Entrepreneur
3.	Support System for Agri Entreprenuership	1. Sources of Financing for entrepreneurs 2. Preparation of Detail Project Report 3. Structure and Government Policy Support

V. Theory

Block 1: Concept of Project Management

Unit I: Concept, characteristics of projects, types of projects, project identification, and Project's life cycle. Project feasibility- market feasibility, technical feasibility, financial feasibility, and economic feasibility, social cost-benefit analysis, project risk analysis.

Unit II: Network Methods: Meaning, Network Analysis, Critical Path Method (CPM), Programme Evaluation and Review Technique (PERT), Project scheduling and resource allocation. Financial appraisal/evaluation techniques- discounted/non-discounted cash flows; Net present values, profitability index, Internal rate of returns; Cost benefits ratio; Accounting rate of return, Payback period, Project implementation; Cost overrun, Project control and information system.

Block 2: Introduction to Agri Entrepreneurship

Unit III: Concept of Agri Entrepreneurship**:** Objective, Introduction to agri entrepreneurship, Entrepreneurial Development Models, Successful Models in Agro Entrepreneurship Intrapreneur, Development of women entrepreneurship with reference to SHGs, Social entrepreneurship

Unit IV: Creativity, Innovation and Agro Entrepreneur: Inventions and Innovation, The Environment and Process of Creativity, Creativity and the Entrepreneur, Innovative Approaches to Agro Entrepreneurship, Business Incubation, Steps and Procedure to start a new business, Business Opportunities in different field of Agriculture and Allied Sectors.

Block 3: Support System For Agri Entreprenuership

Unit V: Sources of Financing, Structure and Government Policy Support: Estimating FinancialRequirements, Preparation of Detail Project Report, Project Appraisal, Sources of Long-Term Financing, Working Capital Financing, Venture Capitalist, Finance from Banking Institutions, Industrial Policy Resolutions in India, Incentives and Subsidies, Schemes for Incentives, Government Organisations like SIDO, DIC, KVIC, NSIC, SIDBI, NABARD and their role, Sick Industries and their Up gradation policy measures

VI. Teaching methods/activities

- Interactive lectures

- Live project in association with innovative farmers/ agri entrepreneur
- Cases related to agri entrepreneurship
- Guest lectures by bankers, entrepreneurs, academicians and venture capitalist firms
- Assignments
- Presentations of Agri Business Plans

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Understand the fundamentals of project management
- Develop a understanding of agri entrepreneurship opportunities and challenges
- Understand the method of developing a agri based venture through the support system available in the Indian scenario

VIII. Suggested Reading

- Arora R and Sood SK. *Fundamentals of Entrepreneurship and Small BusinessManagement*. Kalyani Publishers, Ludhiana.
- Desai V. 2016. *Business Planning and Entrepreneurial Management*, Himalaya Publishing House, Mumbai.
- Ramachandaran K. *Managing a New Business Successfully*. Global Business Press, New Delhi.
- Shukla MB. *Entrepreneurship and Small Business Management*. Kitab Mahal, New Delhi.
- Dandekar VM and Sharma VK. 2016. *Agri-Business and EntrepreneurshipDevelopment*. Manglam Publications, New Delhi.
- Zimmerer TW, Scarborough NM. *Essentials of Entrepreneurship and small Business Management,* 5thEdition, PHI Learning Pvt Ltd
- Panigrahi SR and Singh B. 2017. *Agro Entrepreneurship*. Scientific Publishers(India)

I. Course Title : Agribusiness Environment and Policy

II. Course Code : ABM 543

III. Credit Hours : 2+0

IV. Aim of the Course

To expose the students to the environment in which the agri-business is conducted. The course is organized as follows:

No	Blocks	Units
1.	Agribusiness in India	1. Agri business environment in India 2. Major sub sectors of agri business in India
2.	Economic reforms affecting agri-business	1. Policies and regulations affecting agri business in India 2. WTO Agreement on Agriculture and its compliances
3.	Emerging trends in agri Business	1. Reforms in agri output markets 2. International trade in agri business 3. Food safety and quality management

V. Theory

Block 1: Agribusiness in India

Unit I: Role of agriculture in Indian economy; Problems of agriculture in India;

Agribusiness–definition and nature, Structure of Agriculture and linkages among sub-sectors of the agribusiness.

Block 2: **Economic Reforms Affecting Agri Business**

Unit II: Economic reforms: liberalization, privatization and globalization specifically affectingAgri Business; WTO Agreement on Agriculture and its compliances; changes in policies and regulations related to the sub sectors of agribusiness and its impact on agribusiness in India.

Block 3: Emerging Trends in Agri Business

Unit III: Emerging trends in farm supplies, farm production, agricultural finance, agroprocessing, international trade etc.; reforms in agri output markets: private markets, contract farming, futures trading in agri commodities and e-NAM, etc. Pricing of agricultural outputs, public distribution system, imports and exports.

Unit IV: Importance of food safety and quality management in agri business; Environmentalissues and including carbon markets and Clean Development Management etc.

Unit V: Other major issues: Intellectual property rights, importance of cooperative or collectiveactions in present scenario with examples of mergers and acquisitions, Farmers Producer Organisations, etc.

VI. Teaching methods/activities

- Lectures
- Role plays
- Case studies as group assignment
- Presentations
- Assignments
- Live projects

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Develop an understanding about the role and problems agriculture and agri business is playing in the Indian economy
– Critically evaluate the major economic reforms that have directly or indirectly affected agri business in India
– Understand the emerging trends and challenges in the field of agri business

VIII. Suggested Reading

- Barnard FL, Akridge JT, Dooley FL, Foltz JC and Yeager EA. 2012. *Agribusiness Management*, Routledge, 4th Edition
- Aswathappa K. 2014. *Essentials of Business Environment*. Himalaya Publ.
- Francis Cherunilam 2003. *Business Environment*. Himalaya Publ.
- Kodekodi GK and Viswanathan B. 2009. *Agril. Development, Rural Institution & Economic Policy*, Oxford.

I. Course Title : Agri Business Laws and Ethics

II. Course Code : ABM 544

III. Credit Hours : 2+0

IV. Aim of the course

The objective of this course is to expose the learner to various ethical issues and laws affecting business. Focus will be on understanding provisions of various business laws with reference to agriculture and also ethical practices to conduct the business properly.

The course is organized as follows:

No	Blocks	Units
1	Indian Legal System	1. Indian Contract Act 3. Companies Act
2.	Regulatory environment for agri-business	1. Essential Commodities Act 2. Consumer Protection Act
3.	Business ethics	1. Ethics in agri business functional areas 2. Governance mechanism

V. Theory

Block 1: Indian Legal System

Unit I: Introduction to Indian legal system, The Indian Contract Act-1872: Contract meaning, types of contract, essentials of a valid contract, offer and acceptance, capacity to contract, free consent, performance of contract.

Unit-II: Law of Negotiable Instruments: Promissory Notes, Bills of Exchange, Cheques and Bank Drafts, Endorsements, Law of Sale of Goods, Sales of Goods Act-1930-: Sale and agreement to sale, types of goods, Transfer of property in goods, mode of delivery of goods, performance of contract of sales, rights of an unpaid seller.

Unit III: Companies Act-1956: incorporation, commencement of business, types of companies, management of company, Memorandum of Association and Articles of Association, prospectus, winding of companies.

Block 2: Regulatory Environment For Agri Business

Unit IV: Essential Commodities Act, Consumer Protection Act, RTI Act, MRTP Act- majorprovisions and implications. Competition Act-2002, Regulatory environment for International Business

Block 3: Business Ethics

Unit V: Nature and importance of ethics and moral standards; corporations and socialresponsibilities, scope and purpose of business ethics; Ethics in business functional areas; industrial espionage; solving ethical problems; governance mechanism. implementing business ethics in a global economy

VI. Teaching methods/activities

- Lectures
- Live projects
- Assignments (Individual and Group)
- Presentations about the ethical practices of the firms in India
- News paper analysis about the contemporary issues

VII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Learn about the Indian legal system that directly affects the agri business in India
– Know about the regulatory framework in which the agri business is to be conducted and managed
– Understand the importance of practicing business ethics

VIII. Suggested Reading

- Mathur SB. 2010. *Business Law*. Tata McGraw Hill Edn. Pvt Ltd.
- Gulshan SS and Kapoor GK. 2003. *Business Law including Company Law*. 10th Ed. New Age Publ.
- Kapoor ND. 2005. *Business Law*. S. Chand & Sons.
- Tuteja SK. 2005. *Business Law for Managers*. S. Chand & Sons.
- Tulsian PC and Tulsian B. 2015. *Business Law*. TMH, New Delhi.
- Singh Avtar. 2017. *Contract and Specific Relief,* Eastern Book Company; Twelfth edition
- Pathak A. 2015. *Legal Aspects of Business*. McGraw Hill Education. 6th Edition

Course Title with Credit Load
Ph.D. in Agri-Business Management

Course Code	Course Title	Credit Hours
	Major Courses	**12**
ABM 601	Econometrics for Agri Business	3 (2+1)
ABM 602	Research Methods I	3 (2+1)
ABM 603	Agri Input & Output Marketing	3 (2+1)
ABM 604	Research Methods II	3 (2+1)
	Minor Courses	**6**
ABM 605	Natural Resource Management	2+0
ABM 606	Knowledge Management	2+0
ABM 607	Value Chain Management in Agribusiness	2+0
	Supporting Courses	**5**
ABM 608	Agri-Entrepreneurship and Corporate Governance	1+0
ABM 609	International Food and Agri Business	2+0
ABM 610	Communication for Management Teachers	0+2
	Seminars	**2**
	Doctoral Seminar I	1(1+0)
	Doctoral Seminar II	1(1+0)
	Research	**75**
	Total	**100**

Course Contents
Ph.D. in Agri-Business Management

I. Course Title : Econometrics for Agri-Business

II. Course Code : ABM 601

III. Credit Hours : 2+1

IV. Aim of the course

The course is mainly designed to solid data base analysis of market and policy variables to back up their business strategies. The emphasis will be given on application rather than theoretical details.

The course is organized as follows:

No	Blocks	Units
1.	Formulation and specification of econometric models	1. Simple Regression Analysis 2. Properties of Regression Coefficients and Hypothesis Testing 3. Multiple Regression Analysis 4. Heteroscedasticity 5. Stochastic Regressors and Measurement Errors 6. Simultaneous Equations Estimation
2.	Estimation and testing of models	1. Modelling Dynamic Processes 2. Autocorrelation 3. Logit and Probit (binary choice models)

V. Theory

1. Introduction: Correlation theory, Basic concept of regression analysis, assumptions of regression model, theory of OLS, properties of least square estimates, maximum likelihood, hypothesis testing, interval estimation, prediction in linear regression model.
2. Heteroskedasticity and autocorrelation, multicollinearity, specification errors, selection of regressors, dummy variables, autoregressive and distributed models.
3. Set of regression equations, casuality and simultaneity: application.
4. Time series econometrics- stationarity, unit roots and co-integrassion, error-correction model, AR, MA, ARMA, ARIMA processes.
5. Qualitative dependent variables – LPM, Logit and probit models.

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Acquire the basic knowledge of econometrics

– Learn the basics of econometric models and testing its application in the agri business environment

VII. Suggested Reading

- Gujarati, Damodar, *Basic Econometrics*, McGraw-Hill Company
- James H. Stock and Mark W. Watson: *Introduction to Econometrics*, Pearson Education

I. Course Title : Research Methods-I

II. Course Code : ABM 602

III. Credit Hours : 2+1

IV. Aim of the course

The objective of the course is to enable research scholars in developing the knowledge and skills required to specify, evaluate and utilise different types of unstructured and semi-unstructured information. They are required to develop competence in problem formulation, hypothesis generation and method of carrying scientific research in situations where research work plays a critical role. The course is practical in nature and students are expected to learn by doing live projects and studying the latest researches in different fields related to agri business.

The course is organized as follows:

No	Blocks	Units
1.	Overview of Research Methodology	1. Research process 2. Problems and Hypotheses 3. Processing and analysis of data
2.	Introduction to business analytics	1. Types of Business Analytics 2. Introduction to predictive modelling/analytic

V. Theory

Block 1: Overview of Research Methodology

Unit 1: Translating problems to research issues: Selection of qualitative vs quantitative research definitions, objectives, research methodologies rationale, sample/sources of data, data collection techniques, Questionnaire designing: use of measurement and scaling techniques, reliability testing.

Unit 2: Fieldwork: Data collection, gaining access and entry, ethical considerations, identifying key informants, validation and evaluation of fieldwork, data preparation, field notes and recording

Unit 3: Hypothesis Development and Theoretical Modelling. Business Analytics, Business Intelligence,

Block 2: Introduction To Business Analytics

Unit 4: Types of Business Analytics, Introduction to predictive modelling/analytics. Linear programming, Contemporary applications of marketing research

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Learn about the basics of research methodology
- Understand the application of research for problem solving related to agri business environment

I. Course Title : Agri Input and Output Marketing

II. Course Code : ABM-603

III. Credit Hours : 2+1

IV. Aim of the course

Agricultural Input & Output marketing is a dynamic and competitive field where lot is to be done looking to the gap in technology existing and possible. Changes are taking place in manifolds ranging from farming practices to trading in domestic and international markets. Presence of private players, infrastructure development, impact on prices, concept of e mandietc are becoming more important to understand in current scenario. Scholars will also study the researches and articles to understand interesting changes going on in this field.

The course is organized as follows:

No	Blocks	Units
1.	Introduction to agri input and out marketing environment	1. Current status of agri input and output markets in India 2. Marketing mix for agri inout and output marketing
2.	Evaluation of marketing costs and efficiencies	1. Assessment of different cost components 2. Case studies on various marketing strategies adopted by national and global players

V. Theory

Block 1: Introduction to Agri Input and Out Marketing Environment

Unit 1: Agriculture input and output marketing environment-Current status, trends, market structure, infrastructure, competition, Government intervention in agricultural inputs and outputs marketing

Unit 2: Buyers/users behavior, Market Segmentation, Product and Pricing, Promotion and advancement in promotional strategies, Marketing Channels for different agri inputs and outputs

Block 2: Evaluation of Marketing Costs and Efficiencies

Unit 3: Evaluation of marketing costs and efficiencies, WTO and Indian Agriculture, Case Studies- Competitive marketing strategies and advancements in agricultural marketing, International agri marketing practices

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Develop a understanding about the existing practices of agri input and output marketing in India
– Acquire a deep learning about assessing the marketing cost and related efficiencies to make the agricultural marketing profitable

I. Course Title : Research Method-II

II. Course Code : ABM 604

III. Credit Hours : 2+1

IV. Aim of the course

Once the students are equipped with the information required for interpretive research,

RM II will train the students with advanced analytical tools and their uses.
The course is organized as follows:

No	Blocks	Units
1.	Hypothesis testing	1. Analysis of variance and covariance 2. Multidimensional scaling and conjoint analysis
2.	Data Mining, Data Mining Methods	1. Data Mining Methods 2. Business Process Discovery
3.	Applications of Statistical Softwares	1. Modelling with statistical softwares, Report preparation and presentation

V. Theory

Block 1: Hypothesis Testing

Unit 1: Hypothesis testing, Analysis of variance and covariance, Correlation and regression, Discriminant and Logit analysis, Factor analysis, Cluster analysis, Multidimensional scaling and conjoint analysis.

Block 2: Data Mining

Unit 2: Data Mining, Data Mining Methods—Data Dredging, Data Fishing, Data Snooping and Process Mining—Business Process Discovery, Conformance Checking and Model Enhancement. Arena Modelling.

Block 3: Applications of Statistical Software

Unit 3: Applications of Statistical Softwares like SAS, Modelling with statistical softwares. Report preparation and presentation, International Marketing Research.

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:
- Understand the concepts of hypothesis testing
- Learn the application of statistical analysis softwares by hands on experience in agri business problem solving methods

VII. Suggested Reading

- Cohen L, Lawrence M and Morrison K. 2005. *Research Methods in Education* (5th edition). Oxford: Oxford University Press.
- Denscombes M. 2010. *The Good Research Guide: For small-scale social research projects*. Maiden-Read: Open University Press.
- Dornyei Z. 2007. *Research Methods in Applied Linguistics*. Oxford: Oxford University Press.
- Kothari CR. 1980. *Research Methodology: Research and Techniques*, New Delhi: New Age International Publishers.
- Kumar R. 2011. *Research Methodology: a step-by-step guide for beginners* (3rd edition).
- Singh YK. 2006. *Fundamental of Research Methodology and Statistics*. New International (P) Limited, Publishers, New Delhi.

I. Course Title : Natural Resource Management

II. Course Code : ABM 605

III. Credit Hours : 2+0

IV. Aim of the course

The course on Natural Resource Management will provide indepth knowledge to the participants to look for ways to make responsible natural resource management decisions which will have an impact on all stakeholders.

The course is organized as follows:

No	Blocks	Units
1.	Introduction to natural resources	1. Types and classification of natural resource 2. Economic resource theory and applications
2.	Overview of Natural Resource Management	1. NRM sectors product marketing and their roles 2. Concept of environmental services 3. Ecotourism Policy and practices

V. Theory

Block 1: Introduction To Natural Resources

Unit-I Natural resources: Types and classification of natural resource, concept of Economic value, relevance of environmental economics, ecosystems services, direct and indirect economic benefit from – forest ecosystems, mountain ecosystems, mineral and water resources, ecotourism. Valuation and accounting: Supply and demand, conservation and management, cost/ benefit analysis, methods of costing, cost criteria, evaluating alternative projects, operational vs. total costs, determining benefiting vs. comprehensive stakeholders Application of resource accounting Methods of pricing resources- example forest and mineral resources.

Unit-II Economic resource theory and applications: Concept of CPR, open access, Ecological economics-methodology, economic valuation of non market benefits, environmental accounting, population resources and the environment, command and control vs. emission trading, emission trading vs. exposure trading, hotelling principle, future strategies for mineral resources.

Block 2: Overview of Natural Resource Management

Unit-III Natural Resource Management: Initial concept of market and marketing, NRM sectors product marketing and their roles, promoting NRM products- NTFPs, livestock, watershed, fisheries, agriculture and medicinal plants and ecotourism, Role of national and international organizations in the promotion of sustainable natural resource use and management.

Unit IV: Concept of environmental services: Definitions, ecotourism, alternative examples, development of ecotourism in India and outside. Threats due to large scale ecotourism. Payment for Ecosystem Services, the ecotourism dilemmas: High value may also be high impact, bulk ecotourism and problems, stakeholder challenges, tourist carrying capacity. Ecotourism Policy and practices, national policy frame work, example – Madhya Pradesh & Uttarakhand State case. Successful ecotourism initiative, Criteria and Indicators for sustainable Ecotourism.

VI. Suggested Reading

- Barber E. 1989. *Economics: Natural Resources Scarcity and Development*. Earthscan.
- Harris JM. 2006. *Environmental and Natural Resource Economics: A Contemporary Approach*, 2nd edition. Houghton Mifflin
- Field Barry C. 2008. *Natural Resource Economics: An Introduction*. Waveland Press.
- Honey Martha. 2008. Ecotourism and Sustainable Development: Who Owns Paradise? 2 nd edition. Island Press. 2. Seema Bhat & Syed Liyakhat 2008. Ecotourism Development in India: Communities, Capital and Conservation published by CEE, Ahmedabad

I. Course Title : Knowledge Management

II. Course Code : ABM 606

III. Credit Hours : 2+0

IV. Aim of the course

The objective of the course is to provide the basics of the emerging area of Knowledge Management to students. This course throws light on few important concepts as Knowledge management and Information Technology, Knowledge process, etc.

The course is organized as follows:

No	Blocks	Units
1.	Introduction to knowledge management	1. The Knowledge Economy 2. Knowledge Management and Information Technology
2.	Future of Knowledge Management and Industry perspective	1. Knowledge process 2. Implementation of Knowledge Management:

V. Theory

Block 1: Introduction to Knowledge Management

Unit 1: The Knowledge Economy: Leveraging Knowledge, Data-Information-knowledge-Wisdom relationship, organizational knowledge, characteristics and components of organizational knowledge –Building knowledge societies- Measures for meeting the challenges of implementing, KM programmes.

Unit 2: Knowledge Management and Information Technology: Role Information Technology in Knowledge Management Systems, Knowledge Management tools, Creative effective Knowledge Management Systems through Information Technology, ERP and BPR, Data Warehousing and Data Mining.

Block 2: Future of Knowledge Management and Industry Perspective

Unit 3: Future of Knowledge Management and Industry perspective: Companies on the road to knowledge management, Knowledge Management in Manufacturing and service industry, challenges and future of Knowledge Management.

Unit 4: The Knowledge Process: Universal appeal, Stages of KM Process, Knowledge Capital vs physical capital, Customer Relationship Management, Business Ethics And KM, The Promise of Internet and the Imperatives of the new age.

Unit 5: Implementation of Knowledge Management: Discussion on Roadblocks to success, Business Intelligence and Internet platforms, web Portals, Information Architecture: A three-way Balancing Act, KM, the Indian experience, Net Banking in India. –Role of knowledge Management in Organisational Restructuring. -The Mystique of a Learning Organisation.

VI. Suggested Reading

- Mattison: *Web Warehousing and Knowledge Management*, Tata McGraw-Hill,2009
- Becerra Fernandez: *Knowledge management: An Evolutionary view*, PHI, 2009
- Fernando: *Knowledge Management*, Pearson, 2009
- B. Rathan Reddy: *Knowledge management*, Himalaya, 2009
- Tapan K Panda: *Knowledge Management*, Excel, 2009.
- Barnes: *Knowledge Management systems*, Cengage, 2009.

- Tiwana: *The Knowledge Management tool kit*, 2/e, Pearson Education, 2009.
- Warier: *Knowledge Management*, Vikas Publishing House, 2009
- Sislop: *Knowledge Management*, Oxford University Press, New Delhi, 2009
- Debowski: *Knowledge Management*, Wiley Student Edition, Wiley India, 2007

I. Course Title : Value-Chain Management in Agribusiness

II. Course Code : ABM 607

III. Credit Hours : 2+0

IV. Aim of the course

To recognize the characteristics of Global Food Systems, the multiple variables impacting Global Food Systems, to identify value chain thinking and how it differs from supply chain thinking, the characteristics of agri-food markets, what influences their supply and demand, and what sets them apart from other markets, the role played by external factors such as population and income growth, globalization, climate change, technology, and international tradein global food systems, agribusiness and value chains, to recognize the role the consumer plays in the food system, markets, and value chains

V. Theory

Unit 1: Global Food Systems and Value-Chains

Characteristics of global food systems; identify the variables impacting global food systems; identify value chain thinking and how it differs from supply chain thinking; identify the role that external factors (for example, population and income growth, globalisation, climate change, technology and international trade) play on global food systems, agribusiness and value chains; and identify the actors in, and characteristics of, value chains, demonstrated with the building of a value chain model.

Unit 2: Agribusiness Market Dynamics

Characteristics of agri-food markets, what influences their supply and demand, and what sets them apart from other markets; identify the role that external factors, such as population and income growth, globalisation, climate change, technology and international trade, play on agri-food markets; interpret the key elements of supply and demand; andrecognise the basic characteristics of supply and demand curves.

Unit 3: The Role of the Consumer

Role the consumer plays in the food system, markets and value chains; recognise the consumer characteristics, trends and behaviours that influence value chains; and recognise some of the techniques used in market and consumer researchto better understand consumer behaviour.

VI. Suggested Reading

- Acharya SS and Agarwal NL. 2011. *Agricultural marketing in India*. Oxford and IBH.
- Altekar RV. 2006. *Supply Chain Management: Concepts and Cases*. PHI
- Chopra S, Meindl P and Kalra DV. 2016. *Supply chain management: Strategy, Planning, and Operation*, Pearson Education India
- Mohanty RP. 2010. *Indian Case studies in Supply Chain Management and other Learning Resources*. Oxford.
- Chandrasekaran N. 2010. *Supply Chain Management: Process, system and Practice*. Oxford.

- Singh Sukhpal. *Organic Produce Supply Chains in India-organisation and governance*. Allied Publ.

I. Course Title : Agri Entrepreneurship and Corporate Governance

II. Course Code : ABM 608

III. Credit Hours : 1+0

IV. Aim of the course

The course aims to make students understand the nature of ntrepreneurship, and acquaint the students with challenges of starting new ventures and enable then to investigate, understand and internalize the process of setting up a business. Objective is also to enlighten them with the importance of Corporate Good Governance and Business Ethics.

The course is organized as follows:

No	Blocks	Units
1.	Agri Entrepreneurship and Feasibility Studies	1. Nature of Entrepreneurship 2. Starting the venture 3. Functional plans and Sources of finance
2.	Introduction to Business Ethics and Corporate Governance	1. Business Ethics 2. Corporate Governance

V. Theory

Block 1: Agri Entrepreneurship And Feasibility Studies

Unit I: Nature of Entrepreneurship: Concept, knowledge, skills requirement and functions; characteristic of successful entrepreneurs; ; scenario in India and Abroad, entrepreneurship process; factors impacting emergence of entrepreneurship; managerial vs. entrepreneurial approach and emergence of entrepreneurship, Risk Reduction strategies

Unit 2: Starting the venture: generating business idea – sources of new ideas, methods of generating ideas, SWOT Analysis, environmental scanning, competitor and industry analysis; feasibility study – market feasibility, technical/operational feasibility, financial feasibility; drawing business plan; preparing project report; presenting business plan to investors.

Unit 3: Functional plans: marketing plan – marketing research for the new venture, steps in preparing marketing plan, contingency planning; organizational plan – form of ownership, designing organization structure, job design, manpower planning; Financial plan – cash budget, working capital, proforma income statement, proforma cash flow, proforma balance sheet, break even analysis.

Unit 4: Sources of finance: debt or equity financing, commercial banks, venture capital; financial institutions supporting entrepreneurs, Government Grants and Subsidies, Entrepreneurship Promotion Schemes of Department of Industries (DIC), KVIC, SIDBI, NABARD, NSIC, APSFC, IFCI and IDBI etc.; legal issues – intellectual property rights patents, trademarks, copy rights, trade secrets, licensing; franching.

Block 2: Introduction To Business Ethics And Corporate Governance

Unit 5: Necessity for Business Ethics- Salient Issues in Ethics and Commerce-

Shadow Economy – Basic Principles in Ethics –Corporate Climate and corporate climate audits – Political Issues – Nature and theory of Ethics, Corporate Governance- Historical perspective and issues of Corporate Governance –Corporate Governance mechanisms – Corporate Governance Models, – The confederation of Indian Industry's initiative.; Corporate Social Responsibility

VI. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Understand the concept of agripreneurship and its application for starting a new venture
– Learn the basics of making functional plans like marketing, production and financial
– Acquire the knowledge about business ethics and corporate governance

VII. Suggested Reading

- Robert Hisrich Michael Peters Dean Shepherd Entrepreneurship 10th Ed 2016 by McGraw-Hill Education
- Vasanth Desai: *Entrepreneurship*, HPH, 2011.
- David Martin: *Corporate Governance*, Viva, 2010.
- Nandan H: *Fundamentals of Entrepreneurship*, PHI, 2013.
- Barringer: *Entrepreneurship*, Pearson, 2015.
- RK Mishra, Gitarani: *Corporate Governance*, Excel, 2012.
- V. Balachandran and V. Chandrasekaran: *Corporate Governance & Social Responsibility*, PHI, 2009.
- A.C. Fernando: *Business Ethics*, Pearson, 2009.
- Laura P Hartman and Abha Chatterjee: *Business Ethics*, TMH, 2009.
- Tripat Kaur: *Values and Ethics in Management*, 2/e, Paragon International, 2009.

I. Course Title : International Food and Agri Business

II. Course Code : ABM 609

III. Credit Hours : 2+0

IV. Aim of the course

The objective of the paper is to acquaint the students with the fundamentals of international business, its environment and complexities. The paper provides exposure to multiple dimensions of the field and imparts international perspective to business decisions.

The course is organized as follows:

No	Blocks	Units
1	Global trends in International trade	1. Structure of IB environment 2. Global financial system,
2	Global manufacturing and material management	1. International product life cycle, product and branding decisions; 2. Export assistance and incentives in India 3. Harmonizing accounting difference across countries 4. Ethical dilemmas and social responsibility issues

V. Theory

Block 1: Global Trends In International Trade

Unit I: Global trends in international trade and finance; dimensions and modes of IB; structure of IB environment; risk in IB; organizational structure for IB; world trading system and impact of WTO; exchange rate systems; global financial system; barriers to IB; international business information and communication.

Unit II: Foreign market entry strategies; country evaluation and selection; factors affecting foreign investment decisions; impact of FDI on home and host countries; types and motives for foreign collaboration; control mechanisms in IB.

Block 2: Global Manufacturing and Material Management

Unit I: Decisions concerning global manufacturing and material management; outsourcing factors; managing global supply chain; International product life cycle, product and branding decisions; managing distribution channels; international promotion mix and pricing decisions; counter trade practices; mechanism of international trade transactions. EXIM policy of India. Export costing and pricing, Export procedures and export documentation. Export assistance and incentives in India.

Unit II: Harmonizing accounting difference across countries; currency translation methods for consolidating financial statements; the LESSARD-LORANGE Model; cross cultural challenges in IB; international staffing decisions; compensation and performance appraisal of expatriate staff; ethical dilemmas and social responsibility issues.

I. Course Title : Communication for Management Teachers

II. Course Code : ABM 610

III. Credit Hours : 0+2

IV. Aim of the course

Communication in management education is not limited to classroom teaching. There are lot of innovative techniques to make teaching and learning interesting, practical and effective. There are various researches are done for methodological and effectiveness aspects. This course will be dealt understanding all the methods of communication for management teaching in learning by doing method and presenting the various researches done in this field.

The course is organized as follows:

No	Blocks	Units
1.	Management education	1. Action gaps in education and latest developments and required skills
2.	Theory and techniques of communication in management	1. Active listening, group communication 2. Emotional perspective in teaching 3. Learning in management education
3.	Case teaching and writing	1. Writing a case and teaching note, Critiquing a research article

VI. Theory

Block 1: Management Education

Unit 1: Management education: Action gaps in education and latest developments and required skills

Block 2: Theory and Techniques of Communication in Management

Unit 1: Communication: Active listening, group communication, Language process Presentation on readings- recorded and graded: Oral presentation & computer assisted presentations

Unit 2: Theory and techniques: Didacticism, Group work & discussion method, Simulation, facilitation skills and styles for experiential learning. Emotional perspective in teaching

Unit 3: Learning in management education: Experiential learning, Action Learning, Group learning, Simulation and games, Role Play, Teaching and learning through Electronic Media

Block 3: Case Teaching and Writing

Unit 1: Case method of teaching: Writing a case and teaching note, Critiquing a research article

Restructured and Revised
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- Biochemistry
- Microbiology
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Contents

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Dr Anupama Singh
Dr Amitava Bhattacharya
Agricultural Chemicals

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Basic Sciences
– Agricultural Chemicals

Preamble
(Agricultural Chemicals)

Agricultural chemicals, generally referred to as pesticides, play a vital role in sustaining agriculture productivity by controlling insect pests and diseases that damage field crops and food commodities during cultivation, transport and storage. In addition, they stimulate plant growth, enhance agri-input (water and fertilizer-N use) efficiency to increase farm productivity, and control pests of veterinary and public health importance. The Discipline of Agricultural Chemicals is multidisciplinary as it is linked to various agricultural and basic science disciplines like Entomology, Plant Pathology, Nematology, Toxicology, Weed Science, Environmental Science, Chemistry, Biochemistry, Microbiology, and Soil Sciences & Agricultural Chemistry. Due to the excessive use/ misuse of inherently toxic pesticides, environmental scientists and ecologists from time to time raise concerns about theirharmful effects on humans, domestic animals and the environment. However, since benefits outweigh risks,agricultural chemicals will continue to play a leading role in crop protection.

The world is witnessing huge scientific, technological, digital and socio-economical transformation necessitating nations to launch new initiatives for their development and growth. With emphasis on the holistic education, the new National Education Policy (NEP) declared by the Government of India is aimed at bringing about sea changes in higher education. It will not only transform India into a global knowledge superpower, but will also help it achieve United Nations Sustainable Development Goal-4 aimed at ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all.

Global warming and climate change has posed significant challenges to food security. Changes in crop-pest and host-pathogen complexions haveresulted in minor pests becoming major, and have increased the instances of pest resurgence and resistance development in insect pests and pathogens. In last ten years significant advances have been made globally in the field of crop protection and agricultural chemicals in particular. New molecules with novel chemistries and modes of actions are being developed and registered globally. With change in focus from pest kill to pest control, old generation highly toxic and persistent pesticides are being replaced with new generation reduced risk pesticides with novel chemistries and modes of action. These developments have necessitated restructuring of the course curriculum of the Discipline of Agricultural Chemicals at the Master's and Doctoral level to enable students undertake research in the emerging areas of agrochemical R & D, formulation technology, as well as foodand environment safety through chemical, biochemical, biotechnological and nano-technological interventions. The in-depth understanding of the subject will empower students, researchers, farmers and other stakeholders to take informed decisions about safe use of pesticides in crop and environment protection

In the discipline of Agricultural Chemicals, 20 post-graduate courses have been comprehensively restructured after modification of the existing courses. Of these, 12 are M.Sc. and 8 are Ph.D. courses. Course numbered AC-503,AC-504, AC-505, AC-506, and AC-510 (15 credits) will be compulsory for the M. Sc. students, and the courses numbered

AC-601 and AC-602 (7 credits) will be compulsory for the Ph.D. students. The coursenumbered AC-501 and AC-502 have been designed for students from outside the discipline, and courses AC-503, AC-504, AC-505 and AC-602 may be joint interdisciplinary courses. The doctoral degree level courses (AC-601 to AC-605) are advanced and research oriented.

Basic Chemistry (AC-503) course has been consolidated after clubbing Basic Chemistry I and II courses and modifying/ updating the entire course content. Natural Product Chemistry (AC-504) course has been designed as a new course with more emphasis on metabolomics, health-benefitting nutraceuticals,phytoceuticals,natural antioxidants and food colorants, polymers, enzymes and other natural products for industrial and other applications. The course on Agrochemical Regulation, Quality Control and Management (AC-505) and Pesticide Residue Chemistry (AC-510) have been completely revamped by incorporating provisions of Food Safety and Standards Act 2006 and Rules 2011, Pesticide Management Bill (2017), ecological and consumer risk assessment, and MRL fixation as per the national/ international guidelines. In view of the recent advancements, new topics on acaricides, termiticides, management of resistance in insects, fungi and weeds, NABL accreditation of *laboratories,* and national/international guidelines on good agricultural practices (GAP), and good laboratory practices (GLP) have been added in the revised syllabus. New crop protection concepts like development and use of entomopathogenic nematodes, entomopathogenic fungi, plant inhabited fungal endophytes, nanotechnology, biotechnologyand plant incorporated protectants have also been introduced in the revised syllabus,

Practical content in the designed courses requires modern equipment for extraction, separations, chemical characterization, structure determination, synthesis, and analysis of pesticide residues in food commodities and in soil and aquatic environment. For better research and teaching capabilities, obsolete equipment(s) need to be replaced with new ones like GLC, HPLC, GC-MS-MS, LC-MS-MS, particle size analyzers etc. Additional funds may be required for purchasing such equipment and their spare parts and supplies. Thus, a one-time grant of Rs. 5 crores with a recurring contingency of Rs. 20 lacs per annum will be needed to effectively run Master's and Doctoral programmes in ICAR-IARI/SAUs where the courses of Agricultural Chemicals are taught.

Course Title with Credit Load
M.Sc. (Ag) in Agricultural Chemicals

Course Code	Course Title	Credit Hours
AC 501	Introduction to Agrochemicals	2+0
AC 502	Chemical Laboratory Techniques	1+2
AC 503*	Basic Chemistry	3+1
AC 504*	Natural Product Chemistry	2+1
AC 505*	Agrochemical Regulation, Quality Control and Management	2+0
AC 506*	Agrochemicals for Insect Mite and Termite Management	2+1
AC 507	Agrochemicals for Disease Management	2+1
AC 508	Agrochemicals for Weed and Crop Management	2+1
AC 509	Chromatographic and Spectroscopic Techniques	2+1
AC 510*	Pesticide Residue Chemistry	2+1
AC 591	Master’s Seminar	1+0
AC 599	Master’s Research	30

*Core courses

Course Contents
M.Sc. (Ag) in Agricultural Chemicals

I. Course Title : Introduction to Agrochemicals
II. Course Code : AC 501
III. Credit Hours : 2+0

IV. Why this Course?

Pesticides and allied agrochemicals are required for the management of pests of agriculture, veterinary and public health importance. Since pesticides are inherently toxic, their excessive use has led to the residues detrimental to human health and the environment. This interdisciplinary course provides introductory knowledge to students about the use of crop protection chemicals in pest control.

V. Aim of the Course

To provide basic information about crop protection chemicals, their production/ consumption and trade statistics, and adverse impact of these chemicals on human health and the environment.

The course is organized as follows:

No.	Blocks	Units
1.	Agrochemical use and Trade Statistics	1. Agrochemicals and Pest Management 2. Pesticide Production, Consumption and Trade Statistics
2.	Different Group Pesticides	1. Botanical and Biopesticides 2. Synthetic Pesticides
3.	Pesticides Formulation	1. Solid and Liquid Formulations 2. Role of Adjuvants in Pesticide Formulations
4.	Pesticide Residues, their Adverse Effects and Safe Disposal	1. Pesticide Residues in Food and the Environment 2. Adverse Effect of Pesticides on Non-target Organisms 3. Safe Disposal of Pesticides

VI. Theory

Block 1: Agrochemicals and Trade Statistics

Unit 1: Agrochemicals and Pest Management

Definition of pests and pesticides, Synthetic and natural plant protection chemicals – history and classification, House-hold pesticides, Non-pesticidal agrochemicals like nitrification inhibitors, chemical hybridizing agents, hydrogels, soil conditioners, and plant growth stimulants, Pesticide toxicity ($LD_{50,}$ $LD_{90,}$ LC_{50}, EC_{50}, I_{50}),Pesticide antidotes. Safety precautions in pesticide application, Introduction to integrated pest management (IPM).

Unit 2: Pesticide Production, Consumption and Trade Statistics

Pesticide production and consumption in India and other countries, Pesticide export and import

Block 2: Pesticide Groups

Unit 1: Botanical and Biopesticides

History of botanical and biopesticide use, Structure, properties, and use of conventional botanical insecticides - nicotine, pyrethrins, rotenones and neem limonoids. Plant allelochemicals, Biopesticides and bioagents.

Unit 2: Synthetic Pesticides

History of synthetic pesticide use, Structure, properties, and uses of insecticides-organochlorines, organophosphates, carbamates, synthetic pyrethroids, fungicides (inorganic and organic), nematicides, rodenticides, herbicides, and plant growth regulators (PGR)

Block 3: Pesticide Formulation

Unit 1: Solid and Liquid Formulations

Formulation of pesticides- objective and classification, Conventional solid and liquid formulations such as EC, WP, Dust, Granule etc. Physico-chemical properties of formulations

Unit 2: Role of Adjuvants in Pesticide Formulations

Pesticide adjuvants like synergists, stabilizers and surfactants, Pesticide carriers and diluents General methods of preparation of solid and liquid formulations

Block 4: Pesticide Residues, Their Adverse Effects And Safe Disposal

Unit 1: Pesticide Residues in Food and the Environment

Pesticide residue - definition and significance, Pesticide residues in food commodities and in water, air and in soil environment

Unit 2: Adverse Effect of Pesticides on Non-target Organisms

Adverse effect of pesticides on human health, soil health, and on non-target organisms

Unit 3: Safe Disposal of Pesticides

Various techniques for disposal of unused, obsolete, and expired pesticides and their solid and liquid formulations, Disposal of pesticide containers

VII. Teaching methods/activities

- Lectures assignments
- Review of research documents and its presentation
- Periodical quizzes
- Mid-term and final examination

VIII. Learning outcome

After successful completion of the course, student will acquire basic knowledge about agrochemicals, their formulations and safe use in crop protection. Student will also know about the adverse effects of pesticides and ways to dispose obsolete, expired and unused pesticides and pesticide containers/packaging

IX. Suggsted Reading

- DC Buchel KH. (Ed.). 1992. *Chemistry of Pesticides*. John Wiley & Sons.
- Marrs TC & Bryan BT. (Eds.). 2004. *Pesticide Toxicology and International Regulation*. John Wiley & Sons.
- Parmar BS and Tomar SS. 2004. *Pesticide Formulation Theory and Practice*, CBS Publishers & Distributors-New Delhi, ISBN: 9788123911243, 8123911246
- Tomar SS and Parmar BS. 1992. *Dictionary of Agricultural Chemicals*. Academic India Publ.
- Handa SK 2004. *Principles of Pesticide Chemistry*. Publisher Agrobios (India), Jodhpur (ISBN 10: 8177542168 ISBN 13: 9788177542165)
- Pimentel D. *Encyclopedia of Pest Management* (1st Edition), CRC Press, 931 pp. ISBN 9780824706326.
- Pimentel and Lehman H (Eds.). 1993. The Pesticide Question, Environment, Economics and Ethics, pp442.DOI 10.1007/b102353, Springer US.
- Hassall KA. 2013. *The Chemistry of pesticides, their metabolism, mode of action and uses in Crop Protection* (ISBN: 9789386237118, 9386237113) Scientific Publishers India, pp 372.
- FICCI-TSMG (2016). *Next Generation Indian Agriculture: Role of Crop Protection Solution, A report on Indian Agrochemical Industry*. pp 45.

I. Course Title : Chemical Laboratory Techniques

II. Course Code : AC 502

III. Credit Hours : 1+2

IV. Why this Course?

Students desirous of pursuing research in agrochemicals and crop protectionare expected to know about the safe handling of laboratory chemicals and instruments. They need to be well versed with extraction, purification and separation techniques commonly employed in a chemical laboratory.

V. Aim of the Course

To acquaint students with laboratory hygiene, upkeep and maintenance of laboratory, handling of chemicals/solvents/glassware, as well as distillation and chromatographic techniques:

No.	Blocks	Units
1.	Laboratory Hygiene and Safe Laboratory Practices	1. Safe Storage and Handling of Chemicals 2. Safety Practices in Chemical Laboratory
2.	Distillation, Extraction and Separation Techniques	1. Theory and Practice of Distillation and Drying of Solvents 2. Theory and Practice of Extraction and Other Techniques 3. Theory and Practice of Chromatographic Techniques

VI. Theory

Block 1: Laboratory Hygiene and Safe Laboratory Practices

Unit 1: Safe Storage and Handling of Chemicals

Laboratory hygiene and safety, Handling and storage of hazardous (flammable, volatile, and corrosive) chemicals, Accurate weighing of chemicals, Maintenance of lab-wares, Maintenance of lab notebooks and records of laboratory chemicals/solvents

Unit 2: Safety Practices in Chemical Laboratory

Precautions while carrying out lab experiments, Use of safety gadgets, Safe disposal of reaction wastes and used solvents, Laboratory accidents and their management

Block 2: Distillation, Extractionand Separation Techniques

Unit 1: Theory and Practice of Distillation and Drying of Solvents

Solvent distillation, Fractional distillation, Steam distillation, Hydro-distillation, Drying of solvents,

Unit 2: Theory and Practice of Extraction and Other Techniques

Different extraction techniques, Cold extraction, Soxhlet extraction, liquid-liquid partitioning, Crystallization and sublimation, Determination of melting point, boiling point, and density of organic compounds

Unit 3: Theory and Practice of Chromatographic Techniques

Chromatography - principle and practice, Partition and adsorption chromatography (TLC, Preparative TLC, HPTLC, Paper chromatography, Column chromatography), Chromatography solvents and chromogenic reagents.

VII. Practicals

- Simple distillation, vacuum distillation, and fractional distillation of solvents/ volatile materials (e.g. essential oils)
- Determination of melting point, boiling point, density, etc.
- Purification and drying of organic solvents
- Crystallization and sublimation techniques.
- Solvent extraction techniques (cold extraction, Soxhlet extraction, percolation, accelerated solvent extraction), and refluxing a reaction
- Chromatographic separation of organic compounds by paper chromatography and thin layer chromatography (TLC)
- Separation of compounds by preparative TLC, HP-TLC and column chromatography

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge aboutsafe handling of chemicals, lab safety and basic laboratory techniques

X. Suggested Reading

- Fessenden RJ, Fessenden JS, Feist P. 2001. *Organic Laboratory Techniques* 3rd Edition, Publisher: Cengage Learning, 256 pages
- Feist P. 2002. *Handbook for Organic Chemistry Lab*. 6th Ed. Brooks/Cole
- Vogel AI. 1996. *Vogel's Textbook of Practical Organic Chemistry*. 5th Ed. Prentice Hall.
- Pavia DL, Kriz GS, Engel UJF. 2006. *Organic Chemistry: A Lab Manual*, Thomson and Brooks/Cole 972 pages.
- Brown SL. 2012. *Laboratory Techniques for General Chemistry*, Hayden McNeil; 208 pages
- ICAR Institute/SAU, *Practical Manual on Chemical Laboratory Techniques*

I. Course Title : Basic Chemistry

II. Course Code : AC 503*

III. Credit Hours : 3+1

IV. Why this Course?

Basic knowledge of physical, inorganic and organic chemistry is fundamental for understanding various aspects of pesticides and allied agrochemicals, pesticide residue analysis, and dynamics in the environment. This course empower the students with important aspects of chemistry.

V. Aim of the Course

To acquaint the students about the basics of inorganic, physical and organic chemistry

The course is organized as follows:

No.	Blocks	Units
1.	Basics of Inorganic Chemistry	1. Properties of Atoms, Molecules And Basic Elements 2. Chemical Bonding and Electronic Effects
2.	Basics of Physical Chemistry	1. Chemical Kinetics 2. Chemical Thermodynamics 3. Surface Chemistry 4. Solution and Electrochemistry
3.	Basics of Organic Chemistry	1. Reactive Intermediates in Chemical Reactions 2. Introduction to Stereochemistry 3. Chemistry of Aliphatic and Aromatic Compounds 4. Chemistry of Heterocyclic Compounds

VI. Theory

Block 1: Basics of Inorganic Chemistry

Unit 1: Properties of Atoms, Molecules and Basic Elements

Modern periodic law and periodic table, Properties of atoms, molecules and basic elements like C, H, O, S, and N, Atmospheric pollutants (oxides of C, N, and S), Atomic and ionic radii, Oxidation states and chemical reactivity, Acid-base chemistry, Introduction to organometallic and coordinated compounds

Unit 2: Chemical Bonding and Electronic effects

Nature of chemical bonding, hydrogen bonding, Van der Waals forces, Inductive effect, electromeric effect, Resonance effect, Hyperconjugation, Electronegativity and Dipole moment

Block 2: Basics of Physical Chemistry

Unit 1: Chemical Kinetics

Kinetic theory of gases, Collision theory, Maxwell - Boltzmann distribution law, Order and molecularity of reactions, First order and second order reactions, Effect of concentration, temperature, pressure and catalyst on rate of reaction, Arrhenius equation, Enzyme kinetics, Catalysis.

Unit 2: Chemical Thermodynamics

First law of thermodynamics, concept of work, internal energy and enthalpy, Second law of thermodynamics, entropy and free energy, Third law of thermodynamics

Unit 3: Surface Chemistry

Introduction to surface chemistry, Adsorption, physi-sorption, and chemisorption, Factors affecting adsorption of gases on solids- Freundlich and Langmuir adsorption isotherm

Unit 4: Solution and Electrochemistry

Colligative properties of solutions, law of mass action, Ionic equilibria in solutions, Phase rule and its application to one- and two- component systems, Hydrolysis, Solubility product, pH and buffer solutions, True solutions, colloid and suspensions, Electrochemistry, Redox reactions, Potentiometric analyses, Conductance in electrolytic solutions, Laws of electrolysis, Nernst equation, Metal corrosion

Block 3: Basics of Organic Chemistry

Unit 1: Reactive Intermediates in Chemical Reactions

Carbenes, carbanions, carbonium ion, free radicals and their role in organic reactions

Unit 2: Introduction to Stereochemistry

Chirality and optical isomerism, Geometric isomerism, Designation of configuration (D-L and R-S system), Conformations of acyclic and cyclic systems

Unit 3: Chemistry of Aliphatic and Aromatic Compounds

Preparation, properties and uses of some important aliphatic, alicyclic and aromatic compounds (halogenated, nitro, amino-compounds, diazonium salts, aromatic sulphonic acids, phenols, quinones and aromatic acids, naphthalene and naphthaquinone).

Unit 4: Chemistry of Heterocyclic Compounds

Preparation, properties and uses of some important heterocyclic compounds (furan, thiophene, pyrrole, pyrazole, imidazole, oxazole, thiazole, pyridine, piperidine, quinnoline, isoquinnoline etc.)

VII. Practicals

- Micro-weighing of compounds and preparation of different concentration of solutions Preparation of different pH solutions and buffer solutions
- Detection of elements (C, H, O, N, S Halogens) in organic compounds
- Detection of functional groups
- Experiments to demonstrate adsorption of a chemical on solid substrate
- Separation and identification of organic compounds in binary mixtures.
- Rate kinetics and Colligative properties.

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge about the fundamental aspects and concepts of basic chemistry

X. Suggested Reading

- Eliel EL and Wilen SH. 1994. *Stereochemistry of Organic Compounds*. Wiley-Interscience.
- Finar IL. 1989. *Organic Chemistry*. Vols. I, II. Longmans.
- Hendrickson JB, Cram DJ and Hammond GS. 1970. *Organic Chemistry*. McGraw-Hill.
- Morrison RT and Boyd RN. 1992. *Organic Chemistry*. 6th Ed. Prentice Hall.
- Vogel AI, Tatchell AR, Furnis BS and Hannaford AJ. 1996. *Vogel Textbook of Practical Organic Chemistry*. Forestmillbooks,UK.
- Negi AS and Anand SC. 2003. *A Text Book of Physical Chemistry*. Wiley Eastern.
- Moore WJ. 1987. *Basic Physical Chemistry*. Prentice Hall of India
- Alberty RA and Silbey RJ. 1996. *Physical Chemistry*. 2nd Ed. John Wiley & Sons.
- Moore WJ. 1987. *Basic Physical Chemistry*. Prentice Hall of India
- ICAR Institute/SAU *Practical Manual on Basic Chemistry*

I. Course Title : Natural Product Chemistry

II. Course code : AC 504*

III. Credit Hours : 2+1

IV. Why this Course?

Natural Product Chemistry course is useful to multidisciplinary students of chemistry, agricultural chemicals, entomology, pathology, and biochemistry. The course is designed to improve the student's understanding of bioactive natural products and their role in human welfare.

V. Aim of the Course

To apprise the students about the extraction, purification, and characterization of bioactive natural products and their use in human health, medicines and agriculture The course is organized as follows:

No.	Blocks	Units
1.	Natural Products: Chemistry and Uses	1. Chemistry and Uses of Fats, Lipids, Terpenoids, and Carotenoids 2. Chemistry and Uses f Alkaloids, Flavonoids, Steroids, and Triterpenoids 3. Chemistry and Uses of Carbohydrates, Amino Acids, Proteins, and Nucleic Acids 4. Introduction to Metabolomics
2.	Natural Antioxidants and Food Colorants from Food and Non-Food Sources	1. Natural Antioxidants and Food Colorants from Food Crops 2. Nutraceuticals and Phytoceuticals from Non-Food Sources
3.	Natural Polymers And Enzymes	1. Natural Polymers and their Application 2. Enzymes and Their Industrial Applications

VI. Theory

Block 1: Natural Products: Chemistry and Uses

Unit 1: Chemistry of Fats, Lipids, Terpenoids, and Carotenoid

Introduction to natural products, Structure, chemistry, properties and function of fats, lipids, terpenoids, and carotenoid group of natural products

Unit 2: Chemistry of Alkaloids, Flavonoids, Steroids, and Triterpenoids

Structure, chemistry, properties and function alkaloids (berberine, morphine, caffeine, atropine), flavonoids (Luteolin, quercetin, catechin, naringin, anthocyanins, theaflavins) and phenolic acids (benzoic acid and cinnamic acid derivatives), steroids (cholesterol, cortisone, testosterone, progesterone), and saponin (steroidal, triterpenic and steroid-alkaloidal) group of natural products.

Unit 3: Chemistry of Carbohydrates, Amino Acids, Proteins, and Nucleic Acids

Structure, chemistry, properties and function of carbohydrates, amino acids, proteins, and nucleic acids

Unit 4: Introduction to Metabolomics

Definition, Plant and microbial metabolomics, Metabolome analysis (profiling of secondary metabolites) by GC-MS, LC-MS and NMR spectrometery, Application of metabolomics in different fields

Block 2: Natural Antioxidants and Food Colorants From Food and Non-food Sources

Unit 1: Natural Antioxidants and Food Colorants from Food Crops

Natural oxidants and their mode of action, Different types of natural oxidants from vegetable, fruit and cereal crops (Examples: carotene, lycopene, betanaine, capsanthins, capsicinoids, anthocyanins, curcuminoids etc.)

Unit 2: Nutraceuticals and Phytoceuticals from Non-Food Sources

Nutraceuticals and phytoceuticals from microalgae (e.g. phycocyanins), seabuckthorn (phenolics and flavonoids), medicinal plants (boswellic acid, artemisinin, andrographinolides, withanolides, taxol, forskolinetc.) and marine products

Block 3: Natural Polymers and Enzymes

Unit 1: Natural Polymers and their Application

Different types of natural polymers, Chemistry of natural polymers (Starch, cellulose, Agar, inulin, chitosan, alginate, dextran, guar gum, gum Arabic, gum tragacanthin, xanthan gum, pectin, psyllium etc.). Application of polymers in agrochemical, food and other industries

Unit 2: Enzymes and their Industrial Application

Major classes of enzymes, Enzymes in food industry, industrial enzymes and their application in pharma, leather, textile, detergent and other industries

VII. Practicals

- Extraction of essential oil from mint leaves, lemon and orange peel etc.
- Extraction and purification of bioactive natural products like lycopene, from tomato or watermelon
- Extraction and purification of curcuminoids from turmeric rhizome
- Extraction and purification of anthocyanins from black carrot, purple cabbage, grapes or jamun etc
- Extraction and purification of bioactive natural products namely capsanthin and capsaicinoids from chili/paprika.

- Identification and characterization of the phytochemicals by GC-MS/LC-MS

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge about the bioactive natural products and their use in medicines, crop protection and other industrial applications

X. Suggested Reading

- Thomson RH (Ed). 1993. *The Chemistry of Natural Products*, DOI 10.1007/978-94-011-2144-6, Springer Netherlands, 453 pages
- Sujata V. Bhat, B.A. Nagasampagi, Meenakshi Sivakumar. 2005. *Chemistry of Natural Products* Springer Science & Business Media, 840 pages
- Rensheng Xu, Yang Ye, Weimin Zhao. 2011. *Introduction to Natural Products Chemistry*, CRC Press, 381 Pages
- Bernd Schaefer. 2014. *Natural Products in the Chemical Industry*, Springer-Verlag Berlin Heidelberg, 831 pages.
- Talapatra SK and Talapatra B. 2015. Chemistry of Plant Natural Products, Springer-Verlag Berlin Heidelberg, 1180 pages
- ICAR Institute/SAU. *Practical Manual on Natural Product Chemistry*

I. Course Title : Agrochemical Regulation, Quality Control and Management

II. Course Code : AC 505*

III. Credit Hours : 2+0

IV. Why this course?

Agricultural chemicals being inherently toxic need to be handled with caution during their production, transport, storage, usage and disposal. The national and international regulations and guidelines ensure their safe distribution and use. Students need to be aware of such regulations and guidelines

V. Aim of the course

To acquaint students about the provisions of Insecticide Act 1968, Food Safety and Standard Act 2006, pesticide registration process, and guidelines for their safe use. The course is organized as follows:

No.	Blocks	Units
1.	Pesticide Regulation and Food Safety	1. The Insecticides Act (1968) and Rules (1971) 2. Food Safety and Standard Act (2006) & Rules (2011) 3. Pesticide Registration in India
2.	National/ International Guidelines for Safe Use of Pesticides	1. Good Agricultural Practices (GAP) and Good Laboratory Practices (GLP)

No.	Blocks	Units
		2. International Guidelines for Safe Use of Pesticides
3.	Quality Control, Quality Assurance and Accreditation	1. Quality *Assurance* and *Quality Control* in Pesticide Analysis 2. Accreditation of *Laboratories*

VI. Theory

Block 1: Pesticide Registration in India

Unit 1: The Insecticides Act (1968) and Rules (1971)

Provisions of the Insecticides Act 1968 and Insecticides Rules 1971, Schedule of the Insecticide Act. Directorate of Plant Protection, Quarantine & Storage (DPPQ&S), Central Insecticide Board and Registration Committee (CIB&RC),Guidelines for production and use of pesticides

Unit 2: Food Safety and Standard Act (2006) & Rules (2011)

Provisions of the Food Safety and Standard Act (2006) & rules (2011), Acts relating to protection of air, water and the general environment

Unit 3: Pesticide Registration in India

Requirement of data (Chemistry, Bioefficacy, Residue, Toxicology, Packaging etc) for pesticide registration in the country, Guidelines for pesticide export and import**,** Current status of registered, restricted, and banned pesticides in India

Block 2: National/ International Guidelines for Safe Use of Pesticides

Unit 1: Good Agricultural Practices (GAP) and Good Laboratory Practices (GLP)

Definition of GAP and GLP, National and international guidelines for GAP, and GLP.

Unit-2: International Guidelines for Safe Use of Pesticides

WHO/FAO Joint Meeting on Pesticide Residues (JMPR), Codex Alimentarius Commission (CAC) EU and EPA guidelines for food safety, Sanitary and phytosanitary (SPS) measures and food safety

Block 3: Quality Control, Quality Assurance and Accreditation

Unit 1: Quality Assurance and Quality Control in Pesticide Analysis

Spurious/ fake pesticides and pesticide formulations, Quality Assurance (QA) and Quality Control (QC) Quality control procedures for pesticide residue analysis, Problems related to pesticide residue analysis in a regulatory laboratory.

Unit 2: Accreditation of Laboratories

Accreditation and its importance, General criteria for accreditation of chemical and food laboratories, Introduction to ISO/IEC 17025. NABL and GLP compliance of laboratories, Role of International Laboratory Accreditation Cooperation (ILAC) and Asia Pacific Laboratory Accreditation Cooperation (APLAC) in promoting accreditation recognition arrangements (MRAs) and practices

VII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

VIII. Learning outcome

After successful completion of the course, student will acquire knowledge about the agrochemical regulation, quality control, management, and need for accreditation of chemical laboratory as per ISO/IEC 17025

IX. Suggested Reading

- EU.http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=pesticide.residue.CurentMRL&language=EN&pestResidueID=69.
- Pest Management Regulatory Agency Canada. 21 May 2014. ISSN: 1925-0843 (PDF version), Catalogue number: H113-24/2014-25E-PDF. Cucurbit vegetables (Crop group 9). http://www.hc-sc.gc.ca/cps-spc/pest/part/consultations/_pmrl2014-25/pmrl2014-25-eng.php.
- OECD (Organization for Economic Co-operation and Development), 2011. *OECD MRL calculator: spreadsheet for single data set and spreadsheet for multiple data set*, 2 March 2011. In: Pesticide Publications/Publications on Pesticide Residues. http://www.oecd.org.
- SANTE. 2017. *Guidance document on analytical quality control and validation procedures for pesticide residues analysis in food and feed.* European Commission Health and Consumer Protection Directorate–General. SANTE/11813/2017 Supersedes SANCO/11945/2015.
- USEPA (2016). https://www.epa.gov/sites/production/files/2016-03/documents/flubendiamide_ noic_published_03-04-16.pdf. (accessed 18 May 2016).
- USEPA 2016 United States Environmental Protection Agency https://www.epa.gov/sites / production/files/2016-03/documents/flubendiamide_noic_published_03-04-16.pdf.
- Gnther Voss, Gerardo Ramos &GüNther Voss. 2003. *Chemistry of Crop Protection: Progress and Prospects in Science and Regulation*. Wiley-vch Verlag Gmbh.

I. Course Title : Agrochemicals for Insect, Mite and Termite Management

II. Course Code : AC 506*

III. Credit Hours : 2+1

IV. Why this course?

Insect pests, mites and termites are the major destroyer of the agricultural crops, food commodities as well as buildings and wooden structures. Since synthetic insecticides are used to control such pests, students must learn about the chemistry, mode of action and safe use of such pest control chemicals

V. Aim of the course

To understandchemistry, synthesis, mode of action, and use of insecticides, acaricides and termiticides in agriculture and protection of buildings and wooden structures. The course is organized as follows:

No.	Blocks	Units
1.	Organochlorine, Carbamate and Organophosphorus Group Insecticides	1. Chemistry and Use of Organochlorine Insecticides 2. Chemistry and Use of Carbamate Insecticides

No.	Blocks	Units
		3. Chemistry and Use of Organophosphorus Insecticides
2.	Synthetic Pyrethroid and Neonicotinoid Group Insecticides	1. Chemistry and Use of Synthetic Pyrethroid Insecticides 2. Chemistry and Use of Neonicotinoid Insecticides
3.	Acaricides, Termiticides, Insect Growth Regulators and Newly Discovered Insecticidal Molecules	1. Chemistry and Use of Acaricides 2. Chemistry and Use of Termiticides 3. Chemistry and Use of IGRs and Newly Discovered Insecticidal Molecules
4.	Insecticide resistance	1. Insecticide Resistance and its Management

VI. Theory

Block 1: Organochlorine, Carbamate and Organophosphorus Insecticides

Unit 1: Chemistry and Use Of Organochlorine Insecticides

Introduction and classification of synthetic insecticides, Chemistry, use and mode of action of some important conventional organochlorine and cyclodiene insecticides, Present status of organochlorine pesticides

Unit 2: Chemistry and Use of Carbamate Insecticides

Chemistry, use, and mode of action of carbamate insecticides, Present status of carbamate pesticides

Unit 3: Chemistry and Use of Organophosphorus Insecticides

Chemistry, use and mode of action of some important organophosphorus insecticides. Important reactions namely Michaelis- Arbuzov reaction, Perkow reaction, Thiono-thiolo rearrangement. Present status of OP pesticides

Block 2: Synthetic Pyrethroid and Neonicotenoid Insecticides

Unit 1: Chemistry and Use of Synthetic Pyrethroid Insecticides

History and evolution of synthetic pyrethroid insecticides, Synthesis, properties, structure activity relationships, and mode of action of some important ester and non-ester synthetic pyrethroids. Current status of synthetic pyrethroids insecticides

Unit 2: Chemistry and Use of Neonicotinoid Insecticides

Neonicotinoids: Chemistry, classification, mode of action and uses, Preparation, properties anduses of some important neonicotinoids, Current status of neonicotinid insecticides

Block 3: Acaricides, Termiticides, Insect Growth Regulatorsand Newly Discovered Insecticidal Molecules

Unit 1: Chemistry and Use of Acaricides

Chemistry, classification, mode of action of some important acaricidal molecules.

Unit 2: Chemistry and Use of Termiticides

Termites of different types infesting crops and building materials, Chemistry, mode of action and uses of some important termiticides

Unit 3: Chemistry and Use of Igrs and Newly Discovered Insecticidal Molecules

Chemistry of insect growth regulators: Juvenile hormone mimics, anti-JH, Chitin synthesis inhibitors. Chemosterilants, Mode of action of IGRs, Endocrine disruptor compounds, Chemistry of newly discovered insecticidal molecules

Block 4: Insecticde Resistance

Unit 1: Insecticide Resistance and its Management

Definition, types and mechanism of insecticide resistance, Insecticide Resistance Action Committee (IRAC) guidelines for resistance management, Status of resistance to neo-nicotinoid, synthetic pyrethroids, and other group insecticides

VII. Practicals

- Preparation and characterization of organochlorine insecticides and their intermediates, metabolites and degradation products
- Preparation of representative organochlorine insecticide like dicofol
- Preparation of representative organophosphorus insecticide
- Preparation and characterization of a pesticide intermediate (oxime/oxime ether/ ester etc.)
- Phytotoxicity evaluation of insecticides through germination and growth inhibition study
- Bioefficacy of insecticides against stored grain insect pests

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will stand exposed to recent developments in agrochemicals and their use in insect, mite and termite management in crops, food commodities as well as buildings and wooden structures

X. Suggested Reading

- Melnikov NN. 1971. *Chemistry of Pesticides* (Ed: Gunther, F. A., Gunther, J. D. (Eds.), Springer Nature, Springer-Verlag New York, 480 pp
- Eto M. 1979. *Organophosphorus Pesticides: Organic and Biological Chemistry*. CRC Press.
- Kuhr RJ &Dorough HW. (1979). *Carbamate Insecticide Chemistry and Biochemistry*. CRC Press
- Fest C, Schmidt KJ. 1982. *The Chemistry of Organophosphorus Pesticides*, pp 362, DOI10.1007/978-3-642-68441-8, Springer-Verlag Berlin Heidelber
- Leahey JP. 1985. *The Pyrethroid Insecticides*. Taylor & Francis.
- Matolcsy G, Nadasy M and Andriska V. 1988. *Pesticide Chemistry*. Elsevier.
- Matolcsy M, Nádasy V Andriska. 1989. *Pesticide Chemistry*, Volume 32 (1st Edition) G. eBook ISBN: 9780080874913, Elsevier Science, 1989, pp 805
- Buchel KH. (Ed.). 1992. *Chemistry of Pesticides*. John Wiley & Sons.
- Cremlyn RJ. 1990. *Pesticides: Preparation and Mode of Action*. Wiley.
- Stenersen J. 2004. *Chemical Pesticides Mode of Action and Toxicology*. (ISBN-13: 978-0748409105), CRC Press; 1 edition., 296 pages.
- Ohkawa H, Miyagawa H and Lee PW. (Ed). 2007. *Pesticide Chemistry: Crop Protection,*

Public Health, Environmental Safety. DOI: 10.1002/9783527611249 Wiley VCH Verlag GmbH & Co. KGaA., pp 489.

- Singh DK. 2012. *Pesticide Chemistry and Toxicology* (*Book Series: Toxicology: Agriculture and Environment) Volume 1, pp 142.* DOI: 10.2174/9781608051373 1120101 (Benntham eBook)
- Hassall KA. 2013. *The Chemistry Of Pesticides Their Metabolism, Mode Of Action And Uses In Crop Protection* (ISBN: 9789386237118, 9386237113), Scientific Publishers India, pp 372.
- ICAR Institute/SAU *Practical Manual on Agrochemicals for Insect, Mite and Termite Management*

I. Course Title : Agrochemicals for Disease Management

II. Course Code : AC 507

III. Credit Hours : 2+1

IV. Why this course?

Plant diseases are caused by a diverse group of microorganisms which include fungi, bacteria, viruses, plant parasitic nematodes, etc. Besides reducing crop yield, they also reduce quality of the crop produce. Students must learn about diverse range of fungicidal and nematicidal products and their use in plant disease control

V. Aim of the course

To teach students about the chemistry and use of synthetic fungicides and nematicides and their role in plant diseases and nematode management.

The course is organized as follows:

No.	Blocks	Units
1.	Introduction to Fungicides and Plant Disease Management	1. Important Plant Pathogenic Fungi, Diseases and Fungicides 2. Classification of Fungicides
2.	Chemical Control of Plant Diseases	1. Inorganic and Dithiocarbamate Fungicides 2. Heterocyclic and Organophosphorus Fungicides 3. Strobilurin (β-Methoxy-Acrylate) Group Fungicides 4. Miscellaneousand New Emerging Fungicides
3.	Chemical Control of Plant Parasitic Nematodes	1. Chemistry, Use and Mode of Action of Chemical Nematicides
4.	Fungicide Resistance	1. Fungicide Resistance and its Management

VI. Theory

Block 1: Introduction to Fungicides and Plant Disease Management

Unit 1: Important Fungicides, Plant Pathogenic Fungi and Diseases

Historical development of fungicides, Some important plant pathogenic fungi and crop diseases, Fungicide movement (translocation) in plant

Unit 2: Classification of Fungicides

Fungicide classification based on chemical nature, Fungicide classification based on mode of action.

Block 2: Chemical Control of Plant Diseases

Unit 1: Inorganic and Dithiocarbamate Fungicides

Chemistry, use and mode of action of inorganic fungicides (S, Cu, Hg, Sn, As), Dithiocarbamate fungicides.

Unit 2: Heterocyclic and Organophosphorus Fungicides

Chemistry, use and mode of action of heterocyclic fungicides (Imidazole, benzimidazole, triazole, oxazole, thiazole, pyridine, pyrimidine, quinoline, quinoxaline, morpholine etc.), Organophosphorus fungicides.

Unit 3: Strobilurin (â-methoxy-acrylate) Group Fungicides

Chemistry, use and mode of action of strobilurin (-methoxyacrylaye) group synthetic fungicides e.g. azoxystrobin, kresoximmethyl, picoxystrobin, fluoxastrobin, pyraclostrobin and trifloxystrobin.

Unit 4: Miscellaneous and New Emerging Fungicidal Molecules

Chemistry, use and mode of action of phenol, quinone, polyhalogen, alkane sulfenyl group, formamide, alkane, alkane carboxylic acid carboxamide and dicarboximide group of fungicides, Chemistry of newly discovered fungicide molecules

Block 3: Chemical Control of Plant Parasuitic Nematodes

Unit 1: Chemical Nematicides

Plant parasitic nematodes, Historical development of nematicides. Preparation, properties and uses of aliphatic halogen compounds, methyl isocyanate liberators, organophosphates and carbamates for nematode control.

Block 4: Fungicide Resistance

Unit 1: Fungicide Resistance and its Management

Definition and development of fungicide resistance in crop pathogens, Fungicide Resistance Action Committee (FRAC) guidelines for resistance management, Fungicide resistance status in India

VII. Practicals

- Preparation of chemical fungicide intermediate(s) like triazoles/ benzimidazoles
- Preparation and characterization of some important fungicides (e.g. Zineb, Bordeaux mixture, Burgundy mixture, dichlorophen, Glyodin, DBCP (nematicide), and an organophosphorus fungicide
- Determination of antifungal activity of the representative test agrochemical (bioassay)
- Characterization of the select fungicides by spectral (IR, UV, NMR or MS) analysis

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge about the recent developments in agrochemicals and their use in plant disease and nematode management in agricultural crops

X. Suggested Reading

- Matolcsy M, Nádasy V, Andriska. 1989. *Pesticide Chemistry*, Volume 32 (1st Edition) G. eBook ISBN: 9780080874913, Elsevier Science, 1989, pp 805
- Buchel KH. (Ed.). 1992. *Chemistry of Pesticides*. John Wiley & Sons.
- Cremlyn RJ. 1990. *Pesticides: Preparation and Mode of Action*. Wiley.
- Dehne HW, Deising HB, Gisi U, Kuck KH, Russell PE, Lyr H. (Eds.). 2008. *Modern Fungicides and Antifungal Compounds V*. Proceedings of the 15th International Reinhardsbrunn Symposium on Modern Fungicides and Antifungal Compounds. Friedrichroda, Germany (May 06 – 10, 2007), Deutsche Phytomedizinische Gesellschaft, Braunschweig, Germany, 2008 - ISBN 978-3-941261-02-0
- Ohkawa H, Miyagawa H and Lee PW. (Ed). 2007. *Pesticide Chemistry: Crop Protection, Public Health, Environmental Safety*. DOI: 10.1002/9783527611249 Wiley VCH Verlag GmbH & Co. KGaA., pp 489.
- Carisse O. 2010. (Ed) Fungicides, (ISBN 978-953-307-266-1) Publisher: InTechJanezaTrdine 9, 51000 Rijeka, Croatia. pp 538. (A free online edition of this book is available at www.intechopen.com)
- Lukens RJ. *Chemistry of Fungicidal Action* (ISBN: 9783662113134, 3662113139). Springer-Verlag, Berlin, Heidelberg, Germany.
- Singh DK. 2012. *Pesticide Chemistry and Toxicology* (*Book Series: Toxicology: Agriculture and Environment) Volume 1, pp 142.* DOI: 10.2174/97816080513731120101 (Benntham eBook)
- Hassall KA. 2013. *The Chemistry of pesticides, their metabolism, mode of action and uses in Crop Protection* (ISBN: 9789386237118, 9386237113) Scientific Publishers India, pp 372.
- Oliver and Hewitt H. (Eds). 2014. *Fungicides in Crop Protection*, CABI, Oxfordshire, OX10 8DE, UK pp 200 Pages
- ICAR Institute/SAU. *Practical Manual on Agrochemicals for Fungi and Nematode Management*

I. Course Title : Agrochemicals for Weed and Crop Management

II. Course Code : AC 508

III. Credit Hours : 2+1

IV. Why this Course?

Weeds compete with the crop plant for light, space, water and nutrients and hamper the overall growth of the desired crop. Chemical herbicides are employed to kill or control such weeds. This course provides detailed information about the chemistryand mode of action of diverse group of herbicides for weed management and PGRs for crop growth

V. Aim of the Course

To apprise the students about the chemistry, mode of action and use of different classes of herbicides for weed management, and plant growth regulators for crop growth.

The course is organized as follows:

No.	Blocks	Units
1.	Herbicides and Weed Management	1. Introduction to Herbicides and Weed Management
2.	Aliphatic, Aromatic, and other Group Herbicides	1. Aliphatic and Aromatic Acid Group Herbicides

No.	Blocks	Units
		2. Carbamate, Substituted phenyl urea, and s-Triazine 3. group Herbicides 4. Diphenyl Ethers, Dinitroanilines, Amide, and 5. Anilide Group Herbicides
3.	Heterocyclic and Sulfonyl Urea Herbicides	1. Chemistry and Use of Heterocyclic and Sulfonyl Urea Group Herbicides
4.	Plant growth regulators, herbicide safeners, and newly discovered herbicidal molecules	1. Chemistry and Use of Plant Growth Regulators and Herbicide Safeners 2. Newly Discovered Herbicidal Molecules
5.	Herbicide resistance	1. Herbicide resistance and its management

VI. Theory

Block 1: Herbicides and Weed Management

Unit 1: Introduction to Herbicides and Weed Management

Important crop weeds, Introduction to synthetic herbicides, Classification of herbicides based on time of application, mode of action and selectivity, Herbicide resistance and its management

Block 2: Aliphatic and Aromatic Group Herbicides

Unit 1: Aliphatic Acid and Aromatic Acid Group Herbicides

Chemistry, mode of action, and factors governing structure activity relationship of aliphatic and benzoic acid herbicides, phenoxy acid herbicides, phenoxy-phenoxy acid and phenoxy-phenoxy alkanoic acid herbicides

Unit 2: Carbamate, Substituted phenyl urea, and s-Triazine group Herbicides

Chemistry, mode of action, and factors governing structure activity relationship of carbamate, thiocarbamate, biscarbamate, oxime carbamate, sulfonyl carbamate, Substitutred phenyl urea herbicides, s-Triazine group herbicides

Unit 3: Diphenyl Ethers, Dinitroanilines, Amide, and Anilide Group Herbicides

Chemistry, mode of action, and factors governing structure activity relationship ofdiphenyl ethers, dinitroanilines, amide, and anilide group herbicides

Block 3: Heterocyclic and Sulfonyl Urea Herbicides

Unit 1: Chemistry and Use of Heterocyclic and Sulfonyl Urea Group Herbicides

Chemistry, use, mode of action and factors governing structure activity relationship of triazine, pyridine, bipyridylium, pyridazine, pyrimidine, oxadiazole, imidazolinoneand sulfonylurea and sulfonylamides herbicides

Block 4: Plant Growth Regulators, Herbicide Safeners, and Newly Discovered Herbicidal Molecules

Unit 2: Chemistry and Use of Plant Growth Regulators and Herbicide Safeners

Chemistry and use of plant growth regulators (auxins, gibberallin, cytokinins, brassionosteroids, triacontanol, protein hydrolysates), Synthesis, structure activity relationships of auxins and gibberellins, Herbicide safeners and pro-safeners

Unit 3: Newly discovered Herbicidal Molecules

Structure and herbicidal activity of newly discovered herbicidal molecules

Block 5: Herbicide Resistance

Unit 1: Herbicide resistance and its management

History and types of herbicide resistance, Factors and mechanism of herbicide resistance, Management of herbicide resistance

VII. Practicals

- Synthesis and characterization of 2,4-D by m.p, TLC, and NMR,
- Identification and collection of weed samples from Institute research farm.
- Preparation of propionyl chloride and its use in the synthesis of the propanil herbicide
- Synthesis of maleic hydrazide and its characterization by TLC, NMR,
- Estimation of 2,4-D, alachlor, propanil, simazine and/or other available herbicides by HPLC and spectrophotometry.

VIII. Teaching methods/activities

- – Lectures assignments
- – Review of research documents
- – Presentation of review
- – Periodical quizzes
- – Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will be well versed with safe use of herbicides for weed management and PGR for crop growth

X. Suggested Reading

- Kearnay PC and Kaufman DD. 1975. *Herbicides: Chemistry, Degradation and Mode of Action*. Vols. I, II. Marcel Dekker.
- Matolcsy G, Nadasy M and Andriska V. 1989. *Pesticide Chemistry*, Volume 32 (1st Edition) G. eBook ISBN: 9780080874913, Elsevier Science, pp 805
- Cremlyn RJ. 1990. *Pesticides: Preparation and Mode of Action*. Wiley
- Kramer WK and Ulrich Schirmer. 2007. *Modern Crop Protection Compounds*. Wiley-vch Verlag Gmbh.
- Ohkawa H, Miyagawa H and Lee PW. (Ed). 2007. *Pesticide Chemistry: Crop Protection, Public Health, Environmental Safety*. DOI: 10.1002/9783527611249 Wiley VCH Verlag GmbH & Co. KGaA., pp 489.
- Sondhia S and Varshney JG. 2010. Herbicides. Satish Serial Publication House, New Delhi. P 567.
- Rao VS. CRC Press, 2000. *Principles of Weed Science*, 2nd Edition, 566 pp, ISBN 9781578080694 - CAT# N00115
- ICAR Institute/SAU. *Practical Manual on Agrochemicals for Weed and Crop Management*

I. Course Code : Chromatographic and Spectroscopic Techniques
II. Course Title : AC 509
III. Credit Hours : 2+1

IV. Why this course?

The chromatographic (GC, HPLC) and spectroscopic (IR, UV, NMR) methods are necessary tools for the detection, identification, and quantitation of organic molecules. The knowledge of such analytical techniques is necessary for the students pursuing research in R & D of pesticides and allied agrochemicals

V. Aim of the course

To acquaint the students with the chromatographic and spectroscopic techniques and their use in analysis and characterization of organic compounds.

The course is organized as follows:

No.	Blocks	Units
1.	Chromatographic Techniques	1. Introduction to Separation Science Techniques 2. Gas Chromatography (GC) and its Application 3. High Performance Liquid Chromatography (HPLC) and Its Application
2.	Spectroscopic Techniques	1. UV, Visible and IR Spectrophotometry, and its Application 2. NMR (^{1}H, ^{13}C) Spectroscopy and its Application 3. Mass Spectroscopy (MS) and its Application 4. Tandem Chromatographic and Spectroscopic Techniques

VI. Theory

Block 1: Chromatographic Techniques

Unit 1: Introduction to Separation Science Techniques

Principles of separation science, GC, GPC, and LC chromatography, Super critical fluid chromatograph (SCFC), and Ion exchange chromatography (IEC)

Unit 2: Gas Chromatography and its Application

Theory, principle and instrumentation of GC, GC detectors and columns of different types, Application of GC in analysis of organic compounds, Advantages and limitations of GC

Unit 3: High Performance Liquid Chromatography (HPLC) and its Application

Theory, principle and instrumentation of HPLC, LC detectors and columns of different types, Mobile phase, Application of HPLC in separation and analysis of organic compounds. Advantages and limitations of HPLC

Block 2: Spectroscopic Techniques

Unit 1: UV, Visible and IR Spectrophotometry and its Application

Theory, principle, and instrumentationof absorption (UV, Visible and IR) spectroscopy, Application of UV and IR in structure elucidation of organic compounds

Unit 2: NMR (^{1}H, ^{13}C) Spectroscopy and its Application

Theory, principal and instrumentation of NMR (^{1}H, ^{13}C) spectroscopy, Application of NMR spectroscopy in characterization of organic compounds

Unit 3: Mass Spectroscopy (MS) and its Application

Theory, principal, instrumentation of mass spectroscopy, Mass fragmentation pattern, Application of MS in structure elucidation and confirmation

Unit 4: Tandem GC-MS and LC-MS Techniques

Tandem chromatographic and spectroscopic techniques (GCMS-MS/LCMS-MS), Application of tandem techniques for confirmation of the chemical structure of the analyte constituents.

VII. Practicals

- Separation of organic compound mixture by GC and HPLC
- Application of UV and IR spectrophotometry for detection of organic compounds
- Identification and structure elucidation of organic compounds by NMR (^{1}H, ^{13}C) and MS
- Identification and structure elucidation of organic compounds by GC-MS, LC-MS and MS fragmentation pattern

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire working knowledge of chromatographic and spectroscopic methods for detection, identification, and quantitation of organic molecules.

X. Suggested Reading

- Sharma JM and Follweiler J. 1984. CRC. *Handbook of Chromatography: Pesticides and Related Organic Chemicals*. CRC Press
- Friebolin H and Becconsall JK. 1993. Basic One- and Two-Dimensional NMR Spectroscopy. John Wiley & Sons.
- Dyer JR. 1994. *Application of Absorption Spectroscopy of Organic Compounds*. Prentice Hall of India.
- Silverstein RM, Bassler GC and Morrill TC. 2005. *Spectrometric Identification of Organic Compounds*. 4th Ed. John Wiley & Sons. pages 512.
- Braithwaite A, Smith JF. 1999. *Chromatographic Methods* DOI 10.1007/978-94-011-0599-6, Springer Netherlands, pp 580
- Cazes J and Scott RPW. 2002. *Chromatography Theory* (Chromatographic Science, 88), CRC Press; 1 edition, 496 pages
- Williams DH and Fleming I. 2004. *Spectroscopic Methods in Organic*. Chemistry, Tata McGraw-Hill Education, New Delhi, India, pages 322.
- Nikalje. 2017. *A Handbook of Chromatography* (Editor: Marco Braga), Publisher: Scholar's Press Verlag Omniscriptam, Deutschland, Germany. (ISBN: 978-3-330-65032-9).
- *Practical Manual on Chromatographic and Spectroscopic Techniques* developed by the ICAR Institute/SAU.

I. Course Title : Pesticide Residue Chemistry

II. Course Code : AC 510*

III. Credit Hours : 2+1

IV. Why this course?

Pesticides are inherently toxic and their non-judicious use leaves behind toxic residues. Therefore it needs to be ensured that food commodities we consume are devoid of residues. This course provides exposure to analysis of pesticide residues in food commodities as well as in the soil and aquatic environment. It also provide information about consumer risk assessment and MRL fixation

V. Aim of the course

To teach the students extraction, cleanup, recovery and analysis techniques, develop and validate analytical methodology for risk assessment and MRL fixation.

The course is organized as follows:

No.	Blocks	Units
1.	Introduction to Pesticide Residue Chemistry	1. Pesticide Residue – Concept and Significance 2. Laboratory Data and Proficiency Testing
2.	Analysis of Pesticide Residues	1. Extraction, Clean Up and Recovery 2. Method Development and Validation 3. Monitoring of Pesticide Residue in Food Commodities
3.	Consumer Risk Assessment and MRL Fixation	1. Consumer Risk Assessment 2. MRL Fixation of Pesticides in Food Commodities

VI. Theory

Block 1: Introduction to Pesticide Residue Chemistry

Unit 1: Pesticide Residue – Concept and Significance

Pesticide residue definition, source, Significance of Certified Reference Materials (CRMs) in pesticide residue analysis, Planning and layout of experiments, Good agricultural practices (GAP) and experimental design, Post-harvest interval (PHI)

Unit 2: Laboratory Data Documentation and Proficiency Testing

Documentation and audit of laboratory data, Inter laboratory comparison and laboratory proficiency testing, legal implications of pesticide residue data

Block 2: Analysis of Pesticide Residues

Unit 1: Extraction, Clean Up and Recovery

Sampling, sample processing and testing, Different extraction and clean up techniques for optimum recovery

Unit 2: Method Development and Validation

Method development, Validation and performance verification through linearity, sensitivity, matrix effect, limit of quantification (LOQ), limit of detection (LOD), accuracy and precision of recovery, Measurement uncertainty (MU)

Unit 3: Monitoring of Pesticide Residue

Monitoring of pesticide residue in agricultural produce and environment, Multiresidue analysis by quick, easy, cheap, effective, rapid and safe (QuEChERS) method, GC/LC, GC-MS, LC-MS method. ELISA and Radiotracer techniques in residue analysis.

Block 3: Consumer Risk Assessmentand MRL Fixation

Unit 1: Consumer Risk Assessment

Hazard and risk, Ecological and human health risk assessment, Acceptable daily intake (ADI), theoretical maximum daily intake (TMDI),estimated daily intake, Maximum Residue Limit, No Observed Adverse Effect level (NOAEL), Food factor.

Unit 2: MRL fixation of Pesticides in Food Commodities

Safe waiting period, Lowest, highest and median residue data, OECD MRL Calculator, Significance of Codex, EU and FSSAI MRLs.

VII. Practicals

- Collection, storage and preparation of samples for pesticide residue analysis
- Extraction and clean-up of food, soil and water sample prior to analysis of pesticide residues
- Study the percent recovery of pesticide residues from vegetable, soil, and/or water samples fortified with the standard pesticide analyte
- Validation of analytical method by studying linearity, matrix effect, LOD, LOQ, accuracy (recovery) and precision as per SANTE guidelines
- Identification of organochlorine insecticides in soil and water by TLC/GC/HPLC
- Identification of Carbamate insecticides in water by TLC/GC/HPLC,
- Estimation of carbamate insecticide residues in vegetable by visible spectroscopic method and HPLC
- Estimation of OP insecticide residues in soil by spectroscopic method and HPLC.

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge aboutthe pesticide residue analysis, consumer risk assessment and MRL fixation

X. Suggested Reading

- Handa SK, Agnihotri NP and Kulshrestha G. 2000. *Pesticide Residue Analysis, Significance, Management and Analysis*.
- Gupta A. 2006. *Pesticide Residue in Food Commodities*. Agrobios (India).
- FAO. 2009b. *Submission and evaluation of pesticide residues data for the estimation of maximum residues levels in food and feed* (FAO Plant production and protection paper 197) <http://www.fao.org/ag/AGP/AGPP/Pesticide/p.htm>.
- FAO/WHO. 2013. *Codex Pesticides Residues in Food Online Database*. Pesticide Residues in Food and Feed, doi: http://www.codexalimentarius.net/pestres/data
- Sharma KK. 2013. *Pesticide Residue Analysis Manual* (Second edition), Directorate of

Knowledge Management in Agriculture, ICAR, KAB-I, Pusa, New Delhi-110012, India. pp 248
- Sondhia S. 2014. *Herbicides residues in soil, water, plants and non-targeted organisms and human health implications: an Indian perspective*. Indian Journal of Weed Science 46(1): 66–85.
- FSSAI. 2015. *Food Safety Standard Authority of India*, Fixation of MRL.
- Mohidus SK and Mohammad SR. (Eds.). 2017. *Pesticide Residue in Foods: Sources, Management and Control*. DOI 10.1007/978-3-319-52683-6, Springer Interntnl. Publishing, pp 200.
- SANTE. 2017. *Guidance document on analytical quality control and validation procedures for pesticide residues analysis in food and feed*. European Commission Health and Consumer Protection Directorate–General. SANTE/11813/2017 Supersedes SANCO/11945/2015.
- ICAR Institute/SAU. *Practical Manual on Pesticide Residue Chemistry*

Course Title with Credit Load
Ph.D. in Agricultural Chemicals

Course Code	Course Title	Credit Hours
AC 601*	Agrochemical Formulation Technology	2+2
AC 602*	Chemistry of Biopesticides	2+1
AC 603	Advanced Organic Chemistry	2+1
AC 604	Pesticide Metabolism, Persistence, and Decontamination	2+1
AC 605	Term Paper (Special Topics In Agrochemicals)	1+0
AC 691	Doctoral Seminar-I	1+0
AC 692	Doctoral Seminar-II	1+0
AC 699	Doctoral Research	75

*Core courses

Course Contents
Ph.D. in Agricultural chemicals

I. Course Title : Agrochemical Formulation Technology

II. Course Code : AC 601*

III. Credit Hours : 2+2

IV. Why this course?

Several advancements have been reported in pesticide formulation technology. The course intends to cover recent developments on the subject and will be useful to students interested in pursuing research in R & D of pesticide formulation technology

V. Aim of the course

To apprise the students about the recent developments in formulation technology and delivery systems.

The course is organized as follows:

No.	Blocks	Units
1.	Conventional Pesticide Formulations	1. Overview of Conventional Pesticide Formulations 2. Selection of Adjuvants and Synergists in Formulation Chemistry 3. Physico-Chemical Properties of Pesticide Formulations
2.	New Generation Pesticide Formulations	1. Water and Oil Based Novel Formulation 2. Dry, Controlled Release, and Other Novel Formulations 3. Pesticide Application and Delivery 4. Systems
3.	Nanotechnology and its Application in Pesticide Formulation	1. Production and Characterization of Nano-Materials 2. Application of Nanotechnology in Pesticide Formulation and Delivery

VI. Theory

Block 1: Conventional Pesticide Formulations

Unit 1: Overview of Conventional Pesticide Formulations

Solid and liquid formulation, Conventional pesticide formulations such as Dust (D), Granule, pallet (P), Wettable Powder (WP), Emulsifiable Concentrate (EC), and Solution (S). Biopesticide formulations-specifications and types, Limitations of conventional formulations

Unit 2: Selection of Adjuvants and Synergists in Formulation Chemistry

Role of adjuvants (carriers, diluents, surfactants, emulsifiers, dispersing agent, wetting agents, stickers and spreaders, penetrants,safeners, encapsulants etc.), synergists,antioxidants, stabilizers etc. in formulation chemistry.

Unit 3: Physico-chemical Properties of Pesticide Formulations

Physico-chemical properties (solubility, octanol-water partition coefficient, vapor pressure, soil adsorption coefficient, emulsion stability, half-life, shelf-life etc.) and their testing, Formulant-toxicant interactions.

Block 2: New Generation Pesticide Formulations

Unit 1: Water and Oil Based Novel Formulation

Water soluble concentrates (WSC), Suspension concentrates (SC), Oil-in-water emulsion (EW), suspo-emulsion (SE), Micro-emulsion (ME), Water soluble bags and packets(WSB/WSP), Oil dispersion (OD), Aqueous flowable (AF).

Unit 2: Dry, Controlled Release, and Other Novel Formulations

Water soluble powder, liquid and dispersible granules, Dispersion concentrates, Effervescent tablets, Control/time release formulations. Aerosols, baits, fumigants, and formulations of pesticide mixtures, Seed treatment formulations, Seed dressing.

Unit 3: Pesticide Application and Delivery Systems

Packaging and labelling of pesticide formulations, Machinery and equipment for pesticide formulation, Pesticide application and delivery systems - principles, distribution and coverage.

Block 3: Nanotechnology and its Application in Pesticide Formulation

Unit 1: Production and Characterization of Nanomaterials

Development of nanomaterials – bottom up and top-down approach, nano-sizing of inorganic materials, Techniques for characterization of nanomaterials [Zeta sizer, Dynamic light scattering (DLS), X-ray diffraction (XRD), Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Atomic force microscopy (AFM), and Scanning tunneling microscopy (STM)].

Unit 2: Application of Nanotechnology in Pesticide Formulation and Delivery

Production and use of nano-enabled pesticide formulation (nanoemulsions, nanodispersions, nanoencapsulation, and other polymer based formulations), Nanocarriers for targeted and controlled release, Benefits and environmental risks of nanopesticides.

VII. Practicals

- Study of liquid carriers for the determination of (i) flash point, (ii) specific gravity, (iii) viscosity, and (iv) micelle formation with the surfactants
- Study of solid carriers: Determination of (i) Surface acidity by volumetric method, (ii), surface area, (iii) Sorptivity, and (iv)particle size, of the solid carriers
- Preparation of solid formulations: wettable powder (WP)/granules (G)/WDG/WSG
- Physico-chemical analysis of solid formulations based on BIS/CIPAC/FAO guidelines.
- Physico-chemical analysis of liquid/gel formulations based on BIS/CIPAC/FAO guidelines
- Preparation of toxicant based insect repellent formulations.
- Preparation of liquid and gel formulations: EC/SC/SL/OD/EW/gel, etc.
- Preparation and characterization of a nanopesticide formulation

- Preparation of controlled release (CR) formulation and the release of active ingredient in soil and water

VI. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

VII. Learning outcome

After successful completion of the course, student will acquire knowledge about new generation pesticide formulation and their use in pest control

VIII. Suggested Reading

- Chester L. Foy, David W. 1996. Pritchard Pesticide Formulation and Adjuvant Technology. ISBN-13: 978-0849376788. CRC Press, 384 pages
- Knowles DA. 1998. *Chemistry and technology of Agrochemical Formulations* DOI https://doi.org/10.1007/978-94-011-4956-3 Kluwer Academic Publishers, Springer Nature Switzerland AG.
- Alan K. Viets, Jane C. Mueninghoff (Editors). 2001. *Pesticide Formulations and Application Systems*, 20 ASTM International, 2001, 196 pages.
- Jane C. Mueninghoff, Alan K. Viets (Editors) Pesticide Formulations and Application Systems: A New Century for Agricultural Formulations. 21, (1414), ASTM publication. *Journal of ASTM International: Selected technical papers*, ISSN 1040-1695, 260 pages.
- Parmar BS and Tomar SS. 2004. *Pesticide Formulation Theory and Practice*, CBS Publishers & Distributors-New Delhi, ISBN: 9788123911243, 8123911246
- Valkenburg WV. 2008. *Pesticide Formulation: Recent Developments and Their Applications in Developing Countries* (ISBN-13: 978-8122410693) New Age International (P) Limited, Publishers; First edition (2008) pp 488.
- Goss GR (Editor). 2014. *Pesticide Formulation and Delivery Systems*: 35th Volume, Pesticide Formulations, Adjuvants, and Spray Characterization. ISBN-13: 978-0803176195 (Publisher: ASTM International 2016), 93 pages .
- Teicher HB. 2017. *Pesticides and Biopesticides: Formulation and Mode of Action* (Publisher: BioComm Press) pp 166.
- Practical Manual on Pesticide Formulation Technology developed by the ICAR Institute/ SAU.

I. Course Title : Chemistry of Biopesticides

II. Course Code : AC 602*

III. Credit Hours : 2+1

IV. Why this course?

Biopesticides derived from natural sources (plant, animal, nematodes, bacteria, fungi, virus, natural minerals) are considered as safer alternative to chemical pesticides. In view of their safety, such ecologically sound products are increasingly sought after for use in agriculture, veterinary and public health.

V. Aim of the course

To apprise the students about the usefulness of phytochemical biopesticides, microbial pesticides insect behaviour modifying chemicals, and role of biotechnology in pest management.

The course is organized as follows:

No.	Blocks	Units
1.	Phytochemical Biopesticides	1. Conventional Botanical Pesticides 2. New Generation Botanical Pesticides
2.	Insect Behaviour Modifying Chemicals	1. Insect Hormones and Related Products 2. Pheromones and Allelochemicals 3. Insect Feeding Deterrents and Repellents
3.	Microbial Pesticides and Bioagents	1. Microbial Insecticides 2. Microbial Fungicides and Herbicides 3. Entomopathogenic Nematodes, Fungi, and Plant Inhabiting Fungal Endophytes 4. Application of Biotechnology in Pest Management

VI. Theory

Block 1: Phytochemical Biopesticides

Unit 1: Conventional botanical pesticides

Isolation, characterization, use and mode of action of natural pyrethrins, rotenones,nicotine and neem based azadirachtiniods

Unit 2: New generation botanical pesticides

Isolation, characterization, use and mode of action of toosendanin, ryanodine, rocaglamides, annonins, isobutylamides, quassinoids, and sugar esters from plant sources, Plant essential oils and their constituents as botanical pesticides, Photo-activated pesticides like á-terthieyl, acetylenes and acetylenic thiophenes

Block 2: Insect Behaviour Modifying Chemicals

Unit 1: Insect hormones and related products

Insect hormones (Juvenile hormones, Moulting hormones, Brain hormones), their chemistry, mode of action and use in insect pest control)

Unit 2: Pheromones and allelochemicals

Pheromones (sex, alarm, trail, territorial, aggregation, etc.), Semiochemicals, Allelochemicals – allomones, kairomones, synomones, apneumones, Phytoalexins

Unit 3: Insect feeding deterrents and repellents

Sources, chemistry and mode of action of feeding deterrent and insect repellents

Block 3: Microbial Pesticides And Bioagents

Unit 1: Microbial Insecticides

Pesticides of microbial origin, Bacillus (*Bt, Bs*) and NPV based Insecticides. Chemistry and mode of action of macrolides such as avermectins, milbimycins and spinosyns

Unit 2: Microbial Fungicides and Herbicides

Natural fungicides like strobilurins and other methoxyacrylates, Bioherbicides like biolaphos and phosphonothricin

Unit 3: Entomopathogenic Nematodes, Fungi, and Plant Inhabiting Fungal Endophytes

Entomopathogenic nematodes and entomopathogenic fungi in insect control, Pesticidal secondary metabolites (biotoxins) from EPN (*Photorhabdus* and *Xenorhabdus)* and EPF (Metarrahiza etc.), Plant inhabiting fungal endophytes and their role in plant protection

Unit 4: Application of Biotechnology in Pest Management

Plant incorporated protectants, Recombinant DNA technology, **Genetically-modified** (GM) herbicide resistant crops, **Genetically-modified**insect resistant crops, Potential benefits and risks of GM crops

VII. Practicals

- Isolation of curcuminoids from turmeric rhizome and their characterization,
- Extraction of tobacco leaves, isolation of nicotine and its identification,
- Extraction of neem seed kernels to isolate neem oil
- Saponification of neem oil
- Isolation of azadirachtin concentrate from neem seed kernel powder
- Quantification of azadirachtin content in isolated azadirachtin powder
- Characterization of biopesticides by chromatographic and spectral analysis

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will get acquainted with production of biopesticides from natural sources and their use in crop protection as safer alternative to chemical pesticides.

X. Suggested Reading

- Jacobson M. 1970. *Naturally Occurring Insecticides*. Wiley Khan SU. 1980. Pesticides in the Soil Environment. Elsevier.
- Parmar BS and Devakumar C. 1990. *Botanical and Biopesticides*. Westvill Publ. House
- Copping LG. 1996. *Crop Protection Agents from Nature: Natural Products and Analogues*. Royal Soc. Chem., London.
- Dev S and Koul O. 1997. *Insecticides of Natural Origin*. Harwood Acad. Publ. Godfrey CRA. 1995. Agrochemicals from Natural Products. Marcel Dekker.
- Schmutterer H. 2002. *The Neem Tree: Source of unique natural products for integrated pest management, medicine, industry and other purposes*. (2nd edition) Neem Foundation, Mumbai-400 049, India
- Parmar BS, Walia S, Anupama and Kumar J. 2008. *Neem Pesticides in India, An update of the recent developments*. SPS Publication No. 15, Society of Pesticide Science, India 50pp
- Parmar BS and Walia S. 2001. *Prospects and problems of phytochemical pesticides*. In: O. Koul and G.S. Dhaliwal (eds) Phytochemical Biopesticides, Harwood Academic Publishers Gmbh. Netherlands pp 133-210.
- Koul. 2004. *Insect antifeedants*. CRC Press LLC Boca Raton, Florida 33431, USA, pp 1005
- Franklin R. Hall and Julius J. Menn (Ed) *Biopesticides: Use and Delivery*. DOI 10.1385/0896035158, 2010 edition, 626 pages. Humana Press, Springer Nature. Switzerland. AG
- Singh D. 2014. *Advances in Plant Biopesticides*, Springer Nature India Private Limited, DOI 10.1007/978-81-322-2006-0. Pages 421.

- Leo ML. Nollet and Rathore HS. 2017. *Green Pesticides Handbook: Essential Oils for Pest Control* (ISBN-13: 978-1498759380), CRC Press pp 570.
- ICAR Institute/SAU. *Practical Manual on Chemistry of Biopesticides.*

I. Course Title : Advanced Organic Chemistry

II. Course code : AC 603

III. Credit Hours : 2+1

IV. Why this course?

This course provides a deeper understanding of organic chemistry and covers advanced topics of stereochemistry, photochemistry, pericyclic reactions, name reactions, chemical reagents etc. The knowledge of advanced organic chemistry is essential to students interested in synthesis and technology development of organic compounds including pesticides

V. Aim of the course

The course aims to equip the students with the advanced knowledge about stereochemistry, chemical reactions, chemical reagents in organic synthesis, and photochemistry.

The course is organized as follows:

No.	Blocks	Units
1.	Stereochemistry	1. Understanding Spatial Arrangement of Organic Molecules 2. Application Of Stereochemistry
2.	Important Chemical Reactions and their Mechanisms	1. Electrophilic and Nucleophilic Substitution Reactions 2. Elimination and Addition Reactions 3. Pericyclic Reactions 4. Organic Name Reactions
3.	Reagents in Organic Synthesis	1. Different Reagents and their Application in Organic Synthesis 2. Protection and Deprotection of Functional Groups
4.	Photochemistry	1. Basic Principles and Application of of Photochemistry

VI. Theory

Block 1: Stereochemistry

Unit 1: Understanding Spatial Arrangement of Organic Molecules

Enantimerism and diastereoisomerism, mesomers, Racemic mixture (racemate), Different methods of resolution of enantiomers (optical resolution), Walden inversion, Asymmetric synthesis of stereoisomers

Unit 2: Application of Stereochemistry

Nomenclature of stereo-chemicals with particular reference to agrochemical molecules, Stereospecific and stereoselective reactions, Chiral synthesis

Block 2: Important Chemical Reactions and their Mechanisms

Unit 1: Electrophilic and Nucleophilic Substitution Reactions

Electrophilic aromatic and Electrophilic aliphatic substitution reactions, Nucleophilic substitution reactions, (SN1, SN2 and SNi), Reactions involving carbonium ion, carbanion, carbene and free radicals.

Unit 2: Elimination and Addition Reactions

Elimination reactions (*syn* vs. *anti*-elimination, orientation in elimination reaction, molecular rearrangement, decarboxylation reactions, etc.). Addition reactions. Electrophilic addition of bromine. hydrogenation, hydroboration

Unit 3: Pericyclic Reactions

Cyclic transition states, Types of pericyclic reactions - cycloadditions, sigmatropic rearrangements, and electrocyclic reactions.

Unit 4: Organic Name Reactions

(i) Diels Alder reaction, (ii) Grignard reaction, (iii) Aldol, condensation, (iv) Perkin reaction, (v) Benzoin condensation, (vi) Friedel Craft alkylation and acylation reaction, (vii) Fries rearrangement (viii) Reformatsky reaction, (ix) Wittig Reaction and Sandmeyer reaction (x) Oppenaeur oxidation, (xi) Ziegler Natta reaction

Block 3: Reagents in Organic Synthesis

Unit 1: Different Reagents and their Application in Organic Synthesis

Reagents in organic synthesis: complex metal hydrides, Gilman's reagent, lithium dimethyl curparate, lithium di-isopropyl amide (LDA), dicyclohexylcarbodimide, 1,3-di-thiane, trimethyl selyl iodide, triselenium dioxide, tri-butyl tin hydride, osmium tetroxide, dichlorodicyano quinone etc. Organometallic reagents in organic synthesis, phase transfer catalysis, crown ethers and Merrifield resins

Unit 2: Protection and Deprotection of Functional Groups

Different methods of protection of functional groups in organic synthesis with examples, Deprotection to release the functionality

Block 4: Photochemistry

Unit 1: Basic Principles and Application of Photochemistry

Definition and laws of photochemistry, Light-induced excitation of organic molecules, Singlet and triplet state of oxygen, Application of photochemistry in biological systems, agriculture and industry. Role of light in degradation of pesticides and related xenobiotics

VII. Practicals

- One experiment each of methylation, acetylation, elimination, oxidation, reduction, and hydrolysis
- Preparation of acid chlorides, amides, esters,
- Friedal craft reaction (Alkylation/Acylation),
- Aldol/Claisen/Schmidt reaction,
- Pechmann condensation/Perkin reaction,
- Characterisation of prepared organic compounds by NMR and IR spectroscopy

VIII. Teaching methods/activities

- Lectures assignments
- Review of research documents
- Presentation of review
- Periodical quizzes
- Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will get familiar with advanced organic chemistry and its application for planning, understanding and conducting organic reactions

X. Suggested Reading

- Finar IL. *Organic Chemistry*, Longman Publishing Group
- Corey FA and Sundberg RJ. 1983. *Advanced Organic Chemistry*. *Subseries:* Part A. *Structure & Mechanism*. Part B. *Reaction and Synthesis*. 2nd Ed. Plenum Press,
- Morrison RT, and Boyd RN. 1992. *Organic Chemistry*, 6th edition, ISBN 0136400612 (ISBN13: 9780136436690) Prentice Hall, 1278 pages.
- Eliel EL and Wilen SH. 1994. *Stereochemistry of Organic Compounds*. John Wiley & Sons. Finar IL. 1959. *Text book of Organic Chemistry*. Vols. I, II. 25th Ed. Pearson Edu.
- Kalsi PS. 1996. *Stereochemistry and Mechanism through Solved Problems*. 2nd Ed. New Age International Publ.
- Peter Sykes. 1996. *Organic Chemistry*. *Guidebook to Mechanism in Organic Chemistry*. 6th Ed. Prentice Hall.
- Vogel AI. 1996. *Vogel's Textbook of Practical Organic Chemistry*. 5th Ed. Printice Hall.
- Ahluwalia VK and Aggarwal R. *Comprehensive Practical Organic Chemistry - Preparation and Quantitative Analysis*. Universities Press.
- Bahl A and Bahl BS. 2005. *A Textbook of Organic Chemistry*, S Chand and Company, New Delhi, India, 1074 pages.
- Smith MB and March J. 2007. *March's Advanced Organic Chemistry Reactions, Mechanisms, And Structure*, John Wiley & Sons, Inc., Hoboken, New Jersey, 2190 pages
- Clayden J, Geeves N, Warren S. 2012. *Organic Chemistry* 2nd Edition (ISBN: 978-0199270293), Oxford University Press, Pages 1234.
- ICAR Institute/SAU *Practical Manual on Advanced Organic Chemistry*

I. Course Title : Pesticide Metabolism, Persistence and Decontamination

II. Course Code : AC 604

III. Credit Hours : 2+1

IV. Why this ourse?

The study of pesticide metabolism and dynamics is necessary to understand behaviour of pesticides in the biological systems and the environment. The course is designed to provide deep understanding of the biotic and abiotic transformations affecting fate of the pesticides in the environment

V. Aim of the ourse

To acquaint the students about the persistence, dissipation, and fate of pesticides in the crops and the environment. and about bio-remedial measures to decontaminate pesticide residues.

The course is organized as follows:

No.	Blocks	Units
1	Pesticide Movement in the Environment	1. Translocation of Pesticides in the Plant, Soil and Aquatic Environment 2. Different Phases of Pesticide Metabolism
2	Abiotic and Biotic Transformations of Pesticides	1. Abiotic Transformation of Pesticides 2. Microbial Degradation of Pesticides 3. Metabolism of Pesticides in the Living Systems
3	Pesticide Persistence and Dissipation Kinetics	1. Persistence of Pesticides in the Environment (Soil, Water and Crops) 2. Pesticide Dissipation and Fate in the Environment
4.	Decontamination and Bioremediation Measures	1. Decontamination of Pesticide Residues 2. Bioremediation of Pesticides and Pesticide Contaminated Sites

VI. Theory

Block 1: Pesticide Movement in the Environment

Unit 1: Translocation of Pesticides in the Plant, Soil and Aquatic Environment

Introduction to pesticide metabolism, penetration, uptake, translocation, excretion, and mineralization etc. (Highlight the role of physico-chemical parameters). Uptake, bio-accumulation, bio-concentration, and biomagnifications of pesticides in the plant and the environment.

Unit 2: Different Phases of Pesticide Metabolism

Fate of pesticides in the plant, animal and other living systems, Phase I metabolism (oxidation, reduction, hydrolysis, enzymatic degradation, etc.), Phase II metabolism (conjugation with sugar, amino acid, glutathione, etc.), Phase III metabolism (further conjugation of phase II metabolites), Non-extractable (Bound) residues.

Block 2: Abioticand Biotic Transformations of Pesticides

Unit 1: Abiotic Transformations of Pesticides

Physical and chemical factors affecting fate of pesticides in the environment, Photochemical transformation of pesticides, Role of photosensitizers, quenchers, and light filters in pesticide degradation.

Unit 2: Metabolism of Pesticides in the Living Systems

Biotic transformations and metabolic pathways of different group pesticides in thecrops, insects, animal models.

Unit 3: Microbial Degradation of Pesticides

Types of pesticides-degrading microorganisms in the environment, Factors affecting microbial degradation, Microbial degradation of different group pesticides.

Block 3. Pesticide Persistence and Dissipation in the Environment

Unit 1: Persistence of Pesticides in the Environment

Low, moderate and high persistent pesticides, Persistent organic pollutants, Physical, chemical, biochemical and environmental factors affecting pesticide persistence in the environment.

Unit 2: Pesticide Dissipation and Fate in The Environment

Various dissipation processes, Role of drift, volatilization, adsorption, desorption, runoff etc.in pesticide dissipation, Leaching and risk of groundwater pollution, Dissipation time (Half-life-DT_{50}, DT_{90}), Rate kinetics (1st order, 2^{nd} order), Behaviour and fate of pesticides in soil and crops.

Block 4: Decontamination and Bioremediation Measures

Unit 1: Decontamination of Pesticide Residues

Decontamination of pesticide residues in water and food (vegetables and fruits) commodities, Effect of different processing/culinary methods on reduction pesticide residues, safer methods of pesticide decontamination.

Unit 2: Bioremediation of Pesticides and Pesticide Contaminated Sites

Bioremediation-advantages and applications, Biodegradation and bioremediation of pesticides and related xenobiotic compounds, Microbe-mediated bioremediation, Use of enzymes in bioremediation, bioremediation of pesticide polluted sites.

VII. Practicals

- Synthesis of a pesticide metabolite
- Photodegradation of pesticides on glass and leaf surface,
- Microbial degradation of pesticides in soil.
- Leaching of pesticides in soil columns,
- Recovery of residues from pesticide-spiked farm soil

VIII. Teaching methods/activities

– Lectures assignments
– Review of research documents
– Presentation of review
– Periodical quizzes
– Mid-term and final examination

IX. Learning outcome

After successful completion of the course, student will acquire knowledge about pesticide metabolism and dynamics in the biological systems and the environment and get acquainted with bio-remedial measures for to decontaminating food commodities and pesticide contaminated sites

X. Suggested Reading

- Schnoor JL. (Ed). 1992. *Fate of pesticides and chemicals in the environment.* Wiley New York. 436 pages:
- Alexander M. 1999. *Biodegradation and bioremediation*. 2nd Ed. Academic Press.
- Racke KD, Skidmore MW, Hamilton DJ, Unsworth JB, Miyamoto J and Cohen SZ. 1997. *Pesticide Fate in Tropical Soils*. Pure and Appl. Chem. 69 (6): 1349-1371.
- Hall JC, Hoagland RE and Zablotowicz RM. 2001. *Pesticide Biotransformation in Plants and Microorganisms: Similarities and Divergences.* ACS Symposium Series 777. Washington, DC.
- Shahamat U Khan. 1980. *Pesticides in the Soil Environment* (Editor: R. J. Wakeman) Elsevier. 248 pages.
- Perry AS, Yamamoto I, Ishaaya I, Perry RY. 1998. Insecticides in Agriculture and Environment- Retrospects and Prospects, DOI: 10.1007/978-3-662-03656-3 pp 261. Springer-

Verlag Berlin Heidelber.
- Wheeler WB. (Ed) 2002. *Pesticides in Agriculture and the Environment* (1st Edition), CRC Press.
- Matsumura F (Ed) 2013. *Biodegradation of Pesticides* (ISBN-13: 978-1468440904) Publisher: Springer, pp 312 pages.
- ICAR Institutes/SAU. *Practical Manual on Pesticide Residues and Dynamics in the Environment*

I. Course Title : Term Paper (Special Topics in Agro Chemicals)

II. Course code : AC 605

III. Credit Hours : 1+0

IV. Aim of the course

To develop proficiency of the student in his/her area of specialization. The teacher will give a topic relevant to the area of specialization of the student as a term paper to develop proficiency in his field of research. The term paper can be based on one of the selected current topics in agrochemicals

V. Suggested Reading

Literature on the relevant subject of the term paper in his area of research

Journals

- *Archives of Environmental Contamination and Toxicology*
- *Biopesticide International*
- *Bulletin of Environmental Contamination and Toxicology*
- *Chemosphere*
- *Crop Protection*
- *Current Science*
- *Environment Monitoring and Assessment*
- *Environmental Toxicology and Chemistry*
- *Food Additives and Contaminants*
- *Food Chemistry*
- *Indian Journal of Agricultural Chemistry*
- *Industrial Crops and Products*
- *Integrated Pest Management Reviews*
- *International Journal of Pest Management*
- *International Journal of Pesticide Reform*
- *Journal of Agriculture and Food Chemistry*
- *Journal of AOAC*
- *Journal Environ. Science and Health Part A & B*
- *Journal of Essential Oil Bearing Plants*
- *Outlooks on Pest Management*
- *Pest Management Science*
- *Pesticide Biochemistry and Physiology*
- *Pesticide Research Journal*
- *Pesticide Science Japan*
- *Weed Research*
- *Weed Science*
- *Weed Technology*

e-Resources

- Government of India, Ministry of Agriculture & Farmers Welfare, Department of Agriculture, Cooperation & Farmers Welfare, Directorate of Plant Protection, Quarantine & Storage. http://ppqs.gov.in/about-us/about-department

- Central Insecticide Board and Registration Committee (CIB&RC) www.cibrc.nic.in; http://ppqs.gov.in/contactus/central-insecticide-board-and-registration-committee-cibrc
- The Food Safety and Standards Authority of India (FSSAI) https://www.fssai.gov.in/home
- *Insecticides in Agriculture and Environment- Retrospects and Prospects*, Authors: Perry, A.S., Yamamoto, I., Ishaaya, I., Perry, R.Y. (1998) DOI: 10.1007/978-3-662-03656-3 pp 261. Springer-Verlag Berlin Heidelber
- *CRC Handbook of pest management in agriculture, Volume 1. Author:* Pimentel, D., CRC Series in Agriculture; Editor: Hanson, A.A.]. 1981. 597 pp.
- Food and Agricultural Organization Statistics (FAOSTAT) *Pesticides Use*. http://www.fao.org/faostat/en/#data/RP
- Food and Agricultural Organization (FAO/WHO) *Codex Pesticides Residues in Food Online Database. Pesticide Residues in Food and Feed*, doi: http://www.codexalimentarius.net/pestres/data
- European Food Safety Authority: http://www.efsa.europa.eu/en/pesticides/mrls.htm
- Pest Management Regulatory Agency Canada. https://www.canada.ca/en/health-canada/corporate/about-health-canada/branches-agencies/pest-management-regulatory-agency.html
- OECD (Organization for Economic Co-operation and Development), (2011). OECD MRL calculator: spreadsheet for single data set and spreadsheet for multiple data set, 2 March 2011. In: Pesticide Publications/Publications on Pesticide Residues. http://www.oecd.org.
- Bureau of Indian Standards (BIS), New Delhi, India. http://www.bis.org.in/cert/bis_proc_obt_lic.htm
- EU. http://ec.europa.eu/food/plant/pesticides/eu-pesticides-database/public/?event=pesticide.residue.CurentMRL&language=EN&pestResidueID=69. (accessed 21 October 2016).
- US Environment Protection Agency (USEPA) https://www.epa.gov, https://www.epa.gov/pesticide-registration/about-pesticide-registration

Suggested broad topics for master's/ doctoral research

- New generation pesticides (insecticides, fungicides, herbicides, nematicides), plant growth stimulants, and other allied agrochemicals from synthetic and botanical sources
- Biopesticides from natural sources (plants, fungi, bacteria, algae, nematodes, etc),
- Novel insect antifeedants and other insect behaviour modifying chemicals (pheromones and other semio-chemicals)
- Novel pesticide formulations, time-release formulations, and delivery systems for enhanced activity and stability of single and combination pesticides
- Analysis of pesticide residues (multi-class pesticides, metabolites, degradation products, impurities) in soil, water, food commodities as well as in technical materials and formulations
- Investigations on safety evaluation, fixation of MRLs and safe waiting periods, and risk assessment
- Biotechnological and nanotechnological intervention for developing ecologically sound agrochemicals
- Pesticide-environment (plant, air, water, microbes) interaction, Pesticide persistence, degradation (biotic, abiotic)
- Impact of pesticides on the non-target organisms.
- Pesticide detoxification, decontamination and disposal, Bioremediation of pesticide contaminated sites for safe environment
- Increasing agricultural input (pesticides, water, fertilizers, micronutrient etc.) use-efficiency through technological interventions.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Basic Sciences
– Biochemistry

Preamble
(Biochemistry)

The global advancement of agriculture in the fields of crop production and improvement, crop protection, development of newer and high yielding varieties of different crops are all going hand-in-hand with the advancement and application of biochemistry. Education and research in agriculture, specifically in the fields of photosynthetic efficiency, nitrogen fixation, applications of recombinant DNA technology, genomics and proteomics in varietal development and plant protection, animal and human nutrition and health and the environmental impact of agricultural chemicals are some examples of the wide array of topics in which biochemistry plays significant contributions.

Restructuring the courses of biochemistry associated with agricultural education in our country has become demand of the day to keep pace with the rapid development of the subject as well as to fulfil the objective of doubling farmer's income through use of these cuttingedge developments under the global context. Keeping this in view the ICAR has initiated modification of the existing courses both of M.Sc. and Ph.D. curricula in biochemistry. These alterations will not only help the students to understand the subject better but will also create ample scope to gather advanced knowledge in different areas of the subject which will enable them to proceed a step further towards excelling in advanced studies and research and also serving the industrial field causing benefit to the mankind.

M.Sc. courses

A total of eleven courses belonging to five different categories have been proposed for M.Sc. programme:

1. Basic and fundamental course: BIOCHEM 501 (Basic Biochemistry) deals with the basic andfundamental aspects of biochemistry. It is one of the core courses of M.Sc. study programme which has the objective to enrich the students of biochemistry as well as other disciplines with the knowledge of the basics of the subject. The students will gather basic idea and will have a strong footing prior to entering into the vast realm of the subject. The topic of photosynthesis in this course is replaced by plant secondary metabolites, PR proteins and immunoglobulins. Several relevant and new practicals have also been introduced.

2. Courses covering the major areas of the subject including one of analytical aspects: This category includes four courses, BIOCHEM 502 (Intermediary Metabolism), BIOCHEM 503 (Enzymology), BIOCHEM 504 (Molecular Biology) and BIOCHEM 505 (Techniques in Biochemistry). Students will be able to have a comprehensive idea of the metabolic processes occurring in the living cells, the catalytic activity of the enzymes in the biological systems and the molecular basis of transmission of hereditary information through generations. These courses will appraise the students about the basic biochemical activities occurring in the living systems and will also help them to choose the avenues of their future research programmes with the knowledge of essential tools of analytical techniques being extremely helpful for the students of other disciplines besides thosebelonging to biochemistry itself. The qualitative and quantitative estimation of the plant metabolites is also an important aspect of crop improvement programmes.

In BIOCHEM 502, topics such as, biochemical reaction types, bioavailability of nutrients, defined metabolic processes, and nucleotide metabolism are newly introduced. Course outlines in BIOCHEM 503 are redefined in broader aspects with introduction of enzyme kinetic models and large scale production technology of enzymes in theory and effect of inhibitors on enzyme activity and electrophoretic analysis of isozymes in practical. New topics for theory have also been added to BIOCHEM 504, such as genome editing, DNA sequencing, *in vitro* mutagenesis and techniques in molecular biology. The course BIOCHEM 505 is redesigned with introduction of several modern and widely used techniques, viz. mass spectroscopy - MS/MS, LC-MS, GC-MS, MALDI-TOF, atomic absorption spectrophotometry, microscopic techniques, imaging techniques – MRI and CT scan and immunochemical techniques. Emphasis is also given to practicals with introduction of several important techniques – separation and analysis of fatty acids/lipids by GC, $(NH_4)_2 SO_4$ precipitation and dialysis, PCR, ELISA and Western blotting/Dot blotting.So the course BIOCHEM 505 will enable the students to acquaint with the methods to estimate the phytochemicals and cellular constituents along with their theoretical backgrounds.

3. Courses related to plant metabolism: Two courses within this category are BIOCHEM 507 (Plant Biochemistry) and BIOCHEM 510 (Nitrogen and Sulphur Metabolism). Understanding the basic plant metabolic processes is of prime importance for improvement of crop plants. So these courses will give the basic idea in this field and will help the students to explore further for development of the crops.

Credit load in BIOCHEM507 is changed from 3 (3+0) to 3 (2+1) with one credit for practicals and with introduction of new topic - effect of biotic and abiotic factors on plant metabolism. For BIOCHEM 510 also, the course title is changed from Carbon and Nitrogen metabolism to Nitrogen and Sulfur metabolism as the topics under carbon metabolism have been well addressed in BIOCHEM 501 and BIOCHEM 507. An elaborative course outline on nitrogen as well as sulfurmetabolism covering all the aspects is prescribed. New practicalslikeestimation of cysteine, methionine, pyruvate and glutathione and assay of APS activity are introduced.

4. Courses dealing with diverse specialized areas: Three courses, viz. BIOCHEM 506 (Immunochemistry), BIOCHEM 509 (Nutritional Biochemistry) and BIOCHEM 511 (Biochemistry on Xenobiotics) under this categoryaddress the biochemical aspects of immunity, nutrition and environmental applications of biochemistryrespectively. These courses will widen the area of understanding as well as application of the subject on environmental components and human health as a whole.

In BIOCHEM 506 course outline, aspects on plant immunity, proteasome mediated process, plantibodies, additional immunological techniques: immunoblotting, FACS; basics of PCR and hybridization based methods of detection, microarray based detection, multiplexing are newly introduced. Similarly ELISA, Western blotting, Fluorescent Ab test and Hybridoma technique are newly introduced in the practical part.

Course title for BIOCHEM 509 is changed from Food and Nutritional Biochemistry to Nutritional Biochemistry and the course outline is modified to suit the present aspects in nutrition science with inclusion of phytonutrients, prebiotics and probiotics, interrelationship in nutrient functions, mineral deficiency diseases; nutraceuticals, factors affecting bioavailability of nutrients and food sensitivity. New practicals are also introduced.

A new course, Biochemistry on xenobiotics(BIOCHEM511) is proposed considering the pollution from industrial chemicals and waste water leading to heavy metals contamination of the agricultural crops and thebiological and non-biological remediation techniques.

5. Animal Biochemistry (BIOCHEM 508): Agriculture is a multidisciplinary stream and includes animal husbandry. So study of the topics related to animal system will be of immense help for the students.

The Unit–II in the earlier syllabus under BIOCHEM 508 (Animal Biochemistry) is restructured with inclusion of vitamins, energy nutrients, bioactive peptides and functional oligosaccharides with deletion of biochemistry of reproduction from the Unit-III.

Ph. D. courses

There are seven (7) coursesat the Ph. D. level, most of which are of advanced nature. No new course is proposed in the syllabus. Modification of the courses was done as per suggestions from different experts from state agricultural universities and ICAR institutions.

- Units under BIOCHEM 601 (Advanced Enzymology) are redefined with incorporation new topics such as pseudoenzyme and enzyme promiscuity, extremozymes, catalytic nucleic acids (ribozymes, catalytic DNA), immobilization of enzymes, semisynthetic enzymes and their use as industrial biocatalysts and their practical significance, modern information technologies in enzyme engineering.
- In BIOCHEM 602 (Advanced Molecular Biology), the units are redefined with inclusion of several new topics like concept of epigenome, role of histones, riboswitches, genome sequencing technologies, gene silencing technologies, genome editing – TALENs, CRISPR/cas, ZFN and their application and a new unit Aspects of molecular breeding.
- The different units are newly addressed for BIOCHEM 603 (Biochemistry of Biotic and Abiotic Stresses), a course having enormous importance for understanding the interfaring effects of stresses specially with crop growth and development .
- The course title and the credit load for BIOCHEM 604 are changed with new title Frontier topics in biochemistry and with credit load of (2+0). The broad topics for oral presentations to be delivered by the students registering this course are divided into eight major heads.
- The course title for BIOCHEM 605 is changed to Concepts and Application of Omics in Biological Science with fresh inclusion of ionomics part.
- The course title for BIOCHEM 607 is changed to Application of Techniques in Biochemistry. The entire course is divided into five units with Molecular biology and immunochemical techniques in the fifth unit.

Biochemistry courses are offered to a large number of students hence need for a few common types of equipment in multiple numbers cannot be avoided. Moreover, with the advancement of techniques and to cater quality teaching and research, sophisticated equipment like ultra-low freezers, high speed refrigerated- and ultra-centrifuges, automated bioseparation systems like GLC or HPLC, GC-MS, LC-MS; UV-Vis spectrophotometers suitable for enzyme studies, AAS for minerals, PCRs, electrophoresis systems for proteins and DNA are required as essentials in a Biochemistry laboratory. Additional funds may also be required forpurchasing spare parts and for AMC for the instruments. Provisions for training to the teachers to the new areas in the field of Biochemistry and exposure to modern laboratories within and outside the country become a primary need with the changing academic scenario. Moreover, funds may also be required for the proposed exposure visits of the students to other institutes. Financial assistance for these non-recurring and recurring expenses to the tune of a one-time grant of ₹ 5 crores and ₹ 20 lacs per annum respectively, is the need of the time to effectively run Master's and Doctoral programmes in the Discipline of Biochemistry at ICAR-IARI and State Agricultural Universities.

Course Title with Credit Load
M.Sc. (Ag) in Biochemistry

Code Code	Course Title	Credit Hours
BIOCHEM 501*	Basic Biochemistry	3+1
BIOCHEM 502*	Intermediary Metabolism	3+0
BIOCHEM 503*	Enzymology	2+1
BIOCHEM 504	Molecular Biology	2+1
BIOCHEM 505*	Techniques In Biochemistry	2+2
BIOCHEM 506	Immuno Chemistry	2+1
BIOCHEM 507	Plant Biochemistry	2+1
BIOCHEM 508	Animal Biochemistry	3+0
BIOCHEM 509	Nutritional Biochemistry	2+1
BIOCHEM 510	Nitrogen And Sulphur Metabolism	2+1
BIOCHEM 511	Biochemistry On Xenobiotics	2+0
BIOCHEM 591	Master's Seminar	1+0
BIOCHEM 599	Master's Research	30

*Core course

Course Contents
M.Sc. (Ag) in Biochemistry

I. Course Title : Basic Biochemistry
II. Course Code : BIOCHEM 501*
III. Credit Hours : 3+1

IV. Why this course?

To impart the fundamental knowledge on structure and function of cellular components involved in biological processes and an elementary introduction to the study of molecular biology.

V. Aim of the course

The course is designed to provide elementary knowledge/overview of structure and function of proteins, carbohydrates, lipids, nucleic acids and other biomolecules and their metabolism.

No.	Blocks	Units
1.	Introduction to Biochemistry	1. Scope and importance of biochemistry 2. Foundation of life 3. Water 4. Physical techniques for structure determination
2.	Structure and function of biomolecules	1. Biomolecules 2. Immunoglobulins and PR proteins 3. Plant secondary metabolites
3.	Metabolism – the basics	1. Molecules aiding metabolism 2. Thermodynamics –principles and energetic of life
4.	Catabolism and its regulation	1. Catabolism of energy molecules 2. ATP formation
5.	Fundamentals of Molecular biology and genetic engineering	1. Molecular biology processes 2. Recombinant DNA technology

VI. Theory

Block 1: Introduction to Biochemistry

Unit 1: Scope and importance of biochemistry (1 Lecture)

Biochemistry as modern science and its various divisions, Scope and importance of biochemistry in agriculture and allied sciences.

Unit 2: Foundation of life (2 Lectures)

Fundamental principles governing life, supramolecular structures, significance of weak non covalent interactions in biology

Unit 3: Water (3 Lectures)

Structure of water, ionization of water, acid base concept, pH and buffers, significance of structure-function relationship.

Unit 4: Physical techniques for structure determination (2 Lectures)

General introduction to physical techniques for determination of structure of biopolymers.

Block 2: Structure And Function of Biomolecules

Unit 1: Biomolecules (10 Lectures)

Structure, classification, properties and function of carbohydrates, amino acids, proteins, lipids and nucleic acids.

Unit 2: Immunoglobulins and PR proteins (2 Lectures)

Structure, formation and different forms of immunoglobulins, PR proteins and their classification.

Unit 3: Plant secondary metabolites (3 Lectures)

Structure, classification and function of plant secondary metabolites.

Block 3: Metabolism – The Basics

Unit 1: Molecules aiding metabolism (2 Lectures)

Structure and biological functions of vitamins and coenzymes, enzymes: classification and mechanism of action; regulation, factors affecting enzyme action. Hormones: animal and plants.

Unit 2: Thermodynamics –principles and energetic of life (2 Lectures)

Fundamentals of thermodynamic principles applicable to biological processes, Bioenergetics.

Block 4: Catabolism and its Regulation

Unit 1: Catabolism of energy molecules (5 Lectures)

Important and basic degradative metabolic pathways of carbohydrates, lipids and proteins and their regulation.

Unit 2: ATP formation (3 Lectures)

Formation of ATP, substrate level phosphorylation, electron transport chain and oxidative phosphorylation, chemiosmotic theory and proton motive force.

Block 5: Fundamentals of Molecular Biology and Genetic Engineering

Unit 1: Molecular biology processes (4 Lectures)

Overview of replication, transcription and translation.

Unit 2: Recombinant DNA technology (3 Lectures)

Restriction enzymes, DNA cloning, applications of cloning, transgenics.

VII. Practicals

- Preparation of standard and buffer solutions
- Detection of carbohydrates, amino acids and proteins
- Extraction and estimation of sugars
- Extraction and estimation of amino acids
- Extraction and estimation of proteins

- Estimation of acid value of fat/oil
- Estimation of peroxide value of fat/oil
- Estimation of saponification value in fats and oils
- Fatty acid composition in fat/oil by GC
- Estimation of DNA and RNA by spectroscopic methods
- Estimation of Ascorbic acid
- Separation of biomolecules by TLC and Paper chromatography
- Estimation of alpha amylase activity
- Qualitative tests for secondary plant metabolites.

VIII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz

IX. Learning outcome

With this course, the students are expected to be able to understand the actual chemical concepts and fundamental processes of biology at molecular level.

X. Suggested Reading

- Nelson DL and Cox MM. 2017. *Lehninger Principles of Biochemistry*. 7th edition. W. H. Freeman & Co Ltd
- Satyanarayana U and Chakrapani U. 2017. *Biochemistry*. 5th edition, Elsevier
- Moran LA, Horton HR, Scrimgeour KG and Perry MD. 2012. *Principles of Biochemistry*. 5th edition Pearson.
- Voet D and Voet JG. 2011. *Biochemistry*. 4th edition John Wiley.
- Pratt CW and Cornely K. 2014. *Essential Biochemistry*. 3rd Edition. Wiley
- Moorthy K. 2007. *Fundamentals of Biochemical Calculations*. 2nd edition. CRC Press
- Conn EE, Stumpf PK, Bruening G and Doi RH. 2006. *Outlines of Biochemistry*. 5th edition. Wiley.

I. Course Title : Intermediary Metabolism
II. Course Code : BIOCHEM 502*
III. Credit Hours : 3+0

IV. Why this course?

To understand the interconversion of chemical compounds in the living system, the pathways taken by individual molecules, their interrelationships and the mechanisms that regulate the flow of metabolites through the pathways.

V. Aim of the course

The course is designed to give an insight into the different metabolic pathways, their interrelationship, regulation, metabolic disorders in human and pathway engineering in plants.

No.	Blocks	Units
1.	Introduction to metabolism	1. Overview of metabolism 2. Metabolic pathways
2.	Metabolism of energy nutrients	1. Carbohydrate metabolism

No.	Blocks	Units
		2. Lipid metabolism 3. Protein metabolism 4. Energy transduction and oxidative phosphorylation
3.	Sulphur and nucleotide metabolism	1. Sulphur metabolism 2. Nucleotide metabolism
4.	Metabolic regulation and defects in metabolism	1. Regulation of metabolic pathways 2. Defects in metabolism

VI. Theory

Block 1: Introduction To Metabolism

Unit 1: Overview of metabolism (4 Lectures)

The living cell - a unique chemical system, biochemical reaction types, bioenergetics, bioavailability of nutrients, transport mechanism, signal transduction.

Unit 2: Metabolic pathways (5 Lectures)

Catabolism and anabolism, compartments of metabolic pathways, experimental approaches to study metabolism, metabolic profiles of major organs.

Block 2: Metabolism of Energy Nutrients

Unit 1: Carbohydrate metabolism (5 Lectures)

Major catabolic and anabolic pathways of carbohydrate metabolism, the glyoxylate pathway.

Unit 2: Lipid metabolism (5 Lectures)

Fatty acid oxidation, ketone bodies, fatty acid biosynthesis, synthesis of triacylglycerols, cholesterol, eicosanoids.

Unit 3: Protein metabolism (3 Lectures)

General reactions of amino acid metabolism, degradative and biosynthetic pathways of amino acids, urea cycle, amino acids as metabolic precursors.

Unit 4: Energy transduction and oxidative phosphorylation (4 Lectures)

Mechanisms of energy transduction, electron transport system, oxidative phosphorylation, control of ATP production.

Block 3.sulphur and Nucleotide Metabolism

Unit 1: Sulphur metabolism (5 Lectures)

Sulphate reduction and incorporation of sulphur in to amino acids.

Unit 2: Nucleotide metabolism (3 Lectures)

Synthesis and degradation of purine and pyrimidine nucleotides.

Block 4: Metabolic Regulation and Defects in Metabolism

Unit 1: Regulation of metabolic pathways (4 Lectures)

Regulation of carbohydrate, lipid, protein, nucleotide metabolism and oxidative phosphorylation.

Unit 2: Defects in metabolism (4 Lectures)

Disorders of carbohydrates, lipids, amino acids and nucleic acid metabolism, and inborn errors of metabolism. Metabolic pathway engineering.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

With this course, the students are expected to learn the set of life-sustaining chemical processes that enables organisms transform the chemical energy stored in molecules into useful form and the process by which organisms respond to stimuli and metabolic disorders.

IX. Suggested Reading

- Nelson, D. L. and Cox, M. M. 2017. *Lehninger Principles of Biochemistry*. 7th edition. W. H. Freeman & Co Ltd
- Satyanarayana, U. and Chakrapani, U. 2017. *Biochemistry*. 5th edition, Elsevier
- Campbell M. K. and Farrell S.O. 2009. *Biochemistry*. 6thedition Thomson Higher Education.
- Moran L. A., Horton H. R., Scrimgeour K. G. and Perry, M. D. 2012. *Principles of Biochemistry*. 5th edition Pearson,
- Voet, D. and Voet J. G. 2011. *Biochemistry*. 4thedition . John Wiley.
- Pratt, C. W. and Cornely, K. 2014. *Essential Biochemistry*. 3rd Edition. Wiley
- Moorthy, K. 2007. *Fundamentals of Biochemical Calculations*. 2nd edition. CRC Press

I. Course Title : Enzymology

II. Course Code : BIOCHEM 503*

III. Credit Hours : 2+1

IV. Why this course?

Being highly specific and incredibly efficient biological catalysts, enzymes are responsible for bringing about almost all of the chemical reactions in living organisms. Otherwise these reactions will take place at a rate far too slow for the pace of metabolism. The course will help students in understanding the physical, chemical and kinetic properties of enzymes.

V. Aim of the course

To impart knowledge about the catalytic role of enzymes, their structure, physico-chemical, kinetic and regulatory properties and mechanism of action.

No.	Blocks	Units
1.	Introduction to enzymes	1. Structure and function of enzyme 2. Extraction and purification of enzymes
2.	Enzyme structure and function	1. Chemical nature of enzyme 2. Cofactors and coenzymes 3. Nature of active site
3.	Enzyme kinetics	1. Single substrate kinetics 2. Enzyme inhibition 3. Kinetics of allosteric enzymes

No.	Blocks	Units
		4. Regulation of enzyme activity
4.	Application of enzymology	1. Industrial application of enzymes 2. Biotechnological application of enzymes

VI. Theory

Block 1: Introduction To Enzymes

Unit 1: Structure and function of enzyme (2 Lectures)

Historic perspective, general properties of enzymes, enzyme compartmentalization in cell organelles, nomenclature and classification of enzymes, ribozymes, isozymes, abzymes.

Unit 2: Extraction and purification of enzymes (2 Lectures)

Extraction of soluble and membrane-bound enzymes, purification of enzymes, measurement of enzyme activity.

Block 2: Enzyme Structure and Function

Unit 1: Chemical nature of enzyme (3 Lectures)

Enzyme specificity, monomeric and oligomeric enzymes, catalytic mechanism, mechanism of enzyme action, pseudoenzymes, enzyme promiscuity.

Unit 2: Cofactors and coenzymes (2 Lectures)

Chemical nature and involvement of cofactors and coenzymes in enzyme catalyzed reactions, metal activated enzymes and metalloenzymes, mechanism of enzyme catalyzed reactions without cofactors.

Unit 3: Nature of active site (2 Lectures)

Active site, identification of binding sites and catalytic sites.

Block 3. Enzyme Kinetics

Unit 1: Single substrate kinetics (4 Lectures)

Relationship between initial velocity and substrate concentration, Michaelis-Menten equation, Lineweaver-Burk and Eadie-Hofstee plots, analysis of kinetic data, numerical exercises.

Unit 2: Enzyme inhibition (2 Lectures)

Reversible and irreversible enzyme inhibition, uses of enzyme inhibition.

Unit 3: Kinetics of allosteric enzymes (3 Lectures)

Nature of allosteric enzymes, sigmoidal kinetics, MWC model and allosteric regulation, KNF model and allosteric regulation.

Unit 4: Regulation of enzyme activity (3 Lectures)

Feedback regulation, regulatory enzymes, control of enzymatic activity, symmetry and sequential model, reversible covalent modification of enzymes.

Block 4: Application of Enzymology

Unit 1: Industrial application of enzymes (3 Lectures)

Industrial application of enzyme catalysis in sectors like food processing, detergents, biofuels, paper and pulp, biosensors and clinical applications of enzymes.

Unit 2: Biotechnological application of enzymes (2 Lectures)

Large scale production and purification of enzymes, immobilization of enzymes.

VII. Practicals

- Soluble protein estimation
- Enzyme assay by taking any model enzyme
- Isolation and purification of any model enzyme
- Study of the effect of enzyme and substrate concentrations on enzyme activity
- Determination of K_m and V_{max}
- Determination of pH and temperature optima
- Effect of inhibitors on enzyme activity
- Determination of pH and temperature stability of enzyme
- Electrophoretic analysis of isozymes.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

After completion of this course students are expected to have knowledge on and insight into the chemical principles of enzyme catalysis, action of enzymes as biocatalysts and factors that influence enzyme activity and understand the kinetics of enzymatic reactions. Students will have experience with purification, handling and characterization of proteins and also get exposure of wide applications of enzymes and their future potential.

X. Suggested Reading

- Palmer T and Bonner PL. 2007. *Enzymes: Biochemistry, Biotechnology, Clinical Chemistry*. 2nd edition. Woodhead Publishing
- Okotore RO. 2015. *Essentials of Enzymology*. XLIBRIS
- Herald J. 2016. *Essentials of Enzymology*. Syrawood Publishing House
- Suzuki, H. 2015. *How Enzymes Work: From Structure to Function*. Jenny Stanford Publishing.
- Bugg TDH. 2012. *Introduction to Enzyme and Coenzyme Chemistry*, 3rd Edition. WILEY
- Guo Y. 2014. *Enzyme Engineering*. Science Press
- Bisswanger H. 2011. *Practical Enzymology*. Wiley-Blackwell

I. Course Title : Molecular Biology

II. Course Code : BIOCHEM 504

III. Credit Hours : 2+1

IV. Why this course?

Molecular biology is the study of biology at a molecular level. The concepts and techniques of molecular biology are the foundation for the studies of all aspects of biology in modern time. This course is designed to provide an intensive exposure to the theoretical concepts and experimental techniques of molecular biology and the interrelationship of DNA, RNA and protein synthesis and their regulation.

V. Aim of the course

To provide knowledge of life processes at the molecular and cellular levels, including the storage, transfer and regulation of genetic information and specialist theoretical knowledge and practical experience of gene manipulation and the analysis of nucleic acids and proteins.

No.	Blocks	Units
1.	Introduction to nucleic acids	1. History 2. Properties of nucleic acid 3. Genes and genome
2.	Synthesis of nucleic acids	1. DNA replication 2. Transcription
3.	Protein synthesis	1. Translation machinery 2. Mechanism of protein synthesis 3. Post-translational events
4.	Gene manipulation	1. DNA sequencing 2. Recombinant DNA technology 3. Techniques in molecular biology

VI. Theory

Block 1: Introduction to Nucleic Acids

Unit 1: History (1 Lecture)

Historical development of molecular biology, nucleic acids as genetic material.

Unit 2: Properties of nucleic acid (2 Lectures)

Nucleic acid structure, chemical and physical properties of nucleic acids, spectroscopic and thermal properties of nucleic acids, DNA supercoiling.

Unit 3: Genes and genome (3 Lectures)

Concept of genes and genome,genome complexity, genome organization in prokaryotes and eukaryotes, chromatin structure and function, repetitive and non-repetitive DNA, satellite DNA central dogma, genome editing.

Block 2: Synthesis of Nucleic Acid

Unit 1: DNA replication (3 Lectures)

Modes of replication, DNA polymerases, topoisomerases, DNA ligase, model of replisome, semi conservative replication in prokaryotes and eukaryotes, inhibitors of replication, DNA damage and repair.

Unit 2: Transcription (3 Lectures)

Basic principles of transcription, transcription initiation, elongation and termination, RNA processing, RNA interference, siRNAs, miRNAs and other ncRNAs, DNA/RNA editing. regulation of transcription, reverse transcription.

Block 3. Protein Synthesis

Unit 1: Translation machinery (2 Lectures)

Ribosomes structure and function, organization of ribosomal proteins and RNA genes, genetic code, aminoacyl tRNA synthases.

Unit 2: Mechanism of protein synthesis (2 Lectures)

Initiation, chain elongation and termination of translation, energetics, inhibitors of translation.

Unit 3: Post-translational events (2 Lectures)

Post translational modifications of nascent polypeptide, protein targeting and turnover, regulation of gene expression in prokaryotes and eukaryotes, nucleases and restriction enzymes.

Block 4: Gene Manipulation

Unit 1: DNA sequencing (3 Lectures)

Importance, Sanger method,High-Throughput Sequencing (HTS) techniques, applications of DNA sequencing.

Unit 2: Recombinant DNA technology (4 Lectures)

Vectors, isolation of genes, recombinants vector, selection of recombinants, characterization and expression of cloned DNA, transformation, transgenesis, mutation, molecular mechanism of mutation, site directed mutagenesis, *in vitro* mutagenesis.

Unit 3: Techniques in molecular biology (3 Lectures)

Polymerase chain reaction (PCR), expression cloning, gel electrophoresis, molecular markers, macromolecule blotting and probing, arrays (DNA array and protein array) – principles and application.

VII. Practicals

- Isolation and purification of DNA and RNA
- To check the purity of isolated DNA and RNA
- Restriction fragmentation of genomic DNA
- Separation of oligos by agarose gel electrophoresis
- Southern blotting experiments
- Northern blotting experiments
- Cloning of DNA fragment in vector
- Selection of recombinant
- SSR analysis of DNA
- cDNA synthesis using RT- PCR
- Basic tools in bioinformatics analysis

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

After completion, the student should be able to explain central cell biological processes and how they are regulated and quality assured and understands how molecular cell biology forms the foundation of biotechnology.

X. Suggested Reading

- Snape A, Papachristodoulou D, Elliott, W. H. and Elliott, C. 2014. *Biochemistry and Molecular*

Biology. Oxford University Press.
- Krebs, J. E., Goldstein, E. S. and Kilpatrick, S. T. 2018. *Lewin's GENES XII*. Jones & Bartlett Learning.
- Lodish, H.,Berk, A., Kaiser, C. A., Krieger, M. And Bretscher, A. 2016. *Molecular Cell Biology*.W H Freeman & Co.
- Hoffmann, A. And Clokie, S. 2018. *Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology*. Cambridge University Press.
- Primrose SB, Twyman RM and Old RW.2002. *Principles of Gene Manipulation*: 6th Ed. Wiley
- Karp, G. 2013. *Cell and Molecular Biology*. Wiley.
- Neidle, S. 2008. *Principles of Nucleic Acid Structure*. Elsevier Inc.
- Watson J, Baker TA, Bell SP, Gann A, Levine M and Losick, R. 2014. *Molecular biology of the gene* 7th edition, Pearson.

I. Course Title : Techniques in Biochemistry

II. Course Code : BIOCHEM 505*

III. Credit Hours : 2+2

IV. Why this course?

Biochemical studies rely on the availability of appropriate analytical techniques and their applications. This course will examine modern methods and technologies that are used in biochemical analysis with emphasis on instrumentation, underlying principles, aims, strategies and current applications.

V. Aim of the course

To provide hands-on experience to different biochemical techniques commonly used in research along with the knowledge on principles and the instrumentation**.**

No.	Blocks	Units
1.	Separation techniques	1. Chromatography techniques 2. Electrophoretic technique 3. Hydrodynamic methods 4. Centrifugation
2.	Spectroscopic techniques	1. Spectrophotometry 2. Mass spectroscopy 3. Atomic absorption spectrophotometry
3.	Microscopy	1. Microscopic techniques
4.	Tracer, imaging, immunochemical and other techniques	1. Tracer techniques 2. Imaging techniques 3. Immunochemical techniques 4. Other techniques

VI. Theory

Block 1: Separation Techniques

Principles and applications of separation techniques.

Unit 1: Chromatography techniques (4 Lectures)

Principles and applications of paper, thin layer, gel filtration, ion-exchange, affinity, column & HPTLC, GC, HPLC and FPLC.

Unit 2: Electrophoretic technique (2 Lectures)

General principles,paper and gel electrophoresis, native and SDS-PAGE, 2D-PAGE, capillary electrophoresis.

Unit 3: Hydrodynamic methods (2 Lectures)

Hydrodyanmic methods of separation of biomolecules such as viscosity and sedimentation velocity, - their principles.

Unit 4: Centrifugation (2 Lectures)

Basic principles of sedimentation, type, care and safety aspects of centrifuge preparative and analytical centrifugation.

Block 2: Spectroscopic Techniques

Unit 1: Spectrophotometry (3 Lectures)

Principles and applications of UV-visible, Fluorescence, IR and FTIR, Raman, NMR and FTNMR, ESR and X-Ray spectroscopy.

Unit 2: Mass spectroscopy (3 Lectures)

MS/MS, LC-MS, GC-MS, MALDI-TOF, applications of mass spectrometry in biochemistry.

Unit 3: Atomic absorption spectrophotometry (2 Lectures)

Principle, function and instrumentation ofatomic absorption spectrophotometry.

Block 3. Microscopy

Unit 1: Microscopic techniques (2 Lectures)

Principles and applications, light, UV, phase contrast, fluorescence and electron microscopy, flow cytometry.

Block 4: Tracer, Imaging, Immunochemical and Other Techniques

Unit 1: Tracer technique (2 Lectures)

Tracer techniques in biology: concept of radioactivity, radioactivity counting methods with principles of different types of counters, concept of á, â and ã emitters, scintillation counters, γ-ray spectrometers, autoradiography, applications of radioactive tracers in biology.

Unit 2: Imaging techniques (2 Lectures)

Principles and applications of phosphor imager, MRI and CT scan.

Unit 3: Immunochemical technique (2 Lectures)

Production of antibodies, immunoprecipitation, immunoblotting, immunoassays, RIA and ELISA.

Unit 4: Other techniques (2 Lectures)

Cryopreservation, polymerase chain reaction (PCR), FACS.

VII. Practicals

- Expression of concentration in terms of dilution, molarity, normality, percent expression
- pH measurement and buffer preparation
- Determination of absorption maxima of biomolecules

- Estimation of biomolecules through spectrophotometry and other methods
- Separation of carbohydrates and amino acids by paper chromatography
- Separation and analysis of fatty acids/lipids by GC
- Separation/estimation of biomolecules through HPLC and FPLC
- Separation of proteins using ion exchange, gel filtration and affinity chromatography
- Electrophoretic separation of proteins and nucleic acids
- Centrifugation- differential and density gradient
- $(NH_4)_2SO_4$ precipitation and dialysis
- Use of radioisotopes in metabolic studies
- PCR
- ELISA
- Western blotting/ Dot blotting

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

At the end of the course, the student will acquire the basic knowledge of the main biochemical methods used in the separation, identification, characterization and analysis of biomolecules.

X. Suggested Reading

- Boyer R. 2011. *Biochemistry Laboratory: Modern Theory and Techniques* 2nd Edition. Pearson
- Hofmann A and Clokie S. 2010. *Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology*. 7th edition. Cambridge University Press.
- Sawhney SK and Singh R. 2000. *Introductory Practical Biochemistry*. 2nd Ed. Narosa
- Katoch R. 2011. *Analytical Techniques in Biochemistry and Molecular Biology*. Springer
- Boyer R. 2009. *Modern Experimental Biochemistry*. Fifth impression. Pearson
- Lottspeich F and Engels JW. (Eds). 2018. *Bioanalytics: Analytical Methods and Concepts in Biochemistry and Molecular Biology*. Wiley-VCH
- Wilson K and Walker J. 2010. *Principles and Techniques of Biochemistry and Molecular Biology*, 7th Edition. Cambridge University Press

I. Course Title : Immunochemistry

II. Course Code : BIOCHEM 506

III. Credit Hours : 2+1

IV. Why this course?

This is an introduction to the field of immunology with emphasis on the biochemical aspects of the systems. This course is intended to equip the student with the knowledge and understanding of the vertebrate immune system, its component and mechanism of immune responses with specific reference to the human immune defence system and plant immunity

V. Aim of the course

To give an insight into the biochemical basis of immunity

No.	Blocks	Units
1.	Basics of Immunology	1. Introduction to immunology 2. Antibodies 3. The immune responses 4. Immunoregulation and immunological techniques

VI. Theory

Block 1: Basics of immunology

Unit 1: Introduction to immunology (7 Lectures)

History and scope of immunology, antigens, adjuvants, immune system, organs, tissues and cells, immunoglobulins, molecular organization of immunoglobulin. Haptens, ag-ab interaction, plant immunity, proteasome mediated process, plantibodies

Unit 2: Antibodies (5 Lectures)

Classes of antibodies, antibody diversity, theories of generation of antibody diversity, vaccine, monoclonal and polyclonal antibodies, hybridoma, recombinant antibodies, complement system - classical and alternate.

Unit 3: The immune responses (8 Lectures)

Cellular interactions in immune response, major histocompatibility complex, cell mediated immune response, cytokines.

Unit 4: Immunoregulation and immunological techniques (8 Lectures)

Immunoregulation, immunological tolerance, hypersensitivity, mechanisms of immunity, innate resistance and specific immunity, current immunological techniques – elisa, ria, immunoblotting, facs; basics of pcr and hybridization based methods of detection, microarray based detection, multiplexing.

VII. Practicals

- Handling, inoculation and bleeding of laboratory animals
- Preparation of antigens and antisera, natural antibodies
- Carbon clearance test
- Lymphoid organs of the mouse
- Morphology of the blood leucocytes
- Separation of lymphocytes from blood, viable lymphocyte count
- Antigen-antibody interaction,
- Precipitation and agglutination
- Direct and indirect haemagglutination
- Immunoelectrophoresis
- Complement fixation
- Quantitation of immunoglobulins by zinc sulphate turbidity and single radial immunodiffusion
- ELISA
- Western blotting
- Fluorescent Ab test
- Hybridoma technique

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

It is expected that the student should understand and explain the structure, functioning and importance of human immune system in term of health and disease.

Suggested Reading

- Punt J, Stranford S, Jones P and Owen J. 2018 . Kuby Immunology. 8th edition. W. H. Freeman
- Renshaw S. 2016. *Immunohistochemistry and Immunocytochemistry: Essential Methods*, 2nd Edition. John Wiley & Sons, Ltd.
- Abbas AK, Lichtma AH and Pillai S. 2018. *Cellular and Molecular Immunology*. 9th edition. Elsevier
- Delves PJ, Martin SJ, Burton DR and Roitt IM. 2017. *Roitt's Essential Immunology*, 13th Edition. Wiley-Blackwell

I. Course Title : Plant Biochemistry

II. Course Code : BIOCHEM 507

III. Credit Hours : 2+1

IV. Why this course?

Harnessing sunlight, plants produce a diverse array of chemical compounds to survive in challenging ecological niches. Plant-derived metabolites are major sources of human food, fibre, fuel, and medicine. This course covers topics related to plant metabolism and discusses how plants generate carbon and energy sources by photosynthesis and synthesize various compounds through complex networks of metabolic pathways.

V. Aim of the course

To provide an understanding of metabolic processes in plants and the role of different biosynthetic pathways in plant growth and development.

No.	Blocks	Units
1.	Photosynthesis	1. Photosynthetic machinery 2. Carbon reduction
2.	Conversion of photosynthates	1. Synthesis of major biomolecules 2. Nitrogen and sulphur metabolism
3.	Growth and development	1. Germination and fruit ripening 2. Phytohormones
4.	Secondary metabolites	1. Biochemistry of plant secondary metabolites

VI. Theory

Block 1: Photosynthesis

Unit 1: Photosynthetic machinery (3 Lectures)

Structure and function of plant cell and its organelles, phytochromes, chloroplast morphology structure, structure and chemistry of photosynthetic pigments, light reaction of photosynthesis.

Unit 2: Photosynthesis – the process (4 Lectures)

Carbon reduction in C_3, C_4 and CAM plants, photorespiration, sucrose-starch interconversion.

Block 2: Conversion of Photosynthates

Unit 1: Synthesis of major biomolecules (3 Lectures)

Biosynthesis of structural carbohydrates, storage proteins and lipids.

Unit 2: Nitrogen and sulphur metabolism (5 Lectures)

Basic concepts of nitrogen and sulphur metabolism: biological nitrogen fixation, nitrate assimilation in plants, sulphur chemistry and function, reductive sulphate assimilation pathway, sulphated compounds.

Block 3: Growth and Develpoment

Unit 1: Germination and fruit ripening (4 Lectures)

Biochemistry of seed germination – stages, requirements, metabolism and mobilization of storage material; Biochemistry of fruit ripening – ripening process, cell wall degrading enzymes, role of ethylene and regulation of ethylene production.

Unit 2: Phytohormones (3 Lectures)

Different classes of phytohormones, their biosynthesis and mode of action.

Block 4: Secondary Metabolites

Unit 1: Biochemistry of plant secondary metabolites (6 Lectures)

Biochemistry and significance of plant secondary metabolites – phenolics, terpenoids, alkaloids, cyanogenic glycosides and glucosinolates, effect of biotic and abiotic factors on plant metabolism and plant defense system.

VII. Practicals

- Fractionation of cell organelles,
- Estimation of starch,
- Assay of ADPG pyrophosphorylase/starch synthase,
- Assay of PAL/SOD
- Assay of PPO/LOX,
- Estimation of individual amino acids,
- Qualitative tests of secondary metabolites (alkaloids, sterols etc.)
- Content and composition of carotenoids, anthocyanin and chlorophylls
- Determination of polyphenols/phenolics
- Fractionation of storage proteins
- Estimation of glucosinolates
- Estimation of cyanogenic compounds.

VIII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

IX. Learning outcome

Successful completion of this course will provide students with fundamental knowledge of biochemistry and specific knowledge of compounds and biochemical pathways that occur in plants.

X. Suggested Reading

- Buchannan BB, Gruissem W and Jones R.L. (eds.). 2000. *Biochemistry and Molecular Biology of Plants*. 2nd edition. WILEY Blackwell
- Heldt, H-W. 2010. *Plant Biochemistry and Molecular Biology*. 4th ed. Oxford University Press
- Goodwin TW and Mercer EI. 2005. *Introduction to Plant Biochemistry*. 2nd edition. CBS
- Heldt, H-W. and Piechulla, B. 2010.*Plant Biochemistry*. 4th Edition. Elsevier
- Harinda, Makkeaand Klaus. 2007. *Plant Secondary Metabolites*. Springer
- Cseke LJ, Kirakosyan A, Kaufman PB, Warber S, Duke JA, Brielmann HL. 2006. *Natural Products from Plants*. 2ndEdition. CRC Press

I. Course Title : Animal Biochemistry

II. Course Code : BIOCHEM 508

III. Credit Hours : 3+0

IV. Why this Course?

Biochemistry is one of the few basic sciences where animal and plant kingdoms meet. It provides the knowledge base for all human and animal health studies. Knowledge of biochemistry will enable one to study, or to pursue a line of research in applied sciences.

V. Aim of the Course

To impart knowledge regarding biochemistry of various physiological processes, specialized tissues and hormone action in animal system

No.	Blocks	Units
1.	Animal biochemistry	1. Biochemistry of assimilation 2. Nutrients and their biochemistry 3. Hormones and their role 4. Immune system

VI. Theory

Block 1: Animal Biochemistry

Unit 1: Biochemistry of assimilation (7 Lectures)

Digestion and absorption of food, Detoxification, biochemistry of specialized tissues – connective tissue, skin, muscle, nervous tissue and blood and other body fluids.

Unit 2: Nutrients and their biochemistry (7 Lectures)

Water, electrolyte and acid-base balance, structure, function and mechanism of major trace elements, vitamins, energy nutrients and biochemistry of respiration, bioactive peptides and functional oligosaccharides.

Unit 3: Hormones and their role (7 Lectures)

Hormones of thyroid, hypothalamus, pituitary, pancreas, adrenals and sex hormones, Membrane receptors of hormones, signal transduction.

Unit 4: Immune system (7 Lectures)

Immune systems, immunoglobulins, monoclonal antibodies, formation of antibody, antibody diversity, complement system – classical and alternate, major histocompatibility complexes, cell mediated immune response, mechanisms of immunity.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

Students can acquire essential foundation knowledge for further study in life sciences, agriculture, environmental science, health science, etc.

IX. Suggested Reading

- Bradley, A. 2018. Animal Physiology and Biochemistry. 1st edition. Edtech Press
- Agarwal RA, Srivastava, A.K. and Kumar, K. 2010. *Animal Physiology and Biochemistry*. Fifth revised edition S. Chand.
- Rodwell VA, Bender DA, Botham KM, Kennelly PJ and Weil PA. 2018. *Harper's Illustrated Biochemistry*, 31st edition. McGraw-Hill Education.

I. Course Title : Nutritional Biochemistry

II. Course Code : BIOCHEM 509

III. Credit Hours : 2+1

IV. Why this course?

Nutritional biochemistry deals with the structural and functional characteristics of macro and micronutrients in food consumed by humans. The course will expand understanding of the biological roles of nutrients and their metabolism using basic knowledge in physiology, biochemistry, cell biology and molecular biology. It will integrate information on the roles of nutrients in nutrition and health.

V. Aim of the course

To impart knowledge regarding the biochemical aspects of various nutrients and their interactions in foods during processing, storage and deterioration.

No.	Blocks	Units
1.	Nutritional biochemistry	1. Fundamentals of human nutrition 2. Biochemical functions of nutrients 3. Bioavailability of nutrients 4. Food sensitivity

VI. Theory

Block 1: Nutritional Biochemistry

Unit 1: Fundamentals of human nutrition (7 Lectures)

Fundamentals of human nutrition, concept of balanced diet, biochemical composition, energy and food value of various food grains (including cereals, pulses, oilseeds), fruits and vegetables. Physico-chemical, functional and nutritional characteristics of carbohydrates, proteins and fats and their interactions (emulsions, gelation, browning etc.). Digestion and absorption, digestive secretions, their characteristic features and control, protection of microflora of the GI tract

Unit 2: Biochemical functions of nutrients (7 Lectures)

Biochemical functions of nutrients, macro- and micronutrients- carbohydrates, fats and proteins, vitamins, water soluble and fat soluble vitamins, mineral and phytonutrients, prebiotics and probiotics, enzymes and metabolic protein factors, cofactor role, electrolytic function, constituents of skeletal tissues, interrelationship in nutrient functions, mineral deficiency diseases; nutraceuticals, antinutritional factors, biochemistry of postharvest storage.

Unit 3: Bioavailability of nutrients (7 Lectures)

Factors affecting bioavailability of nutrients, biological value of proteins; effect of cooking, processing and preservation of different food products on nutrients, energy- and micronutrient malnutrition, deficiency diseases of macro and micronutrients.

Unit 4: Food sensitivity (7 Lectures)

Food sensitivity: immunologically mediated food sensitivity, nature and properties of antigens in foods, mechanism of induction of all allergic reactions, diagnostic tests for food, hypersensitivity, non-immunologically mediated food sensitivity, food sensitivity due to metabolic diseases, gastrointestinal diseases, food additives, pharmacologic agents, food toxins and poisonous and psychological factors.

VII. Practicals

- Estimation of amylose and amylopectin
- Estimation of resistant starch
- Estimation of ù3, ù6 and trans fatty acid
- Estimation of phenols in plant tissue/sample
- Estimation of carotenoids
- Estimation of amylase, trypsin and chymotrypsin inhibitor activities
- Estimation of Vitamin C in fruits
- Estimation of reducing & non reducing sugar in fruits
- Estimation of protein contents
- Estimation of dietary fibre
- Determination of limiting amino acids
- Estimation of phytate/ oxalate
- Estimation of total antioxidant activity by different methods
- Estimation of curcumin.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

On successful completion of this course students should be able to critically analyse and evaluate concepts in nutritional biochemistry that are important for an understanding of human nutrition, provide nutritional advice based on sound scientific findings, discuss the efficacy and appropriate use of functional foods and critically evaluate nutrition information appearing in popular magazines and other forms of media.

X. Suggested Reading

- Damodaran S. and Parkin KL (ed.) 2017. *Fennema's Food Chemistry*. CRC Press
- Gibney MJ, Lanham-New SA, Cassidy, A and Voster HH (ed.) 2009. *Introduction to Human Nutrition*. Wiley-Blackwell
- Trueman, P. 2007. *Nutritional Biochemistry*. MJP Publishers
- Cox, C. 2015.*Nutritional Biochemistry: Current Topics in Nutrition Research*. Apple Academic Press Inc.
- Haugen, S. and Meijer, S. 2010. *Handbook of Nutritional Biochemistry: Genomics, Metabolomics & Food Supply*. Nova Science Publishers Inc.

I. Course Title : Nitrogen and Sulfur Metabolism

II. Course Code : BIOCHEM 510

III. Credit Hours : 2+1

IV. Why this course?

Nitrogen and sulfur compounds are continuously synthetized, degraded and converted into other forms in nature. They coexist in the biosphere as free elements or in the form of oxyanions which are to be reduced before undergoing anabolic processes to form N and S containing compounds. This course will provide the students a fundamental understanding of their reduction, assimilation and metabolism in plants.

V. Aim of the course

To impart knowledge of general nitrogen and sulfur metabolism in plants and the assimilatory pathways.

No.	Blocks	Units
1.	Nitrogen and sulfur metabolism	1. Nitrogen metabolism 2. Sulfur metabolism

VI. Theory

Block 1: Nitrogen and Sulfur Metabolism

Unit 1: Nitrogen metabolism (18 Lectures)

Nitrogen cycle, assimilation of inorganic nitrogen, nitrate uptake and transporters, enzymology of nitrate reduction - Nitrate reductase (NR) and Nitrite reductase (NiR), NR regulation, nitrate signaling.

Assimilation of inorganic nitrogen and N-transport amino acids - glutamine synthetase (GS), glutamate synthase (GOGAT), glutamate dehydrogenase (GDH), aspartate amino transferase (AspT) and asparagine synthetase (AS), interaction between carbon metabolism and amino acid synthesis, biosynthesis of amino acids. Nitrogen fixation - an overview, enzymology of nitrogen fixation - nitrogenase, *nif* genes and their regulation, symbiotic nitrogen fixation - biochemical basis of rhizobial infection, nodule development. Mechanism of creation of microaerobic environment for nitrogen fixation. metabolic exchange between host plant and bacteroids.

Unit 2: Sulphur metabolism (10 Lectures)

Overview of sulfate assimilation, sulfur chemistry and function, sulfate uptake and transport, reductive sulfate assimilation pathway, synthesis and function of sulfur containing amino acids, glutathione and its derivatives, role of sulfated compounds in metabolism.

VII. Practicals

- Estimation of nitrite content,
- Estimation of nitrate content,
- *In vivo* assay of nitrate reductase activity,
- *In vitro* assay of nitrate reductase activity,
- *In vitro* assay of nitrite reductase activity,
- *In vitro* assay of glutamine synthetase activity,
- *In vitro* assay of glutamate synthase and glutamate dehydrogenase activity,
- Estimation of ureides and amides,
- Assay of nitrogenase activity by acetylene reduction method,
- Estimation of hydrogen evolution by legume nodules,
- Estimation of cysteine, methionine, pyruvate and glutathione,
- Assay of APS activity.

VIII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

IX. Learning outcome

Students will get an insight into the nitrogen and sulfur metabolism in plants and the coordination between nitrogen (N) and sulfur (S) assimilation

X. Suggested Reading

- Bothe, H. and Trebst, A. (eds.). 1981. *Biology of Inorganic Nitrogen and Sulfur*. Conference proceedings. Springer-Verlag
- De Kok *et al*. 2012. *Sulfur Metabolism in Plants*. Part of the Proceedings of the International Plant Sulfur Workshop book series. Springer
- Bray CM. 1983. *Nitrogen Metabolism in Plants*. Longman.
- Bidwell, R.G.S. 1983. *Plant Physiology: A Treatise*, Vol. 8: Nitrogen Metabolism. Academic Press
- Foyer. C. H. and Zhang, H. 2010. *Nitrogen Metabolism in Plants in the Post-Genomic Era.* Annual Plant Reviews, Vol.42. Wiley-Blackwell
- Buchanan B.B., Gruissem W. and James R. L. (Eds.). 2000. *Biochemistry and Molecular Biology of Plants*. American Society of Plant Physiologists.

I. Course Title : Biochemistry on Xenobiotics

II. Course Code : BIOCHEM 511

III. Credit Hours : 2+0

IV. Why this course?

Xenobiotics are compounds that are foreign to an organism that include compounds like drugs, food additives, and environmental pollutants. Knowledge on metabolic conversion of xenobiotics, especially drugs and environmental contaminants in living system becomes pertinent in present day scenario with increased levels of pollution.

V. Aim of the course

To impart knowledge on xenobiotics and the mechanism of their metabolism and detoxification in living system.

No.	Blocks	Units
1.	Biochemistry on xenobiotics	1. Xenobiotics 2. Mode of degradation 3. Plant metabolism of xenobiotics 4. Phytoremediation

VI. Theory

Block 1: Biochemistry on Xenobiotics

Unit 1: Xenobiotics (7 Lectures)

Xenobiotics: classification and their effects on biological systems, Problems related to xenobiotics degradation, potential effects of toxic agents on immune system function, biotic metabolism of xenobiotics - biodegradation/biotransformation

Unit 2: Mode of degradation (7 Lectures)

Mode of degradation - Enzymatic and Non-enzymatic, Metabolism of toxic compounds with reference to role of detoxifying enzymes, Mechanism of xenobiotics detoxification - in animal using the enzymes of Phase I and Phase II, Role of microbes in xenobiotics degradation and co-metabolism, Biodegradation and its genetics, manipulation of xenobiotic degradative genes

Unit 3: Plant metabolism of xenobiotics (7 Lectures)

Plant metabolism of xenobiotics - transformation, conjugation and compartmentation, Metabolic responses of pesticides in plants, Impact, metabolism, and toxicity of heavy metals in plants, Regulation of xenobiotics in higher plants: signalling and detoxification.

Unit 4: Phytoremediation (7 Lectures)

Phytoremediation, Advances in development of transgenic plants for remediation of xenobiotic pollutants, safety assessment of xenobiotics

VII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

VIII. Learning outcome

Students will gain the basic knowledge and perspectives of bioelimination of xenobiotic compounds.

IX. Suggested Reading

- Richardson, M. 1996. *Environmental Xenobiotics*. CRC Press
- Singh, A., Prasad, S.M. and Singh, R.P.(eds). 2016. *Plant Responses to Xenobiotics*. Springer.
- Chang, Y-C. (ed). 2019. *Microbial Biodegradation of Xenobiotic Compounds*. CRC Press
- Costas Ioannides (ed). 2002. Enzyme Systems that Metabolise Drugs and Other Xenobiotics. Wiley
- Lee, P., Aizawa, H., Gan, L., Prakash, C. And Zhong, D. 2014. *Handbook of Metabolic Pathways of Xenobiotics*. –
- Emerson, M.L. 2012. Xenobiotics*: New Research*. Nova Science
- Shamaan, N.A. 2008. *Biochemistry of xenobiotics: towards a healty lifestyle and safe environment.* PenerbitUniversiti Putra Malaysia.

Course Title with Credit Load
Ph.D. in Biochemistry

Course Code	Course Title	Credit Hours
BIOCHEM 601*	Advanced Enzymology	2+1
BIOCHEM 602	Advanced Molecular Biology	3+0
BIOCHEM 603	Biochemistry Of Biotic And Abiotic Stresses	3+0
BIOCHEM 604	Frontier Topics In Biochemistry	2+0
BIOCHEM 605	Concepts And Aplication Of Omics In Biological Science	3+0
BIOCHEM 606	Biomembranes	2+0
BIOCHEM 607*	Application Of Techniques In Biochemistry	1+2
BIOCHEM 691	Doctoral Seminar I	1+0
BIOCHEM 692	Doctoral Seminar II	1+0
BIOCHEM 699	Doctoral Research	75

*Core course

Course Contents
Ph.D. in Biochemistry

I. Course Title : Advanced Enzymology
II. Course Code : BIOCHEM 601*
III. Credit Hours : 2+1

IV. Why this course?

The course will make the students able to make a conceptual analysis of the enzymatic reaction mechanism and know the principles of the application of enzymes in analytical biochemistry, and some industrial applications.

V. Aim of the course

To provide advanced knowledge about the structure of enzymes, mechanism, kinetics and regulation of enzymatic reactions and use of enzymes as biosensors.

No.	Blocks	Units
1.	Enzymology and enzyme engineering	1. Enzyme catalysis and specificity 2. Enzyme kinetics 3. Enzyme mechanism and regulation 4. Industrial enzymology

VI. Theory

Block 1: Enzymology And Enzyme Engineering

Unit 1: Enzyme catalysis and specificity (Seven Lectures)

Theory of enzymatic catalysis, Specificity and editing mechanisms, concept of active site and enzyme substrate complex, active site mapping, factors associated with catalytic efficiency, mechanism of enzyme reactions,detection of intermediates in enzymatic reactions.

Unit 2: Enzyme kinetics (7 Lectures)

Transition state theory, Arrhenius equation, Determination of energy of activation, effect of pH and temperature on enzyme kinetics, pre-steady state and steady state kinetics, single substrate kinetics, allosteric enzymes and mixed inhibition, substrate and product inhibition, numerical exercises.

Unit 3: Enzyme mechanism and regulation (7 Lectures)

Mechanism determination by radioisotope exchange, role of enzymes in regulation of metabolism, bifunctional enzymes, pseudoenzyme and enzyme promiscuity, extremozymes, catalytic nucleic acids (ribozymes, catalytic DNA).

Unit 4: Industrial enzymology (7 Lectures)

Advantages and disadvantages of biocatalysis in technology driven processes, stabilization and regeneration of enzyme systems used in biotechnology, protein engineering of enzymes, creation of chimeric, bifunctional, immobilization of enzymes, semisynthetic enzymes and their use as industrial biocatalysts, and their practical significance, modern information technologies in enzyme engineering.

VII. Practicals

- Purification and characterization of some model enzymes (peroxidise, á-amylase, lipase)
- Study kinetics of inhibited and un inhibited enzyme catalysed reactions
- Determination of Km values of single substrate reactions
- Determination of enzyme activity by coupled assay
- Electrophoretic separation of isozymes
- Enzyme immobilization.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

After completing the course students will understand the mode of action of enzymes, mechanisms of enzymatic catalysis and also possible applications of enzymes in various technological processes.

X. Suggested Reading

- Aehle, W. 2007. *Enzymes in Industry. Production and Application.* (Third, Completely Revised Edition). Wiley-VCH Verlag GmbH & Co. KGaA
- Buchholz, K., Bornscheuer, U., Kasche, V. 2012. *Biocatalysts and Enzyme Technology*. UK: Wiley-VCH Verlag GmbH
- Fessner, W. and Anthonsen, T. 2009. *Modern Biocatalysis*. Germany: Wiley-VCH Verlag GmbH
- Frey, P.A. and Hegeman, A.D. 2007. *Enzymatic Reaction Mechanisms*. Oxford University Press
- Young Je Yoo, Yan Feng, Yong-Hwan Kim, Camila Flor J. Yagonia. 2017. *Fundamentals of Enzyme Engineering*. Springer

I. Course Title : Advanced Molecular Biology

II. Course Code : BIOCHEM 602

III. Credit Hours : 3+0

IV. Why this course?

To impart knowledge on genome organization and analysis, gene expression and its regulation and modern techniques for genome.

V. Aim of the course

To provide latest information on structure and organisation of genetic materials; genes, their expression in plants and biochemical approaches employed in genetic engineering.

No.	Blocks	Units
1.	Genome organisation and manipulation	1. Concepts of gene and genome 2. Regulation of gene expression 3. Techniques in genome analysis 4. Techniques for gene transfer and genome manipulation 5. Aspects of molecular breeding

VI. Theory

Block 1: Genome Organisation and Manipulation

Unit 1: Concepts of gene and genome (5 Lectures)

Genes, their relationship with chromosomes, gene number hypothesis; Genome – definition, variation and organization in plants and animals, structure of organelle genomes; concept of epigenome, genome size and genome evolution.

Unit 2: Regulation of gene expression (6 Lectures)

Prokaryotic and eukaryotic gene regulation, transcriptional and posttranscriptional regulation; regulation at genome level, role of histones, riboswitches.

Unit 3: Techniques in genome analysis (6 Lectures)

Genome sequencing technologies, Sanger sequencing, next generation sequencing, nanopore sequencing; genome mapping – genetic map construction, physical mapping.

Unit 4: Techniques for gene transfer and genome manipulation (6 Lectures)

Methods of gene isolation and transfer in plants and animals, agrobacterium mediated and direct transfer of genes in plants and animals; gene silencing technologies: virus induced gene silencing, RNA interface; genome editing -TALENs, CRISPR/cas, ZFN and their application, site directed mutagenesis,Application of genetic engineering in different fields, gene therapy.

Unit 5: Aspects of molecular breeding (5 Lectures)

Genome browsing, primer design, marker application for breeding, application of MAS in case studies. Bioethics and bio safety guidelines, IPR in recombinant DNA research

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

On completion of this course, studentswill get an insight into the genome structure, its organization and means for its manipulation for applications in areas such as human and animal health, agriculture, and the environment.

IX. Suggested Reading

• Brown, T. A. 2018. *Genomes 4*. Garland Science

- Rippe, K. 2011. *Genome Organization and Function in the Cell Nucleus*. Wiley VCH Verlag
- Primrose, S. B. and Twyman, R.2006. *Principle of Gene Manipulation and Genomics.* 7th edition. Blackwell Publishing
- Christopher Howe. 2007. *Gene Cloning and Mani*pulation. 2nd edition. Cambridge University Press
- S. Mohan Jain, D S Brar.(eds.). 2009. *Molecular Techniques in Crop Improvement*. 2nd edition. Springer
- Boopathi, N. M. 2013. Genetic Mapping and Marker Assisted Selection: Basics, Practice and Benefits. Springer
- Brown, T. A. 2010. *Gene Cloning and DNA Analysis. An Introduction*. Wiley-Blackwell
- Singh, K. K. 2015. *Biotechnology and Intellectual Property Rights. Legal and Social Implications.* Springer

I. Course Title : Biochemistry of Biotic and Abiotic Stresses

II. Course Code : BIOCHEM 603

III. Credit Hours : 3+0

IV. Why this course?

Plants are constantly confronted to both abiotic and biotic stresses that seriously reduce their productivity. Plant responses to these stresses involve numerous physiological, biochemical, molecular, and cellular adaptations. This course will help to have an insight into the mechanism underlying the stress tolerance and to elucidate the molecular basis of stress adaptation.

V. Aim of the course

To impart knowledge on biochemistry of biotic and abiotic stresses in plants.

No.	Blocks	Units
1.	Biochemistry of biotic and abiotic stresses	1. Plant-pathogen interaction and disease development 2. Biochemistry of plant defence mechanisms 3. Plant host-virus interaction 4. Biochemical basis of abiotic stresses 5. Tolerance against biotic and abiotic stress

VI. Theory

Block 1: Biochemistry of Biotic and Abiotic Stresses

Unit 1: Plant-pathogen interaction and disease development (4 Lectures)

Molecular mechanisms of fungal and bacterial infection in plants; changes in metabolism, cell wall composition and vascular transport in diseased plants.

Unit 2: Biochemistry of plant defence mechanisms (7 Lectures)

Role of secondary metabolites, Plant defence response, antimicrobial molecules; genes for resistance, hypersensitive response and cell death; systemic and acquired resistance, pathogen derived resistance.

Unit 3: Plant host-virus interaction (4 Lectures)

Plant viruses, host-virus interactions, disease induction, virus movement, and host range determination; viroids.

Unit 4: Biochemical basis of abiotic stresses (7 Lectures)

Biochemical basis of abiotic stresses namely osmotic (drought, salinity), temperature, heavy metals, air and water pollutants, synthesis and functions of proline and glycine betaine in stress tolerance interaction between biotic and abiotic stresses; stress adaptation.

Unit 5: Tolerance against stress (6 Lectures)

Reactive oxygen species and biotic and abiotic stress, antioxidants, enzymes of defense system. Role of calcium, nitric oxide and salicylic acid in plant development. Molecular strategies for imparting tolerance against biotic and abiotic stress.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

Upon completion of the course, students will get the suite of molecular and cellular processes that are triggered by plant stress responses.

IX. Suggested Reading

- Buchanan, Bob B., Gruisem, W. and Jones, R. 2015. *Biochemistry and Molecular Biology of Plants*, 2nd edition, Wiley Blackwell.
- Dresselhaus, T. and Hückelhoven, R. (Eds.) 2019. *Biotic and Abiotic Stress Responses in Crop Plants*. MDPI. https://doi.org/10.3390/agronomy8110267
- Rout, G.R. and Das, A.B. 2013. *Molecular Stress Physiology of Plants*. Springer. DOI 10.1007/978-81-322-0807-5
- Shanker, A.K. and Shanker, C. (Eds.) 2016. *Abiotic and Biotic Stress in Plants - Recent Advances and Future Perspectives*.InTech. http://dx.doi.org/10.5772/60477
- Ramakrishna, A. and Gill, S.S. 2018. *Metabolic Adaptations in Plants During Abiotic Stress*. CRC Press
- Khan, M.I.R. and Khan, N.A. (Eds.). 2017. *Reactive Oxygen Species and Antioxidant Systems in Plants: Role and Regulation under Abiotic Stress*. Springer
- Smirnoff, N. (ed.) 2005. *Antioxidants and reactive oxygen species in plants*, Blackwell

I. Course Title : Frontier Topics in Biochemistry

II. Course Code : BIOCHEM 604

III. Credit Hours : 2+0

IV. Why this course?

To update the students to the recent developments in various fields of biochemistry.

Aim of the Course

To acquaint the students with the advanced developments in the field of biochemistry and to inculcate the habit of searching and reading the topics of current importance.

No.	Blocks	Units
1.	Frontier topics in Biochemistry	1. There will be 8 Units related to different areas in Biochemistry

V. Theory

Block 1: Frontier Topics in Biochemistry

Unit 1: Latest development in metabolic nutrition.

Unit 2: Latest development in environmental and industrial biochemistry.

Unit 3: Latest development in molecular biology techniques.

Unit 4: Latest development in metabolic engineering.

Unit 5: Latest development in regulation of gene expression.

Unit 6: Latest development in biotic and abiotic stress response in plants.

Unit 7: Latest development in protein chemistry.

Unit 8: Topics related to recent approaches concerning application of biochemical tools and techniques

VI. Teaching methods/activities

– Oral presentation by students on specified topics based on recent published research paper
– Group discussion

VII. Learning outcome

Students will build up the habit of searching and studying the topics of current importance and the recent developments in the field of biochemistry.

VIII. Suggested Reading

- Selected articles from recent issues of *Thomson Reuters and NAAS rated journals*

I. Course Title : Concepts and Application of Omics in Biological Science

II. Course Code : BIOCHEM 605

III. Credit Hours : 3+0

IV. Why this course?

Omics is a rapidly evolving, multi-disciplinary, and emerging field that encompasses genomics, epigenomics, transcriptomics, proteomics, and metabolomics. This course will be helpful for the students to understand the scope of omics research and methods therein.

V. Aim of the course

To impart knowledge in the upcoming areas of biochemistry and to understand the recent developments in omic technologies.

No.	Blocks	Units
1.	Concepts and aplication of omics in biological science	1. Protein and nucleic acid sequencing 2. Genomics–methods of analysis and application 3. Proteome technology 4. Metabolomics and ionomics

VI. Theory

Block 1: Concepts and Aplication of Omics in Biological Science

Unit 1: Protein and nucleic acid sequencing (7 Lectures)

Various methods of sequencing including automated sequencing and microarrays, whole genome sequence analysis.

Unit 2: Genomics – methods of analysis and application (7 Lectures)

Comparative genomics, functional genomics, nutrigenomics, transcriptomics, gene identification, gene annotation, pairwise and multiple alignments, application of genomics, quantitative PCR, SAGE, MPSS, microarray, role of bioinformatics in functional genomics.

Unit 3: Proteome technology (7 Lectures)

2D-PAGE, MSMS, MALDI-TOF, comparative proteomics and structural proteomics

Unit 4: Metabolomics and ionomics (7 Lectures)

Elucidation of metabolic pathways, Sample preparation for metabolomics. Techniques involved in metabolite identification- LCMS, NMR, FTIR, MS. Metabolomics in biotic and biotic stress in crop plants, SPE, SPME, metabolic pathway engineering and its application, Concept and application of ionome and ionomics.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

The applications of omics allow the complete profiling of genes, proteins and metabolites to understand the intricacy, complexity and dynamics of biological system. This course serves as an applied course for understanding the applications, research methodologies and data analysis of omics approaches enabling students to apply such skills in their respective projects

IX. Suggested Reading

- Lieber D.C. 2002. *Introduction to Proteomics - Tools for the New Biology*. Humana Press.
- Leung, H.E. 2012. *Integrative Proteomics*. InTech
- Lesk, A.M. 2012. Introduction to Genomics, 2nd Edition. Oxford University Press
- Aizat, W.M., Goh, H-H. and Baharum, S.N. (Eds.) 2018. Omics Applications for Systems Biology. Springer International Publishing
- Arivaradarajan, P., Misra, G. (Eds.) 2018. *Omics Approaches, Technologies and Applications*. Springer Singapore
- Fan TWM, Lane AN and Higashi RM. (Eds.) 2012. *The Handbook of Metabolomics*. Humana Press, Totowa, NJ

I. Course Title : Biomembranes

II. Course Code : BIOCHEM 606

III. Credit Hours : 2+0

IV. Why this course?

Biomembranes define the boundaries of cells and their internal organelles and, consequently, are fundamental to the compartmentalisation of vital enzymatic reactions. This course will help the students to acquire an integrated overview of the structure, function and biogenesis of biological membranes and their components and their impacts on different cell activities.

V. Aim of the course

To impart knowledge on the molecular basis of the structure, function and biogenesis of eukaryotic cell membranes.

No.	Blocks	Units
1.	Biomembranes	There will be 4 Units relating to biomembrane structure, organization, movement and signal transduction.

VI. Theory

Block 1: Biomembranes

Unit 1: Concept of biomembranes and their classification based on cellular organelles; physico-chemical properties of different biological and artificial membranes, cell surface receptors and antigen.

Unit 2: Membrane biogenesis and differentiation; membrane components-lipids, their distribution and organization; proteins, intrinsic and extrinsic, their arrangement; carbohydrates in membranes and their function.

Unit 3: Various membrane movements; Membrane transport: Organization of transport at plant membranes, pumps, carriers, ion channels, water transport through aquaporins, transport of macro molecules: exocytosis and endocytosis, energy transduction.

Unit 4: Role of membrane in cellular metabolism, cell recognition and cell-to-cell interaction; signal transduction, recent trends and tools in membrane research.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

This course summarizes the structure and functions of membranes and the proteins within them, and describes their role in trafficking and transport, control the passage of selected compounds, thus maintaining the biochemical integrity of cytosol; communication, allowing the exchange of information between the extra- and intracellular environments, and the physical interaction with the extracellular phase.

IX. Suggested Reading

- Watson, H. 2015. *Biological membranes*. Essays Biochem. **59**, 43–70: doi: 10.1042/BSE0590043
- Shinitzky, M. 2008. *Biomembranes: Structural and Functional Aspects*. VCH. DOI: 10.1002/

9783527616114
- Berk, A., Kaiser, C. A., Lodish, H., Amon, A., Ploegh, H., Bretscher, A., Krieger, M. And Martin, K. C. 2016. *Molecular Cell Biology*. Macmillan Learning
- Stillwell, W. 2013. *An Introduction to Biological Membrane: From Bilayers to Rafts*. Elsevier
- Yeagle, P. 2016. *The Membranes of Cell*. 3rd edition. Academic Press

I. Course Title : Application of Techniques in Biochemistry

II. Course Code : BIOCHEM 607*

III. Credit Hours : 1+2

IV. Why this course?

This course will provide the students the theoretical basis of various separation techniques and their application with practical experience in the use of different biochemical and molecular biology techniques.

V. Aim of the course

To train students the application ofcuttingedge laboratory techniques in research in biochemistry and molecular biology.

No.	Blocks	Units
1.	Application of techniques in Biochemistry	1. Isolation, purification and analysis of metabolites 2. Electrophoretic separation 3. Application of centrifugation 4. Enzyme techniques 5. Molecular biology and immunochemical techniques

VI. Theory

Block 1: Application of Techniques in Biochemistry

Unit 1: Isolation, purification and analysis of metabolites (3 Lectures)

Isolation and purification of important metabolites from microbial/plant/animal source, Applications of paper, thin layer and gas liquid chromatography, PAGE, FPLC and HPLC in the separation of biomolecules. Determination of molecular weight of protein using PAGE/ gel filtration method.

Unit 2: Electrophoretic separation (3 Lectures)

Electrophoretic separation of protein, Experiments on DNA: Isolation, agarose gel electrophoresis and restriction analysis of DNA. Techniques in DNA-protein and protein-protein interaction.

Unit 3: Application of centrifugation (2 Lectures)

Isolation of chloroplast and mitochondria by differential centrifugation and their purification by density gradient centrifugation.

Unit 4: Enzyme techniques (3 Lectures)

Isolation, purification and characterization of enzymes, isozymic analysis and enzyme immobilization.

Unit 5: Molecular biology and immunochemical techniques (3 Lectures)

Application of PCR, yeast 2 hybrid system, Antigen-Antibody interaction, ELISA, Chromatin immunoprecipitation, gel based and gel free proteasome tools.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Demonstration and hands on training
- Exposure visit to institutions equipped with modern facilities

VIII. Learning outcome

This course will help the students in acquiring the laboratory skills required for success in experimental biochemistry and molecular biology.

IX. Suggested Reading

- Katoch, R. 2011. *Analytical Techniques in Biochemistry and Molecular Biology*. Springer
- Wilson, K. and Walker, J. 2010. *Principles and Techniques of Biochemistry and Molecular Biology*, 7th Edition. Cambridge University Press
- Hegyi, G., Kardos, J., Kovács, M., Málnási-Csizmadia, A., Nyitray, L. Pál, G., Radnai, L., Reményi, A. and Venekei, I. 2013. *Introduction to Practical Biochemistry*. EötvösLoránd University

Journals

- *Annual Review of Biochemistry*
- *Annual Review of Genetics*
- *Annual Review of Plant Physiology and Plant Molecular Biology*
- *Biochemical and Biophysical Research Communication*
- *Biochemical Journal*
- *Biochimica Biophysica. Acta*
- *Cell*
- *Current Science*
- *Federation of European Biochemical Society*
- *Food Chemistry*
- *Indian Journal of Experimental Biology*
- *Journal of Agriculture and Food Chemistry*
- *Journal of Biological Chemistry*
- *Journal of Immunology*
- *Journal of Molecular Modelling*
- *Journal of Plant Biochemistry and Biotechnology*
- *Nature*
- *Physiologia Plantarum*
- *Plant Physiology*
- *Plant Science*
- *Planta*
- *Proceedings of National Academy of Sciences, USA*
- *Protein Science*
- *RNA*
- *Science*
- *Scientific American*
- *Trends in Biochemical Sciences*
- *Trends in Biotechnology*
- *Trends in Plant Sciences*

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Basic Sciences
– Microbiology

Preamble
(Microbiology)

World is experiencing a rapid shift of national priorities in research and development. Biological science is emerging as one of the top priorities in the field of science, and among the biological sciences microbiology has gained new stature. Microoganisms and their activities are increasingly central to many of the concerns of the society both nationally and internationally. The problem of global environment, the recognition of the need to recycle natural resources, the discovery of genetic engineering – these and other development have placed microbiology in limelight. It is required to restructure and modify the curriculum and the syllabus to enable graduate students to be reacquainted with the developments through providing comprehensive exposure to the M.Sc and Ph.D. students, on new developments in different areas of microbial science.With this background the structure of curriculum for M.Sc. and Ph.D. programmes and syllabi for the courses needs to be developed keeping in view the mandate of agriculture universities and ICAR institutes.

Microbes are indispensable to our life. Interactions of microbes involved in soil, environment, food, fermentation, medical, or agriculture has been studied using modern techniques. New antibiotics, vaccines are also being produced. Moreover, genome sequence of important genes of interest or complete sequence of microbes, plants, human beings or animals has further paved the ways for detailed study of interactions and their manipulations in the desired direction. Molecular analysis of relevant factors in the plant and microbes and components that modulate plant-microbe interactions for soil and plant health for sustaining crop productivity is now being revealed using different molecular techniques. Microbial diagnostic micro arrays have been developed for the parallel, high-throughput identification of many microorganisms.

There is growing recognition in the potential of microorganisms in many applied areas. The ability of microorganisms to decompose materials such as herbicides, pesticides and oil in oils pills; the potential of microorganisms as food supplements; the exploitation of microbial activity to produce energy such as methane gas for natural consumption; and the potential of new therapeutic substances produced by microorganisms – these and other uses of microorganisms are becoming increasingly attractive. Increased attention has been directed towards use of microorganisms (bioremediation) for wastewater treatment involving decolorization of different industrial effluents, which include distillery waste, textile industries and paper and pulp industries. Microbial degradation and decolorization holds promise and can be exploited. But genetic improvement of strains can be explored in future for improving their decolorization efficiency. Some of the agro wastes are being used for the production of biofuels. Use of recombinant microorganisms for industrial production of useful compounds has reached at commercial levels. All these aspects are covered in the coursecurricula.

For MSc programme, 14 courses including master's seminar and master's research are finalized, out of which minor changes have been done in existing 9 courses and one course MICRO 506, Microbial biotechnology, is completely reframed and modified. The aim is to teach students about industrially useful microorganisms and use of fermenter for the production of various primary and secondary metabolites, this course is job oriented. The students can be absorbed by various agro-industries. One new course MICRO501 entitled

Techniques in microbiology has been newly introduced in the syllabus. This course aims to introduce various techniques and instrumentation methods required for the study of microorganisms. This course provides understating on techniques and methods of microscopy, spectroscopy, chromatography and electrophoresis. Courses MICRO 503 and MICRO 504 entitled Microbial physiology and Microbial genetics, respectively, include recombinant DNA technology, commonly related to as genetic engineering, as one of the principal thrust of the emerging technologies in the biological and agricultural sciences. Recombinant DNA technology makes it feasible to consider genetically manipulated (engineered) microorganisms for commercial production of new and valuable products for variety of purposes, e.g., medicinal, fuel and food.

Course No MICRO 505, Soil Microbiology and MICRO 604 Recent approaches in environmental microbiology are introduced with certain important changes with great emphasis on integrated use of chemical fertilizers, pesticides, herbicides along with biofertilizers, biopesticides and biocontrol agents for sustaining modern agriculture and soil health. Biocontrol agents for control of plant diseases, insects, nematodes have been developed and some of these are commercially available and being used by the farmers. Microbe-plant symbiosis within plant rhizosphere have come up as an effective clean up technology.From the earlier syllabus one course entitled Plant microbe interactions has been upgraded from master's programme to Ph.D. level (MICRO 605).

In Ph.D. programme, 8 courses are finalized (including doctoral seminar and research) out of which 3 are the thorough modifications of existing courses.

MICRO 602 Microbial physiology and regulation has been formulated keeping in view following important concepts:

- Basic metabolic pathways can lead to different metabolic groups such as heterotrophs/phototrophs, etc.
- Measurement of growth as influenced by various factors such as media and environmental factor can help to design specific culture media.
- The role of environmental factors in key regulatory points in microorganisms is important in their adoption to the environment
- Enzyme regulation occurs for the cell to adopt in different conditions.
- Role of enzymes in the microorganisms for degradation of substrates for their growth through metabolic pathways may be inductive or conservative determines their expression.

Course No. MICRO 604 Recent Approaches in environmental microbiology has been introduced with the concept:

- How microbes contribute to successful colonization in environment and their interaction with the environment
- Microbiological prospective of public health.
- Certain process like adsorption, immobilization, mobilization and transformation of metal are main processes that can be mediated by action of several microorganisms.
- Microbial bioremediation, biodegradation through species or strains or consortia which are specific to the degradation of one or more types of contaminants for reclamation of environment or remediate polluted sites.

New course MICRO 605 Plant microbe Interaction has been introduced with the concept that–

- The dynamics of plant community is influenced by the microbial association and activity.

- In the plant ecosystems microbes play a defined role to ascertain that plants benefit through provision of nutrients and growth promoting factors.
- At times pathogenic microbes play havoc on the plants, sometimes threatening their very existence.
- The plant serves as habitat for microbial communities. It is the interplay of the interaction between the plant and the microbiome it hosts, that is critical for the establishment and the maintenance of host-microbial homeostasis and defines the overall health and productivity

With a degree in microbiology, students can get opportunities to work in both government as well as private sector, in various fields like healthcare organizations, forensic science laboratories, environmental organizations, higher education institutions, publicly funded research organizations, pharmaceuticals, food and beverages industries, chemical industries, agriculture department, agro-industries, etc.

Microbiology courses are offered by a large number of students hence need small equipment in multiple numbers. To do quality teaching and research, sophisticated equipment like ultra-low freezers, high speed refrigerated-automated bioseparation systems like GLC or HPLC and UV-Vis spectrophotometers suitable for enzyme studies, PCRs, electrophoresis systems for proteins and DNA are required for Microbiology lab. Consumables will also be needed accordingly. An approximate recurring budget of ₹ 20 lacs per annum apart from one time equipment and maintenance grant of ₹ 2 crore will be required.

Course Title with Credit load
M.Sc. (Ag) in Microbiology

Course Code	Course Tittle	Credit Hours
MICRO 501	Techniques in microbiology	0+2
MICRO 502*	Principles of microbiology	3+1
MICRO 503*	Microbial physiology and metabolism	3+1
MICRO 504	Microbial genetics.	2+1
MICRO 505*	Soil microbiology	2+1
MICRO 506	Microbial biotechnology	2+1
MICRO 507*	Food microbiology	2+1
MICRO 508	Bacteriophages	1+1
MICRO 509	Environmental microbiology	2+1
MICRO 510	Industrial microbiology	2+1
MICRO 511	Biofertilizer technology	2+1
MICRO 512	Cyanobacterial and algal biotechnology	2+0
MICRO 591	Master's seminar	1+0
MICRO 599	Master's research	30

*Core Courses

Course Contents
M.Sc. (Ag) in Microbiology

Course Title : **Techniques in Microbiology**
Course Code : **MICRO 501**
Credit Hours : **0+2**

Why this course?

The science of microbiology is the study of microorganisms and their activities. It is concerned with their form, structure, reproduction, physiology, metabolism and identification. It includes the study of their distribution in nature, their relationship to each other and to their living things, their beneficial and detrimental effects on agriculture and the physical and chemical change they make in their environment. In microbiology laboratories, some special equipment and apparatus are commonly used. Students of microbiology should have a general idea of these equipment regarding their constructive features, operation, precaution for use and also the maintenance of the equipment.

Aim of the course

This course aims to introduce various techniques and instrumentation methods required for the study of microorganisms. This course provides understating on techniques and methods of microscopy, spectroscopy, chromatography and electrophoresis.

The course is organized as follows:

No.	Blocks	Units
1	Techniques in microbiology	1. Practical include estimation of microbiological contents of samples like water, soil, air, etc. 2. Operation and care of microscopes 3. Preparation of smears and their morphological observation using microscope 4. Performance of various staining techniques, study of biochemical activities, Identification of microorganisms, preparation of culture media etc.

Practicals

- Awareness about lab safety measures
- Study of general microbiological equipment, cleaning of glassware and apparatus for laboratory use
- Methods of sterilization used in microbiology laboratory
- Use of simple techniques in laboratory (Colorimetry, Centrifugation, electrophoresis and chromatography)
- Types of culture media

- Isolation techniques and direct microscopic count
- Environmental factors affecting bacterial growth: physical chemical, temperature, pH, osmotic pressure, light (UV) and bacteriostatic agents. Bacteriology of air, water, and soil.
- Characteristics of important types of micro-organisms: major functional groups of bacteria, lactic acid, spore forming and coliforms bacteria, fungi, yeast and mold.
- Assessment of microbial quality of portable water.
- Working in microscope

Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures
- Review of policy documents

Learning outcome

After successful completion of this course, the students are expected to be able to:

- Appreciate the scientific foundation of general microbiology and relate the key learning to the job of an microbiologist professional
- Utilise methods and tools for microbial agricultural development for the nation.
- Increase the probability of use of different microbial cultures for the benefits of agriculture production

Suggested Reading

- Roy A.K. 2010. *Laboratory Manual of Microbiology* (Practical Manual Series).
- Goldman E and Green LH. 2015. *Practical Handbook of Microbiology*. 3rd Edition. http/www. CRC press life science Microbiolgy
- Brock, T.D. 2008. *Biology of microorganisms* (Ed.) Madigan MT, Martinko J M, Dunlap P V, Clark D.P., 12th ed. Pearson, New Jersey.
- Pelczar, M.J. Jr., Chan, E.C.S. and Kreig, N.R. 1997. *Microbiology, Concepts and Application*, 5th edition, Tata McGraw Hill, New York.
- Prescott, L.M., Harley and Klein. 2002. *Microbiology* 5th Edition, Tata McGraw Hill, New York.
- Bhatia, M.S. 2009. *Principles of Microbiology*. Swastik Publishers., DeIhi.
- Madigan, M.T., J.M. Martinko, P.V. Dunlap and D.P. Clark. 2001. *Brock biology of Microorganism* 10th Ed. Pearson Education lnc, USA.
- Singh, U.S. and K. Kapoor 2010. *Introductory microbiology* Oxford Book Company., Jaipur
- Tortora, G.J., B.J. Funke and C.L. Case. 2010. *Microbiology: an introduction*.10th Ed. Benjamin Cummings., New York.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org

Course Title : **Principles of Microbiology**
Course Code : **MICRO 502***
Credit Hours : **3+1**

Why this course?

Microbes has become a part and parcel of our lives This course is required for the future battle against infectious diseases worldwide, understanding the environmental importance of microbes and to exploit them for food production, biotechnological and industrial applications. Hence, this customized course.

Aim of the course

The main focus of our course is the potential of the organisms that cause disease and benefits in the society. You will also cover aspects of the biochemistry, physiology and genetics of microorganisms.

The course is organized as follows:

No.	Blocks	Units
1.	Scope and History of Microbiology and microscopy	1. Scope of microbiology 1. History routes 2. Staining and microscopy
2.	Evolutionary link of prokaryotes	1. Phylogenetic classification 2. Methods of sequencing
3.	Microbial growth, characterization and regulation	1. Microbial growth and reproduction 2. Sterilization techniques 3. Nutritional requirements for microbial growth

Theory

Block 1: Scope and History of Microbiology and Microscopy

Unit 1: Scope of microbiology

Scope of microbiology, microbes and microbiologist. Emergence of Special Fields of Microbiology.

Unit 2: History Routes

The Germ Theory of Disease, Early Studies: Pasteur's Further Contributions, Koch's Contributions, Work Toward Controlling Infections, spontaneous generation theory.

Unit 3: Staining and microscopy

Microscopy; Bright field, Dark field, Phase contrast, Confocal, Fluorescence, TEM, SEM – Working Principles and applications; Properties of light; Simple staining, differential and special staining.

Block 2: Evolutionary Link of Prokaryotes

Unit1: Phylogenetic classification

Evolutionary relationship among prokaryotes. Prokaryotes and Eukaryotes, Phylogenetic and numerical taxonomy. Species concept.

Unit2: Methods of sequencing

Use of DNA and r-RNA sequencing in classifications.

Block 3: Microbial Growth, Characterization And Regulation

Unit1: Microbial growth and reproduction

Microbial growth and reproduction-communication, bacteria, yeast and virus growth, Replication, Cultivation methods, Normal micro flora of Human body; Immune response- specific and non-specific host resistance.

Unit 2: Sterilization techniques

Physical and chemical methods of sterilisation.

Unit 3: Nutritional requirements for microbial growth

Classification of microbes: electron, energy and carbon sources.

Practicals

- Working principles and handling of different types of microscopes – Bright and Dark field microscopy
- Working principles and handling of different types of microscope- SEM and TEM
- Methods of isolation from different environments – soil, water, milk and food
- Use of selective media for isolation
- Purification techniques of bacteria and fungi
- Enumeration and Quantification techniques
- Maintenance and preservation of cultures
- Assessment of microbial quality of portable water.
- Morphological characterization of Bacteria
- Morphological characterization of fungi
- Biochemical characterization of bacteria
- Biochemical characterization of fungus

Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures
- Review of policy documents

Learning outcome

After successful completion of this course, the students are expected to be able to:

- Knowledge on historical perspective of Microbiology
- Basic knowledge on different structure of microbes

Suggested Reading

- Brock TD. 2008. *Biology of microorganisms* (Ed.) Madigan MT, Martinko J M, Dunlap P V, Clark DP, 12th ed. Pearson, New Jersey.
- Pelczar MJ. Jr., Chan, ECS and Kreig NR. 1997. *Microbiology, Concepts and Application*, 5th edition, Tata McGraw Hill, New York.
- Prescott, L.M., Harley and Klein. 2002. *Microbiology* 5th Edition, Tata McGraw Hill, New York.
- Bhatia, M.S.2009. *Principles of Microbiology*. Swastik Publishers., DeIhi.
- Madigan, M. T., J. M. Martinko, P.V. Dunlap and D.P. Clark.2001. *Brock biology of Microorganism* 10th Ed. Pearson Education lnc, USA.

- Singh, U.S and K. Kapoor 2010. *Introductory microbiology* Oxford Book Company., Jaipur
- Tortora, G. J., B.J. Funke and C.L. Case. 2010. *Microbiology: an introduction*.10th Ed. Benjamin Cummings., New York
- Davis BD, Dulbecco R, Eisen HN and Ginsberg HS. 1990. *Microbiology* (4th edition). J.B.Lippincott company, Newyork.
- Alexopoulus CJ and C W. Mims. 1993. *Introductory Mycology* (3rd edition).Wiley Eastern Ltd, NewDelhi.
- Elizabeth Moore-Landecker. 1996. *Fundamentals of the fungi*. (4th edition).Prentice Hall International, Inc, London.
- Heritage,J. Evans E.G.V. and Killington, R.A. 1996. *Introductory Microbiology*. Cambridge University Press.
- Webster J. 1993. Introduction to Fungi.(2nd edition).Cambridge University press,Cambridge.
- Prescott LM, Harley JP and Klein DA. 2006. Microbiology (7th edition) McGraw Hill, Newyork.
- Schaechter M and Leaderberg J. 2004. The Desk encyclopedia of Microbiology. Elseiver Academic press, California.
- Nester, E.W., Roberts, C.V. and Nester, M.T. 1995. *Microbiology: A human perspective.* IWOA, U.S.A.
- Pelczar Jr, M.J. Chan, E.C.S. and Kreig, N.R. 1993. *Microbiology*, Mc. Graw Hill. Inc, New York.
- Holt JG and Bergey DH. 1994. *Bergey's Manual of Determinative Bacteriology* (9th Edition), Williams and Wilkins, Baltimore.
- Mara D. and Horan N. 2003. *The Handbook of Water and waste water Microbiology*. Academic Press-An imprint of Elsevier.
- Madigan M T, Bender K S, Buckley HD, Sattley WM, Stahl DA 2017. *Brock Biology of Microorganisms* - 15th edition. Pearson Education, USA.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org

I. Course Title : Microbial Physiology and Metabolism

II. Course Code : MICRO 503*

III. Credit Hours : 3+1

IV. Why this course?

Microbial physiology is defined as the study of how microbial cell structures, growth and metabolism function in living organisms. Microbial physiology is important in the field of metabolic engineering and also functional genomic. The study of diversity of microbial metabolic processes & their regulation, how microbes respond to environment stress and manipulation and the genetic control of these processes are essential for their potential applications of microbial process for the production of commercial products.

V. Aim of the course

Microorganisms have tremendous metabolic diversity hence it's intriguing to learn how these small creatures deal with different environmental conditions and either adopt themselves to it or convert it to favourable conditions by involving different physiological processes. The contents of this course will help students how microbes can grow on substrates other than glucose, their inorganic metabolism and photosynthesis and how do they respond to the changes in environment. It will elaborate the anaerobic respiration by variety of groups of microbes and non-genetic regulation at metabolic pathways.

The course is organized as follows:

No.	Blocks	Units
1.	Scope of microbial growth and physiology	1. Structure, function and biosynthesis of cellular components
2.	Pathways and their significance; Growthkinetics and nutritional classifications	1. Growth Kinetics, cell cycle, cell division, pathways and fermentation metabolism. 2. Growth and factors affecting growth and culture systems. 3. Nutritional classification and spore formation and germination
3.	Enzymes and microbial metabolisms	1. Kinetics and Mechanism of Enzymes 2. Microbial metabolism
4	Synthesis of macromolecules	1. Biosynthesis of macromolecules

VI. Theory

Block 1: Scope of Microbial Growth and Physiology

Unit 1: Structure, function and biosynthesis of cellular components

Microbial nutrition – Chemical composition of microbial cell – Structure, function and assembly of cell membrane in prokaryotes, archaea and fungi – Macro and Micro- nutrients and their physiological functions – Transport of solutes across the membrane

Block 2: Pathways and their Significance; Growth Kinetics and Nutritional Classifications

Unit 1: Growth Kinetics, cell cycle, cell division, pathways and fermentation metabolism

Microbial growth. Cell cycle and cell division. Bioenergetics -carbohydrate utilization via EMP, HMP, ED, TCA pathways, Aerobic and anaerobic respiration. Fermentative metabolism. Assimilation of nitrogen and sulphur - Oxygenic and anoxygenic photosynthesis - Mechanisms of carbon-dioxide fixation in prokaryotes. Ethanol, lactic acid, butanol, acetone and mixed acid fermentation. Fermentation of nitrogenous organic compounds Regulation of microbial metabolism.

Unit 2: Growth and factors affecting growth and culture systems

Effects of physical, chemical and other environmental factors on growth Continuous culture, Diauxic growth and Synchronous culture. Method of growth measurement. Morphogenesis and cellular differentiation.

Unit 3: Nutritional classification and spore formation and germination

Metabolic diversity in photoautotrophs, photoheterotrophs, chemoautotrophs and chemoheterotrophs. Nutritional grouping/classification of microorganisms. Bacterial endospore-types, morphology, biochemistry and regulation of formation and germination

Block 3: Enzymes and Microbial Metabolisms

Unit 1: Kinetics and Mechanism of Enzymes

Enzyme kinetics: Michaelis Menten kinetics - mechanisms of inhibition of enzyme activity - coenzymes and prosthetic groups.

Unit 2: Microbial metabolism

Methods to determine free energy of biochemical reactions - high energy compounds. Microbial metabolism: generation of ATP, reducing power, development of proton gradient and biosynthesis of ATP.

Block 4: Synthesis of Macromolecules

Unit 1: Biosynthesis of macromolecules

Biosynthesis of macromolecules – Synthesis and assembly of cell wall components – Methods of studying biosynthesis - regulation of microbial metabolism.

VII. Practicals

- Use of simple techniques in laboratory (Colorimetry, Centrifugation, electrophoresis and GLC, etc.).
- Determination of viable and total number of cells.
- Measurement of cell size.
- Gross cellular composition of microbial cell. Growth – Factors affecting growth.
- Study of bacterial spores and factors affecting germination.
- Enzyme activity and kinetics – calculating Km and V_{max} of enzyme.
- Demonstration of thermos-, meso-, and psychrophilic micro-organisms.
- Production and testing of inducible enzymes in bacteria.
- Sporulation and spore germination in bacteria.
- Protoplasts formation and regeneration.
- Estimation of generation time and specific growth rate for bacteria and yeast.
- Diauxic growth curve.
- Production of synchronous cells.
- Effect of chemicals and environmental factors on bacterial growth.
- Isolation and Identification of reserve food material (Glycogen/ polyphosphates, PHB) from bacteria (*Azotobacter*, *Bacillus megaterium*).
- Growth of microorganisms on various carbon and nitrogen sources.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Publication Review
– Student presentation
– Group discussion
– Case Analysis and case studies
– Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Knowledge about cell cycle and microbial pattern
– Growth and practical training on methods to determine microbialgrowth

X. Suggested Reading

- Moat, A. G. and J. W. Foster. 2002. *Microbial Physiology*. John Wiley & Sons, New York,

USA. 11th ed. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
- Madigan, M.T, J.M. Martinko and J. Parker. 2006. *Brock: Biology of Microorganisms*, 11th ed. Prentice-Hall, Inc. Englewood Cliffs, New Jersey.
- White, D. 2007. *The Physiology and Biochemistry of Prokaryotes*, 3rd Edition. Oxford University Press.
- Downs, D. M. 2006. *Understanding microbial metabolism*. Annual Review of Microbiology 60, 533–559.
- Hosler *et al.* 2006. *Energy Transduction: Proton Transfer Through the Respiratory Complexes*. Annual Review of Biochemistry 75, 165-187.
- Okuno *et al.* 2008. *Correlation between the conformational states of F1-ATPase as determined from its crystal structure and single-molecule rotation*. PNAS 105(52): 20722-20727.
- Itoh et al (2004) Mechanically driven ATP synthesis by F1-ATPase. Nature 427, 465-468.
- Doelle HW. 1969. *Bacterial Metabolism*. Academic Press.
- Gottschalk G. 1979. *Bacterial Metabolism*. Springer Verlag.
- Nelson DL and Cox MM. 2017. *Lehninger*, *Principles of Biochemistry,* 4th Edition, W.H.Freeman & Company, 2004. (T1)
- Voet D and Voet JG. 2002. *Fundamentals of Biochemistry*, Upgrade Edition, Wiley.

Journals

- *Journal of Bacteriology.*
- *Advances in Microbial Physiology.*
- *Soil Biology and Biochemistry.*
- *Journal of Applied Bacteriology.*
- *Applied and Environmental Microbiology.*
- *Microbiology.*

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org
- http://www.textbookofbacteriology.net
- https://www.e-education.psu.edu
- http://www.ncbi.nlm.nih.gov/pubmed/12050002
- http://www.journals.elsevier.com/bba-bioenergetics/
- http://www.bmb.leeds.ac.uk/illingworth/oxphos
- http://www.atpsynthase.info/
- https://ocw.um.edu.my/course/view.php?id=67
- https://mic.microbiologyresearch.org/content/journal/micro/10.1099/mic.0.037143-0

I. Course Title : Microbial Genetics

II. Course Code : MICRO 504

III. Credit Hours : 2+1

IV. Why this course?

Microbial Genetics has traditionally been a field of basic science research as microorganisms offer several features that facilitate the study of evolutionary process,understanding the genotype and its expression system. Students also hone their abilities to read, understand and critically evaluate research articles as well as improve presentation skills.

V. Aim of the course

This course is designed to provide an understanding of the fundamentals of genetic processes in prokaryotes and eukaryotes. The study of microbial genetics has provided much of the understanding of fundamental genetic processes for all organisms, especially through the use of *in vivo* and *in vitro* genetic tools.

The course is organized as follows:

No.	Blocks	Units
1.	Introduction to microbial genetics	1. Historical perspectives of microbial genetics 2. Genome of prokaryote, eukaryote (fungi) and virus 3. Genetic elements - chemical structure and property, enzymes associated and replication 4. Extra-chromosomal DNA in bacteria and eukaryotic cells
2.	Gene expression and regulation	1. Introduction to Gene structure and expression 2. Regulation of gene expression
3.	Mutation, genetic recombination and sequencing	1. Principles of mutation and types 2. Mutagens and their mode of action 3. DNA damage – DNA repair mechanisms in bacteria 4. Genetic recombination in bacteria 5. Gene Sequencing

VI. Theory

Block 1: Introduction to Microbial Genetics

Unit 1: Historical perspectives of microbial genetics

Introduction to Microbial genetics; Historically important events and major contributions of scientists in the field of Microbial genetics; Terminologies employed in microbial genetics and definitions; Nucleic acid – overview DNA, RNA.

Unit 2: Genome of prokaryote, eukaryote (fungi) and virus

Bacterial genome Eukaryotic genome; Viral genome; Difference between prokaryotic and eukaryotic genome; Mechanisms and role of prokaryotic genome- an overview.

Unit 3: Geneticelements - chemical structure and property, enzymes associated and replication

Structure of DNA – A form, B form, Z form; RNA- tRNA, mRNA, rRNA; Role and Replication of DNA and RNA; Enzymes involved in Replication and its role.

Unit 4: Extra-chromosomal DNA in bacteria and eukaryotic cells

Plasmids, Mitochondrial DNA, Chloroplast DNA – structure and function.

Block 2: Gene Expression and Regulation

Unit 1: Introduction to gene structure and expression

Gene structure and expression, principles of operon, gene expression in prokaryote and eukaryotes, intron and exons, post transcriptional modifications.

Unit 2: Regulation of gene expression

Regulation of gene expression, negative expression (lac operon and trp operon), positive regulation (cAMP).

Block 3: Mutation, Genetic Recombination and Sequencing

Unit 1: Principles of mutation and types

Principles of mutation, spontaneous and induced mutation, different types of mutations, selection principles of mutants.

Unit 2: Mutagens and their mode of action

Mutagens and their mode of action, transposable elements and insertion sequences.

Unit 3: DNA damage - DNA repair mechanisms

DNA damage, DNA repair mechanisms in bacteria.

Unit 4: Genetic recombination in bacteria

Genetic recombination in bacteria, mechanisms of recombination, transformation, conjugation, transduction.

Unit 5: Gene sequencing

Gene cloning and gene sequencing. Impact of gene cloning, polymerase chain reaction, DNA sequencing, recombinant DNA technology.

VII. Practicals

- Isolation of genomic DNA from pure cultures of bacteria and fungi.
- Visualization of mega plasmids of bacteria.
- Isolation of bacterial plasmids and Plasmid curring.
- Qualitative and quantitative assay of DNA by spectrometry and gel-electrophoresis.
- Inducing mutation by chemicals, physical and biological agents.
- Transformation and selection of transformants.
- Amplification of gene of interest by PCR – cloning and expression.
- Isolation of metagenomic DNA from environmental samples.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Group work in practical
– Field visit
– Case studies

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:
– Identify and distinguish genetic regulatory mechanisms at different levels
– Plan basic experiments in Microbial genetics
– Describe and summarize experimental work in a correct way.

X. Suggested Reading

- Brown TA. 2001. *Gene Cloning and DNA Analysis: An Introduction*. Fourth Edition. Blackwell Science Inc., Oxford, UK.
- Levin B. 2002. *Gene VIII*. Oxford Univ. Press, New York. p.990.
- Maloy SR, Cronan JE, Freifelder D. 2008. *Microbial Genetics* - second edition. Narosa Publising house, New Delhi. p. 525.
- Omoto CK and Lurquin PF. 2004. *Genes and DNA: a beginner's guide to genetics and its applications*. Colambia University Press, USA.
- Sambrook J, Fritsch EF, Maniatis T. 2000. *Molecular Cloning: A laboratory Manuel*. Third Edition. Cold Spring Harbor Press, New York.

- Streips UN, Yasbin RE. 2006. *Modern Microbial Genetics*. Wiley – Liss. John Wiley & sons, Inc. Publication, NY.
- Birge EA. 1981. *Bacterial and Bacteriophage Genetics*. Springer Verlag.
- Gardner JE, Simmons MJ and Snustad DP. 1991. *Principles of Genetics*. John Wiley& Sons.
- Lewin B.1999. *Gene*. Vols. VI-IX. John Wiley & Sons.
- Maloy SR, Cronan JE and Friedfelder D. 2008. *Microbial Genetics*. Narosa.
- Scaife J, Leach D and Galizzi A 1985. *Genetics of Bacteria*. Academic Press. William Hayes 1981. *Genetics of Bacteria*. Academic Press.
- Strips UN, Yasbin RE *2006. *Modern Microbial Genetics*. Wiley-Liss, NY.

Websites

- http://highered.mcgraw-hill.com/sites/0072552980/student_view0/chapter9/
- http://highered.mcgrawhill.com/sites/0072835125/student_view0/animations.html
- http://cwx.prenhall.com/brock/
- http://www.cliffsnotes.com/sciences/biology/microbiology
- http://plato.acadiau.ca/courses/biol/Microbiology/home.HYPERLINK "http://plato.acadiau.ca/courses/biol/Microbiology/home.html"html
- http://www.learner.org/courses/biology/index.html

I. Course Title : Soil Microbiology

II. Course Code : MICRO 505*

III. Credit Hours : 2+1

IV. Why this Course?

Understanding the function of the soil ecosystem in relation to ever changing soil conditions is key to understanding the basic mechanisms of soil productivity. This is important in light of the urgency to change agricultural practices and also the problems of xenobiotic compounds in soils. The possible perturbations caused by pollution, intense agricultural practices or changing land use–are of major concern.

The possibility of involvement of nonculturable or minute cell fractions requires innovative research using molecular biological techniques. Information on the effects of different root parts versus bulk soil is interesting. Role of microorganisms in biogeochemical cycles and their interactions decide the nutrients available to crops.

The rhizosphere–the micro environment around plant roots houses intense biological, physical and geochemical activity distinguishing it from surrounding soil. Diversity, distributions, activities and interactions of innumerable organisms affect and are affected by availability of energy and nutrients, soil-water content and rhizosphere redox states. Soil food webs and nutrient cycling in agro ecosystems is of prime concern.

V. Aim of the course

- To help unlock and harness the potential of microorganisms in soil.
- To know the potential benefit of consortia of microorganisms to protect plants from different stresses.
- To study the role of microorganisms in the ecosystem functioning, nutrient cycling and biogeochemical processes including soil enzymes, through their metabolic activity and interactions.

The course is organized as follows:

No.	Blocks	Units
1.	Developments in soil Microbiology and Soil parameters	1. Historical prospective of soil microbiology. Factors affecting soil microflora 2. Ecology of soil microbiology
2.	Microbiology and Biochemistry of Plant parts	1. Plant parts and soil interface interaction
3.	Role of microorganisms in nutrient biocycle	1. Microbial transformations of various nutrients 2. Microbial degradation of organic matter 3. Microbial diversity 4. Role of microorganisms in biodegradation of xenobiotics and pesticides.

VI. Theory

Block 1: Developments in Soil Microbiology and Soil Parameters

Unit 1: Historical prospective of soil microbiology. Factors affecting soil microflora.

Landmarks in the history of soil microbiology. Abiotic factors (physical and chemical) affecting soil microflora as pH, chemicals, moisture, air, temperature etc.

Unit 2: Ecology of soil microbiology

Soil biota, Soil microbial ecology, types of organisms in different soils; Soil microbial biomass; Microbial interactions: unculturable soil biota.

Block 2: Microbiology and Biochemistry of Plant Parts

Unit 1: Plant parts and soil interface interaction

Microbiology and biochemistry of root-soil interface; phyllosphere, plant growth promoting rhizobacteria, soil enzyme activities and their importance.

Block 3: Role of Microorganisms in Nutrient Biocycle

Unit 1: Microbial transformation of various nutrients

Microbial transformations of nitrogen, phosphorus, sulphur, iron and manganese in soil. Siderophores and antimicrobials.

Unit 2: Microbial degradation of organic matter

Biochemical composition and biodegradation of soil organic matter and crop residues.

Unit 3: Microbial diversity

Endophytic microorganisms Mycorrhizae, types and role in phosphate mobilization. Potassium releasing bacterium. Microbes in biotic and abiotic stress management.

Unit 4: Role of microorganisms in biodegradation of xenobiotics and pesticides

Biodegradation of pesticides, Organic wastes and their use for production of biogas and manures: Biotic factors in soil development.

VI. Practicals

- Determination of soil microbial population

- Determination of Soil microbial biomass
- Decomposition studies in soil, Soil enzymes
- Measurement of important soil microbial processes such as ammonification, nitrification
- N_2 fixation, S oxidation, P solubilization and mineralization of other micro nutrients
- Study of rhizosphere effect
- Microbial diversity Endophytic microorganisms
- Mycorrhizae, types and role in phosphate mobilization Potassium releasing bacterium
- Microbes in biotic and abiotic stress management

VII. Teaching methods/activities

– Lectures. To use ppt and video clippings whenever necessary based on the topics that are hard to understand.
– The students must be assigned either in individual or in groups to identify the soils and crops grown and must get respective soil samples and plants for analyzing the microorganisms. They must subject the culture for various analysis depending upon the culture such a nitrogen fixing ability, phosphate solubilising property etc.
– Testing their efficiency through growth studies

VIII. Learning outcome

– Students will become familiar to the types of microbes in soil and their association with plants.
– The exclusive role of microorganisms in plant growth can be thoroughly understood.

IX. Suggested Reading

- Paul EA. 2015. *Soil Microbiology, Ecology and Biochemistry*. Elsevier
- Jan Dirk Van Elsas, Trevors JT and Elizabeth M.H. Wellington, 1997. *Modern Soil Microbiology*. Marcel Dekker, Inc.
- Paul EA. 2007. *Soil Microbiology and Biochemistry* 3rd Edition. Academic Press.
- Cardon ZG and Whitbeck JL. 2007. *The Rhizosphere An Ecological Perspective*. Academic Press.
- Schulz BJE, Boyle CJC and Sieber TN (Edrs). 2006. *Microbial Root Endophytes*. Pub Springer.
- Magesin R and Schinner F. (Edrs). 2005. *Manual of soil analysis monitoring and assessing soil Bioremediation*. Pub: Springer.
- Pinton R, Varanini Z and Nannipiers P. The Rhizosphere Biochemistry & organic substances at the soil-plant interface. Pub: CRC Press.
- Prasad TV. 2011. *A Text Book of Soil Microbiology*. Dominant Publishers & Distributors, New Delhi.
- Mukerji KG, Manoharachary C and Singh J. 2006. *Microbial activity n the Rhizosphere*. Pub: Springer.

Journals

- *European Journal of Soil biology*.
- *Canadian Journal of Microbiology*
- *Annual Review of Microbiology*
- *Journal of the Indian Society of Soil Science*.
- *Soil Biology and Biochemistry*
- *Applied soil ecology*

Websites

- www.nature.com
- www.microbiologysociety.org
- www.sare.org

I. Course Title : Microbial Biotechnology

II. Course Code : MICRO 506

III. Credit Hours : 2+1

IV. Why this course?

To give practical knowledge on fermentation and to develop fermentation for industrial application. Hence, this customised course.

V. Aim of the course

The aim is to teach students about industrially useful microorganisms and use of fermentor for the production of various primary and secondary metabolites
The course is organized as follows:

No.	Blocks	Units
1.	Scope of Microbial Technology and Fermentation Metabolism	1. Microbial Biotechnology 2. Fermentation Metabolism 3. Fermenter/bioreactor design and 4. operation 5. Fermentation system
2.	Recombinant products	1. Production of recombinant
3.	Microbial conversion and their product formation	1. Industrial production of beverages, acids and solvent 2. New tools and recent advances in microbial biotechnology

VI. Theory

Block 1: Scope of Microbial Technology and Fermentation Metabolism

Unit1: Microbial Biotechnology:

Introduction, Scopes, historical development, application and challenges.

Unit 2: Fermentation Metabolism

Fermentative metabolism, isolation, preservation screening and genetic improvement of industrially important microbes; Microbial growth kinetics.

Unit 3: Fermenter/bioreactor design and operation

Fermenters – types of fermenter, stirred tank reactor, bubble column reactor, airlift reactor, packed bed reactor, fluidized bed reactor and trickle bed reactor, agitation and aeration in a reactor, mass transfer. Foam formation and control.

Unit 4: Fermentation system

Types, Batch, Fed batch and continuous fermentation- multistage system. Solid state fermentation, Overproduction of primary and secondary metabolites e.g. amino acids, organic acids, alcohols, enzymes, organic solvents, antibiotics, etc. Immobilization of enzymes; and cells; Scale-up principles; Down-stream processing, etc.

Block 2: Recombinant Products

Unit 1: Production of recombinant

Current advances in production of antibiotics, vaccines, and biocides; Steroid transformation; Bioprocess engineering; Production of recombinant DNA products, Immobilization techniques.

Block 3: Microbial Conversion and their Product Formation

Unit 1: Industrial production of beverages, acid and solvent

Production of alcohol (ethanol, wine and beer) and improvement by genetic engineering. Microbial production of acids (citric, acetic and gluconic acid) solvents (glycerol acetone and butanol) aminoacids (lysine and glutamic acid).

Unit 2: New tools and recent advances in microbial biotechnology

Concept of probiotics and applications of new tools of biotechnology for quality feed/food production; Microorganisms and proteins used in probiotics; Lactic acid bacteria as live vaccines; Bioconversion of substrates, anti-nutritional factors present in feeds; Microbial detoxification of aflatoxins; Microbial polysaccharides: fermentative production of xanthan gums. Bacterial bioplastics, genetic engineering of microorganisms for the production of poly-3 hydroxyalkanoates. Single cell protein, Bio-insecticides; Bio-fertilizers; Waste as source of energy/food Microbiologically-produced food, colours, and flavours. Retting offlax. Recent advances in microbial biotechnology.

VII. Practicals

- Isolation and maintenance of industrially important microbes
- Production of alcohol
- Production of beer
- Production of citric acid
- Production of lactic acid
- Standardization of physical factors for the higher production of citric acid
- Production and assay of antibiotics
- Production of pullulan
- SCP production
- Study of bioreactors and their operation

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Better knowledge on industrially important microbes
- Important downstreaming processes followed for product development

X. Suggested Reading

- Cruger W and Cruger A. 2004. *Biotechnology - A Textbook of Industrial Microbiology*. 2nd Ed. Panima.
- Ward OP. 1989. *Fermentation Biotechnology*. Prentice Hall.
- Wiseman A. 1983. *Principles of Biotechnology*. Chapman & Hall

- Peppler HJ and Perlman D.1979. *Microbial Technology*. 2nd Ed. Academic Press.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org

I. Course Title : Food Microbiology

II. Course Code : MICRO 507*

III. Credit Hours : 2+1

IV. Why this course?

Food Microbiology focuses on a wide variety of current research on microbes that have both beneficial and deleterious effects on the safety and quality of foods, and are thus a concern of public health.

This course, food microbiology focuses specifically on issues of food spoilage caused by the presence of food-borne pathogens. Students are instructed in methods of sanitation and preservation during food preparation and processing.

V. Aim of the course

To familiarize the students with recent advances in food microbiology including fermented foods, dairy, food preservation, detection of food- borne diseases, their control measures.

The course is organized as follows:

No.	Blocks	Units
1	Historical Perspective and Scope of Microbiology in relation to food	1. Importance and significance of microorganisms in food 2. Factors of special significance in Food Microbiology 3. Microbial spoilage of different types of foods
2	Fermentation and Food Preservation methods	1. Food fermentation 2. Preservatives and preservation methods
3	Food safety and Quality Management Systems	1. Advanced techniques in detecting food-borne pathogens and toxins.

VI. Theory

Block 1: Historical Perspective and Scope of Microbiology in Relation to Food

Unit 1: Importance and significance of microorganisms in food

Introduction and scope; Food Microbiology Important microorganisms in food and their sources. Importance and significance of microorganisms in food.

Unit 2: Factors of special significance in Food Microbiology

Intrinsic and extrinsic factors influencing microbial growth in foods; Spores and their significance; Indicator organisms and Microbiological criteria.

Unit 3: Microbial spoilage of different types of foods

Microbial spoilage of meat, milk, fruits, vegetables and their products. Food-borne pathogens (bacteria, fungi and viruses) and intoxication.

Block 2: Fermentation and Food Preservation Methods

Unit 1: Food fermentation

Fermented dairy, vegetable, meat products.

Unit 2: Preservatives and preservation methods

Physical methods, chemical preservatives and natural antimicrobial compounds. Biologically based preservation systems. Foods for Specified Health Probiotic bacteria; Bifidus factor. Bacteriocins and their applications; Pre-, probiotics and symbiotics. Microbes as food single cell protein.

Block 3: Food Safety and Quality Management Systems

Unit 1: Advanced techniques in detecting food-borne pathogens and toxins

Food safety and Quality Management Systems- General principles of food safety risk management, Recent concerns on food safety- Safe food alternatives (Organic foods), Good agricultural Practices (GAP), Food Indicators of water and food safety and quality Advanced techniques in detecting food-borne pathogens and toxins. HACCP (Hurdle technology and Hazard analysis. Critical control point) CODEX, FSSAI (Food Safety and Standard Authority of India) systems in controlling microbiological hazards infoods. Food safety regulations

VII. Practicals

- Statutory, recommended and supplementary tests for microbiological analysis of various foods
- Infant foods, canned foods, milk and dairy products, eggs, meat, vegetables, fruits, cereals, surfaces, containers, normal, spoiled, processed, fermented food and water
- Testing of antimicrobial agents
- Analysis of water
- HACCP Plan
- Visit to Food processing Industries

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Group Work in Practical
– Visit to Food processing Industries

IX. Learning outcome

With this course the students are expected to be able to learn
– Important microorganisms in food and their sources.
– Various Factors of special significance in Food Microbiology.
– Biologically based preservation systems of foods.
– Advanced techniques in detecting food-borne pathogens and toxins.

X. Suggested Reading

- Bibek Ray. 1996. *Fundamentals of Food Microbiology*. CRC Press.
- Frazier W.C. and Westhoff D.C. 1991. *Food Microbiology*. 3rd Ed. Tata McGraw Hill.
- George J Banwart. 1989. Basic Food Microbiology. AVI. James M Jay. 1987. Modern Food Microbiology. CBS.

- Peppler H.J. and Perlman D. 1979. *Microbial Technology*. 2nd Ed. Academic Press.
- Adams, M.R., and M. O. Moss 1996. *Food Microbiology*, New Age International (Rt) Ltd., New Delhi.
- Frazier, W.C. and D.C. Westhoff, 1988. *Food Microbiology* (Reprint 1995), Tata McGraw Hill Publishing Ltd., New Delhi.
- James M. Jay., Loessner, M.J. and Golden D.A. 2005. *Modern Food Microbiology*, Seventh edition.
- Verma, L.K. and Joshi, V.K. 2000. *Post Harvest Technology of Fruits and Vegetables*, Tata McGraw Hill Publication.
- Bhunia AK. 2008. *Foodborne Microbial Pathogens- Mechanisms and Pathogenesis, Food Science text Series*, Springer International, New York, USA.
- Benwart, G.J. 1987. *Basic Food Microbiology*, CBS Publishers & Distributors, New Delhi.
- Deak, T. and Beuchat LR. 1996. *Hand Book of Food Spoilage Yeasts*, CRC Press, New York.
- Doyle, M.P. and Beuchat, L. R. 2007. *Food Microbiology- Fundamentals and Frontiers*, ASM Press.
- Garbutt, J., 1997. *Essentials of Food Microbiology*, Armold – International Students edition, London.
- Marriott, N.G. and Gravani R. B. 2006. *Principles of Food Sanitation, Food Science text Series*, Springer International, New York, USA.

Websites

- https://www.journals.elsevier.com/food-microbiology
- https://www.nature.com/subjects/food-microbiology
- https://www.frontiersin.org/journals/microbiology/sections/food-microbiology
- https://www.sciencedirect.com/journal/food-microbiology

I. Course Title : Bacteriophages

II. Course Code : MICRO 508

III. Credit Hours : 1+1

IV. Why this Course?

Bacteriophages are viruses that infect and reproduce in bacteria. Phages are inherently highly specific towards bacterial hosts. This characteristic has both negative and positive aspects in that it is beneficial in terms of avoiding negative effects on the host microbiota and a hindrance when it comes to detection and elimination of the target pathogen Course is formulated to demonstrate the complete sequence of host parasite reactions and provide a model by which virus –host cell reactions can be postulated for infection in higher plants and animals.

V. Aim of the course

To familiarize the students about phages and phage- bacterial interactions. Bacteriophages have been of intense value in elucidating many biological phenomena, including those concerned with genetics.

The course is organized as follows:

No.	Blocks	Units
1.	Bacteriophages	1. Historical prospective of bacteriophages 2. Biological processes of phage bacterial interaction 3. Life cycle of bacteriophages 4. Biotechnological Genetic manipulation

VI. Theory

Block 1: Bacteriophages

Unit 1: Historical prospective of bacteriophages.

Historical developments and classification of bacteriophages.

Unit 2: Biological processes of phage bacterial interaction

Physiology, biochemistry, enzymology and molecular biology of phage- bacterial interactions.

Unit 3: Life cycle of bacteriophages.

Structure, functions and life cycles of P2 phage, Lambda phage, M13 phage, ÕX174 phage.

Unit 4: Biotechnological Genetic manipulation

Phages in the development of molecular biology and genetic engineering.

VII. Practicals

- Titration of phages and bacteria.
- Absorption of phages.
- Preparation of phage stocks.
- Isolation of new phages and phage resistant bacteria.
- One step growth curve, phage bursts.
- Induction of lambda.
- Complementation of T_4*rII* mutantsetc.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Group Work in Practical

IX. Learning outcome

With this course the students are expected to be able to learn

– About different phages and phage- bacterial interactions.
– Intensible value Bacteriophage in elucidating many biological phenomena, including those concerned with genetics.
– Development of molecular biology and genetic engineering

X. Suggested Reading

- Birge EA. 2000. *Bacterial and Bacteriophage Genetics*. Springer-Verlag. Mathew CK. 1972. *Bacteriophage Biochemistry*. Am. Chemical Soc.
- Mathew CK, Kutter EM, Mosig G & Berget P. 1988. *Bacteriophage T4*. Plenum Press.
- Nancy T and Trempy J. 2004. *Fundamental Bacterial Genetics*. Blackwell. Stent SG. 1963. *Molecular Biology of Bacterial Viruses*. WH Freeman and Co.
- Winkler J, Ruger W and Wackernagel W. 1979. *Bacterial, Phage and Molecular Genetics - An Experimental Course*. Narosa.
- Winkler U and Rugr W. 1984. *Bacteria, Phage and Molecular Genetics*. ALA.

Websites

- https://www.nature.com/scitable/definition/bacteriophage-phage-293
- https://www.phe-culturecollections.org.uk/news/nctc-news/the-rise-and-rise-of-bacteriophages. aspx

- https://www.khanacademy.org/science/biology/biology-of-viruses/virus-biology/a/bacteriophages

I. Course Title : Environmental Microbiology
II. Course Code : MICRO 509
III. Credit Hours : 2+1

IV. Why this Course?

This course deals with the study of composition and physiology of microbial communities in the environment. Diversity of microbial populations and their important roles in air, water, soils and sediments. Microbial community ecology and interactions with plants and animals. Microbial communities control nutrient cycles and transformation of compounds. Deeper understanding about the beneficial and harmful effects of microbial communities in the environment will help, so this course as been mandated.

V. Aim of the course

The course is designed to introduce students to diverse microbial population and their important roles in environmental processes in air, water, soils and sediments.types of microorganisms found in the air, terrestrial and aquatic environments. Interaction of microbial communities with plants and animals. Geochemically and environmentally significant processes that are contributed by the activities of microorganisms. Methods that are used to identify and enumerate bacteria in natural environments and also how specific microbial activities. Impact of microbial degradation of organic contaminants and xenobiotics.

The course is organized as follows:

No.	Blocks	Units
1.	Microbial ecology	1. Scope of Environmental microbiology and Ecological Niche 2. Microorganisms and their natural habitats 3. Extremophiles
2.	Microbial interaction	1. Biogeochemical cycles 2. Waste water and solid waste treatment 3. Microbial upgradation in fossil fuels and interaction in rumen and gastrointestinal tract

VI. Theory

Block 1: Microbial Ecology

Unit 1: Scope of Environmental microbiology and Ecological Niche

Scope of environmental microbiology,Microbial ecology: Microbial evolution and biodiversity – Ecological niches – Definitions, biotic and abiotic environment. Environmental segments. Composition and structure of environment. Concept of biosphere, communities and ecosystems. Ecosystem characteristics, structure and function. Food chains, food webs and trophic structures. Ecological pyramids.

Unit 2: Microorganisms and their natural habitats

Microorganisms and their natural habitats: Aeromicrobiology, Astrobiology, Methane and chlorates on Mars, terrestrial analogues. Biofilms and microbial mats, Aquatic ecosystems- Public Health Microbiology.

Unit 3: Extremophiles

Extremophiles: Definition and ecological aspects. Thermophiles, Xerophiles, Psychrophiles, Piezophiles, Alkaliphiles, Acidophiles- Halophiles and Barophiles. Environmental Distribution and Taxonomic Diversity, Physiology, Adaptive mechanisms, Enzymes, Applications.

Block 2: Microbial Interaction

Unit 1: Biogeochemical cycles

Biogeochemical cycling and its consequences. Global environmental problems.

Unit 2: Waste water and solid waste treatment

Microbiology of wastewater and solid waste treatment: - Waste-types-solid and liquid waste characterization, physical, chemical, biological, aerobic, anaerobic, primary, secondary and tertiary treatments. Anaerobic processes-Bioremediation of nuclear wastes. Bioconversion of Solid Waste and utilization as fertilizer. Bioaccumulation of heavy metal ions from industrial effluents. Biomining. Microbiology of degradation of xenobiotics in the environment, ecological considerations, decay behavior.

Unit 3: Microbial upgradation in fossil fuels and interaction in rumen and gastrointestinal tract.

Microbial upgradation of fossil fuels and coal gas. Microbial interaction in rumen and gastrointestinal tract.

VII. Practicals

- Determination of indices of pollution by measuring BOD/COD of different effluents.
- Analysis of natural waters.
- Quality control tests, waste treatment and anaerobic digestion; Demonstration of waste water treatment processes such as activated sludge processes, biofilter and fluidized bed process.
- Bacterial reduction of nitrate from ground waters.
- Isolation and purification of degradative plasmid of microbes growing in polluted environments.
- Recovery of toxic metal ions of an industrial effluent by immobilized cells.
- Utilization of microbial consortium for the treatment of solid waste [Municipal Solid Waste]
- Biotransformation of toxic metal ions into non-toxic metals ions.
- Microbial dye decolourization/adsorption.
- Biotrap based isolation of selective functional microbes.
- Thermophlic enzyme in biomass deconstructions.
- Halophilic microbes from salt lake-Pesticide degradation by microbes

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Group Work in practical

– Field visit
– Case studies

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Appreciate the diverse microbial communities in environment and will be able to isolate and enumerate them from different environment.
– Realise the significance of microbial communities in biogeochemical cycles and their beneficial aspects to plants.
– Role of microorganism which are involved for bioremediation of harmful xenobiotic compounds.

X. Suggested Reading

- Campbell R. 1983. *Microbial Ecology*. Blackwell.
- Hawker LE & Linton AH. 1989. *Microorganisms Function, Form and Environment*. 2nd Ed. Edward Arnold.
- Richards BN. 1987. *Microbes of Terrestrial Ecosystem*. Longman.
- Mitchell R. 1992. *Environmental Microbiology*. John Wiley & Sons.
- Baker K.H. and Herson D.S. 1994. *Bioremediation.* McGraw Hill Inc., N.Y.
- Metcalf and Eddy HP. 2004. *Waste Water Engineering - Treatment, Disposal and Re-use* Inc., Tata McGraw Hill, New Delhi.
- McEldowney S Hardman DJ and Waite S. 1993. *Pollution: Ecology and Biotreatment* Longman Scientific Technical.
- Mitchell R, and GuJi-Dong. 2010. *Environmental Microbiology*. John V, Wiley Sons. Inc.
- Waste Water Microbiology 2nd Edition. Bitton. Chemistry and Ecotoxicology of pollution. Edited by Des. W. Connell, G.J. Miller. Wiley Interscience Publications.
- Bitton G. 2010. *Waste Water Microbiology* 2nd Edition.
- Connell OW and Miller GJ. 1984. *Chemistry and Ecotoxicology of pollution*. Wiley Interscience Publications.
- Forster CF and John Wase DA. *Environmental Biotechnology*. Ellis Horwood Ltd. Publication.
- Trivedi RK. 1998. *Advances in Waste Water Treatment Technologies*. Volumes II and I Global Science Publication.
- Lawrence P, Wacekett C and Hershberger D. 2000. *Biocatalysis and Biodegradation: Microbial transformation of organic compounds*. ASM Publications.
- Hurst CJ. 2001. *A Manual of Environmental Microbiology*. 2nd Edition. ASM Publications.

Websites

- http://microbiology.ucsc.edu.
- http://www.asm.org

I. Course Title : Industrial Microbiology

II. Course Code : MICRO 510

III. Credit Hours : 2+1

IV. Why this Course?

The syllabus of industrial microbiology is oriented towards the industrial application of microorganisms and recent microbial products. After studying this course students will know the industrial aspects of microbiology.

V. Aim of the course

To expose the students to the commercial exploitation of microorganisms for production of useful products. Focus will be on understanding of the techniques involved and the application of microorganisms for agribusiness purpose.

The course is organized as follows:

No.	Blocks	Units
1.	Basics of Industrial Microbiology	1. Historical account of microbes in industrial microbiology 2. Fermented Microbial products
2.	Bioplastics, Biopolymers & Biofuels	1. Biocontrol agents and Biopesticides 2. Industrial production of Bioplastics and biopolymers 3. Production of valuable products

VI. Theory

Block 1: Basics of Industrial Microbiology

Unit 1: Historical account of microbes in industrial microbiology

Introduction to Industrial Microbiology. Sources and characters of industrially important microbes; their isolation, purification and maintenance.
types of fermentation and fermenters. Microbial growth kinetics in batch, continuous and fed-batch fermentation process.

Unit 2: Fermented Microbial products

Bioreactors: Types and configuration. Microbiology and production of alcoholic beverages; Malt beverages, distilled beverages, wine and champagne; Commercial production of organic acids like acetic, lactic, citric, and gluconic acids Commercial production of important amino acids (glutamic acid, lysine and tryptophan), vitamins (riboflavin and vitamin A), enzymes, antibiotics and single cell proteins.

Block 2: Bioplastics, Biopolymers and Biofuels

Unit 1: Biocontrol agents and Biopesticides

Biocontrol agents and Biopesticides: Biocontrol agents and their scope in control of plant diseases, nematodes and insect pests. Role of bioagents in sustainable agriculture.

Unit 2: Industrial production of Bioplastics and biopolymers

Introduction & industrial production of Bioplastics: Microorganisms involved in synthesis of biodegradable plastics and microbial pigments and biopolymers.Biosensors: Development of biosensors to detect food contamination and environment pollution. Biofuels: Production of ethanol, biogas and hydrogen from organic residues, fuels from algae; Mushroom cultivation.

Unit 3: Production of valuable products

Genetic engineering of microbes, Role of recombinant microbes in industrial sectors for enhanced production of valuable products. Mechanisms of pesticide degradation by microbes. Biomining: Coal, mineral and gas formation, prospecting for deposits of crude, oil and gas, recovery of minerals from low-grade ores.

VII. Practicals

- Isolation and purification of industrially important microbes (Bacteria, fungus and yeasts)
- Production of industrial compounds such as alcohol, beer, citric acid, lactic acid

acetic acids gluconic acid and their recovery
- Demonstration of biogas production
- Production and assay of enzymes, organic acids and pigments
- Mass production of biocontrol agent
- Visit to industries

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Group Work in Practical
- Field visit/Industries/University lab
- Case studies

IX. Learning outcome

After studying this course students will know and will be able to learn

- The applied and industrial aspects of microbiology such as screening of microorganisms, strain improvement, microbial metabolites, fermented microbial products, microbial enzymes, Biofuels using microbes and microbial production of Biopolymers.
- The recent applications of the microbes for the human welfare.

X. Suggested Reading

- Sylvia DM, Fuhrmann JJ, Hartlly PT and Zuberer D. 2005. *Principles and Applications of Soil Microbiology*. 2nd Ed. Pearson Prentice Hall Edu.
- Waites, M.J., Morgan, N.L., Rockey, J.S. and Higton, G. (2002). *Industrial Microbiology: An Introduction.* Blackwell Science Publishers.
- Crueger W and Crueger A. *Biotechnology: A Text Book of Industrial Microbiology* Panima Publishing Corporation.
- Reed G. 1999. *Prescott and Dunn's Industrial Microbiology*. CBS Publishers.
- Demain AL. 2001. *Industrial Microbiology and Biotechnology* IInd Edition. ASM Press, Washington.
- Stanbury PF, Whitaker W and Hall SJ. 1997. *Principles of Fermentation Technology* Aditya Books (P) Ltd., New Delhi.
- Baltz RH, Davies JE and Demain AL. 2010. *Manual of Industrial Microbiology and Biotechnology*. 3rd Edition, ASM Press.
- Forciniti D. 2008. *Industrial Bioseparations: Principles and Practice*. 1st Edition, Wiley-Blackwell.
- OkaferN. 2007. *Modern Industrial Microbiology and Biotechnology,* Scientific Publishers, Enfield, USA.
- Nduka O and Benedict OC. 2018. *Modern Industrial Microbiology and Biotechnology*, Taylor and Francis 465p.
- ElMansi EMT, Bryce CFA, Dahhou A, Sanchez S, Demain AL, Allman AR. 2012. *Fermentation Microbiology and Biotechnology* 3rd Ed. CRC Press, Taylor and Francis, Boca Raton.
- Stanbury AF and Whitaker A. 1984. Principles of Fermentation Technology –Oxford Pergamon press New York.
- Moses V and Cape RE. 1991. *Biotechnology* - The Science and the Business Harwood Academic Publishers, USA.
- Casida LE Jr. 1989. *Industrial Microbiology* Wiley Eastern Ltd., N. Delhi.
- Miller BM and Litsky W. 1976. *Industrial Microbiology*, McGraw Hill Co.,New York 451p.
- Crueger W and Crueger A. 1984. *Biotechnology – a Text book of Industrial Microbiology*. Science Tech. Inc., Madison.
- Glazer AN and Nikaido HN. 1995. *Microbial Biotechnology: Fundamentals of Applied Microbiology*, W.H.Freeman Co., New York.

- Demain AL and Solomon MA. 1986. *Manual of Industrial Microbiology and Industrial Microbiology*, American Society of Microbiology, Washington.
- Atkinson B and Marituna F. 1983. *Biochemical Engineering and Biotechnology* Handbook, McMillian Publishers.
- Jones DG. 1983. *Exploitation of Microorganisms*. Chapman & Hall, Oxford.
- Peppler HJ and Perlman D. 1979. Microbial technology Vol.1 Fermentation Tecnology, Vol.2, Academic Press.
- Rehm HJ and Reed G. 1995. *Biotechnology, a Comprehensive Treatise*, 8 Vols. (Reference Book) Verlag Chemie,Wienheim. Also refer Second edition, 12 vols,1995 (Rehm,H.J.: Reed, G.: Puhler,A; Stadler, P Eds)
- Moo-Young Y. 1985. *Comprehensive Biotechnology*- 5 vols. (Reference Book) Pergamon Press, Oxford.
- Arora DK. 1992. *Handbook of Applied Mycology* – 5 Vols. (Reference Book) Marcel Dekker, New York.
- Glick BR and Pasternak JJ. 2003. *Molecular Biotechnology-principles and applications of recombinant* DNA,ASM press,Washington,760 pp.

Also consult latest issues of:
- Advances in Applied Microbiology, Biotechnology Advances,
- Biotechnology & Genetic Engineering Reviews,Advances in Biochemical Engineering & Biotechnology, Advances in Microbial Physiology

Websites
- https://www.biomerieux.com/en/industrial-microbiological-control-0
- https://icar.org.in/content/food-and-industrial-microbiology

I. Course Title : Biofertilizer Technology

II. Course Code : MICRO 511

III. Credit Hours : 2+1

IV. Why this Course?

The exploitation of beneficial microbes as a biofertilizer is of prime importance in agriculture sector for their potential role in food safety and sustainable crop production. There is wide gap between nutrient removal and supplies. There is increase in cost of fertilizers due to deplete in the feed stock fossil fuels besides growing concern of environmental hazards due to chemical fertilizers. It is essential to exploit Biofertilizers having functional traits for enhancing plant growth and productivity, nutrient profile, plant defense and protection with special emphasis to its function to trigger various growth- and defense-related genes in signaling network of cellular pathways to cause cellular response and thereby crop improvement.

The syllabus Biofertilizers technology is oriented towards application of biofertilizer to trap atmospheric nitrogen to the soil and convert them into plant usable forms. They also convert the insoluble phosphate forms into plant available forms. They stimulate root growth by producing some hormones and antimetabolites. Improved Plants.

V. Aim of the course

To familiarize the students and farmers with mass scale production of different agriculturally important microorganisms which are being used as biofertilizers for maintaining the soil and plant health for sustaining crop productivity and their importance in organic farming.

The course is organized as follows:

No.	Blocks	Units
1.	Agriculturally important beneficial microorgansims	1. Agriculturally important beneficial nitrogen fixing microorganisms. 2. Agriculturally important beneficial microorganisms related to phosphorous, potassium, Sulphur and Zinc nutrition 3. Agriculturally important beneficial microorganisms having plant growth promoting rhizobacteria 4. Agriculturally important biocontrol microbial inoculants 5. Economics of biofertilizer production.
2.	Production of Biofertilizer	1. Production and quality control of biofertilizer

VI. Theory

Block 1: Agriculture Important Beneficial Microorganisms

Unit 1: Agriculturally important beneficial nitrogen fixing microorganisms.

Different agriculturally important beneficial microorganisms: Chemical Vs Biofertilizers: Current Scenario in biofertilizer technology in world-In India-List of biofertilizers-their applications in agriculture.

Brief introduction about Agriculturally beneficial microorganisms (free living, symbiotic (rhizobial, actinorhizal), associative and endophytic nitrogen fixers including phosphobacteria, cyanobacteria, their types and importance taxonomic classification, Nitrogen fixing biofertilizers: nodule formation, competitiveness and quantification of N_2 fixed and their use. Mechanism of phosphorous solubilization by photobacteria. BIS standards of biofertilizers

Unit 2: Agriculturally important beneficial microorganisms related to phosphorous, potassium, Sulphur and Zinc nutrition

Different agriculturally important beneficial microorganisms: phosphate solubilizing bacteria and fungi, including mycorrhiza; Mechanism of phosphorous solubilization by phosphobacteria. Bacteria for potassium, Sulphur and Zinc nutrition.

Unit 3: Agriculturally important beneficial microorganisms having plant growth promoting rhizobacteria.

Different agriculturally important beneficial microorganisms: plant growth promoting rhizobacteria. FCO norms and biofertilizer production and usage at national and international levels

Unit 4: Agriculturally important biocontrol microbial inoculants

Different agriculturally important beneficial microorganisms: Biocontrol microbial inoculants. Requirements for establishing bioinoculants production unit Economics of biofertilizers production Constraints in biofertilizers production and usage

Unit 5: Economics of biofertilizer production

Different agriculturally important beneficial microorganisms for recycling of organic waste and compositing, bioremediators and other related microbes.

Block 2: Production of Biofertilizer

Unit 1: Production and quality control of biofertilizer

Different agriculturally important beneficial microorganisms - selection, establishment, competitiveness, crop productivity, soil & plant health, mass scale production and quality control of bio inoculants. Biofertilizer inoculation and microbial communities in the soil. Different formulations of biofertilizers. Advantages and limitations of Liquid formulations.

VII. Practicals

- Isolation of phosphate solubilizing microorganisms.
- Development and production of efficient microorganisms,
- Determination of beneficial properties in important bacteria to be used as biofertilizer, Nitrogen fixing activity, indole acetic acid (IAA), siderophore production etc,
- Bioinoculant production and quality control.
- Population dynamics in broth and carrier materials during storage.
- Development of cultures from starter.
- Preparation of broth for large scale cultivation in fermenter/ large containers. Inoculation and development of culture.
- Mass production of carrier based and liquid biofertilizers. Mass production of important two or three biocontrolagents (*Trichoderma viride, Pseudomonas fluorescens* and *Metarhiziumanisopliae*).
- Form, dose and method of application.
- Mass production of AM fungi in pot and root organ culture.
- Quality control and BIS standards.
- Mass production of Azolla and BGA.
- Visit to a biofertilizer production plant

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures
- Review of policy documents

IX. Learning outcome

After successful completion of this course, the students are expected to be able to learn:

- Agriculturally important beneficial microorganisms for fixation of various important elements and compounds.
- Biofertilizer production and usage at national and international levels.
- Requirements for establishing bioinoculants production unit, economics (solid liquid carrier) production, constraints in biofertilizers production and usage.
- A complete exposure to all kinds of agriculture important biofertilizers along with their functions and properties,
- Helps to develop as entrepreneur.

X. Suggested Reading

Books

- Alexander M. 1977. *Soil Microbiology*. John Wiley.
- Bergerson FJ. 1980. *Methods for Evaluating Biological NitrogenFixation*. John Wiley & Sons.
- Sylvia DM, Fuhrmann JJ, Hartlly PT and Zuberer D. 2005. *Principles and Applications of Soil Microbiology*. 2nd Ed. Pearson Prentice Hall Edu.
- Van Elsas JD, Trevors JT and Wellington EMH. 1997. *Modern Soil Microbiology*. CRC Press.
- Panwar JDS and Jain AK. 2016. *Organic farming scope and use of biofertilizers*. Pub: NIPA, New Delhi.
- Gaur AC. 2010. *Biofertilizers in Sustainable Agriculture*, ICAR, New Delhi.
- Chanda P and Srivathsa RSH. 2005. *Liquid Biofertilizers*. Ministry of Agriculture Department of Agriculture & Cooperation, GOI.
- DeshMukh AM, Khobragade RM and Dixit PP. 2007. *Handbook of Biofertilizers & Biopesticides*. Oxford Book Company, Jaipur, India.
- Gupta RP, Kalia A and Kapoor S. 2007. *Bioinoculants a Step towards Sustainable Agriculture* .NIPA, New Delhi.
- Somani LL, Shilkar P and Shilpkar D. 2011. *Biofertilizers Commercial Production Technology & Quality Control*. AgroPublishing Acadamy, Udaipur.
- Srivastava HS and Singh RP. 1995. *Nitrogen nutrition in higher plants*. Associated Publishing Company, New Delhi.
- Kannaiyan S and Kumar K. 2005. *Azollabiofertiliser for sustainable Rice Production*. Daya Publishing House, Delhi.
- Kannaiyan S, Kumar K and Govindarajan K. 2010. *Biofertilizer Technology*. Scientific Publishers (India), Jodhpur.
- Vora MS, Shelat HN and Vyas RV. 2013. *Handbook of Biofertilizers & Microbial Pesticides*.
- Chanda JK. 2008. *Biofertilizer Statistics 2006-07*. The fertilizer Association of India, New Delhi.

Journals

- *Journal of Biofertilizer& Biopesticides*
- *Journal of Botanical Sciences*

Websites

- Biofertilizer in organic Agriculture (www.Journalphytology.com)
- Microbial biofertilizers (www.Boffinaccess.com)
- Biofertilizer as a prospective input for sustainable agriculture in India. http://www.krishisewa.com/articles/organic-agriculture/115-biofertilizers.html
- Handbook of Microbial Biofertilizers M. K. Rai, PhD Editor Pub: Food Products Press, NY.
- Bio fertilisers https://www.worldcat.org/search?q=biofertilisers&fq=dt%3Abks&dblist=638&qt =sort&se=yr&sd=desc&qt=sort_yr_desc

I. Course Title : Cyanobacterial and Algal Biotechnology

II. Course Code : MICRO 512

III. Credit Hours : 2+0

IV. Why this Course?

Cyanobacteria and algal biomass contribute major role in carbon cycle in turn influencing the climate. The blooms of cyanobacteria and algae in different ecosystems is worth exploiting due to their wide biodiversity. They play an important role in agriculture by contributing to the fertility of soil in terms of biomass, biofertilizer, and act as herbicides, insecticides and in bioremediation. Their physiological and biochemical properties disclose their significant potential for colorants, polysaccharides, pharmaceutical & nutraceutical compounds, and valuable biomolecules of industrial importance. With the population explosion and scarcity of land, these can provide better feed stock due to their high protein content, easy cultivation, and versatile growth and easy to harvest. It is challenging for designing bioreactor and utilizes waste waters for growing and harvesting cyanobacteria and algae for these purposes. They are capable of producing and accumulating lipids which can be the source for biodiesel in future.

This course will help the student to understand taxonomy and molecular biology methods of cyanobacteria. The course will give knowledge on cyanobacterial and algal fuels,

V. Aim of the course

The aim is togive exposure on the potential applications of cyanobacteria and algae in Agriculture, Industry and Environment; to inculcate knowledge on algal mass production techniques and their valuable products of commercial importance and to introduce the R&D and entrepreneurial opportunities algae. Students will learn about biodiversity of cyanobacteria and their classification, the biotechnological applications in agriculture – biofertilizers, biocontrol, bioenergy and bioprocessing, their applications in pharmaceuticals, production of antioxidative enzymes and pigments, as source of food, etc.

The course is organized as follows:

No.	Blocks	Units
1.	Importance of cyanobacteria and algae	1. Ecology and evolution of algae and cyanobacteria
2.	Physiology and culturing of cyanobacteria and algae	1. Algal pigments, storage products 2. Metabolism of carbon and nitrogen 3. Culturing methods.
3.	Role of cyanobacteria and algae in agriculture and their products of industrial importance	1. Importance as fuels, neutraceuticals and industrial importance 2. Role of algae related to environment

VI. Theory

Block 1: Importance of Cyanobacteria and Algae

Unit 1: Ecology and evolution of algae and cyanobacteria

Introduction to cyanobacteria and algae. Definition, occurrence and distribution, thallus structure, reproduction, life cycles, origin and evolution of cyanobacteria, molecular evolution; role of algae in evolution of land plants and horizontal transfer of genes. Brief classification of algae: different classes, occurrence and distribution.

Block 2: Physiology and Culturing of Cyanobacteria and Algae

Unit 1: Algal pigments, storage products.

Algal pigments, storage products, physiology and metabolism including photosynthesis.

Unit 2: Metabolism of carbon and nitrogen

Ecology of algae –primary colonizers and cycling in soil and water. Cellular differentiation and nitrogen fixation, nitrogen metabolism carbon metabolism.

Unit 3: Culturing methods

Algal culturing and cultivation. Culture types, culture conditions, culture vessels, culture media, sterilization, culture methods, synchronous cultures, photobioreactors, algal density and growth, seaweed cultivation.

Block 3: Role of Cyanobacteria and Algae in Agriculture and their Products of Industrial Importance

Unit 1: Importance as fuels, neutraceuticals and industrial importance.

Cyanobacterial and algal fuels, Fine chemicals (restriction enzymes etc.) and nutraceuticals from algae; UV absorbing pigments Industrial products from macro algae - seaweed biotechnology, sustainable aquaculture. Ecology of algae- distribution in soil and water; primary colonizers, carbon sequestration and cycling in soil and water. Cellular differentiation and nitrogen fixation, nitrogen metabolism.

Unit 2: Role of algae related to environment.

Algae in pollution control - as pollution indicators, eutrophication agents and role in Bioremediation and reclamation of problem soils. Cyanobacterial and algal toxins, allelopathic interactions, Algae in global warming and environmental sustainability. Cyanobacteria and selected microalgae in agriculture – biofertilizers &algalization; soil conditioners; reclamation of problem soils.

VII. Teaching methods/activities

– Lecture
– Assignment (reading/writing)
– Publication review
– Student presentation
– Group discussion
– Case analysis and case studies
– Guest lectures

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

– Types of cyanobacteria and algae along with their physiological and biochemical properties that provides base for selection for further exploitation of industrial use.
– Algal culturing and cultivation. Culture types, culture conditions, synchronous cultures, photobioreactors, algal density and growth, seaweedcultivation.
– Production of cyanobacterial and algal fuels
– Industrial products from macro algae – seaweed biotechnology, sustainable aquaculture.
– Ecology of algae – distribution in soil and water; primary colonizers, carbon sequestration and cycling in soil and water.

IX. Suggested Reading

- Ahluwalia AS. 2003. *Phycology: Principles, Processes and Applications*. Daya Publ.
- Barsanti L and Gualtieri P. 2006. *Algae: Anatomy, Biochemistry and Biotechnology*. Taylor & Francis, CRC Press.
- Carr NG and Whitton BA. 1982. *The Biology of Cyanobacteria*. Blackwell.
- Herrero A and Flores E. 2008. *The Cyanobacteria Molecular Biology,Genomics and Evolution*. Calster Academic Press

- Kumar HD. 2005. *Introductory Phycology*. East West Press. Linda E Graham & Lee W Wilcox. 2000. *Algae*. Prentice Hall.
- Andersen RA. 2005. *Algal Culturing Techniques*. Academic Press.
- Venkataraman LV and Becker EW. 1985. *Biotechnology and Utilization of Algae: the Indian Experience*. DST.
- Das MK. 2010. *Algal Biotechnology*. Daya Publishing House.
- Tiwari. 2014. *Cyanobacteria: Nature, Potentias and Applications*. Daya Publishing House.
- Khattar JIS, Singh DP, Kaur G. 2009. *Algal Biology and Biotechnology*. I.K. International Publishing HousePvt. Ltd.
- Bhatnagar SK, Saxena A, Kraan S. 2011. *Alga Biofuels*. Stadium Press (India) Pvt. Ltd.
- Sahoo D and Kaushik BD. 2012. *Algal Biotehcnolgoy and Environment*. I.K. International Publishing HousePvt. Ltd.

Journals

- *Journal of Phycology*
- *Journal of Applied Phycology*
- *Frontiers in Microbiology*

Websites

- Cyanbacterial and algal Biotechnology
- https://www.worldcat.org/search?q=cyanobacterial+and+algal+biotechnology&qt=results_page#%2528x0%253Abook%2Bx4%253Aprintbook%2529format
- www.cyanosite.bio.purdue.edu
- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org
- http://www.bbsrc.ac.uk/organisation/policies/reviews/scientific-areas/1107-algal-research.aspx
- http://asulightworks.com/resources/videos/arizona-center-algae-technology-and-innovation.html

Course Title with Credit load
Ph.D. in Microbiology

Course Code	Course Tittle	Credit Hours
MICRO 601*	Improvement in fermentation Technology	2+1
MICRO 602	Microbial physiology and regulation	2+0
MICRO 603*	Recent development in soil microbiology	2+0
MICRO 604	Recent approaches in environmental microbiology	2+0
MICRO 605*	Plant microbe interactions	2+1
MICRO 691	Doctoral seminar I	1+0
MICRO 692	Doctoral seminar II	1+0
MICRO 699	Doctoral Research	75

*Core Courses

Course Contents
Ph.D. in Microbiology

I. Course Title : Improvements in Fermentation Technology

II. Course Code : MICRO 601*

III. Credit Hours : 2+1

IV. Why this Course?

This course aims to introduce technological advancement of fermentation and bioprocess for industrial applications. Microorganisms are capable of growing on a wide range of substrates and can produce a remarkable spectrum of products. This course will enlighten the students on basics of fermentation, metabolic engineering, fermenter design and downstream processing. The economics of industrial products are introduced to understand commercialization of microbial products.

V. Aim of the course

The aim is to teach students regarding fermentation industry using industrially useful microorganisms including yeast technology. To introduce the students to broad coverage of a diverse field of fermentation technology, provide an understanding of the exploitation of microorganisms in the manufacture of bio products and provide the students with skill in operation of fermenter.

The course is organized as follows:

No.	Blocks	Units
1.	Rise of Fermentation Technology	1. Development in Fermentation 2. Types of Fermenters
2.	Fermenter	1. Component of fermenter and use
3.	Fermentation process	1. Types of Fermentation
4.	Recombinant Strategies Followed	1. Strategies for isolation of industrially important microbes

VI. Theory

Block 1: Rise of Fermentation Technology

Unit 1: Development in Fermentation

Definition of fermentation – rise of fermentation technology –current trends in fermentation industry – scope and importance of fermentation technology.

Unit 2: Types of fermenters

Continuous, batch and fed batch culture –anaerobic fermentation - range of fermentation process – microbial growth cycle – diauxic growth – growth kinetics – substrate uptake kinetics (Jacob and Monod) - primary and secondary metabolites – future prospects of fermentation microbiology

Block 2: Fermenter

Unit 1: Components of fermenter and use

Peripheral parts and accessories – alternative vessel designs –containment in fermentation – fermenter preparation and use - aeration and agitation – instrumentation and control – biosensors in monitoring – computer applications in fermentation technology

Block 3: Fermentation Process

Unit 1: Types of Fermentation

Solid state and submerged fermentation – acidic/alcoholic fermentation - recovery of product – effluent treatment – Economics of fermentation

Block 4: Recombinant Strategies Followed

Unit 1: Strategies for isolation of industrially important microbes

New strategies for isolation of industrially important microbes and their genetic manipulations; Antibiotic fermentation research; steroid transformation; Yeast technology – classification, genetics, strain improvement for brewing, baking and distilleries

VII. Practicals

- Studying the various components of fermenter
- exposure to different types of fermenter
- sterilization and operating procedures
- designing the production medium
- isolation and purification of industrially important microbes
- Genetic manipulations in microbes
- Fermentation by improved strains of yeast for production of alcohol
- microbial production of enzymes by solid state fermentation
- Microbial production of important antibiotics
- Bioremediation of industrial effluents

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Publication Review
- Student presentation
- Group discussion
- Case Analysis and case studies
- Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- Students should have an understanding of the variety of fermentation and subsequent processing approaches available for the manufacture of biological products and the design and operation of these systems.

X. Suggested Reading

- Stanbury PF, Whitaker A and Hall SJ. *Principles of fermentation technology*, Second edition
- Patel AH. *Industrial Microbiology*
- ElMansi EMT and Bryce CFA. *Fermentation Microbiology and Biotechnology*

- Srivastava ML. *Fermentation Technology*
- Singh T and Purohit SS. *Fermentation Technology*
- ElMansi EMT, Bryce CFA, Demain AL and Allman AR. *Fermentation Technology – Microbiology and Biotechnology*
- Peppler HJ and Perlman D. 1979. *Microbial Technology*. 2nd Ed. Academic Press.
- Reed G. 1987. *Presscott& Dunn's Industrial Microbiology*. 4th Ed. CBS.
- Stanbury PF and Whitaker A. 1987. *Principles of Fermentation Technology*. Pergamon Press.
- Wiseman A. 1983. *Principles of Biotechnology*. Chapman & Hall.

Websites

- http://www.asmscience.org
- http://www.asm.org
- http://www.microbiologyonline.org.uk
- http://www.microbeworld.org
- http://www.scribd.com/doc/46151150/Fermentation-Technology
- http://www.chalmers.se/en/areas-of-advance/lifescience/research/Pages/Fermentation-Technology.aspx

I. Course Title : Microbial Physiology and Regulation

II. Course Code : MICRO 602

III. Credit Hours : 2+0

IV. Why this Course?

Microorganisms have tremendous metabolic diversity hence it's intriguing to learn how these small creatures deal with different environmental conditions and either adopt themselves to it or convert it to favorable conditions by involving different physiological processes. The contents of this course will help students how microbes can grow on substrates other than glucose, their inorganic metabolism and biosynthesis and how do they respond to the changes in environment

V. Aim of the course

To acquaint students with current topics in molecular microbiology. Course imparts thorough knowledge about the synthesis of biomolecules in microorganisms by various pathways and their regulation.

The course is organized as follows:

No.	Blocks	Units
1.	Historical evaluation of microbial physiology	1. Molecular aspects of various cell component
2.	Regulation and pathways	1. Regulatory Pathways 2. Regulatory control 3. Current topics

VI. Theory

Block 1: Historical Evaluation of Microbial Physiology

Unit 1: Molecular aspects of various cell component

Origin, evolution, structure, function and molecular aspects of various cell components. Differentiation in bacteria, slime molds, yeasts. Molecular biology of bioluminescence, bacterial virulence. Heat shock response. Extracellular protein secretion in bacteria.

Block 2: Regulation and Pathways

Unit 1: Regulatory Pathways

Regulation of initiation, termination and anti-termination of transcription. Global regulation and differentiation by sigma factor. Regulatory controls in bacteria - inducible and biosynthetic pathways. Oxidative stress control. Fermentative and respiratory regulatory pathways.

Unit 2: Regulatory control

Ribosomal RNA and ribosomal proteins regulation under stress condition. Specific regulatory systems; SOS regulatory control; Antisense RNA regulation of gene expression.Biosynthesis of micromolecules (Nucleotides and Aminoacids) macromolecules (DNA, RNA, Proteins) Global nitrogen control and regulation of nitrogen fixation

Unit 3: Current topics

Topics of current interest in Molecular microbiology and regulatory systems.

VII. Teaching methods/activities

– Class room Lecture
– Assignment (Reading/Writing)
– Student presentation
– Seminar presentation by students

VIII. Learning outcome

With this course, the students are expected to be able to learn
– Current topics in molecular microbiology.
– Thorough knowledge about the synthesis of biomolecules in microorganisms by various pathways and their regulation.
– About the synthesis of biomolecules in microorganisms by various pathways and their regulation.

IX. Suggested Reading

Websites

- https://www.frontiersin.org/journals/microbiology/sections/microbial-physiology-and-metabolism
- https://www.sciencedirect.com/bookseries/advances-in-microbial-physiology
- https://www.researchgate.net/journal/0065-2911_Advances_in_Microbial_Physiology
- https://bmb.psu.edu/undergraduate/courses/course-archive/2016/fall-2016/microbiology-micrb/micrb-401-fall-2016/micrb-401-microbial-physiology-and-structure
- Selected articles from journals.

I. Course Title : Recent Developments In soil microbiology

II. Course Code : MICRO 603*

III. Credit Hours : 2+0

IV. Why this Course?

Directly or indirectly the waste of human and other animals, their bodies, and the tissues of plants are dumped onto or buried in the soil. It is the microbes that make these changes –the conversion of organic matter in to simple organic substances that provide the nutrient material for the plant and agriculture world. Thus microorganisms play a vital role in maintaining life on earth. The prerequisite for this class is SOIL. To be completely prepared for this class a course taken in Microbiology is very useful.

V. Aim of the course

To make students learn the latest trends in soil microbiology like diversity, biological control and bioremediation.

The course is organized as follows:

No.	Blocks	Units
1.	Recent developments in soil microbiology	1. Ecology and microorganisms diversity 2. Role of microorganisms in soil 3. Bioremediation

VI. Theory

Block 1: Recent Developments in Soil Microbiology

Unit 1: Ecology and microorganisms diversity

Molecular ecology and biodiversity of soil microorganisms; Survival and dispersal of microorganisms. Interaction between agricultural chemicals, pollutants and soil microorganism

Unit 2: Role of microorganisms in soil

successions and transformation of organic matter; Role of microorganisms in soil fertility. Soil health and quality: Microbial indicators

Unit 3: Bioremediation

Bioremediation of polluted soils; Biological control. Other topics of current interest.

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Seminar presentation by students.
– Case studies

VIII. Learning outcome

With this course, the students are expected to be able to learn

– Latest trends in soil microbiology like diversity, biological control and bioremediation.

IX. Suggested Reading

Websites

- https://www.springer.com/in/book/9789811073793
- https://www.researchgate.net/publication/322952969_Advances_in_Soil_Microbiology_Recent_ Trends_and_Future_Prospects_Volume_2_Soil-Microbe-Plant_Interaction
- Selected articles from journals.

I. Course Title : Recent Approaches in Environmental Microbiology
II. Course Code : MICRO 604
III. Credit Hours : 2+0

IV. Why this Course?

The activities of the microorganisms at large in nature/ environment are considered in this course. Microbes play far more important roles in nature than their small sizes would suggest. In order to evaluate the roles of microorganisms in ecosystems, it is essential to understand the precise natural habitats and how their activities can be explored.

V. Aim of the course

To apprise the students about the role of microbiology in environment management for sustainable eco-system and human welfare.

The course is organized as follows:

No.	Blocks	Units
1.	Recent environmental issue	1. Basic concepts and environmental issues 2. Methodology of environmental management 3. Microbial waste treatment.
2.	Energy harnessing from organic waste	1. Pollution through conventional fuel 2. Renewable sources of energy.
3.	Treatment of waste for safe disposal.	1. Disposal of domestic and industrial wastes 2. Global environmental problems

VI. Theory

Block 1: Recent Environmental Issue

Unit 1: Basic concept and environmental issues

Types of environmental pollution; problems arising from high-input agricultural residues. Air and water pollution.

Unit 2: Methodology of environmental management

Waste water treatment -physical, chemical, biological and microbial processes; need for water and natural resource.

Unit 3: Microbial waste treatment

Microbiology and use of micro-organisms in waste treatment; biodegradation; degradation of Xenobiotic, surfactants; bioremediation of soil & water contaminated with oils, pesticides & toxic chemicals, detergents, etc.; aerobic processes (activated sludge, oxidation ditches, trickling filter, rotating drums, etc.); anaerobic processes: digestion, filtration, etc.

Block 2: Energy Harnessing from Organic Waste

Unit 1: Pollution through conventional fuel

Conventional fuels and their environmental impact.

Unit 2: Renewable sources of energy.

Energy from solid waste; ; biogas; land filling, microbial hydrogen production; use of agro-industrial waste, agricultural waste for sugar to alcohol; gasohol; biodegradation of lignin and cellulose; biopesticides; biofertilizers; composting; vermiculture, etc.

Block 3: Treatment of Waste for Safe Disposal

Unit 1: Disposal of domestic and industrial wastes.

Treatment schemes of domestic waste and industrial effluents; food, feed and energy from solid waste; bioleaching; enrichment of ores by micro-organisms.

Unit 2: Global environmental problems

Ozone depletion, UV-B, greenhouse effects, and acid rain; biodiversity and its conservation; Microbial and biotechnological approaches for the management of environmental problems.

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Seminar presentation by students.
– Case studies

VIII. Learning outcome

With this course, the students are expected to be able to learn

– Latest trends in environmental microbiology like Treatment schemes of domestic waste and industrial effluents; food, feed and energy from solid waste; bioleaching; enrichment of ores by micro-organisms
– Renewable and non-Renewable resources of energy; energy from solid waste; conventional fuels and their environmental impact; biogas; land filling, microbial hydrogen production

IX. Suggested Reading

- Evans GM and Furlong JC. 2002. *Environmental Biotechnology: Theory and Application*. Wiley International.
- Jordening HJ and Winter J. 2006. *Environmental Biotechnology: Concepts and Applications*. Wiley-VCH Verlag.

Websites

- https://www.springer.com/series/11961
- http://microbiology.ucsc.edu.
- http://www.asm.org

I. Course Title : Plant Microbe Interactions

II. Course Code : MICRO 605*

III. Credit Hours : 1+1

IV. Why this Course?

In the course, interactions between plants and microbes are discussed on general and detailed level for both pathogenic and symbiotic interactions. This course will be helpful in imparting knowledge to student about Infection mechanisms, defense of plants and stress responses and a large number of important problems within agriculture, horticulture and forestry

V. Aim of the course

The aim is to familiarize the students with the biochemical and biophysical mechanisms, genetics, genomics, proteomics and advanced microscopy, spectroscopy of different interfaces of beneficial and pathogenic plant microbe interactions. Molecular analysis of relevant factors in the plant and microbes, and components that modulate plant-microbe interactions for soil and plant health for sustaining crop productivity.

The course is organized as follows:

No.	Blocks	Units
1.	Types of ecosystem and microbial interaction	1. Different interfaces of interactions 2. Ecosystem- Concept and Dynamics.
2.	Signaling and interaction among microbes	1. Microbial interaction.
3.	Genomic and proteomic study in plant microbe interaction	1. Methodology/resources in plant-microbe interaction.

VI. Theory

Block 1: Types of Ecosystem and Microbial Interaction

Unit 1: Different interfaces of interactions

Plant-microbe, microbe-microbe, soil- microbe, soil-plant-microbe interactions leading to symbiotic (rhizobial and mycorrhizal, *Azolla-Anabaena*), associative, endophytic and pathogenic interactions.

Unit 2: Ecosystem- Concept and Dynamics

Types of ecosystems: Concept and dynamics of ecosystem, Food chain and energy flow, Microbial communities in the soil. Community dynamics and population interactions employing DGGE, TGGE, T-RFLP.

Block 2: Signaling and Interaction among Microbes

Unit 1: Microbial interaction

Quorum-sensing in bacteria, flow of signals in response to different carbon or other substrates and how signals are recognized.

Block 3: Genomic and Proteomic Study in Plant Microbe Interaction

Unit 1: Methodology/resources in plant-microbe interaction

Methodology/resources to study plant-microbe interaction, biosensors, transcriptome profiling, metabolic profiling, genomics, and proteomics Induced systemic resistance against pathogens and tolerance against abiotic stress: Molecular basis; Molecular diversity of microbes, plants and their interactions including transgenic microbes and plants

VII. Practicals

- Phylochip based microbial community analyses-
- Endophytic and phyllosphere microbial community
- PCR-DGGE-Rhizosecretion
- secretome -FT-IR, HPLC
- Multifunctional protein identification and characteriation-2DE, MALDI-TOF.
- Examination of mycorrhizal infection in roots of different plants.
- Characterization of PGPR; Quantification of siderophores, HCN and IAA

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Publication Review
– Student presentation

– Group discussion
– Case Analysis and case studies
– Guest Lectures

IX. Learning outcome

After successful completion of this course, the students are expected to be able to: Better understanding of soil – plant – microbe interaction and how the plant/ microbial system select their host. In addition this course will also provide new insight about the various biomolecules secreted by the plant root as well as microbes which forms the basis for their intimate association and exert multiple benefits to the plants.

X. Suggested Reading

- Kosuge T and Nester, E.W. 1989. *Plant Microbe Interactions: Molecular and Genetic Perspectives*, Vol.I-IV, McGraw Hill.
- Paul Eldor, A. 2007. *Soil Microbiology, Ecology and Biochemistry*
- Robert L. Tate III. 1995. *Soil Microbiology*, John Wiley & Sons, INC.
- Sylvia David, M., Fuhrmann, T.A., Hartel, P.G. and Zuberer, D.A. 2005. *Principles and Applications in Soil Microbiology* (II nd Edition).
- Verma, D.P.S. and Kohn, T.H. 1984. *Genes involved in Microbe-Plant Interactions*, Springer-Verlag
- Jaya Kumar Arjun, Kumarapillai Harikrishnan. 2011. Metagenomic analysis of bacterial diversity in the rice rhizosphere soil microbiome. *Biotechnol. Bioinf. Bioeng*. 1(3): 361-367
- Andrea Porras-Alfaro and Paul Bayman.2011. Hidden Fungi, Emergent Properties: Endophytes and Microbiomes. *Annu. Rev. Phytopathol*. 49: 291-315.
- Eleonora Rolli *et al*. 2014. Improved plant resistance to drought is promoted by the root-associated microbiome as a water stress-dependent trait. *Environmental Microbiology*. doi: 10.1111/1462-2920.12439
- Roeland L. Berendsen, Corne´ M.J. Pieterse and Peter A.H.M. Bakker. 2012. The rhizosphere microbiome and plant health. *Trends in Plant Science*, Vol. 17, No. 8.
- Josep Penuelas and Jaume Terradas. 2014. The foliar microbiome. *Trends in Plant Science*. http://dx.doi.org/10.1016/j.tplants.2013.12.007

Journals

- *Advances in Microbial Physiology*
- *Annual Review of Genetics/Biochemistry*
- *Annual Review of Microbiology*
- *Applied and Environmental Microbiology*
- *Biology and Fertility Soils*
- *Indian Journal of Microbiology*
- *Journal of Bacteriology*
- *Journal of Basic Microbiology*
- *Microbiology and Molecular Biology Reviews*
- *Nature/Science/EMBO Journal*
- *Reviews in Microbiology and Biotechnology*
- *Soil Biology and Biochemistry*
- *Trends in Biotechnology*
- *Trends in Microbiology*
- *Trends in Plant Sciences*

Websites

- http://testweb.science.uu.nl/pmi/
- popups.ulg.ac.be/1780-4507/index.php?id=7578
- www.researchgate.net/...The_rhizosphere_microbiome_and_plant_health...
- journal.frontiersin.org/Journal/10.3389/fpls.2013.00165/abstract

- http://www.aw-bc.com/microplace/
- http://www.personal.psu.edu/jel5/micro/index.htm
- http://microbiology.ucsc.edu/
- http://www.suite101.com/links.cfm/microbiology
- http://www.microbeworld.org/resources/links.aspx
- http://www.asm.org/
- http://www.microbiologyiworld.com/
- http://www.sciencemag.org/cgi/collection
- http://www.latrobe.edu.au/microbiology/links
- www.uwstout.edu/lib/subjects/microbi
- http://www.aemtek.com

Journal related to Microbiology

- http://www.fems-microbiology.org/website/nl/default.asp
- http://www.blackwellpublishing.com/journal
- http://www.springer.com/
- http://www.e-journals.org/microbiology/
- http://pubs.nrc-cnrc.gc.ca/
- http://www.elsevier.com/
- http://www.academicjournals.org/ajmr/
- http://www.horizonpress.com/gateway/journals.html
- http://www.scielo.br/bjm
- http://www.jmb.or.kr/
- http://microbiologybytes.wordpress.com/
- http://www.topix.net/science/microbiolog

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Basic Sciences
– Plant Physiology

Preamble

The last decade witnessed phenomenal progress in science and technology resulting in the accruement of significant new scientific developments in plant sciences, more specifically on plant growth, development and productivity. This necessitates restructuring the curriculum and the syllabus to enable graduate students to be abreast with the developments through providing comprehensive exposure to the M.Sc and Ph.D. students, on new developments in different areas of plant sciences. With this background the structure of curriculum for M.Sc. and Ph.D. program and syllabi for the courses needs to be developed keeping in view the mandate of agriculture universities and crop specific ICAR institutes.

Genetic enhancement to achieve crop improvement is the major mandate of state agricultural universities (SAU) and crop specific institutes. The emphasis has systematically shifted towards improving specific physiological traits and mechanisms to enhance crop productivity, yield potentials, adaptation to stresses, etc. Yet another major mandate is to optimize agronomic inputs for yield enhancement to rationalize utilization of natural resources. As the crop improvement success heavily depends on improving physiological processes, plant/crop physiology will immensely contribute to the envisaged goals. With this background the M.Sc and Ph.D. students must be provided with adequate exposure and trainings on plant/crop physiology to complement national and state level crop improvement and crop production programs. The focus is to restructure the course content and syllabi of physiology courses to achieve these objectives. While restructuring and modifying the course curriculum it is necessary to take into cognisance the recent developments in molecular biology, genomics and phenomics which provide options to identify traits and their genetic enhancement. Besides potential interventions, the restructured courses should provide insight based on sound physiological process which now provided options to regulate the plant growth and productivity. Therefore, emphasis is on,

- Providing basic knowledge on plant physiological processes and plant responses to environment and other constraints
- Providing exposure to undertake programs for crop improvement by exploiting well characterized physiological processes
- Provides exposure on potential interventions based on principals of plant physiology to improve growth and productivity

M.Sc courses

Twelve courses for M.Sc have been developed, out of which 8 are the meticulous modification of existing courses, and rest 4 courses are newly designed with focus on applications of physiological process for crop improvement and crop productivity.
For M.Sc. Programme – emphasis is on four aspects:

I. Basic Plant Physiology Courses (PP 501, PP 502, PP 503)

These fundamental courses give exposure on basic principles of plant physiology, water relations, plant metabolic processes and on developmental biology. Also provides exposure on recent developments on plant growth and development, and aspects related to photomorphogenesis, photoperiodism, fruit ripening and senescence. Attempts were made to remove redundancy from UG programme and add new recent concepts and developments.

II. Physiology courses that provide insights on plant responses to environmental and internal factors (PP 504, PP 505, PP 506)

Plant Phenome is a reflection of genetic makeup, interaction with environment and internal factors. Therefore, basic aspects of plant responses to abiotic stresses and stress tolerance mechanisms form the basis for improving adaptation of crops to stress. Phytohormones are major internal factors and signaling molecules to regulate plant growth, differentiation and development. Mineral nutrients are essential for plant metabolic processes besides being essential constituents of many macromolecules. Emphasis is to introduce new emerging concepts and molecular mechanisms.

III. Crop physiology courses related to crop productivity (PP 507, PP 508, PP 509, PP 510)

Agronomic inputs and environmental factors enhance crop growth through optimizing photosynthesis processes and canopy photosynthesis and net carbon gain drives the crop growth rates. Further, components of growth and yield structure with environmental interaction forms the basis for crop modeling.

In recent years, phenomenal progress has been made in understanding plant processes which are crop specific. Therefore, physiological aspects of crop growth and productivity of specific field and horticultural crops needs to be discussed.

The physiological aspects that need to be discussed should focus not only to address basic growth and developmental aspects of these crops but also emphasis should be given on the major production constraints and the physiological approaches to overcome.

IV. Student ready courses – application of physiological processes for crop improvement and crop production (PP 511, PP 512)

The mandate of SAUs and crop specific institutes of ICAR is crop improvement and crop production. These "*student-ready*" courses provide exposure on quantifying relevant physiological processes and capturing genetic variability, which complement breeding programs aimed at improving specific plant traits. Further, many physiological processes can now be exploited to improve growth and productivity. Several interventions that alter the developmental growth processes can be exploited to bring in synchronization of flowering, soilless cultures, pollen biology, light regulation in polyhouses, etc. Emphasis is to complement the crop improvement and productivity approaches.

Ph.D. courses

In PhD programme, 10 courses are finalized, out of which 7 are the thorough modification of existing courses, and rest 3 courses are newly designed. From the existing syllabus, one course is shifted to MSc programme with comprehensive modification.
For Ph.D. Programme – emphasis is on five aspects:

I. Exposure to the genomic tools and genetic resources (PP 601, PP 602, PP 603)

Focus is on identifying genes regulating the specific mechanisms/traits. Objective is to provide comprehensive exposure on different approaches and technologies to assess the functions of genes regulating plant physiological processes and biochemical mechanisms. It is well documented that plant response to external and internal factors is mainly through signal perception and amplification leading gene expression which bring in altered metabolism regulating physiological and biochemical processes and finally plant processes and growth. There is need to provide sufficient information on diverse receptors, ligand-receptor interactions and the role of secondary messengers in signal amplification leading to gene expression.

Phenomenal progress in understanding the basic physiological mechanisms that determine crop performance and "physiological traits" that have enormous relevance to improve yield potentials as well as adaptation to various biotic and abiotic stresses have been enumerated, well studied and documented. Although most of the physiological traits have been considered as complex and hard to breed, recent advances in understanding the sub-components of most of the major mechanisms coupled with the progress made in "phenotyping" to capture genetic variability in such subcomponent traits, have paved way for the adoption of "trait-based breeding" approaches. Finally, assess the relevance of physiological processes/mechanisms and develop options to combine/introgress them.

II. To characterize and capture the genetic variability in plant traits and adaptive mechanisms (PP 604, PP 605)

Phenotyping plant traits is the crucial input to complement the progress made in genomics. Phenomenal progress made in genomics cannot be exploited for improving plant traits/mechanisms unless phenotyping technologies are developed to capture genetic variability. Several technologies have been developed to quantify the traits and assess genetic variability. Genetic enhancement of specific plant traits is now "Pheno-centric".

Further, techniques, tools and instrumentation facilities drive the research in modern biology. These courses address recent developments related to phenotyping and phenomics and advances made in quantification methods based on novel methodologies and instruments. Emphasis on recent concepts on high throughput phenotyping options for crop improvement.

III. Predicting climate change, causative factors, their quantification, and effect on plant growth and development (PP 606)

Main focus is prediction of climate change, mitigation options and adaptive mechanisms. Predicting climate change variability, causative factors and their quantification and finally effects on plant growth and development is the main emphasis.

IV. Comprehensive insight and options to address major constraints in crop improvement (PP 607, PP 608)

Yield level reached plateau in many crops. Improving yield potential and crop growth rate forms the basis for further improvement in productivity. Photosynthesis and the establishing sink capacity are crucial processes to achieve this goal. Comprehensive exposure is needed as progress made in deciphering the molecular mechanisms to regulate several photosynthetic processes at cellular and canopy level, and also sink development processes.

Seed as a propagule is an important input for agriculture. From this context aspects related to seed development, its dormancy and viability etc. assumes significance. Besides seed is the major source of nutrition to mankind, hence quantitative and qualitative differences in seed constituents and their modification and improvement has been the area of focus in recent years. Emphasis on new conceptual approaches to enhancing yield potential and qualitative traits of seeds and fruits.

V. Plant interaction with biotic factors (Pathogens, Insects and weeds) (PP 609, PP 610)

Besides the genetic makeup expression of the phenotype is regulated by environment and the plant microbe interaction especially the endophytes. Besides it is relevant to understand the plant pathogen and plant insect interactions to improve tolerance mechanisms by altering specific physiological and biochemical processes. Weeds are one of the major biotic factors that affects yield in agricultural crops. Besides understanding weed biology and reproductive strategies of weeds recent concepts in developing selective herbicides based on mode of action and herbicide tolerance mechanisms provided greater insights in weed management. Genome editing options to develop herbicide tolerant transgenics is an exciting option.Implemntation of the revised syllabus needs a sanction of an approximate recurring budget of ₹ 20 lacs per annum in addition to aone time equipment and maintenance grant of ₹ 2 crores.

Course Title with Credit Load
M.Sc. (Ag) in Plant Physiology

Course Code	Course Title	Credit Hours
PP 501*	Principles of Plant Physiology-I: Plant Water Relations and Mineral Nutrition	2+1
PP 502*	Principles of Plant Physiology-II: Metabolic Processes and Growth Regulation	2+1
PP 503*	Plant Developmental Biology: Physiological and Molecular Basis	2+1
PP 504	Physiological and Molecular Responses of Plants to Abiotic Stresses	2+1
PP 505	Hormonal Regulation of Plant Growth and Development	2+1
PP 506	Physiological and Molecular Mechanisms of Mineral Nutrient Acquisition and their Functions	2+1
PP 507	Photosynthetic Processes, Crop Growth and Productivity and Concepts of Crop Modelling	2+1
PP 508	Physiology of Field Crops	2+0
PP 509	Physiology of Horticulture Crops	2+0
PP 510*	Seed Physiology	2+1
PP 511	Phenotyping Physiological Processes	2+0
PP 512	Crop Growth Regulation and Management	2+0
PP 591	Master’s Seminar	1+0
PP 599	Master’s Research	30

Course Contents
M.Sc. (Ag) in Plant Physiology

I. Course Title : **Principles of Plant Physiology I - Plant Water Relations and Mineral Nutrition**

II. Course Code : **PP 501***

III. Credit Hours : **2+1**

IV. Why this Course?

Plant's growth and development and therefore, agricultural productivity depends on two major inputs like water and nutrients. In this regard, this course being a fundamental course will acquaint the students with the basic concepts of plant water relations and mineral nutrition. The course provides a basic knowledge on water and nutrient acquisition and their transport throughout the phenological stages. Further, it also provides hands on experience in assessing the plant and soil water status besides nutrient acquisition by plants.

V. Aim of the Course

The aim of this course is to impart knowledge in the field of water relations and mineral nutrition and how plants acquire water and transport it under different soil water regimes and also make use of the water in an effective way to maximize use efficiency. In addition, the other aim is to impart knowledge of how plants minimize water loss under stress conditions besides educating the students of how plants make use of nutrients in a best possible way.

The course is organized as follows:

No.	Blocks	Units
1.	Plant Water Relations	1. Soil and Plant Water Relations 2. Water Absorption and Translocation 3. Transpiration and Evaporative Cooling 4. Water Productivity and Water Use Efficiency 5. Moisture Stress and Plant Growth
2.	Mineral Nutrition	1. Nutrient Elements and their Importance 2. Nutrient Acquisition 3. Concept of Foliar Nutrition

VI. Theory

Block 1: Plant Water Relations

Unit 1: Soil and Plant Water Relations

Water and its importance; Molecular structure of water; Properties and functions of water. Concept of water potential; Plant cell and soil water potential and their components; Methods to determine cell and soil water potential; Concept of osmosis and diffusion. Soil physical properties and water availability in different soils;

Water holding capacity and approaches to improve WHC; Concept of FC and PWP; Water holding polymers and their relevance.

Unit 2: Water Absorption and Translocation

Root structure and functions; Root architecture and relevance in water mining; Mechanism of water absorption and translocation; Theories explaining water absorption and translocation; Aquaporins. Mycorrhizal association and its relevance in water mining.

Unit 3: Transpiration and Evaporative Cooling

Evaporation and transpiration; relevance of transpiration; factors regulating transpiration; Measurement of transpiration; approaches to minimize evaporation and transpiration; Concept of CCATD and its relevance. Energy balance: Solar energy input and output at crop canopy level. Stomata- its structure, functions and distribution; Molecular mechanisms of stomatal opening and closing; Concept of guard cell turgidity; role of K and other osmolytes; role of ABA in stomatal closure; Guard cells response to environmental signals; Signaling cascade associated with stomatal opening and closure. Antitranspirants and their relevance in agriculture.

Unit 4: Water Productivity and Water Use Efficiency

WUE and its relevance in water productivity; Transpiration efficiency, a measure of intrinsic WUE; Approaches to measure WUE; Stomatal and mesophyll regulation on WUE; Passioura's yield model emphasizing WUE.

Unit 5: Moisture Stress and Plant Growth

Physiology of water stress in plants; Effect of moisture stress at molecular, cellular, organ and plant level. Drought indices and drought tolerance strategies. Drought tolerance traits.

Block 2: Mineral Nutrition

Unit 1: Nutrient Elements and Their Importance

Role of mineral nutrients in plant's metabolism; Essential elements and their classification; Beneficial elements; factors influencing the nutrients availability; critical levels of nutrients. Functions of mineral elements in plants. Deficiency and toxicity symptoms in plants.

Unit 2: Nutrient Acquisition

Mechanism of mineral uptake and translocation; Ion transporters; genes encoding for ion transporters; localization of transporters; xylem and phloem mobility; Nutrient transport to grains at maturity; Strategies to acquire and transport minerals under deficient levels. Role of mycorrhiza, root exudates and PGPRs in plant nutrient acquisition.

Unit 3: Concept of Foliar Nutrition

Foliar nutrition; significance and factors affecting total uptake of minerals; Foliar nutrient droplet size for effective entry; role of wetting agents in entry of nutrients.

VII. Practicals

- Standard solutions and preparation of different forms of solutions
- Studies on the basic properties of water
- Demonstration of surface tension of water and other solvents
- Measurement of plant water status: Relative water content and rate of water loss

- Determination of water potential through tissue volume and Chardakov's test
- Determination of water potential using pressure bomb, osmometer, psychrometer
- Determination of soil moisture content and soil water potential
- Use of soil moisture probes and soil moisture sensors
- Measurement of transpiration rate in plants; use of porometry
- Measurement of CCATD and its relevance
- Demonstration and use of anti-transpirants to reduce transpiration
- Influence of potassium and ABA on stomatal opening and closing respectively
- Deficiency and toxicity symptoms of nutrients
- Effect of water stress on plant growth and development

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

- comprehend the fundamental concepts of plant physiological processes associated with water relation and mineral nutrition.
- describe the physiological mechanisms of water relation and mineral nutrition.
- recognize and describe how plants respond to mineral deficiency and toxicity.

X. Suggested Reading

- Vilalta JM and Forner NG. 2017. *Water potential regulation, stomatal behaviour and hydraulic transport under drought: deconstructing the iso/anisohydricconcept Plant, Cell and Environment* 40, 962–976
- Mangrich AS, Cardoso EMC, Doumer ME, Romão LPC, Vidal M, Rigol A, Novotny EH. *Improving the Water Holding Capacity of Soils of Northeast Brazil by Biochar Augmentation*. Chapter 16, pp 339–354.
- McElrone AJ, Choat B, Gambetta GA and Brodersen CR. 2013. *Water Uptake and Transport in Vascular Plants*. *Nature Education Knowledge* 4(5): 6
- Hodson RC and J Acuff. 2006. *Water transport in plants: anatomy and physiology*. Pages 163-183, *Tested Studies for Laboratory Teaching*, Volume 27 (M.A. O'Donnell, Editor). Proceedings of the 27th Workshop/Conference of the Association for Biology Laboratory Education (ABLE), 383 pages.
- Chater CCC, Caine RS, Fleming AJ, Gray JE. 2017. *Plant Physiology,* 174 (2) 624-638; DOI: 10.1104/pp.17.00183
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- Sreeman SM, Vijayaraghavareddy P, Sreevathsa R, Rajendrareddy S, Arakesh S, Bharti P, Dharmappa P, Soolanayakanahally R. 2018. *Introgression of Physiological Traits for a Comprehensive Improvement of Drought Adaptation in Crop Plants. Front. Chem*. 6, 92.
- Seyed Yahya Salehi-Lisar Hamideh Bakhshayeshan-Agdam, (2016). Drought Stress in Plants: Causes, Consequences, and Tolerance. Drought Stress Tolerance in Plants, Vol 1 pp 1-16
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- Barker AV and DJ Pilbeam. 2015. Handbook of Plant Nutrition, Second Edition. Books in Soils, Plants, and the Environment Series, the 2nd Edition, CRC Press.
- Vatansever R, Ozyigit II and Filiz E. 2017. *Essential and beneficial trace elements in plants, and their transport in roots: a review. Applied biochemistry and biotechnology* 181(1), 464-482..

- Tahat MM and Sijam K. 2012. *Arbuscularmycorrhizal fungi and plant root exudates bio-communications in the rhizosphere. African Journal of Microbiology Research*, 6(46), 7295-7301.
- Rajasekar MD, Nandhini DU and Suganthi S. 2017. *Supplementation of Mineral Nutrients through Foliar Spray – A Review. Int.J.Curr.Microbiol.App.Sci.* 6(3): 2504-2513.https://doi.org/10.20546/ijcmas.2017.603.283
- Tarek A and Hassan ER. 2017. *Foliar application: from plant nutrition to biofortification*. Environment, Biodiversity and Soil Security. 10.21608/jenvbs.2017.1089.1006.

General Source of Information

- Taiz T, Zeiger E and Max Mller IM, 2018, *Fundamentals of Plant Physiology*
- Taiz L and Zeiger E. 2015. *Plant Physiology and development*.6th Ed
- Salisbury FB and Ross C. 1992 (4th Ed.) *Plant Physiology*
- Epstein E and Bloom AJ. 2004. *Mineral nutrition of plants: principles and perspectives*.2nd Ed.
- Hopkins WG and Huner NPA. 2004. *Introduction to Plant Physiology*
- Kramer, P. J., *Water relations of plants*
- Kirkham, M. B., *Principles of soil and plant water relations*
- Hopkins WG, 2008, *Introduction to Plant Physiology*

I. Course Title : Principles of Plant Physiology-II: Metabolic Processes and Growth Regulation

II. Course Code : PP 502*

III. Credit Hours : 2+1

IV. Why this course?

Mechanisms associated with growth and development determine crop performance under any given condition. Metabolic and growth processes are quite sensitive to environmental factors and hence comprehensive understanding of the physiological basis of growth and development would be essential.

V. Aim of the course

This course will impart knowledge on cellular structure and function that determine of carbon and nitrogen metabolism, lipids, enzymes and secondary metabolites in plants. Relevance of metabolic processes on growth and development leading to productivity will be dealt.

The course is organized as follows:

No.	Blocks	Units
1.	Metabolic processes and growth regulation	1. Carbon Metabolism–Photochemical Processes 2. Carbon Metabolism: Biochemical Processes 3. Carbon Metabolism: Respiration 4. Product Synthesis and Translocation Leading to Crop Growth 5. Nitrogen Assimilation and Protein Synthesis 6. Lipid Metabolism and Secondary Metabolites 7. Hormonal Regulation of Plant Growth and Development 8. Synthetic Growth Promoters 9. Morphogenesis and Reproductive Phase

VI. Theory

Block 1: Metabolic Processes and Growth Regulation

Unit 1: Carbon Metabolism – Photochemical Processes

- Chloroplast ultrastructure with special mention of lamellar system
- Excitation, electron and proton transfers and their relevance in energy conservation
- Concepts of pigment systems and generation of powerful reductant and oxidant
- Water oxidation, Water-water cycle and other aspects of electron transfer

Unit 2: Carbon Metabolism: Biochemical Processes

- CO_2 diffusion mechanisms and diffusive conductances, concept of Ci determining Photosynthesis
- RuBisCO enzyme kinetics and Calvin cycle mechanisms, Regulation of Calvin cycle and metabolite fluxes
- Photorespiration: the advantages and inefficiencies of photosynthesis because of photorespiration
- Concepts of CO_2 concentrating mechanisms (CCM) and spatial and temporal differences in carboxylation
- Ecological aspects of $C_4$and CAM photosynthesis
- Product synthesis, Starch and Sucrose biosynthesis

Unit 3: Carbon Metabolism: Respiration

- Mitochondrial organization and functions
- Aspects of Glycolysis, TCA cycle and mitETC.
- Relevance of growth and maintenance respiration
- Concepts of CN resistance respiration – Alternate and SHAM sensitive ETC

Unit 4: Product Synthesis and Translocation Leading to Crop Growth

- Phloem loading and sugar transporting, concepts of bi-directional transport of sugars and other metabolites
- Source-Sink relationship and modulation of photosynthesis
- Concepts and definitions of Growth and Differentiation
- Growth and yield parameters, NAR, CGR, HI and concepts of LAI, LAD

Unit 5: Nitrogen Assimilation and Protein Synthesis

- Developments in d-nitrgen fixation
- Nitrate reduction and assimilation GS-GOGAT process for amino acid synthesis
- Inter-Dependence of carbon assimilation and nitrogen metabolisms

Unit 6: Lipid Metabolism and Secondary Metabolites

- Storage, protective and structural lipids.
- Biosynthesis of fatty-acids, diacyl and triacyl glycerol, fatty acids of storage lipids.
- Secondary metabolites and their significance in plant defense mechanisms.

Unit 7: Hormonal Regulation of Plant Growth and Development

- Growth promoting and retarding hormones: biosynthesis, transport, conjugation
- Mode of action of these hormones and their application in plant physiology

Unit 8: Synthetic Growth Promoters

- Different synthetic hormones: Salicylic acid, strigolactones etc
- Roles and biological activities of various synthetic hormones
- Commercial application of hormones to maximize growth and productivity

Unit 9: Morphogenesis and Reproductive Phase

- Photoperiodism: Phytochromes, their structure and function
- Circadian rhythms,
- Blue light receptors: Cryptochrome and morphogenesis.
- Vernalization and its relevance in germination.

VII. Practicals

- Radiant energy measurements
- Separation and quantification of chlorophylls
- Separation and quantification of carotenoids
- O_2 evolution during photosynthesis
- Anatomical identification of C_3 and C_4 plants
- Measurement of gas exchange parameters, conductance, photosynthetic rate, photorespiration
- Measurement of respiration rates
- Estimation of reducing sugars, starch
- Estimation of NO_3, free amino acids in the xylem exudates, quantification of soluble proteins
- Bioassays for different growth hormones- Auxins, Gibberellins, Cytokinins, ABA and ethylene
- Demonstration of photoperiodic response of plants in terms of flowering

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

– figure out the fundamental metabolic processes in plant
– describe the physiological mechanisms and metabolic events associated with regulation of plant growth

X. Suggested Reading

- Kirchhoff H. 2019. *Chloroplast ultrastructure in plants*, New Phytologist. Doi.org/10.1111/nph.15730
- Jafari T, Moharreri E, Amin A, Miao R, Song W and Suib S. 2016. *Photocatalytic water splitting—the untamed dream: a review of recent advances. Molecules*, *21*(7), 900.
- Jensen E, Cle´ment R, Maberly SC, Gontero B. 2017. *Regulation of the Calvin –Benson–Bassham cycle in the enigmatic diatoms: biochemical and evolutionary variations on an original theme. Phil. Trans. R. Soc. B* 372: 20160401. doi.org/10.1098/rstb.2016.0401
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- Hagemann M, Weber AP and Eisenhut M. 2016. *Photorespiration: origins and metabolic integration in interacting compartments. Journal of experimental botany*, 67(10), 2915.
- Kühlbrandt W. 2015. *Structure and function of mitochondrial membrane protein complexes. BMC biology*, 13(1), 89.

- Liesche J., and Patrick, J. 2017. *An update on phloem transport: a simple bulk flow under complex regulation. F1000Research*, 6.
- Jensen KH, Berg-Sørensen K, Bruus H, Holbrook NM, Liesche J, Schulz A and Bohr T. 2016. *Sap flow and sugar transport in plants. Reviews of modern physics*, 88(3), 035007.
- Julius BT, Leach KA, Tran TM, Mertz RA and Braun DM. 2017. *Sugar transporters in plants: new insights and discoveries*. Plant and Cell Physiology, 58(9), 1442-1460.
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- Mus, F., Crook, M. B., Garcia, K., Costas, A. G., Geddes, B. A., Kouri, E. D.andUdvardi, M. K. 2016. *Symbiotic nitrogen fixation and the challenges to its extension to nonlegumes. Appl. Environ. Microbiol.*, *82*(13), 3698-3710.
- Pagare S, Bhatia M, Tripathi, N., Pagare, S., and Bansal, Y. K. 2015. *Secondary metabolites of plants and their role: Overview. Curr Trends Biotechnol Pharm*, 9(3), 293-304.
- Jain C, Khatana S and Vijayvergia R. 2019. *Bioactivity of secondary metabolites of various plants: a review. Int J Pharm Sci and Res* 10(2): 494-04. doi: 10.13040/IJPSR.0975-8232.10(2).494-04..
- Li, C., Li, J., Chong, K., Harter, K., Lee, Y., Leung, J.,and Schroeder, J. 2016. *Toward a molecular understanding of plant hormone actions. Molecular plant*, 9(1), 1-3.
- Eckardt, N. A. 2015. *The plant cell reviews dynamic aspects of plant hormone signaling and crosstalk.*
- Jiang, K., andAsami, T. 2018. *Chemical regulators of plant hormones and their applications in basic research and agriculture. Bioscience, biotechnology, and biochemistry*, 82(8), 1265-1300.
- Zwanenburg, B., Pospíšil, T., and Zeljkoviæ, S. Æ. 2016. *Strigolactones: new plant hormones in action. Planta*, 243(6), 1311-1326.
- Kumar, R., Khurana, A., and Sharma, A. K. 2014. *Role of plant hormones and their interplay in development and ripening of fleshy fruits. Journal of experimental botany*, *65*(16), 4561-4575.
- Gururani, M., Mohanta, T., and Bae, H. 2015. *Current understanding of the interplay between phytohormones and photosynthesis under environmental stress. International journal of molecular sciences*, *16*(8), 19055-19085.
- Song, Y. H., Shim, J. S., Kinmonth-Schultz, H. A., and Imaizumi, T. 2015. *Photoperiodic flowering: time measurement mechanisms in leaves. Annual review of plant biology*, *66*, 441-464.
- Sanchez, S. E., and Kay, S. A. 2016. *The plant circadian clock: from a simple timekeeper to a complex developmental manager. Cold Spring Harbor perspectives in biology*, *8*(12), a027748.

General Text books

- *Taiz, Lincoln, Zeiger. 2007 Plant Physiology, Eduardo Original American edition Sinauer Associates, Inc., 2006; 4th ed., XXVI, ISBN: 978-3-8274-1865-4; © Springer.*
- *Plant Physiology* Frank Boyer Salisbury and Cleon Ross.
- *Introduction to Plant Physiology* (Wie)by William G. Hopkins.

I. Course Title : Plant Developmental Biology: Physiological and Molecular Basis

II. Course Code : PP 503*

III. Credit Hours : 2+1

IV. Why this Course?

From the conventional description information on plant growth and development based on morphology and anatomy, phenomenal changes and leads taken place in the last one and half decade to address these processes at physiological, biochemical and molecular levels. This basic understanding has provided options to regulate these processes genetically using genetic and molecular tools and by interventions using chemicals and external factors. To give an example on flowering, the progress made regarding the molecular players that regulate flowering, initiation, the photoreceptors like phytochromes and their regulation by the photoperiod-short and long days has provided options to manipulate the flowering time to bring in synchrony, etc. Phenomenal progress also made in several other processes like germination, viability, root development and pollination, etc. The other major area of contribution is in tissue culture where is understanding of plant developmental biology has been put o practical use and knowledge on morphogenesis is exploited to maximum. It is very essential that the students get exposed on these aspects to complement the research programs on crop improvement.

V. Aim of the course

To explain about basic physiological and molecular processes concerning various facets of growth and development of plants. It provides knowledge on basic physiological processes governing developmental events in plants including senescence and fruit development and ripening. Development of vegetative tissue like shoot, leaf and root and morphogenetic phenomena like flower induction and development, factors associated with photoperiod and thermoperiod response. Regulation of morphogenesis would be studied at the molecular level providing information on genes involved. In addition, students will study how to apply the knowledge on plant development and morphogenesis using tissue culture.

The course is organized as follows:

No.	Blocks	Units
1.	Plant Developmental Biology	1. Evolutionary Development of Plants and Role of Environment 2. Physiological and Molecular Determinants of Seed Biology 3. Vegetative Growth and Organ Development 4. Physiological and Molecular Aspects of Reproductive Growth and Development 5. Ripening and Senescence 6. Physiological and Molecular Regulation of Plant Development Influenced by Light and Temperature
2.	Practical application of morphogenesis	1. Tissue culture and micro-propagation 2. Application of in-vitro techniques for crop improvement

VI. Theory

Block 1: Plant Developmental Biology

Unit 1: Evolutionary Development of Plants and Role of Environment

Plant development and plasticity, evolution, Biodiversity. Novel features of plant growth and development, Concept of plasticity-evolution and biodiversity, Model plants for study; Environment and development. Developmental stages and program; Cell-cycle, totipotency and regeneration.

Unit 2: Physiological and Molecular Determinants of Seed Biology

Seed development- Physiology of seed development, role of hormones in embryo development; seed development and maturation. Seed dormancy- Physiological and molecular mechanism of seed dormancy regulation. Seed germination- seed structure and Hormonal regulation of germination, Mobilization of food reserves during seed germination.

Unit 3: Vegetative Growth and Organ Development

Regeneration and totipotency- organ differentiation and development – role of hormones- developmental control genes in crop plants. Meristems in plant development. Shoot, Leaf, Trichome and stomate development and differentiation. Axillary shoot branching; Bud dormancy and growth. Root development; Nodule development; Tuber development- hormonal control, signaling and molecular regulation- genes involved. Vascular bundle development- xylem and phloem differentiation

Unit 4: Physiological and Molecular Aspects of Reproductive Growth and Development

Floral Induction and Development: Molecular and physiological mechanism of transition -vegetative to reproductive phase- floral organ initiation and development their controls. Development of male and female gametophyte; gametophytic mutants: pollen-stigma interaction- Pollen germination and tube growth; role of imprinting; Male sterility: and fertility restoration; Self incompatibility; Sterility and fertility restoration, Maternal gene effects, Zygotic gene effects. Sex determination in plants, mate choice in plants. Embryo and endosperm development- fertilization, role of imprinting; Parthenocarpy and apomixes

Unit 5: Ripening and Senescence

Fruit development, enlargement, maturation and ripening; climacteric and non-climacteric fruit ripening mechanism. Hormonal, biochemical & Molecular aspects of fruit ripening. Senescence and its regulation; Hormonal and environmental control of senescence; PCD in the life cycle of plants.

Unit 6: Physiological and Molecular Regulation of Plant Development Influenced by Light and Temperature

Light control of plant development: Phytochromes and cryptochromes, phototropins, their structure, biochemical properties and cellular distribution. Molecular mechanisms of light perception, signal transduction and gene regulation. Photoperiodism and its significance, vernalization and hormonal control. Circadian rhythms-biological clocks and their genetic and molecular determinants. Thermomorphogenesis- Thermoperiodism

Block 2: Application of Morphogenesis and its Practical Application

Unit 1: Tissue culture and micro-propagation

Applications of tissue culture for plant production, callus induction, somatic embryogenesis, regeneration from different explants. Micro-propogation, tip and axillary node culture of commercially important crops, hardening and ex-vitro establishment, concept of somatic hybridization and protoplast culture.

Unit 2: Application of *in-vitro* techniques for crop improvement

Development of somoclones, identification and exploitation of somoclonal variants.

Haploid production, pollen/anther, ovule/ovary culture. Production of secondary metabolites by tissue culture, concept of bio-fermenters. Plant transformation, development of transgenic plants and their characterization. Germplasm storage, cryopreservation and regulation

VII. Practicals

- Studying shoot apical meristem, floral meristem development and pollen tube development
- Phenotyping photomorphogenesis: (a) Studying effect of day length (short day and long day) in regulating floral induction/ flowering time in short day/long day/day neutral plants and (b) effect of light on seed germination in light-sensitive and -insensitive seeds.
- Studying effect of temperature on– (a) thermomorphogenesis- measuring hypocotyl elongation under different temperature conditions and (b) sex determination using cucurbits/sesame plants.
- Measure physiological paramters of fruit ripening and study the expression of key genes regulating ripening.
- Study the effect of ethylene, its inhbibitor and scruber on ripening (tomato).
- Study different sterilization techniques, prepare media stocks and plant hormones.
- Inoculate explant (seed and leaf tissue) of model plant for callus induction.
- Subculture the callus and standerdize regeneration protocol for shoot and root induction using callus and leaf explant.
- Micro-propagation using meristem tip and axillary node culture.
- Standerdize anther/ pollen culture for haploid production in model/crop/horticultural plant.
- Isolation of protoplast from Arabidopsis/tobacco and its culturing
- Study about selectable marker, reporter gene, PCR, southern and northern blotting techniques.
- Transformation of tobacco callus or leaf explant by *Agrobacterium tumefacines* and *Agrobacterium rhizogenes* for production of transgenic
- Molecular characterization of transgenic- PCR, southern blotting, gene expression.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

IX. Learning outcome

After completion of this course students are expected to have knowledge on and insight into the physiological and molecular basis of plant growth and development. The student will develop critical insight in physiological aspects of vegetative growth and reproductive development at molecular level.

X. Suggested Reading

- Niklas KJ. *Plant Evolution- An Introduction to the History of Life*.
- Bahadur *B et al.* (eds.), *Plant Biology and Biotechnology:* Volume I: Plant Diversity, Organization, Function and Improvement
- Jong MD and Leyser O. *Developmental Plasticity in Plants*. Cold Spring Harbor Symposia on Quantitative Biology. 63-73.
- Inze D and Veylder LD. 2006. *Cell Cycle Regulation in Plant Development*. Annu. Rev. Genet. 2006. 40: 77–105

- J. Derek Bewley *et al.*, Seeds-Physiology of Development, Germination and Dormancy.
- Kent J. Bradford and Hiroyuki Nonogaki (2007). *Seed Development, Dormancy and Germination*. Blackwell publishing.
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- Jiang K and Feldman LJ. 2005. *Regulation of Root Apical Meristem Development*. Annu. Rev. Cell Dev. Biol. 21: 485–509.
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- Maureen L. Condic (2014). *Totipotency*: *What It Is and What It Is Not. Stem Cells And Development*. 23(8). 796- 812.
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- Koltunow AM and Grossniklaus U. 2003. *APOMIXIS: A Developmental Perspective. Annu. Rev. Plant Biol*. 54: 547–74.
- Vernonica E. Franklin-Tong. *Self-Incompatibility in Flowering Plants-Evolution, Diversity, and Mechanisms*, Springer
- Thomas H. 2013. *Senescence, ageing and death of the whole plant. New Phytologist*. 197: 696–711.
- Lam E, Fukuda H and Greenberg J. *Programmed cell death in higher plants*. Reprinted from Plant Molecular Biology, Volume 44 (3).
- Pua EC and Davey MR. *Plant Developmental Biology - Biotechnological Perspectives*.
- Meng Chen. 2004. *Light Signal Transduction In Higher Plants Annu. Rev. Genet*. 38: 87–117.
- Fankhauser C and Chory J. 1997. *Light Control Of Plant Development Annu. Rev. Cell Dev. Biol*. 13: 203–229.
- Mieke de Wit. 2016. *Light-Mediated Hormonal Regulation of Plant Growth and Development. Annu. Rev. Plant Biol*. 67: 22.1–22.25
- Franklin KA and Wigge PA. *Temperature and Plant Development*. Wiley Blackwell.
- Franklin KA *et al*. 2014. *Interaction of light and temperature signaling. Journal of Experimental Botany*. 65(11): 2859–2871.
- Bhojwani SS and Razdan MK. *Plant tissue culture: theory and practice, a revised edition*. Elsiver publication.
- Bhojwani SS, Dantu SS and Kumar P. *Plant Tissue Culture: An Introductory Text*.
- George EF and Hall MA. *Plant Propagation by Tissue Culture* 3rd Edition.
- Krishna H, Alizadeh M, Singh D, Singh U, Chauhan N, Eftekhari M and Sadh RK. 2016. *Somaclonal variations and their applications in horticultural crops improvement. 3 Biotech*, 6(1), 54.
- Evans DA. 1989. *Somaclonal variation-genetic basis and breeding applications. Trends in genetics*, 5, 46-50.
- Benson EE, Dumet DJ and Harding K. 2009. *Cryopreservation of plant cells, tissues and*

organs. Encyclopedia of Industrial Biotechnology: Bioprocess, Bioseparation, and Cell Technology, 1-22.
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General Source Information

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- B. Bahadur *et al.* (eds.), *Plant Biology and Biotechnology*: Volume I: Plant Diversity, Organization, Function and Improvement.
- Bewley JD *et al.*, *Seeds-Physiology of Development, Germination and Dormancy.*
- Jong MD and Leyser O. *Developmental Plasticity in Plants. Cold Spring Harbor Symposia on Quantitative Biology.* 63-73.
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I. Course Title : Physiological and Molecular Responses of Plants to Abiotic Stresses

II. Course Code : PP 504

III. Credit Hours : 2+1

IV. Why this course?

With the changing climate, plants are being more frequently exposed to abiotic stresses like, water, salinity, temperature, nutrient, radiation, etc. limiting the productivity. This will not only affect livelihoods of individual farmers but also the food security. Concerted efforts have been made to grow crops under resource limited/stressful environmental conditions and advances in physiology, molecular biology and genetics have significantly helped in this endeavor. In recent years, our understanding of the physio-morphological, biochemical and molecular adaptation of plants to resource limited/stressful environment is phenomenal. This course will outline different abiotic stresses, their impacts on agricultural productivity, stress tolerance mechanisms, stress mitigation strategies, crop improvement approaches and traits for stress tolerance.

V. Aim of the course

This course aims to describe students the abiotic-stress physiology and their effects on plant growth and productivity. This will also help students gain insights into latest developments in stress physiology and stress tolerance mechanisms, approaches for crop improvement under stressful environment.

The course is organized as follows:

No.	Blocks	Units
1.	Abiotic Stresses	1. Introduction to Abiotic Stresses
2.	Drought Stress	1. Moisture Stress Responses in Plants 2. Stress Perception and Molecular Responses of Plants to Drought Stress 3. Plant Adaptive Mechanisms to Drought 4. Approaches to Improve Drought Tolerance
3.	Salt, Heavy Metal, Water Logging, Temperature and Light Stress	1. Salt Stress 2. Heavy Metal Stress and Water Logging 3. Temperature and Light Stress

VI. Theory

Block 1: Abiotic Stresses

Unit 1: Introduction to Abiotic Stresses

Abiotic stresses major constraints to realize potential yields of crop plants, yield losses. Drought prone areas in India- Frequency of occurrence of drought, Rainfed-kharif, Rabi, Areas affected by salinity, heavy metals, water logging, high temperature scenario due to global warming.

Block 2: Drought Stress

Unit 1: Moisture Stress Responses in Plants

Drought-characteristic features; water potential in the soil-plant-air continuum. Physiological and biochemical processes affected by drought.Oxidative stress-generation of ROS and other cytotoxic compounds, their effect on cellular process. Effect on total carbon gain- decrease in photosynthetic area and function, protein turn over and lipid characters, phenology-reproductive aspects, critical stages.

Unit 2: Stress Perception and Molecular Responses of Plants to Drought Stress

Stress perception andsignal transduction leading to expression of regulatory genes, stress specific kinases, stress specific transcription factors, functional genes associated with adaptive mechanisms.

Unit 3: Plant Adaptive Mechanisms to Drought

(a) Escape and desiccation avoidance mechanism

Concept of stress escape- exploiting genetic variability in phenology, Drought avoidance mechanisms- Maintenance of cell turgor, water mining by root characters. Moisture conservation- Regulation of transpiration- traits reducing heat load, Stomatalfactors guard cell metabolism, moisture conservation by waxes. Water use efficiency (WUE) and concept of water productivity- regulation of transpiration efficiency-stomatal conductance, mesophyll efficiency, relevance of WUE and Passioura's model.

(b) Desiccation tolerance- Concept of acquired tolerance

Decreased turgor mediated upregulation of cellular tolerance mechanisms, Osmolytes, managing cytotoxic compounds, ROS, RCC, scavenging - enzymatic and non-enzymatic, protein turnover, stability, chaperones, membrane stability, photo-protection of chlorophylls.

Unit 4: Approaches to Improve Drought Tolerance

Development of genetic resources- donor genotypes for specific traits, Genomic resources- genes, QTL's regulating adaptive mechanisms, Conventional, transgenic and molecular breeding approaches to improve relevant adaptive traits, concept of trait introgression.

Block 3: Salt, Heavy Metal, Water Logging, Temperature and Light Stress

Unit 1: Salt Stress

Soil salinity-Effect of salt stress, ionic and osmotic effects; species variation in salt tolerance; glycophytes and halophytes, Salt tolerance mechanisms - exclusion, extrusion and compartmentalization, Signaling during salt stress – SOS pathway, Approaches to improve salt tolerance.

Unit 2: Heavy Metal Stress and Water Logging

Heavy metal toxicity in plants (eg., Al, Cd), tolerance mechanisms and approaches to improve. Plant response to water logging, role of hormones- ethylene, mechanism of tolerance and approaches to improve.

Unit 3: Temperature and Light Stress

High and low temperatures; effect on plants; adaptive mechanisms, evaporation cooling, concept of cellular tolerance, protein stability, chaperones, HSPs, HSFs, membranes. High light and high ionizing radiation- photo oxidation and photo-inhibition; mechanisms of tolerance, plant adaptation to low light, concept of shade avoidance response (SAR).

VII. Practicals

- Measurement of soil and plant water status.
- Drought stress imposition and measurement of physiological and biochemical changes in plants under stress –gas exchange and fluorescence measurements.
- Determination of water use efficiency as a drought resistant trait.
- Drought Susceptibility Index (DSI) -precise field technique to identify productive genotypes under stress.
- Approaches to quantify root characters
- Determination of stomatal parameters and canopy temperature as a reflection of transpiration and root activity.
- Determination of Salinity Tolerance Index.
- Studying acclimation response - Temperature induction response.

- Heat tolerance and membrane integrity- Sullivans heat tolerance test.
- Quantification of osmolytes – proline under stress.
- Oxidative stress imposition- Quantification of oxidative stress
- Quantification of ROS under stress.
- Estimation of ABA content in leaf and root tissues under stress.
- Determination of Sodium and Potassium in plant tissue grown under salt stress.
- Estimation of antioxidant enzymes.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

IX. Learning outcome

After completion of this course students are expected to have knowledge on and insight into the physiological and molecular responses of plants to abiotic stresses. The student will develop critical insight in adaptive mechanisms of plants against various abiotic stresses.

X. Suggested Reading

- *Plant Physiology Book by Eduardo Zeiger and Lincoln Taiz.*
- Plant Physiology Book by Frank B. Salisbury, Cleon W. Ross Salisbury, Frank B
- Pereira A. 2016. *Plant Abiotic Stress Challenges from the Changing Environment. Front. Plant Sci*. 7: 1123. doi: 10.3389/fpls.2016.01123
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- Lata C and Muthamilarasan M and Prasad M. 2015. *Drought Stress Responses and Signal Transduction in Plants. In elucidation of abiotic stress signaling in plants* (PP.195-225). Springer, New York,Ny. DOI: 10.1007/978-1-4939-2540-7_7.
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environment: key roles of membrane-localized kinases in plant perception and response to abiotic stress. Journal of experimental Botany, 64(2), pp.445-458.

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I. Course Title : Hormonal Regulation of Plant Growth and Development

II. Course Code : PP 505

III. Credit Hours : 2+1

IV. Why this Course?

Many plant growth and developmental processes are regulated by phytohormones.

It is important to understand the hormone biosynthesis, structure, function, signal transduction and their practical application. It is also important to provide basic knowledge on manipulating growth and developmental processes using plant hormones.

V. Aim of the course

It provides knowledge on the fundamentals of hormone biosynthesis, homeostasis, transport and signaling and the role in regulating basic physiological processes governing developmental events in plants.The role of classical hormones on developmental processes from germination, shoot and root apical meristem differentiation, flowering, seed maturation and senescence. The aim of this course is to appraise the students about structure and function of plant growth regulators. The course is organized as follows:

No.	Blocks	Units
1.	Plant Growth and Development: Hormonal Regulation	1. Introduction to Plant Hormones 2. Plant Hormones - Discovery and Metabolism 3. Physiological Role of Hormones in Plant Growth and Development 4. Endogenous Growth Substances other than Hormones 5. Hormone Signaling 6. Key Genes Regulating Hormone Levels and Functions 7. Crosstalk of Hormones in Regulation of Plant Growth and Development Processes 8. Practical Utility of Growth Regulators in Agriculture and Horticulture

VI. Theory

Block 1: Plant Growth and Development: Hormonal Regulation

Unit 1: Introduction to Plant Hormones

Growth, differentiation and development regulated by plant growth substances, Definition and classification of growth regulating substances: Classical hormones, Definition and classification of growth regulating substances: Endogenous growth substances other than hormones, Synthetic chemicals.

Unit 2: Plant Hormones – Discovery and Metabolism

Discovery, biosynthetic pathways and metabolism of Auxin, Discovery, biosynthetic pathways and metabolism of Gibberellins, Discovery, biosynthetic pathways and metabolism of Cytokinins, Discovery, biosynthetic pathways and metabolism of Abscisic acid, Discovery, biosynthetic pathways and metabolism of Ethylene, Discovery, biosynthetic pathways and metabolism of Brassinosteroids, Discovery, biosynthetic pathways and metabolism of Strigolactones.

Unit 3: Physiological Role of Hormones in Plant Growth and Development

Physiological functions of Auxin and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Gibberellins and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Cytokinins and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Abscisic acid and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Ethylene and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Brassinosteroidsand Strigolactones and use of mutants and transgenic plants in elucidating the physiological functions, Discovery, biosynthetic pathways metabolism and physiological roles of Salicylic acid and Peptide hormones.

Unit 4: Endogenous Growth Substances other than Hormones

Discovery, biosynthetic pathways metabolism and physiological role of Polyamines and Karrikins, Discovery, biosynthetic pathways metabolism and physiological roles of Jasmonates and Tricontanol, Discovery, biosynthetic pathways metabolism and physiological roles of systemins Concept of death hormone, Recent developments in elucidating responses of Salicylic acid, Peptide hormones and Polyamines at physiological and molecular level, Recent developments in elucidating responses of Jasmonates, Systemins, Karrikins and Tricontanol at physiological and molecular level.

Unit 5: Hormone Signaling

Hormone signal perception, transduction - Receptors, components and mechanism (Auxin, Gibberellin, Cytokinin, ABA and Salicylic acid), Hormone signal perception, transduction - Receptors, components and mechanism (Ethylene, Jasmonate, Brassinosteroids and strigolactones), Advances in elucidating the structure and function of receptors and signaling components of important hormones.

Unit 6: Key Genes Regulating Hormone Levels and Functions

Genomics approaches to regulate hormone metabolism and its effect on plant growth and development – case studies.

Unit 7: Crosstalk of Hormones in Regulation of Plant Growth and Development Processes

Crosstalk of Hormones in Regulation of Plant Growth and Development Processes: Floral transition, reproductive development, Shoot and root apical meristem development

Unit 8: Practical Utility of Growth Regulators in Agriculture and Horticulture

Practical Utility of Growth Regulators in Agriculture and Horticulture: Rooting of cuttings, Vine and brewing industry, Promotion of gynoecious flowers, hybrid rice production, induction of flowering in pine apple, cucurbits, Practical Utility of Growth Regulators in Agriculture and Horticulture: Delaying of senescence and ripening, Production of dwarf plants for ornamental purpose, As herbicides, Reduction in flower and fruit drop.

VII. Practicals

- Extraction of Auxins from plant tissue
- Separation and detection of Auxins by GC / GC-MS / HPLC / Immunological technique
- Bioassay of auxin- effect on rooting of cuttings
- Extraction of abscisic acid (ABA) from plant tissue
- Separation and detection of ABA by HPLC/Immunological technique
- ABA bioassays- effect on stomatal movement

- Preparation of samples for ethylene estimation in plant tissue
- Estimation of ethylene in plant tissues using gas chromatography
- Ethylene bioassays, estimation using physico-chemical techniques- effect on breaking dormancy in sunflower and groundnut
- Extraction of Gibberellins from plant tissue- GC / GC-MS / HPLC
- Separation and detection of GA by GC / GC-MS / HPLC/Immunological technique
- GA bioassays- effect on germination of dormant seeds
- Cytokinin- extraction from plant tissue
- Separation and detection of cytokinin by GC / GC-MS / HPLC
- Cytokinin bioassays- effect on apical dominance and senescence / stay green

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:

- acquire basic knowledge about plant hormones and plant growth regulators.
- understand the physiological roles and mechanisms of actions of plant hormone.
- obtain practical knowledge about application of plant growth regulators in agricultural and horticulture.

X. Suggested Reading

- Davies P.J. 2004, *Plant Hormones: Biosynthesis, Signal Transduction and Action,* 2nd Edition. Kluwer Academic Publishers, Dordrecht, The Netherlands.
- Hedden, P. and Thomas, S.J. 2006. *Plant Hormone Signalling*, Blackwell Publishing Ltd., Oxford, UK.
- Osborne, D.J. and McManus, M.T. 2005. *Hormones, Signals and Target Cells in Plant Development*. Cambridge University Press, New York, USA.
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- Buchanan B B, Gruissem W and Jones R L. *Biochemistry and Molecular biology of Plants*, 2nd Edition
- Lincoln Taiz and Eduardo Zeiger. *Plant Physiology and Development*, 6th Edition.
- *Teaching Tools in Plant Biology*, The American Society of Plant Biologists
- *The Arabidopsis* Book(http://www.arabidopsisbook.org/)

I. Course Title : Physiological and Molecular Mechanisms of Mineral Nutrient Acquisition and their Functions

II. Course Code : PP 506

III. Credit Hours : 2+1

IV. Why this course?

In both basic and applied plant sciences, an understanding of the mineral nutrition of plants is of fundamental importance. Nutrient element forms the skeleton of any organic molecule in the organism vis-à-vis plant. Apart from the conventional information on criteria of essentiality, nutrient uptake pathways, function of essential elements and their deficiency and toxicity symptoms, remarkable advances have been made at physiological and molecular level. Exploration of the physiological mechanisms adopted by plants to tolerate the deficiency of specific nutrient element provides an opportunity alter the plants' ability to cope with the low nutrient condition. Identification and functional validation of various transporters involved in nutrient uptake and distribution, deciphering the sensing and signaling of nutrient starvation response and their regulatory network provides options to develop nutrient uptake and utilization efficient crops. In the era of Omics, 'ionomics' provides the total elemental composition of the plant and is a powerful approach to the functional analysis of its genes and the gene networks. Besides, it is also essential to expose the students to various conventional and high-throughput phenotyping techniques to identify the nutrient efficient 'donors', traits and QTLs/ candidate genes to complement the research program on crop improvement.

V. Aim of the course

It provides knowledge on basic physiological processes governing nutrient uptake, physiological role of elements, factors influencing uptake, internal remobilization of nutrient element during starvation and adaptation strategies. Regulation of nutrient uptake and translocation would be studied at the molecular level providing information on genes and other signaling factors involved. The aim of this course is to make the students understand the physiological and molecular basis of nutrient uptake, translocation and utilization and to apply this knowledge in genetic improvement of crop plants.

The course is organized as follows:

No.	Blocks	Units
1.	Mineral Nutrient: Classification, Function, Availability, Deficiency and Toxicity	1. Mineral Elements: Classification, Function, Deficiency and Toxicity 2. Nutrient Availability at Rhizosphere
2.	Nutrient Uptake, Translocation and Acquisition	1. Ion Uptake Mechanisms 2. Ion Transport to Shoot and Grains 3. Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Macronutrients 4. Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Micro and Beneficial Nutrients 5. Microbes, Fungal Association for Nutrient Acquisition 6. Nutrient Delivery
3.	Nutrient Efficiency of Crop	1. Improving Nutrient Acquisition and Efficiency of Crops

VI. Theory

Block 1: Mineral Nutrient: Classification, Function, Availability, Deficiency and Toxicity

Unit 1: Mineral Elements: Classification, Function, Deficiency and Toxicity

Classification based on mobility and characteristic features; physiological role in regulating plant growth, metabolism, development and human health- Regulatory Dietary Allowance (RDA), Deficiency and toxicity of macro, micro and beneficial elements, Tolerance of plants to nutrient toxicity, hyper-accumulators of nutrients: Concept of phytoremediation.

Unit 2: Nutrient Availability at Rhizosphere

Biological and chemical reactions influencing nutrient availability near the root system, interaction between ions in the rhizosphere, Rhizosphere chemistry in relation to plant nutrition- chemical reactions, root exudates to mobilize nutrients.

Block 2: Nutrient Uptake, Translocation and Acquisition

Unit 1: Ion Uptake Mechanisms

Mineral salt absorption- chemical potential of solute- Nernst equation- passive uptake- diffusion, ion exchange-Donnan Equilibrium, mass flow of ions, Mediated transport- Facilitated diffusion-ionophores; membrane transport proteins- active transport-ion channels, Primary and secondary transport- carriers and pumps.

Unit 2: Ion Transport to Shoot and Grains

Long distance transport in plants - Mechanism of xylem and phloem transport, Radial movement of ions across the root, Mechanism of phloem transport, remobilization of mineral nutrients - phloem loading, phloem unloading.

Unit 3: Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Macronutrients

Molecular structures of LAT and HAT, their localization and regulation by various external factors, Nitrate transporters and their functional regulation - Nitrate transporters (NRT1, NRT2, dual-affinity nitrate transporter NRT1.1/CHL1), Phosphate transporters and their functional regulation - PT1/PHT1, PHT2, PHT3, PHT4, Potassium transporters and their functional regulation - KT/HAK/KUP family Ion transporters involved in transport of multiple elements, for example, sulphate transporter for Selenate transport, phosphate transporter for Arsenate transport, etc.

Unit 4: Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Micro and Beneficial Nutrients

Plant Strategies: Different Strategies I & II adopted by plants for uptake of Fe under Fe deficient condition, Transporters and genes regulating uptake and transport of micronutrients, genes encoding transport/channel proteins, Examples of genes encoding mineral ion transporters for Zn, Fe, Mn, Cu, B, Mo, Ni, Cl, Na, Si, Se, Beneficial nutrients and their role in plant growth and development – Sodium, Silicon, and Cobalt.

Unit 5: Microbes, Fungal Association for Nutrient Acquisition

Microbes to improve nutrient availability – Bio-inoculation technology- P solubilizers and Zinc solubilizers in nutrient absorption, Microbial systems for biological nitrogen fixation – process of nodulation, biochemistry of N2-fixation, Endophytes to improve nutrient availability, Mycorrhiza- Mycorrhizal symbiosis on nutrient uptake by root. Role of AMF on nitrogen, phosphorus and zinc uptake.

Unit 6: Nutrient Delivery

Foliar application of nutrients, absorption and their compartmentation, Concept of slow release fertilizers and chelates (organic and inorganic), Soil less cultures- aeroponics, hydroponics, fertigation.

Block 3: Nutrient Efficiency of Crop

Unit 1: Improving Nutrient Acquisition and Efficiency of Crops

Concept of nutrient uptake and use efficiency- Genotypic differences- physiology and molecular mechanisms, Nutrient use efficiency in selected crops, Root system architecture (RSA), root characters associated with nutrient acquisition, Genes and QTLs to improve nutrient acquisition and efficiency for important nutrients in few crop species, Transgenic and molecular breeding approaches to improve traits associated with acquisition and efficiency – Case studies, Biofortification strategies – for micronutrients, agronomic approaches, Influence of nutrition status on plant response to biotic and abiotic stresses.

VII. Practicals

- Techniques to develop the deficiency symptoms of nutrients –Hydroponics/ Aeroponics- diagnosis of deficiency symptoms in agriculturally important crop plants
- Physiological and biochemical markers to identify nutrient deficiency levels
- Biochemical markers for essential elements: Assay of nitrate reductase activity for N
- Estimation of chlorophyll concentration in leaves of N deficient and N sufficient plants
- Collection of acid phosphatase from root exudates and enzyme assay for P
- Measuring anthocyanin and chlorophyll pigments concentration in leaves for P
- Collection of organic acid in root exudates, characterization and quantification for P
- Assay of carbonic anhydrase activity for Zn
- Assay of SOD Activity for Cu, Zn and Mn
- Estimation of nitrogen concentration in plant tissue - Kjeldhal and Dumas method
- Estimation of phosphorus concentration in plant tissue – colorimetric method
- Estimation of potassium, magnesium and sodium concentration in plant tissue – flame photometer
- Estimation of micronutrients (Zn, Cu, Fe, Mn, Co etc) concentration in plant tissue – atomic absorption spectrometer/ ICP-OES
- Measurement of simple root traits such as root length, angle, volume, surface area, etc. (using conventional methods or root scanner and WinRhizo)
- ‘Shovelomics’ in the field grown crops (for measuring root architecture) and using ‘ImageJ’ for analysis
- Non-invasive techniques to quantify nutrients – XRF (X-Ray Fluorescence) and hyper spectral reflectance.

VIII. Teaching methods/ activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

– comprehend the fundamental concepts of mineral nutrition of plant.
– describe the physiological and molecular mechanisms of acquisition and translocation of nutrient.
– describe the basis of differential nutrient efficiency.

X. Suggested Reading

- *Recommended Dietary Allowances*: 10th Edition (https://www.ncbi.nlm.nih.gov/books/NBK234932/pdf/Bookshelf_NBK234932.pdf)
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- Mitra GN. *Regulation of Nutrient Uptake by Plants: A Biochemical and Molecular Approach*
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- Riaz, A., Abbas, A. and Raza, S., 2017. *Techniques for the Enrichment of Micronutrients in Crops through Biofortification: A Review. Journal of Advances in Biology and Biotechnology*, 1-7.

I. Course Title : Photosynthetic Processes, Crop Growth and Productivity and Concepts of Crop Modelling

II. Course Code : PP 507

III. Credit Hours : 2+1

IV. Why this Course?

Agronomic inputs and environmental factors enhance crop growth by improving photosynthetic processes and photosynthate partitioning. Carbon metabolism is the most important physiological process that has a direct influence on crop growth and productivity which is quite sensitive to biotic and abiotic constraints. Hence a comprehensive understanding canopy photosynthetic process is crucial. This is an important component in crop improvement program, especially in the scenario of plateauing yields. These photosynthetic processes and their response to environmental factors form the basis for developing growth and yield predicting models.

V. Aim of the Course

The course provides a comprehensive theoretical and hands on experience and expertise to students on various aspects of photosynthesis including biophysical, biochemical and molecular regulations. While canopy photosynthesis drives crop growth rates, factors associated with sink activity and partitioning determine productivity. Hence, adequate emphasis would be given to canopy photosynthesis, translocation and its feedback regulation, Crop growth and yield structure analysis and their responses to environmental factors. Growth and yield prediction models and their relevance will be adequately discussed.

The course is organized as follows:

No.	Blocks	Units
1.	Photosynthetic Processes	1. Canopy Architecture and Energy Utilization 2. Photochemical Processes 3. Biochemical Processes 4. Product Synthesis and Translocation 5. Growth and Yield forming Mechanisms
2.	Yield Improvement and Modelling	1. Molecular Options to Improve Photosynthesis, Growth and Productivity 2. Fundamentals of Dynamic Simulation Models 3. Description of Well-established Yield Models 4. Examples of Robust Models Extensively Used

VI. Theory

Block 1: Photosynthetic Processes

Unit 1: Canopy Architecture and Energy Utilization

Parameters associated with canopy architecture that determine radiation interception and absorption, Energy absorption by primary and accessory pigments and energy utilization efficiency, Light distribution inside the canopy and concepts of light extinction coefficient.

Unit 2: Photochemical Processes

Ultrastructure of chloroplast: structure and composition of lamellar system, Components of electron transport, Water oxidation system and energy conservation processes, Pigment systems and the generation of a powerful oxidant and a powerful reductant, Chlorophyll fluorescence and fluorescence quenching: qN, qP, NPQ.

Unit 3: Biochemical Processes

CO_2 diffusion and resistances (g_s and g_m). Concept of Ci determining CO_2 diffusion. RuBisCO activation state, kinetics and catalytic properties, Carboxylation processes in C_3, C_4 and CAM plants and their relevance, CO_2 concentrating mechanisms and their importance in improving carbon assimilation, Ecological significance of C_4 and CAM photosynthesis, Photorespiration and Mitochondrial respiration and net carbon gain, Carbon isotope discrimination and its importance as a surrogate of Ci.

Unit 4: Product Synthesis and Translocation

Triose phosphate utilization and regulation of Calvin cycle mechanisms, Product synthesis and partitioning between starch and sucrose, Concepts of end-product inhibition or Pi-regeneration limitation, Phloem transport and factors that regulate phloem loading and un-loading.

Unit 5: Growth and Yield forming Mechanisms

Carbon gain and the concepts of Canopy photosynthesis. Relevance of LAI and LAD in determining total carbon gain and crop growth rates, Source: Sink relationship and its relevance in governing differences in crop growth rates and productivity. Concepts of HI and partitioning coefficient and remobilization of carbon from vegetative organs to reproductive structures, Growth analysis and parameters that explain growth rates: NAR, CGR, HI and their inter-dependence.

Block 2: Yield Improvement and Modelling

Unit 1: Molecular Options to Improve Photosynthesis, Growth and Productivity

Characteristic features of the Chloroplast genome: its structure and genes associated with various photosynthetic mechanisms, coordinated expression of chloroplast and nuclear genome for maintaining photosynthetic activities. Genomic and genetic resources such as specific genes and QTL associated with photosynthetic processes Transgenic options to enhance photosynthetic performance such as transferring genes to mitigate oxidative stress damage (SOD, APX, AKR etc), Theoretical concepts of crop improvement through inducing CCM in C_3 plants and reducing photorespiration.

Unit 2: Fundamentals of Dynamic Simulation Models

Collection of crop specific genetic coefficient, Crop, soil and historic weather data

Unit 3: Description of Well-established Yield Models

Application and limitations of modeling, Yield prediction models such as APSYM, PeanutGrowetc, Machine learning approaches and IoT for making informed on-farm decisions.

Unit 4: Examples of Robust Models Extensively Used

Duncan'syield prediction model, Passioura'smodelfor growth maximising.

VII. Practicals

- Plant sampling for leaf area and biomass estimation; analysis of growth and yield parameters – LAD, NAR. CGR, LAI, LAR, SLA portioning efficiency, HI.
- Measurement of light interception, light extinction coefficient, energy utilization efficiency based energy intercepted, and realized.
- Gas exchange: principles and uses to assess variations in CO_2 and water vapour transfer, determination of A/gs and intrinsic WUE
- Quantification of chlorophyll content by various methods: colorimetric and SPAD meter. The concept of SLN
- Chlorophyll fluorescence and quenching coefficients
- Theoretical aspects of carbon isotope fractional and its use in determining WUE
- Quantification of RuBisCO content by ELISA (if possible)
- Determination of RuBisCO activity and activation state using radioactive $CO\text{-}_2$
- CO_2 and light response curves and computation of carboxylation efficiency, quantum efficiency, relative limitations of photosynthesis at single leaf level.
- Adoption of crop models: Growth and yield prediction by Duncan's and Passioura's models

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

IX. Learning outcome

After completion of this course students are expected to have in depth knowledge on Photosynthetic processes associated with product synthesis and yield development. Students will also obtain current knowledge on various crop models.

X. Suggested Reading

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- https://www.mdpi.com/1424-8220/18/8/2674/pdf
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- Splinter, W.E. (1974). Modelling of plant growth for yield prediction. *Agricultural Meteorology*, 14(1-2), 243-253.

General Source Information

- Blankenship RE. 2014. *Molecular mechanisms of Photosynthesis* 2nd Edition
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- Pessarakli M. 2016. *Handbook of Photosynthesis* 3rd Edition.

I. Course Title : Physiology of Field Crops

II. Course Code : PP 508

III. Credit Hours : 2+0

IV. Why this course?

In recent years, phenomenal progress has been made in understanding plant processes which are crop specific. Genetic gain in productivity can be achieved only by improving plant physiological traits/adaptive mechanisms. Even crop management should be based on sound physiological principles. For example, crop's response to the increase in global warming has to be looked from thermo morphogenesis concept in terms of GDD and its effect on phenological processes in some of the important field crops exposure on crop specific physiological processes is necessary and has particular significance.

V. Aim of the course

This course provides a broad exposure on the physiological aspects of field crops. The objective is to impart comprehensive information on physiological processes and physiological basis of growth, development and productivity of field crop plants. Besides, the emphasis is on unique crop specific features.

Broad categories of crops that can be selected for this course are as follows.

1. Cereals– Rice, Wheat, Maize etc.
2. Millets– Finger millet, Sorghum etc.
3. Pulse crops– Green gram, Black gram, Lentil, Pigeon pea, Chickpeas, Cowpea, Beans etc.
4. Oilseed crops– Groundnut, Rapeseed Mustard, Soybean etc.
5. Sugarcane
6. Fibre crops– Cotton, Jute, Ramie, Hemp etc.

The course is organized as follows:

No.	Blocks	Units
1.	Physiology of Field Crops	1. Introduction 2. Crop Establishment, Crop Growth and Development 3. Reproductive Growth 4. Seed Nutrient Quality 5. Plant Nutrition 6. Abiotic Stress Response 7. Crop Specific Physiological Processes and Importance

VI. Learning outcome

After completion of this course, students will accrue comprehensive knowledge on various physiological processes of variety of field crops.

VII. Theory

Block 1: Physiology of Field Crops

Unit 1: Introduction

Origin- Variability in physiology of crop plants between wild species and cultivated. Adaptability to growing environments (ecosystems), Importance in food grain contribution.

Unit 2: Crop Establishment, Crop Growth and Development

Seed characteristic features, dormancy, viability, concept of seed priming seedling establishment and crop stand. Different crop growth stages, concept of source establishment and optimum LAI, Canopy architecture, light interception/radiation use efficiency, thermal time, heat units, GDD, determining growth duration.

Unit 3: Reproductive Growth

Photo and thermo-periodic response for flowering, sink development, sink source relationship, partitioning efficiency, improvement in HI, yield determining factors, genetic gain in yield over years, structuring of ideal plant type, limitations to improve source to sink size, options to improve yield potential.

Unit 4: Seed Nutrient Quality

Seed quality, seed as a source of nutrients, seed constituents and their improvement, concept of pathway engineering to improve seed quality.

Unit 5: Plant Nutrition

Nutrient requirement, genetic variability in nutrient acquisition under constraint conditions, specific nutrient disorders.

Unit 6: Abiotic Stress Response

Response to different abiotic stresses, plant traits/mechanics to improve adaptation to realize potential yields. Global warming responses, thermomorphogenesis, approaches to overcome the constraints.

Unit 7: Crop Specific Physiological Processes and Importance

Choosing location specific crop species exposure will be given on physiological process as described above. Besides, emphasis is on providing information on crop specific features/productivity constraints.

Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

Suggested Reading

- *Grain Legumes*: Ed De Ron, Antonio M. (Ed.) 2015. Springer
- *Legumes under Environmental Stress: Yield, Improvement and Adaptations*. Eds MM Azooz P Ahmad and Hoboken, NJ: John Wiley and Sons, Ltd., 328 pages. ISBN: 978-1-118-91708-4
- *Pulse Crops: Biotechnological Strategies to Enhance Abiotic Stress Tolerance*. Ganeshan S, Gaur PM, Chibbar RN, Tuteja N, Gill SS, Tuteja R. chapter 17
- *Climate Change and Management of Cool Season Grain* Legume *Crops*. Eds Yadav GS, McNeil DL, Redden R, Patil SA. Springer
- *Nature's pulse power: legumes, food security and climate change.* Considine MJ, Siddique

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- Fahad S, Bajwa AA, Nazir U, Anjum SA, Farooq A, Zohaib A, Sadia S, Nasim W, Adkins S, Saud S and Ihsan MZ. 2017. *Crop production under drought and heat stress: plant responses and management options. Frontiers in Plant Science* 8(1147): 1-16.
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- Kole C. 2006. *Cereals and millets. Genome Mapping and Molecular Breeding in Plants. Springer*.
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- Rinki, Mamrutha HM, Sareen S, Tiwari V, Singh GP. 2018. *Dissecting the physiological and anatomical basis for high yield potential in HD 2967. Vegetos*. 31: 121-124.
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- Tiwari R and Mamrutha HM. 2014. *Precision Phenotyping for Mapping of Traits for Abiotic Stress Tolerance in Crops. Biotechnology: Prospects and Applications.* Ed. Salar RK, Gahlawat SK, Siwach P and Duhan JS. Pp79-85. Publisher: Springer.
- Sleper DA and Poehlman JM. 1995. *Breeding for field crops*
- Reynolds *M. Wheat Physiological Breeding volume I and II (CIMMYT): Wheat Physiological Breeding: A Field Guide to Wheat Phenotyping*.
- Mamrutha HM *et al*. 2019. *Physiological and Molecular Basis of Abiotic Stress Tolerance in Wheat*. In: Rajpal V., Sehgal D., Kumar A., Raina S. (eds) *Genetic Enhancement of Crops for Tolerance to Abiotic Stress: Mechanisms and Approaches*, Vol. I. Sustainable Development

and Biodiversity, vol 20. Springer, Cham
- Tiwari V. *et al*. 2017. *Managing Abiotic Stresses in Wheat*. In: Minhas P., Rane J., Pasala R. (eds) *Abiotic Stress Management for Resilient Agriculture*. Springer, Singapore

I. Course Title : Physiology of Horticulture Crops
II. Course Code : PP 509
III. Credit Hours : 2+0

IV. Why this Course?

Improving physiological processes forms the basis to enhance the productivity or to improve a specific growth processes. Several interventions based on principals of physiological processes provide options to enhance crop productivity. Basic insight on photoperiodic response is crucial for determining planting dates. Understanding the mechanisms of rooting for vegetative propagation has lead in developing rooting hormones etc., In view of this, a comprehensive exposure on growth and development of horticulture crops and providing insights on major production constraints and physiological approaches to overcome is highly essential.

V. Aim of the Course

This course should provide a broad exposure on the physiological aspects of horticulture crops. The objective is to impart comprehensive information on physiological processes and physiological basis of growth, development and productivity of horticultural crop plants. To describe basic and applied physiology behind the production and productivity of horticultural crops and their pre and postharvest management, ideal storage conditions, quality retention, processing and value addition.

Broad categories of crops that can be selected for this course are as follows.

1. Fruit crops: Mango, Grapes, Apple, Banana, Citrus etc.
2. Vegetable crops: Tomato, Onion, Brinjal, Cauliflower, Okra etc.
3. Tuberous crops: Potato, Cassava, Sweet potato, Yam etc.
4. Plantation crops: Coconut, Oil palm, Cashew, Tea, Coffee, Rubber, Areca nut, Cocoa etc.
5. Floriculture crops: Rose, Marigold, Carnation, Chrysanthemum, Gladiolus, Orchids, Tuberose etc.
6. Other groups: Medicinal crops, Aromatic crops, Spices crops.

The course is organized as follows:

No.	Blocks	Units
1	Physiology of Horticultural Crops	1. Introduction 2. Crop growth and Development 3. Reproductive Growth 4. Pre and Post-harvest Physiology 5. Plant Nutrition and Abiotic Stress Responses 6. Specific Aspects and Unique Crop Features

VI. Learning outcome

After completion of this course, students will accrue comprehensive knowledge on various physiological processes of variety of horticultural crops.

VII. Theory

Block 1: Physiology of Horticultural Crops

Unit 1: Introduction

Origin, distribution and adaptability of crops to different agro-climatic conditions

Unit 2: Crop growth and Development

Internal factors (hormone, etc.) influencing various physiological processes linked to vegetative growth or growth of specific organ, correlative and algometric growth External factors (water, nutrition, temperature, etc.) influencing various physiological processes linked to vegetative growth or growth of specific organ, correlative and algometric growth, Propagation methods, grafting, cutting, budding, air layering. Physiology of pruning, dwarfing, branch bending, canopy management etc., Physiological and biochemical aspects of scion and root stock interaction and compatibility.

Unit 3: Reproductive Growth

Physiology of flowering, photo- and thermo-periodism and response to vernalization, Factors influencing reproductive growth, fruit and seed set/retention, physiology of flower sex ratio, Physiological processes governing source-sink relationship and productivity.

Unit 4: Pre and Post Harvest Physiology

Preharvest factors influencing postharvest physiology, Physiological and molecular mechanisms of ripening, Physiological and molecular mechanisms of senescence, Hormonal and chemical control of postharvest deterioration of fruits/vegetable/ flowers. Regulation of ripening at physiological and molecular levels, Regulation of senescence at physiological and molecular levels, Approaches to improve shelf life and storability. Approaches to improve postharvest management, Approaches to improve processing and value addition.

Unit 5: Plant Nutrition and Abiotic Stress Responses

Nutrient acquisition and requirement, plant phenology and nutrient requirement; Role of rootstocks in nutrient acquisition and in abiotic stress tolerance, Adaptive mechanisms and approaches to improve performances under drought and high temperature, Adaptive mechanisms and approaches to improve performances under frost, chilling and nutrient deficient conditions, Root physiology in abiotic stress tolerance.

Unit 6: Specific Aspects and Unique Crop Features

Specific aspects

Polyhouse cultivation, Hormones/PGRs for improving crop performance, Major and micronutrients for improving crop performance, Light interception, shade regulation, dwarfing root stocks, Chilling requirement for flowering, photoperiodic response, pollen viability, stigma receptivity, Flower (blossom) and fruit drop.

Unique crop features

Maturity and maturity indices, Source-sink relations, Vegetative propagation, Physiology of tuberization and rhizome initiation and formation, Virus free planting material, Bulbs/tubers dormancy, bud break, Physiological disorders, Storage, Packaging, Quality.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

IX. Suggested Reading

- Sethuraj MR and Raghavendra AS. 2012. *Tree Crop Physiology*. ISBN-13: 978-0444428417, ISBN-10: 0444428410, Elsevier Science Publishers.
- Bhatnagar P. *Physiology of Growth and Development of Horticultural Crops*, ISBN-10: 817754666X, ISBN-13: 978-8177546668
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- Hare K. 2012. *Physiology of Fruit Production*, ISBN-10: 9380012373, ISBN-13: 978-9380012377, Studium Press India Pvt. Ltd
- Durner EF. 2013. *Principles of Horticultural Physiology*, ISBN-13: 978-1780643069, ISBN-10: 1780643063, CABI.
- Bleasdale JKA. *Plant Physiology in Relation to Horticulture*, ISBN-10: 8192686094, ISBN-13: 978-8192686097, SENTIFIC (2014) 2nd edition
- Kumar M. 2015. *Physiology of Fruit Production*, ISBN-10: 9384568384, ISBN-13: 978-9384568382.
- Yahia EM and Carrillo-Lopez A. 2018. *Postharvest Physiology and Biochemistry of Fruits and Vegetables*, ISBN-10: 0128132787, ISBN-13: 978-0128132784, Woodhead Publishing.
- Freitas ST and Pareek S. *Postharvest Physiological Disorders in Fruits and Vegetables*, ISBN-9781138035508, 1138035505,Taylor and Francis Ltd.
- Dhillon WS and Bhat ZA. 2012. *Fruit Tree Physiology*. Narendra Publishing House.
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- Schaffer B and Andersen PC. 2018. *Handbook of environmental physiology of fruit crops.* CRC Press.
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- Jameel MA, Naik SR, Madhumathi C, Reddy DS and Venkataramana KT. 2018. *Physiology of flowering in mango. Journal of Pharmacognosy and Phytochemistry*, 7(6), 2375-2382.
- Lin HL, Shiesh CC and Chen PJ. 2012. *May. Physiological disorders in relation to compositional changes in mango (Mangiferaindica L.'Chiin Hwang') fruit. In VII International*

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Grapes

- Keller M. 2015. *The science of grapevines: anatomy and physiology*. Academic Press.
- Williams LE. 2017. *Grape. In Photoassimilate Distribution Plants and Crops Source-Sink Relationships* (pp. 851-882). Routledge.
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Guava

- Rodrigues AAM, Silva SDM, Dantas AL, Silva AFD, Santos LDS and Moreira DDN. 2018. *Physiology and postharvest conservation of 'Paluma'guava under coatings using Jack fruit seed-based starch. RevistaBrasileira de Fruticultura*, 40(2).
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- Adhikari S. 2012. *Guava Pruning and Its Physiology*

Tomato

- Aivalakis G and Katinakis P. 2008. *Biochemistry and molecular physiology of tomato and*

pepper fruit ripening. Eur J Plant SciBiotechnol, *2*(special issue 1), 145-155.
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Onion

- Brewster JL. 2018. *Physiology of crop growth and bulbing. In Onions and allied crops* (53-88). CRC Press.
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- Khokhar, K.M., 2017. *Environmental and genotypic effects on bulb development in onion–a review. The Journal of Horticultural Science and Biotechnology* 92(5): 448-454.
- Khokhar KM. 2014. *Flowering and seed development in onion—A review.* Open Access Library 1(07).

Brinjal

- Sharma SP and Brar JS. 2008. *Nutritional requirements of brinjal (Solanum melongena L.)-A review. Agric. Rev,* 29(2), pp.79-88.
- Byari, S.H. and Al-Rabighi, S.M., 1995. *Morphological and physiological responses of egg plant cultivars (Solanum melongena L.) to drought*. J. KAU: *Met. Env, Arid Land Agric. Sci*, *6*, pp.41-47.

I. Course Title : Seed Physiology
II. Course Code : PP 510*
III. Credit Hours : 2+1

IV. Why this course?

Seeds are considered as propagule and as a major source of nutrition for humans and other animals. Therefore, all information concerning their nutritive value, chemical composition; storability, retention of viability are very important. Looking into the importance of seeds, emphasis has been given to produce high quality seeds with excellent genetic potential to improve seed germination and to produce vigorous seedlings. In fact, recently techniques are employed to raise healthy and vigorous seeds to obtain vigorous seedlings. Several hormones and chemicals are used to improve the oil, protein, and other economic attributes of seeds. Therefore, to give more insight into the development of quality seeds and also protecting them without losing much of nutritive value, this course has been proposed.

V. Aim of the course

This course will approach the subjects from two perspectives –physiology of seed development and seed germination. It aims to describe students the physiological processes involved in regulation and mechanism of seed development, dormancy and germination. Further, to provide an insight into physiological processes governing seed quality and its survival. Accordingly.

The course is organized as follows:

No.	Blocks	Units
1.	Physiology of Seed Development	1. Introduction to Seed Physiology 2. Seed Development 3. Seed Maturation 4. Metabolism in Developing Seed
2.	Physiology of Seed Germination and Dormancy	1. Seed Germination 2. Seed Dormancy and Viability

VI. Theory

Block 1: Physiology of Seed Development

Unit 1: Introduction to Seed Physiology

Importance of seed as a propagule, seed structure and functions; chemical composition of seeds. Embryogenesis: pollination and fertilization, pollen and pistil interaction, signal for interaction; pollen load hypothesis; genetical and environmental influence on seed development. Source-Sink relationship affecting seed yield and quality. Concept of seed viability and seedling vigour and their relevance; approaches to improve the storability of seeds. Physiological and molecular mechanisms of seed germination; approaches to improve seed germination; seed size and its influence on seed germination.

Unit 2: Seed Development

Physiology and molecular mechanisms of embryo, endosperm and seed coat development; cellularization during endosperm development; morphological and cellular changes during seed coat development, anatomy and function of seed coat, programmed cell death (PCD) in seed coat, Deposition of seed storage reserves during development.

Unit 3: Seed Maturation

Seed maturation and maturation indices; physiological and anatomical changes during seed maturation; Seed drying and acquisition of desiccation tolerance in seeds; mechanisms of desiccation tolerance; role of ABA LEA's, HSP's, dehydrins and other stress proteins during seed maturation and drying, Seed abortion and approaches to reduce it.

Unit 4: Metabolism in Developing Seed

Chemical composition of seeds (carbohydrates, proteins, fats etc.), source of assimilates for seed development, pathways of movement of assimilates to developing seed, approaches to increase the chemical composition of seeds. Seed respiration and mitochondrial activity; seed respiration rate and storability of seeds. Seed ageing, Mobilization of stored resource in seeds; Chemistry of oxidation of starch, proteins and fats; Utilization of breakdown products by embryonic axis.

Block 2: Physiology of Seed Germination and Dormancy

Unit 1: Seed germination

Seed germination, types of germination, imbibition kinetics of germinating seed; Physiological events during germination: seed respiration, mitochondrial activity, mobilization of food reserve; energy utilization by the germinating seed.

Environmental regulation of germination: hydro-time, thermal time and hydrothermal time models; Influence of environmental factors on germination; Role of plant hormones/PGR's during seed germination.

Unit 2: Seed Dormancy and Viability

Physiological and molecular basis of seed dormancy, hormonal regulation of dormancy, After ripening, dormancy breaking treatments; Ecological perspective of seed dormancy. Seed viability: concept and physiology of seed viability, theories of seed ageing, seed storage and regulation of storage life of seeds; methods to prolong seed viability; Conservation of orthodox and recalcitrant seeds. Seed vigour: concept, importance, measurement; Physiological, biochemical and molecular basis of seed vigour.

VII. Practicals

- Determination of seed reserves: carbohydrates, proteins and lipids
- Study of different seed structures
- Kinetics of seed imbibition; Seed germination test, enzymatic activities and respiration during germination and vigour testing methods etc.
- Accelerated ageing test to know the seed vigour and storability
- Measurement of seed moisture content
- Determination of amylase activity in germinating seeds
- Measurement of electrical conductivity in seed leachate
- Measurement of seed viability using tetrazolium chloride
- Determination of dehydrogenase activity
- Seed germination study- Determination of Germination Index and seedling growth
- Measurement ofseed vigour index
- Dormancy breaking treatments
- Seed priming techniques
- Effect of environmental stresses on seed germination and seedling growth
- Effect of hormones on seed germination

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

At the end of the course the students are expected to be able to understand the physiology of seed development and seed germination. The students will be able to identify the physiological processes involved in regulation of seed development, dormancy and germination.

IX. Suggested Reading

- Bewley, JD, Bradford K, Hilhorst H, Nonogaki H. (2013). *Seeds: Physiology of Development, Germination and Dormancy*, Springer-Verlag.
- Larkins BA and Vasil IK (Ed), *Cellular and Molecular Biology of Plant Seed Development*, 2010, Springer.
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- Bewley JD and Black M. 1994. *Seeds: Physiology of Development and Germination*, Springer
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- Roberto Benech-Arnold, Rodolfo Sanchez. 2004. *Handbook of Seed Physiology: Applications to Agriculture*. CRC Press.
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- Tina Steinbrecher Gerhard Leubner-Metzger. 2017. *The biomechanics of seed germination*. *Journal of Experimental Botany*, 68(4): 765–783.
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I. Course Title : Phenotyping Physiological Processes

II. Course Code : PP 511

III. Credit Hours : 2+0

IV. Why this course?

One of the main mandates of SAU and crop specific institutes is crop improvement. Seed industry and academic institutes need contribution from physiologists on these aspects. Conceptual changes in breeding approaches in terms of breeding for specific physiological traits necessitates that the students develop conceptual approaches for phenotyping in different physiological processes. Characterizing the parents, germplasm accessions, segregating populations for specific physiological traits like flowering response, variation in root system architecture, etc is crucial for genetic enhancement of these traits. This student ready Course can contribute richly to research and development of the seed sectors and crop specific institutions where the major emphasis in recent years is genetic enhancement of traits.

V. Aim of the course

The major emphasis in this course is to phenotype well characterized physiological processes/plant traits associated with plant growth, development and productivity, besides, comprehensive approach to precise imposition of various abiotic stresses and capture genetic variability in adaptive traits. The aim is to employ these techniques for crop improvement programs.

The course is organized as follows:

No.	Blocks	Units
1.	Phenotyping Physiological Processes	1. Concept of Phenotyping 2. Phenotyping for Traits for Crop Establishment 3. Concept and Approaches to Identify Genotypes with Superior Growth Rate 4. Identifying Photo-insensitive Genotypes-options and Approaches 5. Identifying Thermo-insensitive Genotypes-options and Approaches 6. Yield Structure Analysis- Relevant Yield Attributes 7. Source-sink Relationship- Assessment of Limitation

No. Blocks	Units
	8. Identify Genetic resources for Abiotic Stress Constraints

VI. Theory

Block 1: Phenotyping Physiological Processes

Unit 1: Concept of Phenotyping

Phenotyping technologies are essential component for assessing plant responses, identify superior trait donors, mitigation responses, trait introgression and trait based breeding.

Unit 2: Phenotyping for Traits for Crop Establishment

Seed viability, seed dormancy, seed hydration rates, seed density and weight, Seedling vigour in normal and adverse conditions.

Unit 3: Concept and Approaches to Identify Genotypes with Superior Growth Rate

Phenotyping for leaf expansion, leaf area index, light interception and crop extinction coefficient. Pigment quantification for nitrogen and chlorophyll status - SPAD, anthocyanin and flavonoids – Duolex. Growth rates by non-invasive techniques like NDVI, Concept of Net assimilation rate and DM/LAD; surrogates for photosynthetic traits; stomatal characteristic.

Unit 4: Identifying Photo-insensitive Genotypes-options and Approaches

Exposing to longer and shorter photoperiod by staggered sowing; extending the day length- light interception by red light; days to heading/ anthesis, approaches for synchronization of flowering.

Unit 5: Identifying Thermo-insensitive Genotypes-options and Approaches

Altering total degree days- staggered sowing at lower latitudes or by growth chambers; quantifying heading, anthesis, maturity and grain filling days, grain number and weight, grain filling rate.

Unit 6: Yield Structure Analysis- Relevant Yield Attributes

Pollen biology, stigma receptivity, spikelet sterility (cereals), floral abscission (other crops), fruiting points / productive tillers, number of grains/ fruits per panicle/ inflorescence and grain characteristic. Phenotyping for lodging- culm traits, intermodal length, lignification, Phenylalanine ammonia lyase (PAL) and Tyrosine ammonia lyase(TAL). Approaches to identify genetic resources with traits to improve yield potential.

Unit 7: Source-sink Relationship- Assessment of Limitation

Phenotyping for source-sink size, Concept of sink-source limitation- defloration and defoliation. Remobilization of stored metabolites and concept of stay green; estimation of water soluble carbohydrates; partitioning coefficient and harvest index.

Unit 8: Identify Genetic Resources for Abiotic Stress Constraints

Approaches for precise stress imposition to diverse stresses, Identify trait donor lines for different stresses: approaches by Stress Susceptibility Index (SSI), Stress Induction Response (SIR), Capturing variability for adaptive traits: root traits, stomatal factors/wax, osmolyte, surrogate approach for acquired tolerant traits, Flowering response, Spikelet fertility, Abscission and Senescence, Screening high density response-based on SSI – root adaptation and Shade Avoidance Response (SAR).

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation

VIII. Learning outcome

After completion of this course students are expected to develop clear concept and insight into phenotyping technologies associated with plant growth, development and productivity.

IX. Suggested Reading

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- Ouzounis, T., Rosenqvist, E., and Ottosen, C., 2015. *Spectral Effects of Artificial Light on Plant Physiology and Secondary Metabolism: A Review American Society Horticulture Science.* 50(8); 1128–1135 doi.org/10.21273/HORTSCI.50.8.1128
- *The Flowering Response of the Rice Plant to Photoperiod: A Review of The Literature* Fourth Edition.
- Sehgal A, Sita K, Siddique KH, Kumar R, Bhogireddy S, Varshney RK and Nayyar H. 2018. *Drought or/and Heat-Stress Effects on Seed Filling in Food Crops: Impacts on Functional Biochemistry, Seed Yields, and Nutritional Quality. Frontiers in Plant Science*, 9.
- Prasad, P. V., Bheemanahalli, R., andJagadish, S. K. 2017. *Field crops and the fear of heat stress—Opportunities, challenges and future directions. Field Crops Research* 200, 114-121.
- Gómez JF, Talle B and Wilson ZA. 2015. Anther and pollen development: a conserved developmental pathway. *Journal of Integrative Plant Biology* 57(11), 876-891.
- Khobra R, Sareen S, Meena BK, Kumar A, Tiwari V and Singh GP. 2019. *Exploring the traits for lodging tolerance in wheat genotypes: A review. Physiology and Molecular Biology of Plants*, 1-12.

  Hirano K, Ordonio RL and Matsuoka M. 2017. *Engineering the lodging resistance mechanism of post-Green Revolution rice to meet future demands. Proceedings of the Japan Academy, Series B*, 93(4), 220-233.

  White, A. C., Rogers, a., Rees, M and Osborne, C.P., 2016. *How can we make plants grow faster? A source–sink perspective on growth rate Journal of Experimental Botany*, 67(1): 31–45.

  Ragheba, A., El-Shimyb, H and Raghebb, G. 2016. *Green architecture: a concept of sustainability, Procedia - Social and Behavioral Sciences* 216: 778 – 787.

- Wang H, Wu G, Zhao B, Wang B, Lang Z, Zhang C and Wang H. 2016. *Regulatory modules controlling early shade avoidance response in maize seedlings*, *BMC Genomics* **17**: 269, https://doi.org/10.1186/s12864-016-2593-6.
- Carriedo, L., Maloof, J and Brady, S. 2016. *Molecular control of crop shade avoidance. Current Opinion in Plant Biology*. 30. 151-158. 10.1016/j.pbi.2016.03.005.

I. Course Title : Crop Growth Regulation and Management

II. Course Code : PP 512

III. Credit Hours : 2+0

IV. Why this Course?

Besides crop improvement, the approach to regulate physiological processes for improving crop production made very good leads in recent years. The focus is to employ the basic knowledge of several physiological processes to manipulate the plant growth and specific processes like ripening, flowering to achieve higher economic yields. This dynamic course will address many of these technologies that are being developed for crop production based on principles of plant physiological processes. Training the students in this student ready coursewill provide the required practical knowledge which will be of immense relevance to contribute private agricultural sectors and for agri-based industries.

V. Aim of the Course

A comprehensive information needs to be provided in this course like light regulation in polyhouse cultivation, photoperiod responses by red/far red light for synchronizing flowering, techniques for soil less culture like aeroponics, pollen biology and hybrid production, chemical regulation of plant growth processes like flower initiation, flower sex, flower drop, fruit maturity, ripening and shelf-life, etc.

The course is organized as follows:

No	Blocks	Units
1	Propagation - Crop Establishment	1. Seed as a Propogule 2. Vegetative Propogule
2	Regulation of Plant Growth Processes	1. Regulation of Plant Growth and Flowering 2. Fruit Ripening and its Regulation 3. Concept of Senescence and its Retardation
3	Protective Cultivation–Stress Mitigation	1. Protective Cultivation Interventions to Alter Physiological Processes and Growth 2. Drought Mitigation Options and Approaches 3. Specific Plant Processes Regulated by Chemicals and Growth Hormones

VI. Theory

Block 1: Propagation - Crop Establishment

Unit 1: Seed as a Propogule

Concept of improving seed characteristics for crop establishment. Mechanisms of regulating seed dormancy, precocious germination, ways to control pre-harvest sprouting in crop plants. Seed viability and its regulation, factors to minimize loss of viability and improve seedling vigour. Concept of seed priming, techniques of priming, seed priming to induce tolerance to stresses. Role of media, nutrition and PGPR's on seedling vigour and subsequent crop establishment.

Unit 2: Vegetative Propogule

Chemical and hormonal regulation of vegetative propagation. Regulation of rooting, bud sprouting, Bulb/tuber dormancy. Chemical regulation of graft union. Concept of *in vitro* micropropogation.

Block 2: Regulation of Plant Growth Processes

Unit 1: Regulation of Plant Growth and Flowering

Chemical and hormonal regulation of plant architecture, tillering, branching, bud breaking, Regulation of flowering by photo and thermoperiod, nutrients, chemicals and hormones, concept of speed breeding, Flowering synchrony in hybrid seed production, Sex ratio alteration, flower and fruit thinning, Pollen viability in relation to environment, harvesting, storage and transportation, Prevention of abscission, flower and fruit drop, seed and fruit growth regulation- role of hormones.

Unit 2: Fruit Ripening and its Regulation

Approaches to improve shelf life – storage environment, water loss, respiration, Modified atmosphere, gaseous environment for storage, storage disorders, chilling injury.

Unit 3: Concept of Senescence and its Retardation

Physiology of senescence and options to regulate, Chemical regulation of senescence, maintenance of chlorophyll during storage, role of hormones/micronutrients in reducing senescence, Concept of stay green, advantages and limitations. Relevance of stay green traits in plant breeding for crop improvement.

Block 3: Protective Cultivation–Stress Mitigation

Unit 1: Protective Cultivation Interventions to Alter Physiological Processes and Growth

Spectral characteristics of light in polyhouse, light regulation to optimize plant photosynthetic and photomorphogenic processes and plant growth, LED sources of monochromatic light to regulate growth, etiolating and flowering, High temperature induced thermomorphogenic processes, Artificial growing media, soilless cultures, aeroponics, fogoponics, Concept of CO_2 fertilization. Effect of humidity on leaf expansion and growth.

Unit 2: Drought Mitigation Options and Approaches

Moisture conservation options at soil and plant level, Concept of increasing water holding capacity, role of Hydrogels – water and mineral nutrients release pattern. Approaches to improve transpiration over evapo-transpiration, stomatal and non-stomatal regulation of water loss, antitranspirants, Osmoprotectants, ROS scavengers, plant nutrients, Root stocks in improving tolerance, Chemical regulation of flower drop due to temperature, Chemicals to improve pollen viability during abiotic stress.

Unit 3: Specific Plant Processes Regulated by Chemicals and Growth Hormones

Rooting of cuttings, Wine brewing industry, Promotion of gynoecious flower, Hybrid rice production, Induction of flowering in pine apple, cucurbits, Delaying of senescence and ripening, Production of dwarf plant for ornamental purpose, Reduction in flower and fruit drop, Increase in berry size in grapes.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

VIII. Suggested Reading

- Wu X, Ning F, Hu X and Wang W. 2017. *Genetic Modification for Improving Seed Vigor Is Transitioning from Model Plantsto Crop Plants. Front. Plant Sci*. 8: 8. doi: 10.3389/fpls.2017.00008
- William E. Finch-Savage and Steven Footitt. 2017. *Seed dormancy cycling and the regulation of dormancy mechanisms to time germination in variable field environments Journal of Experimental Botany*, 68, (4), 843 856, https://doi.org/10.1093/jxb/ erw477
- Afzal I, Ur Rehman H, Naveed M and ShahzadMaqsood, Basra A. 2016. *Recent Advances in Seed Enhancements* Intech.
- *Techniques and Experiments Plant Tissue Culture Techniques and Experiments* Elsevier Inc. 2013.
- Nanda AK and Melnyk CW. 2018. *The role of plant hormones during grafting. Plant Res*. 131(1): 49–58. doi: 10.1007/s10265-017-0994-5PMCID: PMC5762790
- Casa JJ and Balasubramanian. SK 2019. *Thermomorphogenesis, Annual Review of Plant Biology*, 70: 321-346 https://doi.org/10.1146/annurev-arplant-050718-095919
- Halevy AH. 2018. *Handbook of Flowering*. V*CRC press*
- Watson A, Ghosh S, Lee T. Hickey. 2018. *Speed breeding is a powerful tool to accelerate crop research and breeding. Nature Plants* 4, 23–29.
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- Bian, Z., Jiang, N., Grundy, S. and Lu, C., 2017. *Uncovering LED light effects on plant growth: new angles and perspectives-LED light for improving plant growth, nutrition and energy-use efficiency*. In *International Symposium on New Technologies for Environment Control, Energy-Saving and Crop Production in Greenhouse and Plant* 1227. 491-498.
- Barrett, G.E., Alexander, P.D., Robinson, J.S. and Bragg, N.C., 2016. *Achieving environmentally sustainable growing media for soilless plant cultivation systems–A review. Scientia horticulturae*, 212: 220-234.
- Raviv, M., Lieth, J.H. and Bar-Tal, A. (eds), 2019. *Soilless Culture: Theory and Practice: Theory and Practice*. Elsevier.
- Wang, P., Deng, Y., Li, X.Y., Wei, Z., Hu, X., Tian, F., Wu, X., Huang, Y., Ma, Y.J., Zhang, C. and Wang, Y. 2019. *Dynamical effects of plastic mulch on evapotranspiration partitioning in a mulched agriculture ecosystem: Measurement with numerical modeling. Agricultural and Forest Meteorology*, 268: 98-108.
- GernotBodner, Alireza, Hans-Peter *Management of crop water under drought: A review. Agronomy for sustainable development*. 2: 401-442

Course Title with Credit Load
Ph.D. Plant Physiology

Course Code	Course Title	Credit Hours
PP 601	Functional Genomics and Genes Associated with a Few Physiological Processes	2+0
PP 602*	Signal Perceptions and Transduction and Regulation of Physiological Processes	2+0
PP 603	Molecular Approaches for Improving Physiological Mechanisms Through Trait Introgression	2+1
PP 604	Plant Phenomics – Next Generation Phenomics Platforms	2+0
PP 605	Experimental Techniques to Characterize Plant Processes for Crop Improvement	0+2
PP 606	Global Climate Change and Crop Response	2+0
PP 607*	Physiological and Molecular Aspects of Source-sink Capacity for Enhancing Yield	3+0
PP 608	Seed and Fruit Growth and their Quality Improvement	2+0
PP 609	Plant-microbe Interactions	2+1
PP 610	Weed Biology and Physiology of Herbicide Action	2+0
PP 691	Doctoral Seminar I	1+0
PP 692	Doctoral Seminar II	1+0
PP 699	Doctoral Research	75

*Core courses

Course Contents
Ph.D. in Plant Physiology

I. Course Title : Functional Genomics and Genes Associated with a Few Physiological Processes

II. Course Code : PP 601

III. Credit Hours : 2+0

IV. Why this Course?

Agriculture in India faces tremendous challenges on multiple fronts. There is a need for targeted improvement of crops to meet the increasing food demand. Thorough understanding of the plant physiological processes, pathways and genes associated with the pathways are needed for speed breeding and trait improvement. With help of modern tools and techniques, in the genomic ear, a large amount of data on genomic resources has been developed. The post-genomic era concentrates on assigning functions to the every gene identified in plants. The PhD scholar working on plant biology and related field must be exposed to recent trends and developments in this new emerging area. The major emphasis would be on new developments in genomics to regulate plant growth.

V. Aim of the Course

The major goal is to expose the students of higher education program on functional genomic approaches, which is needed for crop improvement in a targeted way:

(i) Identify genes regulating the specific mechanisms/traits.

(ii) Assess the relevance of physiological processes/mechanisms and options to combine/ introgress them.

The course is organized as follows:

No.	Blocks	Units
1.	Functional Genomics and Genes: Physiological Processes	1. Gene Discovery
		2. Genetic Tools for Plant Development
		3. Gene Knock Out Approaches
		4. Chemical Genomics
		5. Gene Over Expression Approaches
		6. Synthetic Biology and Interaction Studies
		7. Case Studies

VI. Theory

Block 1: Functional Genomics And Genes: Physiological Processes

Unit 1: Gene Discovery

Finding genes in complex plant system, Constructing gene-enriched plant genomic libraries, Recent advancements in genome sequencing, RNA sequencing and expression, In Silico prediction of plant gene function, Quantitative Trait Locus analysis as a gene discovery tool, Gene expression analysis –micro-array and deep sequencing, small RNA and Degradome, Study of methylome and its significance

Unit 2: Genetic Tools for Plant Development

Understanding the importance of mutants in unrevealing the physiological processes, genome wide insertional mutagenesis – T-DNA insertion mutants, Gain in function, Transposon mutagens, Transposition, Physical and Chemical mutagenesis, Gene and Enhancer Traps for Gene Discovery, High-Throughput TAIL-PCR as a Tool to identify DNA Flanking insertions, High-Throughput TILLING for functional Genomics, Genome editing approaches for functional analysis of genes.

Unit 3: Gene Knock Out Approaches

PTGS-Antisense technology, Virus induced gene silencing (VIGS), Custom Knock-outs with Haripin RNA-mediated Gene Silencing and other silencing tools, Complementation studies.

Unit 4: Chemical Genomics

Reverse chemical genomic approaches for functional validation of genes, Protein structure prediction, homology modelling and virtual screening by using bioinformatic approaches to identify the small molecules and their validation through phenotyping assessment.

Unit 5: Gene Over Expression Approaches

Vector Construction for Gene Overexpression as a Tool to Elucidate Gene Function Transient expression, Transgenics, Targeted and conditional expression of transgene. Multiple gene expression by Nanostring technology, Co-expression analysis and gene networking to identify potential genes in the pathway (informatics), Epigenetics.

Unit 6: Synthetic Biology and Interaction Studies

Engineering microbial pathways in plants (eg, photosynthesis), DNA-protein & Protein-protein interaction studies, yeast hybrid system, Correlating the data from genome, transcriptome, proteome, metabolome and ionome with phenome, Multivariate analysis and identification of metabolite as biomarkers.

Unit 7: Case Studies

Functional characterization of genes associated with important cellular processes influencing crop growth and development: genes controlling photosynthesis and nutrient uptake, Functional characterization of genes associated with important cellular processes influencing crop growth and development: genes controlling respiration and photorespiration, Functional characterization of genes associated with important cellular processes influencing crop growth and development: fatty acid biosynthesis, seed protein quality and quantity, Functional characterization of genes associated with important cellular processes influencing crop growth and development: genes controlling flowering.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

VIII. Learning outcome

After successful completion of this course students are expected to have in depth knowledge on the genetic tools for plant development.

IX. Suggested Reading

Regulation of Gene Expression in Plants. **Gatehouse JA. 1997.** ***Plant Biochemistry.***

Plant genome sequencing, Fleury D, Langridge P. 2012. *Plant Biotechnology and Agriculture.*
Baxevanis, A. D. and Ouellette, B. F. F. (eds). 2001. *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins, Methods of Biochemical Analysis*, vol. 43, 2nd ed., New York: John Wiley and Sons, Inc.
Gene Expression Analysis: Methods and Protocols, Raghavachari N, Garcia-Reyero, N (Eds.) 2018. ISBN 978-1-4939-7834-2, Springer
Transcriptome Data Analysis: Methods and Protocols. Wang Y, Sun, M (Eds.), 2018. ISBN 978-1-4939-7710-9; Springer
Comparative Genomics: Methods and Protocols. Setubal, J C., Stoye, Stadler P (Eds.) ISBN 978-1-4939-7463-4; Springer

- Rosenberg E. 2017. *It's in Your DNA*. 2017
- *Recombinant DNA Technology and Genetically Modified Organisms*. 2017. Nambisan P. An Introduction to Ethical, Safety and Intellectual Property Rights Issues in Biotechnology.
- He F, Zhang F, Sun W, Ning, and Wang GL. 2018. *A Versatile Vector Toolkit for Functional Analysis of Rice Genes* 11: 27.doi: 10.1186/s12284-018-0220-7.
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- Bhardwaj R, Singh R. 2014. *Gene Silencing in Emerging Technologies and Management of Crop Stress Tolerance*, Volume 1.
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- *Gene Overexpression in Cereals for Functional Genomics and Discovery of Useful Genes*, Abe K and Ichikawa H. 2016. *Front Plant Sci.* 7: 1359. doi: 10.3389/fpls.2016.01359
- *Gene Overexpression: Uses, Mechanisms, and Interpretation*, Prelich G. 2012. 190 no. 3 841-854; https://doi.org/10.1534/genetics.111.136911
- Wusheng Liu C. Neal Stewart Jr *Plant synthetic biology* https://doi.org/10.1016/j.tplants.2015.02.004, REVIEW| 20, 5, P309-317, 2015
- *Plant Synthetic Biology*: Quantifying the "Known Unknowns" and Discovering the "Unknown Unknowns" R. Clay Wright, Jennifer Nemhauser, 2019. DOI: https://doi.org/10.1104/pp.18.01222
- *Plant synthetic biology for molecular engineering of signalling and development.* Nemhauser JL and Torii KU. 2016. *Nat Plants* 2: 16010.doi: 10.1038/nplants.2016.10

I. Course Title : Signal Perceptions And Transduction And Regulation Of Physiological Processes

II. Course Code : PP 602*

III. Credit Hours : 2+0

IV. Why this course?

Biosignaling is emerging as an import fields in plant biology. Thorough understanding of signal perception, activation and cellular changes associated is needed for manipulation of specific traits or events in plants. The M.Sc. PhD scholar working on plant biology and related field must be exposed to this new emerging area. Plant response to external and internal factors is mainly through signal perception and amplification leading gene expression which brings in altered metabolism regulating physiological and biochemical processes and finally plant processes and growth. The course provides insights on the diverse receptors, ligand receptor interaction and the role of secondary messengers in signal amplification leading to gene expression and finally regulating plant growth.

V. Aim of the course

Objective of this course is to provide comprehensive exposure on different signaling events and associated cellular changes in plants. The course will include lectures on the signalling mechanisms employed by plants to perceive and transduce environmental signals.

The course is organized as follows:

No	Blocks	Units
1	Signal Perceptions and Transduction: Regulation of Physiological Processes	1. Concept of Receptor and Ligands 2. Receptors – Signal Perception and Transfer 3. Hormone Signaling 4. Light Signaling 5. Abiotic Stress Signaling and Nutrient Signalling 6. Signaling Cascade during Developmental Events 7. Signal Perception and Transduction in Plant Defense Responses

VI. Theory

Block 1: Signal Perceptions and Transduction: Regulation of Physiological Processes

Unit 1: Concept of Receptor and Ligands

Signal, signal types, long (diffusible) and short (contact) range signaling and components of signaling. Types of receptors, nature of ligands, downstream components like primary, secondary signaling components.

Unit 2: Receptors – Signal Perception and Transfer

Cell surface trans-membrane receptors- GPCRs, Receptor Tyrosine Kinases (RTKs), Receptors Serine Threonine kinases (RSTKs), Receptor-Like Kinases (RLKs), receptor two component systems. Signal transfer phosphor-relay and generation of secondary signaling components and activation of TFs or enzymes. Downstream components- G-proteins, second messengers-Cyclic AMP, Adenylate cyclase cascade, cyclic GMP, calcium-calmodulin-kinases; effector molecules (transcription factor).

Unit 3: Hormone Signaling

Hormone binding receptors-Transduction process. Effector molecules and gene expression. Specific signaling pathways of Auxins, Cytokinin, Gibberellins, Ethylene, ABA, Brassinosteroids, Salicylic Acid, Strigolactone, polyamines, Jasmonic acid, etc. which leads to formative effects. Cross talk in the signaling of different hormones-significance of studies with hormone action mutants.

Unit 4: Light Signaling

Perception of light-pigments involved- activation of phytochrome/cryptochrome (study of mutants). Light signal transduction. Multiple signaling cascades-identification of signaling components through mutant analysis-changes in gene expression.

Unit 5: Abiotic Stress Signaling and Nutrient Signalling

Sensing of environmental factors (Temperature-Osmotic-Ionic stress), Activation of specific molecules and secondary messengers, activation of downstream components-leading to stress gene expression, Case studies with different abiotic stresses, Retrograde signaling, Nitrogen fixation, nitrogen and phosphorus uptake, nutrient translocation.

Unit 6: Signaling Cascade during Developmental Events

Leaf senescence/fruit development and ripening, Tuberization, Sugar signaling. Signaling during seed germination.

Unit 7: Signal Perception and Transduction in Plant Defense Responses

General mechanisms to pathogen response, Role of salicylic acid and active oxygen species, Cross Talk Signaling- Stress matrix under field conditions, cross talk between abiotic-abiotic stress, biotic-abiotic stress signaling networks.

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation

VIII. Learning outcome

By the end of this course, the student will be able to:

1. comprehendvarioussignaling events and associated physiological changes in plants.
2. understand the diverse roles of receptors, ligand receptor interaction and the role of secondary messengers in signal amplification leading to gene expression.

IX. Suggested Reading

- He, Y., Zhou, J., Shan, L. and Meng, X., 2018. *Plant cell surface receptor-mediated signaling–a common theme amid diversity*. J Cell Sci, 131(2), p.jcs209353.
- Hall, M.A., Smith, A.R., Novikova, G.V. and Moshkov, I.E., 1999. *Perception and transduction of ethylene. New Comprehensive Biochemistry*, 33, 475-490.
- Huber, A.E. and Bauerle, T.L., 2016. *Long-distance plant signaling pathways in response to multiple stressors: the gap in knowledge. Journal of Experimental Botany*, 67(7), 2063-2079.
- Pollard, T.D., Earnshaw, W.C., Lippincott-Schwartz, J. and Johnson, G., 2016. *Cell Biology* E-Book. Elsevier Health Sciences.
- Braun, Y., Smirnova, A.V., Weingart, H., Schenk, A. and Ullrich, M.S., 2007. *A temperature sensing histidine kinase—function, genetics, and membrane topology*. Methods In Enzymology: 423: 222-249. Academic Press.
- Unden, G., Wörner, S. and Monzel, C., 2016. *Cooperation of secondary transporters and sensor kinases in transmembrane signalling: the DctA/DcuS and DcuB/DcuS sensor complexes of Escherichia coli. In Advances in Microbial Physiology* (Vol. 68, 139-167). Academic Press.
- Ortiz-Urquiza, A. and Keyhani, N.O., 2016. Molecular genetics of *Beauveria bassiana* infection of insects. *Advances in Genetics* 94: 165-249). Academic Press.
- Snijders, L. and Naguib, M., 2017. *Communication in animal social networks: a missing link. Adv Study Behav*, 49, pp.297-359.

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- Chow, B. and McCourt, P., 2006. *Plant hormone receptors: perception is everything. Genes and development,* 2015, 1998-2008.
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I. Course Title : Molecular Approaches for Improving Physiological Mechanisms through Trait Introgression

II. Course Code : PP 603

III. Credit Hours : 2+1

IV. Why this Course?

Phenomenal progress in understanding the basic physiological mechanisms that determine crop performance has been made in recent years. Extensive deciphering of the molecular and genetic basis of variations in these mechanisms has led to the enumeration of several “physiological traits” that have enormous relevance to improve yield potentials as well as adaptation to various biotic and abiotic stresses. Although most of the physiological traits have been considered as complex and hard to breed, recent advances in understanding the sub-components of most of the major mechanisms coupled with the progress made in “phenotyping” to capture genetic variability in such subcomponent traits have paved way for the adoption of “trait based breeding” approaches. The tremendous progresses made in genomics have also led to the development of extensive molecular and genetic resources that can be used for a focused “breeding by design”.

V. Aim of the course

Deep understanding of modern translational research methods such as molecular breeding, transgenics, genome editing, grafting and reverse breeding approaches such as Doubled haploidization will be provided to the students. Contemporary developments in molecular approaches in accelerated crop improvement would be dealt with. Acquainting with the approaches and techniques is crucial for young students to groom themselves into focused and successful scientists in future. Theoretical and practical concepts of trait introgression (or trait pyramiding) will be discussed in this course so as to provide recent developments in this area of research. To acquaint with regulatory aspects of working with transgenic plants is crucial and will be discussed elaborately.

The course is organized as follows:

No.	Blocks	Units
1.	Trait Introgression through Molecular Breeding	1. Physiological Traits Relevant for Crop Improvement and their Phenotyping 2. Identification of QTL by Bi-parental Mapping Approach 3. Identification of QTLs by Association Mapping Approach 4. Trait Introgression by Molecular Breeding Approaches
2.	Trait Introgression through Transgenic Technology	1. Gene Discovery and Gene Constructs for Relevant Plant Traits/Adaptive Mechanisms 2. Trait Improvement or Pyramiding through Transgenic Technology 3. Genome Editing, a Potential Option for Gene Regulation by Transgenic Approach 4. Characterization of Transformed Plants and Event Selection Strategies
3.	Other Approaches for Trait Introgression	1. Trait Introgression through Tissue Grafting and Asexual Propagation 2. Doubled haploids for Trait Introgression

VI. Theory

Block 1: Trait Introgression through Molecular Breeding

Unit 1: Physiological Traits Relevant for Crop Improvement and their Phenotyping

Physiological traits with relevance to growth, development, biotic/abiotic stress tolerance, nutrient acquisition, Concept of complex, multi-gene control of physiological traits, Concepts of trait introgression to augment crop productivity and/or stress adaptation.

Unit 2: Identification of QTL by Bi-parental Mapping Approach

Concepts of developing trait-specific mapping population and identification of contrasting parental lines through phenotyping, Mapping populations and their developments – F_2, RIL, doubled haploid populations, Accurate phenotyping of bi-parental mapping populations, Conventional Genotyping strategies using SNP and SSR markers, other rapid approaches like GBS, RADseq, QTLseq etc., Composite interval mapping and other approaches for QTL discovery.

Unit 3: Identification of QTLs by Association Mapping Approach

Concepts of assembling a "Panel" of germplasm amenable for association mapping based on molecular and phenotypic diversity, Concepts of linkage disequilibrium, LD decay and population structure, Concepts QTL discovery in structured populations. Phenotyping of the association mapping populations, Concepts of Genome wide association studies (GWAS).

Unit 4: Trait Introgression by Molecular Breeding Approaches

Strategies for QTL introgression and Marker Assisted Selection (MAS), Various breeding methods for trait introgression: Marker assisted backcross breeding (MABC), Marker assisted recurrent selection (MARS), Marker assisted phenotypic selection (MAPS), etc.

Block 2: Trait Introgression through Transgenic Technology

Unit 1: Gene Discovery and Gene Constructs for Relevant Plant Traits/ Adaptive Mechanisms

Map-based cloning to identify novel genes and their allelic variants, Identification of differentially expressed genes through transcriptome, metabolome and proteome analysis in contrasting genotypes, Gene identification through forward (inducing mutations with radiation, chemicals, or insertional mutagenesis)and reverse genetic approaches (site-directed mutagenesis, gene knockout or knockdown), Cloning full-length candidate genes, inducible promoters, Concepts of "codon optimization" to make constructs for specific crops.

Unit 2: Trait Improvement or Pyramiding through Transgenic Technology

Introduction to GMOs and its application in crop improvement, Gene stacking strategies for trait improvement, *Agrobacterium* and other methods of plant transformation including gene gun, *in planta*, etc.

Unit 3: Genome Editing, a Potential Option for Gene Regulation by Transgenic Approach

Genome editing techniques: CRISPR/Cas9, Zinc finger nucleases, etc, CRISPR as tool to generate loss-of-function and gain-of-function transgenics.

Unit 4: Characterization of Transformed Plants and Event Selection Strategies

Molecular analysis bySouthern, qRT-PCR/Northern analysis, and immunoassays, Concepts of copy number and desirable number of independent events, Evaluation of transgenics based on empirical/physiological/biochemical processes under specific conditions – containment and confined field trials, Generation of T1 populations, event characterization, Molecular data as per regulatory requirements, Biosafety and Regulatory aspects of GMO.

Block 3: Other Approaches for Trait Introgression

Unit 1: Trait Introgression through Tissue Grafting and Asexual Propagation

Concept of identifying root stocks with superior traits, grafting, scion root stock interaction, compatibility, concept of chimeric grafting in transgenic technology involving a non-transgenic shoot to a transgenic root.

Unit 2: Doubled haploids for Trait Introgression

Concept of crossing trait donor lines and developing doubled haploids from the F1 anthers, Screening and identifying trait introgressed doubled haploids.

VII. Practicals

- Phenotyping approaches for the different physiological traits. Development of SSR, SNP and SCAR markers, resolution of polymorphism on agarose gels and PAGE, genotyping options for SSR markers using capillary and chip based fragment analysis systems. scoring of gels and assessment of polymorphism
- Statistical approaches to assess genetic variability, heritability and other parameters. Phylogenetic analysis and principle component analysis and construction of dendrograms. Construction of Linkage map, QTL maps, population structure, LD decay etc leading to identification of QTLs.
- Bioinformatics – sequence analysis, structure analysis, designing primers for SSR regions, SNP2CAPS approaches of genotyping.
- Molecular biology - genomic/plasmid DNA isolation, RNA isolation. Full-length gene cloning, vector construction with specific promoter, gene stacking and transient assays. Transformation in model system
- Crop transformation - *Agrobacterium* mediated transformation (in-planta and invitro), particle-gun transformation.
- Evaluation of transgenics – semiquantitative and quantitative RT-PCR, southern blot, northern blot, western blot and ELISA, biochemical/physiological assay based on the function of gene and testing LOD.
- Improvement of traits based on grafting options.
- Techniques in developing doubled haploids and characterization.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

1. comprehend the basic concepts of modern translational research methods such as molecular breeding, transgenics, genome editing, grafting etc.
2. describe reverse breeding approaches such as doubled haploidization
3. accumulate both theoretical and practical concepts of trait introgression

X. Suggested Reading

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Reynolds M and Langridge P. 2016. *Physiological Breeding*. Current Opinion in Plant Biology, 31: 162–17.1

Sheshshayee MS, Preethi NV, Rohini S, Sowmya HR, Smitharani A, Pooja B, Prathibha MD and Soolanayakanahally R. 2018. *Introgression of Physiological Traits for a Comprehensive Improvement of Drought Adaptation in Crop Plants. Front. Chem.*, 10.

Cossani M and Reynolds M. 2012. *Physiological Traits for Improving Heat Tolerance in Wheat. Plant Physiology*, Vol. **160**: 1710–1718

Payne T, Reynolds M and Skovmand B. *Searching genetic resources for useful variation in physiological traits* Chapter 5. *Physiological Breeding* I: Interdisciplinary Approaches to Improve Crop Adaptation Reynolds, M.P. (ed).

Bonnett D. *Optimizing marker-assisted selection (MAS) strategies for crop improvement*. Chapter 14: 153 Physiological Breeding I: Interdisciplinary Approaches to Improve Crop Adaptation Reynolds, M.P. (ed).

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- Collard BCY, Jahufer MZZ, Brouwer JB and Pang ECK. *An introduction to markers, quantitative trait loci (QTL) mapping and marker-assisted selection for crop improvement: The basic concepts.Euphytica* 142: 169–196
- Lipka AE, Kandianis CB, Hudson ME, Yu J, Drnevich J, Bradbury PJ and Gore MA. 2015. From association to prediction: statistical methods for the dissection and selection of complex traits in plants. *Current Opinion in Plant Biology* 2015, 24: 110–118
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- Sandhu N, Dixit S., Swamy BPM, Raman A, Kumar S, Singh SP., ... and Yadav S. 2019. *Marker Assisted Breeding to Develop Multiple Stress Tolerant Varieties for Flood and Drought Prone Areas. Rice*, 12(1): 8.
- Assefa T, Mahama AA, Brown AV, Cannon EK, Rubyogo JC, Rao IM and Cannon SB. 2019. *A review of breeding objectives, genomic resources, and marker-assisted methods in common bean* (Phaseolus vulgaris L.). *Molecular Breeding*, 39(2), 20.
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I. Course Title : Plant Phenomics-next Generation Phenomics Platforms

II. Course Code : PP 604

III. Credit Hours : 2+0

IV. Why this course?

Crop improvement in the present scenario is increasing focusing on trait based breeding. The phenomenal progress made in genomics cannot be exploited for improving plant traits/mechanisms unless phenotyping technologies are developed to capture genetic variability. Several technologies have been developed to accurately quantify genetic variability in specific traits.

V. Aim of the course

The course aims at providing cutting edge knowledge on the current progress made in various phenotyping techniques and approaches. The students will be versed with principles of various phenotyping approaches. The aim is to provide hands-on expertise in analyzing trait diversity. Exposure will be provided on Non-invasive imaging technologies that drive the phenomics platforms. The course provides comprehensive exposure on recent developments in phenomics platforms imaging tools/techniques and recent trends in designing specific phenomics platforms e.g. drought studies/root phenotyping etc.
The course is organized as follows:

No	Blocks	Units
1.	Concepts of High throughput Phenotyping and its Requirement	1. Concepts of Phenotyping 2. Physio-Morphological Traits Associated with Crop Performance 3. Features of Phenomic Platforms 4. Trends in Phenomics 5. Non-invasive Phenotyping Approaches
2.	Applications of the Phenomics Platforms	1. Basic Studies to Assess the Crop Response 2. Applied Studies Focused on Crop Improvement Programs

VU, Theory

Block 1: Concepts of High throughput Phenotyping and its Requirement

Unit 1: Concepts of Phenotyping

The concepts of “phene and trait” analogous to gene and allele. Genome-phenome relationship, definition of phenotyping, GxE interaction on phenome.

Unit 2: Physio-Morphological Traits Associated with Crop Performance

Overview of phenotyping needs to complement genomic resources, specific traits associated with yield potential, stress adaptation (both biotic and abiotic stresses). Need for high throughput precision phenotyping approaches for basic studies and to generate genetic and genomic resources.

Unit 3: Features of Phenomic Platforms

Precision growth conditions, maintenance of light, temperature/VPD and RH to realize the potential crop growth response, Controlled environmental facilities for simulating challenging climatic conditions to phenotype diverse plant traits, Concept of sensors, diverse sensors and their utility in precise quantification of environmental variables, soil moisture sensors, Imaging to capture plant traits, image acquisition. Automated big data access, processing, etc.

Unit 4: Trends in Phenomics

Types of phenomic platforms- Laboratory, Greenhouse and the field-based platforms. Platforms designed for specific needs i.e., root phenotyping, drought studies etc., Crop specific phenotyping, mobile and stationary platforms, Global trends in establishing major phenomics platforms, and their characteristic features and impact.

Unit 5: Non-invasive Phenotyping Approaches

The concept of non-invasive capturing of plant growth and health, Imaging technologies - image acquisition, segmentation and data analysis, Critical aspects of Visual, IR Thermal, Fluorescence, NIR, Hyperspectral imaging, Development and validation of models for deriving relevant physiological traits from image phenome. Concepts of Plants to sensors and sensors to plants, Stationary and ground based tractor mounted sensors/imaging tools, Unmanned aerial vehicle (UAV) sensors, Machine learning and its integration to analyze ground and aerial based images.

Block 2: Applications of the Phenomics Platforms

Unit 1: Basic Studies to Assess the Crop Response

Functional validation of genes, chemicals and other interventions, Characterize the growth and stress response in contrasts to identify the relevance of adaptive trait.

Unit 2: Applied Studies Focused on Crop Improvement Programs

Characterizing the pre-released promising lines for productivity under defined environmental variables. Phenotyping germplasm accessions, mapping populations for specific traits for mapping, Concept of Phenome Wide Association Studies (PWAS). Genomic selection, gene-based crop models to predict complex traits, Impact of phenomics platform, progress made, case studies.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

VIII. Learning outcome

By the end of this course, the student will be able to understand the current progress made in various phenotyping techniques and approaches.

IX. Suggested Reading

- Pieruschka R and Poorter H. 2012. *Phenotyping plants: genes, phenes and machines. Functional Plant Biology*, 39(11), 813-820.
- Noah F, Gehan MA and Baxter I. 2015. *Lights, camera, action: high-throughput plant phenotyping is ready for a close-up. Current Opinion in Plant Biology* 24 2015: 93-99.
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- Development of high throughput plant phenotyping facilities at aberystwyth (ppt)
- Zhou J, Reynolds D, Websdale D, Le Cornu T, Gonzalez-Navarro O, Lister C and Clark M. 2017. *CropQuant: An automated and scalable field phenotyping platform for crop monitoring and trait measurements to facilitate breeding and digital agriculture*. BioRxiv, 161547.
- Bradshaw JE. 2017. *Plant breeding: past, present and future. Euphytica*, 213(3), 60.
- Lee U, Chang S, Putra GA, Kim H and Kim DH. 2018. *An automated, high-throughput plant phenotyping system using machine learning-based plant segmentation and image analysis. PloS one*, 13(4), e0196615.
- Furbank RT and Tester M. 2011. *Phenomics–technologies to relieve the phenotyping bottleneck. Trends in Plant Science* 16(12): 635-644.

I. Course Title : Experimental Techniques to Characterize Plant Processes for Crop Improvement

II. Course Code : PP 605

III. Credit Hours : 0+2

IV. Why this Course?

Techniques, tools and instrumentation facilities drive the research in modern biology. The course addresses recent developments related to advanced quantification methods based on novel methodologies and instruments. Besides the emphasis is on new emerging trends in assessing physiological and biochemical processes based on surrogate methods. Several molecular biology techniques are now essential to comprehend physiological processes. The course provide comprehensive picture on these areas addressing recent developments in this area.

V. Aim of the course

Aim of this course is to provide exposure to phenotype very specific physiological processes which have direct relevance in crop improvement programmes. The course provides insight on recent techniques and methodologies on each of the major physiological processes like stress responses, photosynthetic process, hormone area, photo-morphogenesis and genomics aspects.

The course is organized as follows:

No.	Blocks	Units
1.	Characterization of Plant Processes: Experimental Techniques and Crop Improvement	1. Stress Responses 2. Photosynthetic processes 3. Hormonal Response on Specific Plant Growth Processes and Quantification 4. Nutrient Response Acquisition and Quantification 5. Photo and Thermo Morphogenesis 6. Recent Approaches for Functional Genomics

VI. Theory

Block 1: Characterization of Plant Processes: Experimental Techniques and Crop Improvement

Unit 1: Stress Responses

Thermal (reflectance) characters as a measure of water status and root characteristics, Oxidative stress induction and assessing the response on lipid peroxidation and quantification of ROS, RCC's, RNS, Fluorescence to assess the stress response, Water use efficiency quantification at leaf, plant level, surrogates for WUE, Tissue localization of ROS, RNS by qualitative staining and fluorescence-based methods.

Unit 2: Photosynthetic processes

Concept and approaches to assess of radiation utilization efficiency (RUE), Quantification of mesophyll and other diffusive resistances regulating photosynthesis. Carboxylation efficiency (light and CO_2 response curves), RuBiSCO activation status

Unit 3: Hormonal Response on Specific Plant Growth Processes and Quantification

Bioassays to assess the biological process regulated by hormones – new in-vivo assays, Promoter assays for hormone response- GUS/YFP/GFP based assays-expression of hormone responsive genes, Recent analytical tools and techniques to quantify hormones – GC-MS, LC-MS, Capillary electrophoresis.

Unit 4: Nutrient Response Acquisition and Quantification

Recent advances in soil less cultures to study the nutrient response- Hydroponics/

Aeroponics/Fogoponics, Noninvasive techniques to quantify nutrients – XRD (X-Ray Diffraction analysis) and hyper spectral reflectance.

Unit 5: Photo and Thermo Morphogenesis

Photo receptors, light and temperature regulation of plant growth and flowering, Thermal time, heat units, GDD, Concept and approaches for speed breeding.

Unit 6: Recent Approaches for Functional Genomics

In silico prediction of gene function, Flanking sequence identification in insertional (T-DNA/transposon) mutants, Concept of insertional mutagenesis and mutant experiments, Utilization of genetic resources for functional genomics – mutants and tilling, eco tilling, VIGS, RNAi, miRNA, Genome editing –CRISPR, Concept of chemical genomics for functional validation, Relevant molecular tools to assess gene expression or (to regulate the process and assign a function to gene), Multiple gene expression by Nano String technology, Cap analysis gene expression (CAGE) – to identify start point of transcription, Yeast hybrid interaction, Immunoprecipitation, Chip-PCR.

VII. Teaching methods/activities

– Practical Assignments
– Results presentation

VIII. Learning outcome

After completion of this course students are expected to develop practical skill and knowledge on various experimental techniques employed in crop improvement programme. Moreover, students will have experience with characterization of plant processes.

IX. Suggested Reading

- Costa, Miguel and Grant, Olga and Chaves M. 2013. *Thermography to explore plant-environment interactions. Journal of Experimental Botany* **64**. 10.1093/jxb/ert029.
- Padhi Jyotiprakash and K Misra R and Payero Jose. 2009. *Use of infrared thermography to detect water deficit response in an irrigated cotton crop*.
- Root Phenotyping for Drought Tolerance: A Review, Wasaya A, Zhang X, Fang Q and Yan Z. 2018. *Agronomy* 8, 241; doi: 10.3390/agronomy8110241
- Zhang Y, Menghong D and Zonghui Y. 2018. *Methods for the detection of reactive oxygen species. Analytical Methods* 10 (38): 4625-4638.
- Maxwell K and Giles NJ. 2000. *Chlorophyll fluorescence—a practical guide. Journal of Experimental Botany* 51 (345): 659-668.
- Sinclair TR and Muchow RC. 1999. *Radiation use efficiency. In Advances in Agronomy* 65: 215-265. Academic Press, 1999.
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- DeBlasio, Stacy L., Anne W. Sylvester, and Jackson D. 2010. *Illuminating plant biology: using fluorescent proteins for high-throughput analysis of protein localization and function in plants. Briefings in Functional Genomics* 9 (2): 129-138.
- Ljung K, Sandberg G, Moritz T. 2010. *Methods of Plant Hormone Analysis*. Davies P.J. (eds) *Plant Hormones*. Springer, Dordrecht
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- Qian F, Hong H, Zhao L, Kukolich S, Yin K and Wang C. 2018. *Visible and near-infrared reflectance spectroscopy for investigating soil mineralogy: a review. Journal of Spectroscopy*.
- Moe, Roar and Heins RD. 2000. *Thermo-and photomorphogenesis in plants. Advances in Floriculture Research Report* 6 : 52-64.
- Watson A, Ghosh S, Matthew JW, Cuddy WS, Simmonds J, Rey MD *et al*. 2018. *Speed breeding is a powerful tool to accelerate crop research and breeding. Nature Plants* 4 (1): 23.
- Kahl G and Khalid M (eds.). 2008. *The handbook of plant functional genomics: concepts and protocols.* John Wiley and Sons.
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- Shan Q, Wang Y, Li J, Yi Z, Chen K, Liang Z, Zhang K *et al*. 2013. *Targeted genome modification of crop plants using a CRISPR-Cas system. Nature Biotechnology* 31 (8): 686.
- Sadhukhan A and Sahoo L and Panda S. 2012. *Chemical Genomics in Plant Biology. Indian Journal of Biochemistry and Biophysics*. 49. 143-154.
- Fung TH, WeiwenXue V, Koh SP, Chiu YM, Ng LP and Wong SC. 2017. *NanoString, a novel digital color-coded barcode technology: current and future applications in molecular diagnostics. Expert review of molecular diagnostics* **17** (1): 95-103.
- Rimantas K, Kojima M, Nishiyori H, Nakamura M, Fukuda S, Tagami M, Sasaki *D et al*. 2006. *CAGE: cap analysis of gene expression." Nature Methods* 3 (3): 211.

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- Li L, Zhang Q and Huang D. 2014. *A Review of Imaging Techniques for Plant Phenotyping*. Sensors. 14, 20078-20111; doi: 10.3390/s141120078

I. Course Title : Global Climate Change and Crop Response

II. Course Code : PP 606

III. Credit Hours : 2+0

IV. Why this Course?

Present Indian agriculture encounters tremendous challenges due to rapid climate change. Climate change exerts remarkable negative impact on food, nutritional and ecological security. It significantly affects the plant physiological processes, hence yield is severely affected. Therefore students of plant physiology need to quip themselves with knowledge and skill sets required to navigate the climate change scenario and its impact on crops physiological processes. Hence, this course is designed .

V. Aim of the Course

The course is designed to provide basic knowledge on the subjects of crop responses to climate change. The aim of this course is to address both long-term and short-term effects of climate change on crops, natural vegetations and ecosystems.

The course is organized as follows:

No.	Blocks	Units
1.	Climate Change: Crop Response and Mitigation	1. Fundamentals of Climate Change 2. Manifestations of Climate Change 3. Major GHGs (CO_2, Methane, NO_2 etc.), their Production Rates, Monitoring and their Influence on Climate Change 4. Agricultural Practices on GHG Production 5. Direct and Indirect Effects of Climate Change on Plant Processes 6. Climate Change Scenario and Impact on Crops 7. Ozone Depletion leading to Increased Ionizing Radiations and its Implications on Crop Growth 8. Long-term and Short-term Projections of Climate Change: Effects on Natural Vegetation and Ecosystems 9. Technologies for Climate Change Mitigation in Agriculture 10. Climate-resilient Agriculture 11. Climate Change: Technologies for Crop Response Studies 12. Politics of Climate Change Negotiations

VI. Theory

Block 1: Climate Change: Crop Response and Mitigation

Unit 1: Fundamentals of Climate Change

Definition of climate change, history and evidences of climate change and its implications. Natural and anthropogenic climate change. Sources of Greenhouse Gas (GHG) emission, Global Warming Potential of GHGs, accumulation of GHGs in the atmosphere and science behind climate change, industrial revolution and GHG build-up in the atmosphere, Energy-Emission-Economy Interactions, carbon intensity of economy, carbon equity/justice.

Unit 2: Manifestations of Climate Change

Impact on monsoons, occurrence of extreme weather events, hydrological cycle and water availability, effect on crop growing period in tropics, subtropics and temperate regions, shifts in distribution of flora and fauna, effects on biodiversity and migration of tropical plant species to higher latitudes and altitudes.

Unit 3: Major GHGs (CO_2, Methane, NO_2, etc.), their Production Rates, Monitoring and their Influence on Climate Change

GHGs: An Overview, - role of CO_2, methane and major uncertainties. Mechanism of their production and emission from various, source and sinks of GHGs; and contribution of GHGs to global warming. Techniques used in monitoring GHGs.

Unit 4: Agricultural Practices on GHG Production

Carbon footprint analysis of agriculture and various agricultural practices contribute to climate change. Impacts of natural factors and farming practices on greenhouse gas emissions. Sources of agricultural GHG emission- Agricultural Soil Management, enteric fermentation, manure management, other sources. Opportunities to reduce GHG emission from Agriculture.

Unit 5: Direct and Indirect Effects of Climate Change on Plant Processes

Problems and Prospects of Crops with changing temperature: Growth and Development of Crop plants, Thermo-morphogenesis, phenology, Physiological processes such as photosynthesis, Net carbon assimilation, C_3 and C_4 plants adaptation,Respiration, Nutrient acquisition and metabolisms, Plant water relations and Heat shock proteins, Grain/seed development: Grain Quality parameters and yield.

Unit 6: Climate Change Scenario and Impact on Crops

Different scenarios for temperature, rainfall in different agro-climatic zones of India and their impact on crop growth and productivity. Major climate change (temperature, CO_2, and rainfall) impact quantification using field or controlled environment experiments, meta-analysis and simulation models. Some examples of crop simulation models calibration and their application in short-term and long-term predictions.

Unit 7: Ozone Depletion leading to Increased Ionizing Radiations and its Implications on Crop Growth

Role of CFCs in ozone depletion, penetration of ionizing UV radiations and its implications on crop growth.

Unit 8: Long-term and Short-term Projections of Climate Change: Effects on Natural Vegetation and Ecosystems

Response of natural ecosystems to increasingatmospheric CO_2 concentration and climate warming, effect of climate change on quality of feed i.e leaf and stored grains/seeds, its implications on pollinators and pests

Unit 9: Technologies for Climate Change Mitigation in Agriculture

Agricultural biotechnology to produce crop varieties with enhanced carbon uptake.
Nutrient management: Management of nitrogenous fertilizers.
Tillage/residue management: 1.Conservation tillage CO_2 mitigation technology; 2. Biochar: A potentialtechnique for carbon sequestration.
Methane mitigation using reduced tillage technology, change in methanogenic bacterial activity using electron acceptors.
Carbon sequestration potential, concept and measurement.

Unit 10: Climate-resilient Agriculture

Conventional and biotechnological approaches to improve the crop adaptation to climate change. Relevance of “Genome wide mutants” to identify genes/processes for improved adaptation to changing environments.

Unit 11: Climate Change: Technologies for Crop response studies

Temperature Gradient Chambers, Temperature Gradient Greenhouses, Soil plant atmosphere research system (SPAR), Infra-red warming Technology, Free Air temperature enrichment technology, Soil Warming system etc.

Unit 12: Politics of Climate Change Negotiations

IPCC, Major International conventions/treaties, Kyoto Protocol, Paris Agreement, Global initiatives on Carbon sequestration, carbon trading.

VII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

VIII. Learning outcome

After completion this course, students will be able to obtain in depth and basis knowledge on crop responses to climate change.

IX. Suggested Reading

- Uprety DC and Reddy VR. 2016. *Crop responses to Global warming*, Springer publication, ISBN 978-981-10-2004-9, pp 1-125 (2016)
- Torquebiau E. 2015. *Climate Change and Agriculture Worldwide* Springer Netherlands
- Lipper L, McCarthy N, Zilberman D, Asfaw S, Branca. 2018. *Climate Smart Agriculture: Building Resilience to Climate Change*. Springer, FAO.
- *Handbook of Climate Change and Agroecosystems: The Agricultural Model Intercomparison and Improvement Project* (AgMIP) in 2 parts Kindle Editionby Rosenzweig Cynthia and Hillel Daniel (Author), Cynthia Rosenzweig (Editor), 2015
- Climate Smart Agriculture FAO source book, 2013
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- Lamb HH. 2013. *Climate: Present, Past and Future* (Routledge Revivals): Volume 1: Fundamentals and Climate Now. Routledge.
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- Lobell, D.B. and Gourdji, S.M., 2012. *The influence of climate change on global crop productivity. Plant Physiology*, 160(4). 1686-1697.
- Tubiello, F.N., Soussana, J.F. and Howden, S.M., 2007. *Crop and pasture response to climate change. Proceedings of the National Academy of Sciences*, 104(50): 19686-19690.
- Iizumi, T., Furuya, J., Shen, Z., Kim, W., Okada, M., Fujimori, S., Hasegawa, T. and Nishimori, M., 2017. *Responses of crop yield growth to global temperature and socioeconomic changes. Scientific Reports*, 7(1), p.7800.
- Najafi, E., Devineni, N., Khanbilvardi, R.M. and Kogan, F., 2018. *Understanding the changes in global crop yields through changes in climate and technology. Earth's Future*, 6(3), 410-427.
- Wheeler, T. and Von Braun, J., 2013. *Climate change impacts on global food security. Science*, 341(6145), 508-513.
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- Lobell, D.B. and Field, C.B., 2007. *Global scale climate–crop yield relationships and the impacts of recent warming. Environmental Research Letters*, **2**(1), 014002.
- Howden, S.M., Soussana, J.F., Tubiello, F.N., Chhetri, N., Dunlop, M. and Meinke, H., 2007. *Adapting agriculture to climate change. Proceedings of the national academy of sciences,* 104(50), 19691-19696.

- Sanz-Cobena, A., Lassaletta, L., Aguilera, E., Del Prado, A., Garnier, J., Billen, G., Iglesias, A., Sanchez, B., Guardia, G., Abalos, D. and Plaza-Bonilla, D., 2017. *Strategies for greenhouse gas emissions mitigation in Mediterranean agriculture: A review. Agriculture, Ecosystems and Environment* 238: 5-24.
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- Uprety, D.C., Baruah, K.K. and Borah, L. 2011. *Methane in rice agriculture. J. Sci. Ind. Res.* **70**: 401-411.
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- Bhatia, A *et al.* 2010. *Mitigating nitrous oxide emission from soil under conventional and no tillage in wheat using nitrification inhibitors. Agriculture, Ecosystem and Environment*, **136** (3-4): 247-253.
- Datta A, *et al.* 2011. *Greenhouse gas emissions and rice based cropping systems: Economic and Technologic challenges and Opportunities. Mittig. Adapt. Strateg. Global Change*, **16** (5): 597-615.
- Uprety, D.C. 2014. *Greenhouse gases and Crops. Publishing India Group*, ISBN 978-81-928337-0-5, pp 250-308.
- Adhya, T.K., Patnaik, P, Satpathy, S.N., Kumarswami, S. and Sethunathan, N. 1998. *Influence of Phosphorus application on methane emission and production in flooded paddy soils. Soil Biol. Biochem* **30**: 177-181
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- Uprety, D.C., Dhar, S., Hongmin, D., Kimball, B.A., Garg, A and Upadhyay, J. (2012), *Technologies for Climate change Mitigation –Agriculture Sector- GEF*, TNA Guidebook series, UNEP RISO Center, DTU, Denmark, pp 1-117.
- Uprety, D.C., Baruah, K.K. and Borah, L. 2011. *Methane in rice agriculture. J. Sci. and Indust. Res.* **70** (6): 401-411
- IPCC AR5 Reports WG I 2013
- IPCC AR5 Reports WG II and III 2014
- IPCC Special Reports
- UNFCCC website
- IPCC website
- NOAA website
- CCAFS website
- India's Second National Communication to UNFCCC

- INCCA Report, MoEF and CC
- MoEF and CC website

I. Course Title : Physiological and Molecular Aspects of Source-sink Capacity for Enhancing Yield

II. Course Code : PP 607*

III. Credit Hours : 3+0

IV. Why this course?

Yield level reached plateau in many crops improving yield potential and crop growth rate forms the basis for further improvement in productivity. Photosynthesis and the establishing sink capacity are crucial processes to achieve this goal. Very good progress has been made in deciphering the molecular mechanisms to regulate several photosynthetic processes at cellular and canopy level. Similar insights now exist regarding establishing sink size (capacity). In the last five years, phenomenal conceptual approaches have been developed to understand the basic physiological and molecular mechanisms to enhance the source through photosynthetic processes. Besides, scientific insights in recent years provided leads in improving sink ie., yield associated traits. Yield plateau can be broken only by enhancing yield potential by structured improvement in source capacity and sink size.

V. Aim of the course

The course addresses the recent development in photosynthetic processes that can be exploited to improve yield potential. Besides, other major emphasis is to provide exposure on recent developments in regulating the sink characters ie., yield attributes at molecular level to achieve higher potential yields.

The course is organized as follows:

No.	Blocks	Units
1.	Source Size and Function- Basic Concepts, Physiological and Molecular Mechanisms, Genomic RESOURCES to Regulate Source Characters	1. Source Establishment 2. Source Function- Photochemical Reactions 3. Source Function- CO_2 Diffusion and Concentration 4. Source Function- Metabolic Engineering of CO_2 Fixation 5. Case Studies to Improve Source Capacity
2.	Improving Sink Size and Capacity	1. Sink Establishment 2. Increase the Sink Size by Enhancing the Relevant Constituent Traits 3. Genetic Genomic RESOURCES, Genes/QTLs, Genetic RESOURCES to Improve Sink Traits– Case Studies 4. Source to Support the Sink Capacity

VI. Theory

Block 1: Source Size and Function–Basic Concepts, Physiological and Molecular Mechanisms, Genomic Resources to Regulate Source Characters

Unit 1: Source Establishment

Maximize energy capture by improved light interception, light distribution and its utilization efficiency, concepts of shade avoidance response (SAR) and option to increase, Increase canopy size by vertical expansion – concept of increasing optimum LAI levels, Concepts of semi-tall varieties with resistance to lodging: traits associated with lodging resistance, Sustain net carbon gain with age – the relevance of stay green character, photon capture and achieve high CO_2 reduction to photon ratio under low light, Options for increasing canopy photosynthesis, Relevance of maintaining cell turgor and nutrient status.

Unit 2: Source Function- Photochemical Reactions

Maximize conversion efficiency of intercepted radiation by improving net carbon gain - Emerging solutions to increase carbon fixation rate, Improve efficiency of photochemical reaction by - Engineering the pigments to expand PAR spectrum into IR range; reduce antenna size, optimize energy dissipation mechanisms; optimize components of ETC and downstream acceptors; accelerate adaptation for shifting light intensities.

Unit 3: Source Function- CO_2 Diffusion and Concentration

Enhance stomatal conductance (g_s) and mesophyll conductance (g_m) – guard cell metabolism; concepts of leaf mesophyll tissue thickness (SLW), Concepts of VPD responses of g_s to enhance duration of photosynthesis during the day, Bicarbonate transports and aquaporins; achieve higher CCM - Engineering C4 cycle, CAM, cyanobacteria, carboxysomes, algal pyrenoids.

Unit 4: Source Function- Metabolic Engineering of CO_2 Fixation

RuBisCO carbon fixation activity - Increase and optimize kinetics of RuBisCO with enhanced specificity to CO_2, Engineer RuBisCO to minimize feedback regulation by metabolite inhibitors, Increased activation state by improving stability and function of RuBisCOactivase; optimize RuBp regeneration – modulate specific enzyme levels. New concepts on photorespiratory synthetic bypass.

Unit 5: Case Studies to Improve Source Capacity

Genetic and genomic resources, genes/QTLs associated with specific yield potential traits and/or photosynthetic mechanisms, Genetic resources to improve source traits-case studies.

Block 2: Improving Sink Size and Capacity

Unit 1: Sink Establishment

Optimise duration of phenological stages related to sink establishment, genetic and environmental factors, GDD and phenology.

Unit 2: Increase the Sink Size by Enhancing the Relevant Constituent Traits

Role of hormones in regulating molecular mechanisms of yield structure development, Genomic and genetic resources developed for regulation/improvement of such traits. – Sink Size: Tillering associated traits, branching patterns/fruiting points, spikelet number, pod number, fruit number. – Sink development: Basic concepts and molecular mechanisms associated with pollination, fertilization, ovary development in determining the spikelet fertility/sterility components and strategies for engineering seed/fruit size in crop plants.

Unit 3: Genetic and Genomic Resources, Genes/ QTLs, Genetic Resources to Improve

Sink Traits- Case Studies. Progress and status in developing genomic and genetic resources of validated genes/ QTLs to improve sink traits- Specific case studies.

Unit 4: Source to Support the Sink Capacity

Canopy architecture to support sink requirements in cereals: plant height, tillering, leaf area, shading or senescence of lower canopy leaves, canopy photosynthesis, Canopy architecture to support sink requirements in Pulses: Leaf senescence, abscission, mobilization of N and other nutrients, Symbiotic N fixation to support sink size and capacity in pulses.

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation

VIII. Learning outcome

By the end of this course, the student will be able to:

1. comprehend the current development in photosynthetic research
2. know how to employ the theoretical concept of photosynthetic research in yield improvement programme
3. understand the mechanisms of source and sink establishment

IX. Suggested Reading

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- Paul *et al*. 2018. *The Role of Trehalose 6-Phosphate in Crop Yield and Resilience, Plant Physiology* 177: 12–23.
- Narnoliya *et al*. *Transcriptional Signatures Modulating SAM Morphometric and Plant Architectural Traits Enhance Yield and Productivity in Chickpea, The Plant Journal.*

I. Course Title : Seed and Fruit Growth and their Quality Improvement

II. Course Code : PP 608

III. Credit Hours : 2+0

IV. Why this Course?

Seed as a propagule is an important input for agriculture. From this context, aspects related to seed development, its dormancy and viability etc. assumes significance. Besides, seed is the major source of nutrition to mankind and hence, quantitative and qualitative differences in seed constituents and their modification and improvement have been the area of focus in recent years. Several molecular approaches are now being adapted to improve the seed characters like longevity, vigour and seed quality. In addition to seed and fruit development, processes regulating the post-harvest deterioration of fruits and vegetables, increasing their self-life are another area that needs comprehensive intervention involving molecular biology tools and techniques. The course therefore addresses recent developments on these aspects.

V. Aim of the course

The major aim of the course is to train and educate the students about the importance of seeds and fruits as a source of nutrition for human health. Further, this course also addresses how to improve the nutritional status besides protecting the nutritive value of seeds and fruits. In addition, the other aim of the course is to address to regulate the post harvest deterioration of seeds and fruits to minimize the losses.

The course is organized as follows:

No.	Blocks	Units
1.	Physiological and Molecular Aspects of Seed and Fruit Growth: Quality Improvement	1. Physiology of Seed Growth and Development 2. Seed as a Propagule 3. Seed as a Source of Nutrition 4. Quality Deterioration during Storage 5. Fruit Growth and Development 6. Fruit as a Source of Phytochemicals: Nutraceuticals 7. Fruit Ripening, Post Harvest Deterioration and Shelf life

VI. Theory

Block 1: Physiological and Molecular Aspects of Seed and Fruit Growth: Quality Improvement

Unit 1: Physiology of Seed Growth and Development

Mechanism of seed development and different developmental stages; synthesis, mobilization and accumulation of stored reserves, Forms of stored reserves and their localization, Sink drawing ability (SDA) and its relevance in seed growth and development, Role of plant hormones in seed growth and development and SDA.

Unit 2: Seed as a Propagule

Seed as a propagation material; seed size and seed chemical composition and their relevance in seed germination, Physiological, biochemical and molecular mechanisms and approaches to regulate seed germination, seedling emergence and establishment and seedling vigour, Physiological, biochemical and molecular mechanisms and approaches to regulate seed priming and crop establishment: seed dormancy, precocious germination and controlling pre-harvest sprouting in crops, Physiological, biochemical and molecular mechanisms and approaches to regulate seed viability, improving the viability and storability of seeds.

Unit 3: Seed as a Source of Nutrition

Seed as a source of nutrition to humans: approaches to improve the quality of seeds through synthesis of seed storage reserves and other constituents, Genes/ QTL's regulating these processes and concept of pathway engineering to improve the quantity and quality of seed constituents, Carbohydrates- Amylose and amylopectin ratios for glycemic index, resistant and digestable starch, improving dietary fibre, alter gelatinisation, Protein content, modified proteins, essential amino acids, Oil content, fatty acid composition, Omega 3 fatty acids. Carotenoids and vitamins, Biofortification strategies to enhance the grain zinc, iron, other minerals and other essential compounds, Engineering for low protease inhibitors, phytic acid, tannins, phenolic substances, lectins, oxalates as anti-nutritional factors, Case studies of improving seed nutrition components by molecular breeding and transgenic approaches.

Unit 4: Quality Deterioration during Storage

Changes in chemical composition during storage; factors influencing the deterioration of nutritional quality of seeds during storage; approaches to minimize nutritional quality deterioration, Effect of quality deterioration on human and animal health

Unit 5: Fruit Growth and Development

Flower and fruit development; concept of parthenocarpy, Physiological and biochemical changes during fruit development and chemical composition, Molecular approaches to regulate flower and fruit drop/ abscission; Role of hormones.

Unit 6: Fruit as a Source of Phytochemicals: Nutraceuticals

Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Antioxidants, Flavanoids, anthocyanins, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Vitamins- Vitamin C, Tocopherol, Carotenoids, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Alkaloids, Mangiferin, tomatins, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of DigestableFiber lycopene, stillbeans, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Aroma, monoterpenoids and Fatty acid esters.

Unit 7: Fruit Ripening, Post Harvest Deterioration and Shelf life

Physiological and molecular mechanisms of fruit ripening, Postharvest deterioration of fruits; factors regulating fruit deterioration; hormonal and environmental aspects of reducing post harvest deterioration of fruits, Physiological and Molecular approaches to regulate fruit ripening and shelf life: Role of Ethylene and Ethylene response factors regulating specific processes of fruit ripening; Approaches to regulate specific shelf life characters, Improving fruit ripening and shelf life by molecular approaches-Case studies.

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:

1. comprehend the importance of seeds and fruits as a source of nutrition
2. describe how to improve the nutritional status of grains and fruits
3. know how to protect the nutritive value of seeds and fruits
4. detect the post harvest deterioration of seeds and fruits and to minimize the losses

IX. Suggested Reading

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- Larkins BA and Vasil IK (Ed). 2010. *Cellular and Molecular Biology of Plant Seed Development,* Springer
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- Robert HS. 2019. *Molecular Communication for Coordinated Seed and Fruit Development: What Can We Learn from Auxin and Sugars? Int. J. Mol. Sci. 20*, 936.
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I. Course Title : Plant-Microbe Interactions

II. Course Code : PP 609

III. Credit Hours : 2+1

IV. Why this Course?

Plant microbe encounters can be friendly or hostile. Plants are associated with a variety of microorganisms, including endophytes, phylloplane and rhizosphere microbes which provide plants with mineral nutrients and other benefits. In contrast phytopathogens obtain nutrition from plants leading to reduction in plant growth and subsequent killing. Besides the genetic makeup expression of the phenotype is regulated by environment and the plant microbe interaction especially the endophytes. It is also relevant to understand the plant-pathogen and plant-insect interactions to improve tolerance mechanisms by altering specific physiological and biochemical processes. The combined effects of biotic and abiotic are another aspects of importance. Understanding how physiology of plants simultaneously exposed to abiotic stress and pathogens decides the outcome of their interactions is important. The course provides comprehensive information on these aspects. Plant-microbe interaction is an emerging area and PhD scholar must be exposed to this new knowledge which might help in manipulation plant traits and boost crop growth.

V. Aim of the Course

The objective of the course is to provide the understanding how beneficial microbes (endophyte/rhizosphere/phylloplane microbiome) play a role in boosting the plant immune system and thereby stimulate plant health and growth. The course also aims to understand how plant pathogens are able to infect plants and how resistant plants are able to defend themselves. The course covers comprehensive interactive information from physiology, microbiology and genomics.

The course is organized as follows:

No.	Blocks	Units
1.	Plant Pathogen Interaction	1. Introduction to Plant Pathogen Interaction 2. Genetic Basis of Host Pathogen Interaction 3. Growth Regulators of Plant Defense and Susceptibility 4. Bioenergetics in Plant Pathogen Interaction
2.	Plant-Endophytes/ Rhizosphere/ Phylloplane Microbes Interaction	1. Interaction of Endophytes/ Rhizosphere/ Phylloplane Microbes with Plants 2. Role of Endophyte/ Rhizospheric/ Phylloplane Microbiota in Plant Physiological Processes 3. Endophyte/ Rhizospheric/ Phylloplane Microbes in Improving Biotic and Abiotic Stress Tolerance 4. Bioethics, Biosafety, Intellectual property rights and implications in plant-microbe research
3.	Microbial Interaction with Plants in The Presence of Abiotic Factors	1. Disease Triangle and the Contribution of the Environmental Factors in Influencing the Plant-microbe Interaction 2. Physiological and Molecular Basis for Predisposition or Endurance of Plant during Abiotic-biotic Stress Interaction

VI. Theory

Block 1: Plant Pathogen Interaction

Unit 1: Introduction to Plant Pathogen Interaction

Introduction to plant microbe interaction and importance, the concepts of holobiome and hologenome, Differences between endophytes/ rhizosphere/phylloplane microbes and phytopathogens, Types of endophytes/rhizosphere/phylloplane microbes, and their classifications

Unit 2: Genetic Basis of Host Pathogen Interaction

Genetics of immune response, Signal perception, Host-pathogen interaction (bacteria, fungus and virus), Nature of resistance to diseases-pathogenecity genes *(pat)* in plant pathogens-disease specific genes *(dsp), avirulence genes (avr), avr gene – coded proteins-structure of avr genes,* Transmission of the alarm signal to host defense producers: signal transduction, pathogen elicitors, protein kinases, calcium ions, phosphorylases, phospholipases, ATPases, Accumulation of Phytoalexins as a Resistance mechanism-Biosynthesis and metabolism of Phytoalexins, Modes of action of Phytoalexins, Pathogenesis-Related proteins (PR) and Disease Resistance- intro-Characterization and biological functions of PR proteins, Biosynthesis of PR proteins.

Unit 3: Growth Regulators of Plant Defense and Susceptibility

Regulation of hormones countering the pathogen infection and toxins modulating the plant physiology, ABA-SA cross talk and role of JA during plant interaction biotrophic and necrotrophic pathogens respectively.

Unit 4: Bioenergetics in Plant Pathogen Interaction

An overview of energy-capture and energy-utilization processes in higher plant, Energy-capture and utilization process as affected by pathogenic infection, Molecular basis of pathogenesis and the process of interaction- classical examples of pathogens causing necrosis, wilts, tumours and soft rots, Role of primary metabolism in plant-pathogen interaction.

Block 2: Plant-Endophytes/ Rhizosphere/ Phylloplane Microbes Interaction

Unit 1: Interaction of Endophytes/ Rhizosphere/ Phylloplane Microbes with Plants

Approaches to study endophytic/ rhizosphere/ phylloplane microbes bacteria and fungi, Intracellular bacteria 'Cytobacts', Possible mechanisms of host plant genotype influence in recruitment of endophytic microbes vertical/ seed transmission, Inter-kingdom signaling regulating endophyte/ rhizosphere/phylloplane microbes development, Adaptation with respect to colonization of endophytes/ rhizosphere/ phylloplane microbes.

Unit 2: Role of Endophyte/ Rhizospheric/ Phylloplane Microbiota in Plant Physiological Processes

Phytohormones role in beneficial endophyte/rhizospheric/phylloplanerecruitment, Hormonal regulation of assimilate partitioning in plant-microbe interactions, Plant-Fungus-Bacteria, the three fold interaction for improved plant nutrition.

Unit 3: Endophyte/ Rhizospheric/ Phylloplane Microbes in Improving Biotic and Abiotic Stress Tolerance

Importance in imparting stress (biotic and abiotic) adaptations, in the regulation of bioactive compound (alkamide) accumulation; acclimatization of root-interacting fungi for improved plant nutrition and stress tolerance, Cultivable versus uncultivable endophytes with respect to their extent of tissue colonization and diversity, Genetic engineering of endophytes for production of industrially important bioactive compounds, endophyte-enrichment technologies in crops for traits manipulation, Role of existing microbiome on introduced endophyte, symbiotic microbes and their interaction, Modern techniques for examining plant-microbe-insect interactions.

Unit 4: Bioethics, Biosafety, Intellectual property rights and implications in plant-microbe research

DBT biosafety regulations on working with microbial organisms associated with plants, Standard operating procedure (SOP), Committees dealing with biosafety and safe release of microorganisms.

Block 3: Microbial Interaction with Plants in the Presence of Abiotic Factors

Unit 1: Disease Triangle and the Contribution of the Environmental Factors in Influencing the Plant-microbe Interaction

Disease triangle involving plant-pathogen-environment and the importance of environmental stresses (drought, heat, humidity and soil factors) in influencing the resistance or susceptibility, Role of environmental factors in influencing establishment and sustenance of introduced beneficial microbes.

Unit 2: Physiological and Molecular Basis for Predisposition or Endurance of Plant during Abiotic-biotic Stress Interaction

Plant-water relations and changes in physiology in deciding the microbe interaction with plants, Metabolites in deciding the microbe interaction with plants, Hormonal cross talk, signal transduction, role of R-genes and other defense pathways during the simultaneous exposure to abiotic stress.

VII. Practicals

- *In-planta* bacterial/fungal multiplication in plant under drought stress
- Detection of plant pathogens using molecular tools
- Stomatal conductance in plants under drought stress and pathogen stress
- Apoplast isolation from plants subjected to bacterial infection
- Virus induced gene silencing in plants
- Acetylene reduction assays to check nitrogen fixation in plant (The effect of beneficial microbes in plant)
- Biochemical analyses of beneficial and pathogen-effector proteins
- Plant colonization and disease or growth promotion scoring
- In-vivo detection of plant immune responses and their inhibition by effectors
- Estimation of phytoalexins, PR proteins, ACC deaminase and growth hormones in pathogen challenged plants
- Effect of plant microbe interaction on plant physiological processes, viz. photosynthesis, chlroroplast, transpiration, etc.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

IX. Learning outcome

By the end of this course, the student will be able to:

1. understand how beneficial microbes enhance the plant immune system
2. comprehend how beneficial microbes stimulate plant growth
3. describe plant-microbe interaction
4. understand plant defense and susceptibility

X. Suggested Reading

- Jones JDG and Dangl JL. 2006 *The plant immune system. Nature* Vol. 444, Pages 323–329
- Dodds PN and Rathjen JP. 2010. *Plant immunity: towards an integrated view of plant–pathogen interactions. Nature Reviews. Genetics.* Vol. 11, Pages 539–548
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- Vandenkoornhuyse P, Quaiser A, Duhamel M, Van AL, Dufresne A. 2015. *The importance of the microbiome of the plant holobiont. New Phytologist*. 206: 1196-1206 .

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- Atkinson NJ and Urwin PE. 2012. *The interaction of plant biotic and abiotic stresses: from genes to the field. Journal of Experimental Botany*, 63: 3523–3543.

General Source Information

- Matveeva T, Provorov N, Valkonen JPT. *Cooperative Adaptations and Evolution in Plant-Microbe Systems*. Frontiers Media SA.
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- Tejesvi MV, Pirttilä AM, Frank AC. *Emerging Tools for Emerging Symbioses—Using Genomics Applications to Studying Endophytes* by Frontiers Media SA
- Jyoti Shah, Linda Walling. *Advances in Plant-Hemipteran Interactions*, by Frontiers Media SA.
- Huang JS. 2009. *Plant Pathogenesis and Resistance* (*Biochemistry and Physiology of Plant-Microbe Interactions),* Kluwer Academic Publishers.
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- Sharma PD. 2006. *Plant Pathology,* Narosa Publishing House Pvt. Ltd.
- Mahadevan A. 1979. *Physiology of Host-Pathogen Interaction*, Today and Tomorrow Printers and Publishers.
- Stainhaus EA. 1963. *Insect Pathology*, Academic Press, New York and London.
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- Velmourougane K, Saxena G, Prasanna R. 2017. *Plant-microbe interactions in the rhizosphere: mechanisms and their ecological benefits*. Singh D., Singh H., Prabha R. (eds) *Plant-Microbe Interactions in Agro-Ecological Perspectives*. Springer, Singapore. doi: https://doi.org/10.1007/978-981-10-6593-4_7.
- Schikora, A. (Ed.). 2018. *Plant-microbe interactions in the rhizosphere.* Caister academic press. doi: https://doi.org/10.21775/9781912530007.

I. Course Title : Weed Biology and Physiology of Herbicide Action

II. Course Code : PP 610

III. Credit Hours : 2+0

IV. Why this course?

Weeds pose a serious threat to Crop production leading to a yield loss ranging from

30% to sometimes total failure. Weed management is a significant input on part of the producers. Chemical weed management through herbicides have been the most effective among various methods. Various herbicides with different modes of actions are used to control weeds. Prolonged chemical control has led to adverse environmental consequences and development of herbicide resistance. There is a need to understand the biology of weeds as well as herbicide actions at physiological and molecular levels for resistance management as well as development of more effective and less harmful chemicals for weed management. The aim of this course will be to apprise the students about these aspects of chemical weed control.

V. Aim of this course

The course is designed to provide both basic and applied knowledge on the weeds. It will help to understand the fundamental physiology, biochemistry, and molecular biology of herbicides and their effects on plants; To study the physiological and molecular mechanisms of herbicide resistance.

This course will provide knowledge on biology of weeds, classification and mode of action of herbicides, herbicide resistance and its management and environment friendly weed management strategies.

The course is organized as follows:

No.	Blocks	Units
1.	Weed Biology	1. Weed Biology and its Importance in Weed Management 2. Life Cycle and Population Dynamics of Weeds 3. Crop Weed Competition
2.	Physiology of Herbicide Action	1. Introduction to Herbicides 2. Mechanism of Action of Herbicides 3. Herbicide Resistance and its Management

VI. Theory

Block 1: Weed Biology

Unit 1: Weed Biology and its Importance in Weed Management

Introduction to weeds, Classification of weeds, Yield losses caused by weeds, Environmental impacts of invasive weed species, Aspects of Weed biology, Germination, Dormancy and growth behaviour of weed species, Effect of environmental factors on weeds, Adaptation of weeds to different ecologies

Unit 2: Life Cycle and Population Dynamics of Weeds

Growth duration and reproductive potential of weed species, Population dynamics, Weed Shift due to weed management, weed Seed Bank,

Unit 3: Crop Weed Competition

Understanding the nature of crop-weed competition, critical stages of crop weed competition, growth stages of weeds for improved control by herbicides

Block 2: Physiology of Herbicide Action

Unit 1: Introduction to Herbicides

Introduction, Chemistry and classification of herbicides by mechanism of action, HRAC Classification, Site of Actions, Application techniques, doses, active ingredients, formulations, Absorption and translocation of soil and foliar applied herbicides, Methods to increase the efficiency of soil and foliar applied herbicide – role of membranes, adjuvants, surfactants, synergists,

Unit 2: Mechanism of Action of Herbicides

Physiological and biochemical effects of herbicides: Effects on membrane structure and functions, cell division and cell development, Effects on chloroplast, photosynthesis, respiration, protein synthesis, synthesis of lipids, Molecular mechanism of action, Molecular mechanisms of herbicide resistance in relation to chloroplast gene expression,

Unit 3. Herbicide Resistance and its Management

Herbicide resistance-Definition, history, magnitude; Mechanisms of resistance: Target site and non-target site, cross and multiple resistances, Role of management practices on resitance development, Resistance management: Strategies; HR crops, Super weeds,

VII. Teaching methods/activities

– Lectures
– Assignment (Reading/Writing)
– Text Books / reference books and materials
– Student presentations

VIII. Learning outcome

After successful completion of this course, the students are expected to be able to:
– Understand the importance of weed biology in weed management
– Understand the mechanism of herbicide action
– Understand the problem of herbicide resistance development
– Appreciate and suggest sustainable weed management strategies

IX. Suggested Reading

- Inderjit (Ed). 2004. *Weed Biology and Management*. Springer Netherlands
- Monaco, TJ, Weller SC, Ashton FM. 2002. *Weed Science: Principles and Practices*. John Wiley and Sons Inc., New York
- De Prado R, Jorrin J, and Garcia-Torres L. 1997. *Weed and Crop Resistance to Herbicides*. Kluwer academic Publishers, The Netherlands.
- Heap I. (2018.). *The International Survey of Herbicide Resistant Weeds*. www.weedscience.com
- *Herbicide Handbook of the Weed Science Society of America*, 9th Edition. 2008. http://wssa.net.
- Devine, M.D., Duke S.O. and Fedtke C. 1993. *Physiology of Herbicide Action*. Prentice-Hall, Inc. Englewood, NJ. 441 pp
- Zimdahl, R L .2007. *Fundamentals of Weed Science* (Third Edition). Academic Press-Elsevier, USA.

Restructured and Revised
Syllabi of Post-graduate Programmes
Vol. 2

Biotechnology and Bioinformatics

– Bioinformatics
– Molecular Biology and Biotechnology

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Executive Summary
(Bioinformatics)

- Bioinformatics has emerged as an interdisciplinary and integrated scientific discipline, which links the computational and statistical sciences with life sciences. A big hurdle in the development of Bioinformatics in India is the limited availability of trained human resource, faculty and Ph.D. scholars in the field. However, with the constant efforts put forth by ICAR and SAUs in recruiting ARS scientists/ Assistant Professors in bioinformatics, the problem of faculty shortage has been reduced to some extent. Also, the students from this discipline get motivated with such employment opportunities. Wherever the new recruitments take time, the faculty drawn from computer science, statistics, biotechnology, biochemistry disciplines may be sent for training in bioinformatics within India or at abroad. In order to reach the unreached discoveries and innovations through bioinformatics, one should have a reasonably good infrastructure with high-end servers, high-speed internet connectivity, CPU/GPU based high performance computing system, high storage, smart classrooms, open source software, Linux-Apache-MySQL-Perl/PHP (LAMP) technology, etc. The need of the hour is to deploy advanced techniques of artificial intelligence, machine learning and big data analytics to unravel the underlying mechanisms and factors involved in complex biological phenomena and thus, the syllabus has been revised in this light. Recent developments in bioinformatics have become indispensable for use in omics and systems biology approaches. Thus, these developments have now been made part of the syllabus as follows.
- Five new courses have been added including (i) “Non-Coding RNAs”, (ii) “Comparative and Functional genomics”, (iii) “Systems Biology”, (iv) “R and high dimensional genome data” and (v) “Big data analytics” to prepare the students for meeting the challenges arising out of complex genomes.
- Emphasis has been laid on disassociating the overlaps in the existing courses, incorporating the new concepts in the courses like network modelling and systems biology, machine learning techniques in bioinformatics, parallel programming and algorithm development so that any student after completing his M.Sc. degree in bioinformatics can discharge his duties both as bioinformaticist and bioinformatician.
- More emphasis was given on practicals so that the students can efficiently deal with the high dimensional data sets of Next Generation Sequencing (NGS), Genotype-By-Sequencing and Genome Wide Association Studies (GWAS) with special skills.
- The revised syllabus addresses the recent advances and modern concepts of AI, Machine Learning in analyzing big data coming from genomics, transcriptomics, proteomics and other omics researches.
- The demand for trained manpower in bioinformatics is increasing in private sector, which is a healthy sign for the PG students. Care has been taken while devising the syllabus to incorporate more practicals on computer programming and high-dimensional genome data analysis software.

Preamble

Driven by the recent developments in high throughput Genomics, Bioinformatics is taking an ever-increasing role in Agri-genomics. In a similar way, advances in information technology and computational methods are driving the mathematical sciences forward. Artificial Intelligence and Big Data analytics have revolutionized the bioinformatics-based genome data analysis. Now with the availability of next generation sequencing technologies, a high volume of both structured and unstructured data is available. Further, data is also available from many genome data repositories like GenBank at National Centre for Biotechnology Information in the public domain. All these have led to the availability of the huge amount of data from different agricultural organisms that need to be analyzed and elicit the hidden information for knowledge discovery to unravel the underlying complex biological phenomena.

In order to achieve the goals of bioinformatics: (i) designing of algorithms for handling and analysis of genomic big data (ii) development of statistical-computational methods and techniques, automated pipelines, tools for high dimensional genome data analysis (iii) accessing the existing databases and sharing the developed tools and databases in public domain; planning strategies and human resources are to be developed in genomics research to solve the national level problems and issues. To mention a few, the priority areas are: (i) plant and animal improvement through genomics-assisted breeding and genomic selection (ii) climate smart crop production for food security (iii) metagenome wide association study of soil microbiome with crop productivity by machine learning (iv) GWAS, PheWAS and phenomics aided improvement programmes (v) artificial intelligence (AI); machine learning – an approach to achieve AI; and deep learning– a technique for implementing machine learning; for knowledge discovery through agri-genomics (vi) blockchain technology and data science for agricultural value chain (vii) role of microbiota in plant and animal health care and expression of economically important traits (viii) designing and development of Agri-Encyclopedia of DNA Elements (A-ENCODE) (ix) identification of bioremediation bacteria and probiotics from Indian river system for pollution remediation (x) improved and efficient algorithms for robust genome assembly from data generated under different Next Generation Sequencing platforms. Possessing expertise and skills in computer programming languages like R and python is essential for bioinformaticians, who are developers of bioinformatics tools and pipelines in the system. Above all, there exists always a rapidly increasing demand for individuals to be trained in bioinformatics with special skills and knowledge to handle high dimensional genomic data. The emerging trends in genomic research, need for human resources for teaching and application of bioinformatics in genomic research for crop improvement, shrinking job opportunities in the public sector etc would warrant students to possess the technical knowledge and skills in bioinformatics coupled with good practical and management skills, to be competitive for both public and private sectors. Hence a thorough restructuring of course curriculum and delivery system is needed.

In this revised course curriculum of Bioinformatics, the BSMA sub-group organized a series of meetings to develop the courses for M.Sc. and Ph.D. programs for the NAREE system. The meetings were focused on keeping different courses on AI/ML/DL, programming languages, big data analytics in the curriculum without compromising on the quality and the content in terms of imparting the requisite up to date knowledge to the students. Thus, the basic platform courses are kept as core courses that need to be taken by all the students irrespective of the subject specialization from which they entered the PG education. The course curriculum also targets the M.Sc. and Ph.D. students separately by providing two sets of courses and advanced courses to the Ph.D. students only. Also, substantial inputs were provided by the experts to introduce recent developments in the advanced courses so that the concepts are ingrained when the M.Sc. graduates enter to the Ph.D. system. An additional input received during discussion was on enabling the SAUs and Deemed-to-be Universities to have reasonably good infrastructure that helps students to have comprehensive knowledge with hands on training. This will help the students build confidence in becoming entrepreneurs in bioinformatics, get employment in R&D companies so that the gains in education gets translated to the end user, the producers, processors and the consumers.

The opinions and suggestions invited from the institutions, eminent scientists and other stakeholders were revived by the BSMA sub-committee. The new look and restructured PG programme in bioinformatics has been designed by considering the needs of private sector, modern statistical and computational methods, algorithms, artificial intelligence and machine learning, and big data science to enhance the global competitiveness and employability of the students. Thus, considerable and markable efforts have gone into the preparation of the present revised course curriculum of Bioinformatics.

Course Title with Credit Load
M.Sc. in Bioinformatics

Course Code	Course Title	Credits (L+P)
	Major: 20 credits	
	(12 credits of core plus 8 credits of optional)	
BI 501	Introduction to Bioinformatics & Computational Biology*	2+1
BI 502	Statistical Genomics*	2+1
BI 503	Genome Assembly and Annotation	1+1
BI 504	Biomolecular Modelling and Simulation*	2+1
BI 505	Transcriptomics and Metagenomics	2+1
BI 506	Biological Data Management*	2+1
BI 507	Biological network modelling and analysis	2+1
BI 508	Computer programming in bioinformatics	2+1
BI 509	Machine Learning Techniques in bioinformatics	2+1
	Minor (8 credits)	
	Molecular Biology and Biotechnology	
	Biochemistry	
	Genetics and Plant Breeding	
	Microbiology	
	Any other related discipline	
	Supporting (6 credits)	
	Statistics	
	Mathematics	
	Computer Science	
	Any other appropriate discipline	
	Common courses	5
BI	Seminar	0+1
BI 500	Research	0+30
	Total	70

*Core courses

Courses Contents
M.Sc. in Bioinformatics

I. Course Title : Introduction to Bioinformatics and Computational Biology

II. Course Code : BI 501

III. Credit Hours : 2+1

IV. Aim of the course

To provide theoretical and practical knowledge about handling and processing of genomic data, optimization and data mining techniques used in bioinformatics.

V. Theory

Unit I (15 Lectures)

Overview of available genomic resources on the web; NCBI/ EBI/ EXPASY etc; Nucleic acid sequence databases; GenBank/EMBL/ DDBJ; Database search engines: Entrez, SRS. Overview/concepts in sequence analysis; Pairwise sequence alignment algorithms: Needleman and Wunsch, Smith and Waterman; BLAST, FASTA; Scoring matrices for Nucleic acids and proteins: PAM, BLOSUM, Multiple sequence alignment: PRAS, CLUSTALW. Sequence based gene prediction and its function identification.

Unit II (5 Lectures)

Preprocessing of gene expression data; Data Normalization techniques, Data quality control: Modelling of errors, Imputation etc; High-throughput screening.

Unit III (6 Lectures)

Optimization Techniques: concept and applications, Simulated Annealing, Genetic Algorithms: *Ab initio* methods for structure prediction; Information theory, entropy and relative entropy.

Unit IV (6 Lectures)

Foundations for Machine learning Techniques: Unsupervised and Supervised Learning, Cross Validation Techniques, Markov Model, Bayesian Inference: concepts and applications, Hidden Markov Model and applications, Introduction to WEKA package.

VI. Practicals

Database Similarity Searches, Multiple sequence alignment, Genome databases, Structural databases, Derived databases, Gene annotation, Gene prediction software. Analysis of DNA microarray experiments, Expression profiling by microarray/gene chip, Proteomics, Pattern recognition, Hidden Markov Models, Gibbs Sampling, Analysis of single and multiple DNA or protein sequences.

VII. Suggested Reading

- Baldi, P. and Brunak, S. 2001. *Bioinformatics: The Machine Learning Approach*. MIT Press.
- Baxevanis, A.D. and Francis, B.F. 2004. *Bioinformatics: A Practical Guide to the Analysis of*

Genes and Proteins. John Wiley.
- Wang JTL, Zaki MJ, Toivonen HTT and Shasha D. 2004. Data Mining in Bioinformatics.Springer.
- Amaratunga D and Cabrera J. 2004. *Exploration and Analysis of DNA Microarray and Protein Array*. John Wiley.
- Gupta GK. 2006. *Introduction to Data Mining with Case Studies*. Prentice Hall of India, New Delhi.
- Han J and Kamber M. 2006. *Data Mining: Concepts and Techniques*. Morgan Kaufman.
- Hand DH, Mannila P Smyth. 2001. *Principles of Data Mining*. Prentice Hall of India, New Delhi.

I. Course Title : Statistical Genomics

II. Course Code : BI 502

III. Credit Hours : 2+1

IV. Aim of the course

This course builds the basic understanding of statistical methods used in genetics and genomics.

VI. Theory

Unit I (14 Lectures)

Fundamentals of Population genetics: Hardy –Weinberg law, Effect of systematic forces on changes in gene frequency; Principles of Quantitative genetics: Values, Means and Variances, Detection and Estimation of Linkage, Inbreeding, Selection, Genetic Parameter Estimation, Variance component estimation, BLUP, G x E interaction, Path Analysis

Unit II (10 Lectures)

Molecular Marker based classification: similarity measures, clustering methods, bootstrapping; QTL mapping: Detection and Estimation of QTL, Single Marker Analysis, Interval Mapping and MQM;

Unit III (8 Lectures)

Design and Analysis of Expression Data; Genome Selection; Genome Prediction, Genetic Markers, Association Mapping; Genome Wide Association Analysis

VII. Practicals (16 Lectures)

Population genetics: Hardy-Weinberg law, Estimation of linkage, Inbreeding, Selection, Genetic parameter estimation, Variance component estimation, BLUP, Path analysis, Molecular marker based classification, Estimation of QTL, Single marker analysis, MQM, Analysis of gene expression data, Genome selection and Genome prediction.

VIII. Suggested Reading

- Xu, Shizhong. 2013. *Principles of Statistical Genomics*. Springer
- Ben Hui Liu. 1997. *Statistical Genomics: Linkage, Mapping, and QTL Analysis.*
- Sorensen D and Gianola D. 2002. *Likelihood, Bayesian and MCMC Methods in Genetics.* Springer.
- Ben HL and Leming MS. 2013. *Statistical Genomics and Bioinformatics.*

I. Course Title : Genome Assembly and Annotation

II. Course Code : BI 503

III. Credit Hours : 2+1

IV. Aim of the course

The primary objective of this course is to develop practical understanding of techniques and tools used in genome assembly with emphasis on issues and challenges of its structural and functional annotation.

V. Theory

Unit I (6 Lectures)

Types and methods of genome sequence data generation; Shot gun sequencing method; Problems of genome assembly, Approaches of genome assembly: Comparative Assembly, DE novo Assembly; Read coverages; Sequencing errors, Sequence Quality Matrix, Assembly Evaluation; Challenges in Genome Assembly.

Unit II (5 Lectures)

Various tools and related methods of genome assembly: MIRA, Velvet, ABySS, ALLPATHS-LG, Bambus2, Celera Assembler, SGA, SOAP*denovo,* etc.

Unit III (5 Lectures)

Basic concepts of genome annotation; Structural and Functional Annotation; Identification of open reading frame (ORF) and their regularization, Identification of gene structure, coding regions and location of regulatory motifs

VI. Practicals (16 Lectures)

Genome assembly methods for data from various sequencing platform, Sequencing error determination, Sequence quality matrix; Various tools for genome assembly: MIRA, Velvet, ABySS, ALLPATHS-LG, Bambus2, Celera Assembler, SGA, SOAP *denovo*, etc. Structural and functional Genome annotation.

VII. Suggested Reading

- Jung, S., Paul, Gordon, M.K., Sensen, C. W. 2012. *Genome Annotation*. Chapman and Hall/ CRC
- Venter, J. C., 2000. *Annotation of the Celera Human Genome Assembly*. Celera.
- Mark Menor. 2007. *Multi-genome Annotation of Genome Fragments Using Hidden Markov Model Profiles*
- Carson Hinton Holt. 2012. *Tools and Techniques for Genome Annotation and Analysis*
- Alistair G. Rust, Emmanuel Mongin and Ewan Birney Loraine A.E and Helt G.A. 2002. *Genome annotation techniques: new approaches and challenges. Drug Discovery Today*. 570-576 p.
- Weizhong Li and Adam Godzik. 2002. *Discovering new genes with advanced homology detection. Trends in Biotechnology*, 20: 8, 315-316 p.

I. Course Title : Bio-molecular Modelling and Simulation

II. Course Code : BI 504

III. Credit Hours : 2+1

IV. Aim of the course

The course aimed to develop understanding of bio molecular modelling techniques and simulation.

V. Theory

Unit I (8 Lectures)

Methods for 3D Structure Prediction: Homology modeling of protein 3D structures – approaches to loop building, energy considerations and evaluation of the accuracy of the model. *ab initio* approach to 3D structure prediction; Threading approach to 3D structure prediction. A Comparison of protein structure prediction methods: CASP

Unit II (8 Lectures)

Basic principles of modeling, modeling by energy minimization technique, concept of rotation about bonds, energy minimization by basic technique for small molecules, Ramachandran plot, torsional space minimization, energy minimization in Cartesian space, molecular mechanics-basic principle

Unit III (8 Lectures)

Basic concepts of Simulation Modelling: Units and derivatives, Force field and energy landscape, Truncation of non-bonded interactions, Introduction to solvation, Periodic boundary condition, Wald summation, implicit solvent model and continuum electrostatics, Monte Carlo simulation on parallel computers. Replica-exchange simulations, Restraint potentials, Free energy calculations, Membrane simulations

Unit IV (8 Lectures)

Energy Minimization: Concept of energy minimization - hypersurface, local and global energy minima, statement of problem. Derivative minimization methods - first derivative methods: the steepest descents method, line search in one dimension, arbitrary step approach, conjugate gradients minimization. Second derivative method – the Newton-Raphson method. Applications of energy minimization.

VI. Practicals: (16 Lectures)

Protein structure databases: PDB, MODBASE, Structure visualization – Rasmol and PyMol, Structural analysis- classification, CATH, SCOP, Protein geometry – bond length, bond angle, torsion angle, calculation of surface area, volume and radii: Swiss PDB Viewer. Small molecule generation - peptides and nucleic acids: ISIS draw / ChemSketch, Selection of query sequence, template selection: pdbBLAST, Comparative 3D structure prediction – SWISSMODEL, Model generation - building side chains and loops using Modeller, Threading, *ab initio* modeling, Structure validation - generation and analysis of Ramachandran plot using PROCHECK, WHATCHECK via SAVS server, Force field calculation and energy minimization, Structure refinement - loop building, removing non-bonded contacts, adding missing side chains via WhatIf interface, Scoring structural similarity - 3D structure alignment - RMS superimposition – VMD, Molecular dynamics simulation using Tinker. Simulation dynamics, Monte carlo simulation on parallel computers. Replica exchange simulation, free energy calculation. Docking

VII. Suggested Reading

- Schlick T. 2010. *Molecular Modeling and Simulation: An Interdisciplinary Guide*. Science.
- Gunsteren WF, Weiner PK, Wilkinson AJ. 1997. *Computer Simulation of Biomolecular Systems: Theoretical and experimental application*. Springer.
- Martin JF. 2007. *A Practical Introduction to the Simulation of Molecular Systems*. Cambridge University Press.
- Leach AR. 2001. *Molecular Modeling: Principles and Applications*. Prentice Hall. 784p.

- Bourne PE and H Weissig. 2003. *Structural Bioinformatics*. Wiley-Liss. 650 p.
- Marx D and Hutter J. 2009. *Ab Initio Molecular Dynamics: Basic Theory and Advanced Methods*. Cambridge University Press. 578p.

I. Course Title : Transcriptomics and Metagenomics

II. Course Code : BI 505

III. Credit Hours : 2+1

IV. Aim of the course

The course aims to teach basic concepts of metagenomics and various techniques used in the analysis of metagenomic data

V. Theory

Unit I (8 Lectures)

Microarrays, RNA-seq, Chip-Seq, EST-clustering, differential expression analysis

Unit II (6 Lectures)

Taxonomic and genetic annotation of high throughput sequence data, microbial diversity analyses, analyses of microbial community composition and change and metabolic reconstruction analyses.

Unit III (9 Lectures)

Comparison between Metagenomics and AL, EC, Comparison between LCS and Metagenomics, Symbiotic Evaluations: SANE, Comparison between SANE and Metagenomics, Horizontal Gene Transfer: Microbial GA.

Unit IV (9 Lectures)

Metagenome Sequencing, Single Cell Analysis, Host-Pathogen Interaction; Shotgun metagenomics; High-throughput sequencing; Comparative metagenomics; Community metabolism; Metatranscriptomics.

VI. Practicals (16 Lectures)

Meta genome annotation, Analyses of microbial community composition and change and metabolic reconstruction analyses; Metatranscriptomics; Comparative metagenomics. Microarray data analysis; RNA-seq, chip-seq, EST-clustering.

VII. Suggested Reading

- Diana marco. 2010. *Metagenomics: Theory, Methods and Applications*. Ceister academic press
- Streit WR and Daniel R. 2010. *Metagenomics: Methods and Protocols*. Springer protocols.
- Yeh WK, Yang H, McCarthy JR. 2010. *Enzyme Technologies: Metagenomics, Evolution, Biocatalysis and Biosynthesis*.wiley
- Muthukumar V. 2003. *Metagenomics for the Identification of Plant Viruses*. ProQuest.

I. Course Title : Biological Data Management

II. Course Code : BI 506

III. Credit Hours : 2+1

IV. Aim of the course

The course aims at teaching database management system and familiarizing with the techniques of data sources, data curation and integration of data sources

V. Theory

Unit I (6 Lectures)

Database Management System (DBMS): Need for DBMS - File system vs Database system, Advantages of DBMS - DBMS Architecture – DBMS services - Data abstraction - Overview of Data Models: Hierarchical Model - Network Model - Entity-Relationship (E-R) Model: Symbols - Components of E-R Model: Entities, Attributes, Relationships - Relational Model, Object-oriented Model.

Unit II (8 Lectures)

Overview of Relational Database Objects – Relation – Tuple - Cardinality – Attribute – Degree - Domain - Primary key – Foreign key - Relational data structure – Relational Data Integrity and Constraints: Domain constraints, Entity integrity, Referential Integrity, Operational constraints - Codd's Rules – Normalization: 1NF, 2NF, 3NF, BCNF, 4NF and 5NF.

Unit III (8 Lectures)

Structured Query Language (SQL): Overview of SQL – SQL Data types and Literals – SQL Commands: Data Definition Language (DDL), Data Manipulation Language (DML), Data Querying Language (DQL), Data Control Language (DCL), Data Administration Statements (DAS), Transaction Control Statements (TCS), SQL Operators: Arithmetic, Comparison, Logical and Set Operators – SQL Query, Nested Query - SQL Aggregate functions.

Unit V (10 Lectures)

Curation of genomic, genetic, proteomic data, High-throughput screening, array, qPCR data sets; Quality management of data: tools and techniques. Biological data sources, Data granularity, Schema modelling, architecture, query design, extraction, transformation and loading, Long term data management, storage and security. Bio-chip information system, visualization and reporting, Risk factors for data quality management. Un-structured or noSQL database; AI and BIG data Analytics

VI. Practicals (16 Lectures)

Understanding the data sources, Data granularity, Data modeling and architecture, development of database, Storage, Security, Visualization and reporting.

VII. Suggested Reading

- Kozak K. 2010. *Large scale data handling in biology*. Ventus Publishing ApS. ISBN 978-87-7681-555-4.
- Harold, E. and Means W.S. 2004. *XML in a Nutshell*, Third Ed. O'Reilly, Sebastopol, CA
- Witten, I.H. and Frank E. 2005. *Data Mining: Practical Machine Learning Tools and Techniques* (WEKA), 2nd Ed. San Francisco, Morgan Kaufmann,
- Lodish, H. *et al*. 2000. *Molecular cell biology*. New York: Freeman & Co.
- Kaneko K. 2006. *Life: An Introduction to Complex Systems Biology*. Springer.

I. Course Title : Biological Network Modelling and Analysis

II. Course Code : BI 507

III. Credit Hours : 2+1

IV. Aim of the course

This course aims to develop basic understanding of system biology through biological network modelling and its analysis.

V. Theory

Unit I (12 Lectures)

Introduction to biological networks, Graph theoretic modelling and analysis of biological networks, Discrete Dynamic modelling (Boolean networks, Petri nets), Continuous dynamic modelling (ODEs, stochastic simulation, etc.)

Unit II (12 Lectures)

Probabilistic modelling (Probabilistic Boolean networks, Bayesian networks, Mutual Information), Network inference from experimental data, Genome-scale modelling and network integration

Unit III (8 Lectures)

Evolution of molecular networks, Network-guided GWAS studies, FBA and epistasis detection, protein function prediction

VI. Practicals (16 Lectures)

Biological networks, Graph theoretic modelling and analysis of biological networks, Discrete Dynamic modeling; Continuous dynamic modeling; Probabilistic modeling; Genome-scale modelling and network integration; Evolution of molecular networks, Network-guided GWAS studies, FBA and epistasis detection, protein function prediction.

VII. Suggested Reading

- Junker BH. 2008. *Analysis of Biological Networks*.
- Koch I Reisig, W. Schreiber F. 2010. *Modeling in Systems Biology: The Petri Net Approach*.
- Ramadan EY. 2008. *Biological Networks: Modeling and Structural Analysis*.
- Laubenbacher R. 2007. *Modeling and Simulation of Biological Networks*.

I. Course Title : Computer Programming in Bioinformatics

II. Course Code : BI 508

III. Credit Hours : 2+1

IV. Aim of the course

To learn programming skills for parsing biological data, parallel computing, database connectivity and web-interface.

V. Theory

Unit I (7 Lectures)

BioJava- Packages, Data Import, Manipulation; Python- Basic Syntax, Loops, Functions; BioPython.

Unit II (7 Lectures)

Bioperl: Introduction, Modules: SeqIO, SearchIO, Seq Feature, Finding introns, Alignments, LiveSeq and Tree.

Unit III (12 Lectures)

OpenMP: Clauses, Worksharing constructs, Synchronization constructs, Environment variables, Global Data, Runtime functions, Message Passing Interface (MPI): Introduction and programming, Point to point communications, Collective communications, Advanced MPI1 concepts, MPI2 introduction, Hybrid (openMP + MPI) programming.

Unit IV (6 Lectures)

Compute Unified Device Architecture (CUDA): Introduction and Programming, GPU computing.

VI. Practicals (16 Lectures)

BioPerl programing using bioperl modules such as SeqIO, SearchIO, LiveSeq and Tree; OpenMP programming on Work sharing and Synchronization constructs, Environment variables and global data; MPI programming on Point to point communications and Collective communications; Compilation of OpenMP and MPI programs; Execution of OpenMP and MPI programs; Use of high performance computing, computing resources and job scheduling.

VII. Suggested Reading

- Tisdall J. 2001. *Beginning Perl for Bioinformatics*. O-Reilly.
- Schwartz RL, Phoenix T, Foy BD. 2008. Learning Perl. O-Reilly.
- Orfali R and Harkey H. 1999. *Client/Server Programming with JAVA and CORBA*. John Wiley.
- Sriram Srinivasan. 1997. *Advanced Perl Programming*. O-Reilly.
- Bunce T and Descartes A. 2000. *Programming the Perl DBI*. O-Reilly.
- Mitchell L Model. 2010. *Bioinformatics Programming Using Python*, O'Reilly media, Cambridge, Bal HP 2003. *Perl Programming for Bioinformatics*, Tata McGraw Hill.

I. Course Title : Machine Learning Techniques in Bioinformatics

II. Course Code : BI 509

III. Credit Hours : 2+1

IV. Aim of the course

The purpose of the course is to explain various machine learning techniques and its applications on biological data.

V. Theory

Unit I (10 Lectures)

Introduction to statistical learning theory, Empirical Risk Minimization, Structural Risk Minimization; Classification: Decision tree, Bayesian, Rule based classification, ANN, SVM, KNN; Case based reasoning and Applications in Bioinformatics.

Unit II (12 Lectures)

Clustering: Partition Methods, Heirarchical methods, Density based methods, Grid based clustering, Model based clustering, clustering of high dimensional data, constraints based clustering, Analysis of MD trajectories, Protein Array data Analysis.

Unit III (10 Lectures)

Dimensional Reduction Techniques, Methods of Feature Selection, Resampling Techniques, Elements of Text Mining and Web Mining, Soft Computing and Fuzzy logic system and application in bioinformatics.

VI. Practicals (16 Lectures)

Decision tree, classification techniques: ANN, SVM, KNN, Case based reasoning and its applications on biological data. Clustering techniques; Clustering of high dimensional data; Dimensional reduction techniques; Resampling techniques; Text mining and Web mining. Soft Computing and Fuzzy logic system & application in bioinformatics.

VII. Suggested Reading

- Witten, H.I., Frank, E. and Hall, M.A. 2011. *Data Mining: Practical Machine Learning Tools and Techniques*.
- Hastie, T., Tibshirani, R., Friedman, J.H. 2009. *The Elements of Statistical Learning: Data Mining Interface and Prediction*.
- Clarke, S.B., Fokoue, E. and Zhang, H.H. 2009. *Principles and Theory for Data Mining and Machine Learning*.

Course Title with Credit Load
Ph.D. in Bioinformatics

Course Code	Course Title	Credits (L+P)
	Major: 12 credits	
	(5 credits of core plus 7 credits of optional)	
BI 601	Genome wide association study*	2+1
BI 602	#Computational analysis of Non-coding RNAs	1+1
BI 603	#Big data analytics	1+1
BI 604	#Systems Biology	3+0
BI 605	#Comparative and functional genomics*	1+1
BI 606	Phylogenetics	2+1
BI 607	#R and high dimensional genome data	1+1
BI 608	Pharmacogenomics & IPR	3+1
BI 609	Biological data integration and quality control	1+1
BI 610	Quantum theory and applications in bioinformatics	1+1
	Any other from 500 series	
	Minor (6 credits) – Any one/two of the following disciplines	
	Molecular Biology and Biotechnology	
	Biochemistry	
	Genetics and Plant Breeding	
	Microbiology	
	Supporting (5 credits) Any from the following disciplines	
	Statistics	
	Mathematics	
	Computer Science	
	Common Courses	
BI	Seminar I	0+1
BI	Seminar II	0+1
BI 600	Research	0+75
	Total	**100**

Course Contents
Ph.D. in Bioinformatics

I. Course Title : Genome Wide Association Study

II. Course Code : BI 601

III. Credit Hours : 2+1

IV. Aim of the course

To introduce the concepts, principles, various designs and techniques of genome wide association study.

V. Theory

Unit I (12 Lectures)

Definition, Allelic spectra of common diseases, Allele frequencies for susceptibility loci, Risks associated with disease-susceptibility variants, Applications of linkage-disequilibrium metrics, SNP map, Genome resequencing for full coverage in genome-wide association studies, Transmission Disequilibrium Test, common variant hypothesis, rare allele hypothesis, Genome-wide graph theory algorithms

Unit II (12 Lectures)

Case-Control design, Trio design, Cohort design, Cross-sectional designs for GWAS Selection of Study Participants, Environmental confounders in GWAS, Confounding by population stratification, Genotyping and Quality Control in GWA Studies, Analysis of association between SNP and traits.

Unit III (8 Lectures)

Uses of GWAS: gene-gene interaction, detection of candidate haplotypes, association between SNPs and gene expression.

VI. Practicals (16 Lectures)

Allelic spectra of common diseases, Allele frequencies for susceptibility loci, linkage-disequilibrium metrics, SNP map, Genome resequencing for full coverage in GWAS; Case-Control design, Trio design, Cohort design, Cross-sectional designs for GWAS Selection; Genotyping and Quality Control in GWA Studies; Analysis of association between SNP and traits.

VII. Suggested Reading

- Qin H. 2008. *Statistical Approaches for Genome-wide Association Study and Microarray Analysis*.
- Yang C. 2011. *SNP Data Analysis in Genome-wide Association Studies*.
- Kraft JS. 2010. *Genome-wide Association Study of Persistent Developmental Stuttering.*

I. Course Title : Computational analysis of Non-coding RNAs

II. Course Code : BI 602

III. Credit Hours : 1+1

IV. Aim of the course

To introduce non-coding RNAs, its role and regulation in model organisms and tools and methods for *in silico* analyses

V. Theory

Unit I (8 Lectures)

Course overview; RNA molecules: biogenesis, types, structure and functions. Introduction to ncRNAs: types of ncRNAs, small ncRNAs, long ncRNAs, function of ncRNAs, Role of ncRNAs in plants and animals

Unit II (6 Lectures)

Small ncRNA: Introduction, miRNAs, siRNAs, hiRNAs, piRNAs, shRNAs; Post-transcriptional processing of microRNA; microRNA: target pairing and RISC function; miRNA target genomics; Functions and roles of miRNAs in growth & development of plants and animals. Stress responsive miRNAs, oncomiRs & tumour suppresser miRNAs.

Unit III (6 Lectures)

lncRNAs: biogenesis, classifications, structure and function of lncRNAs. Endogenous target mimic lncRNAs, triplet associated lncRNAs (miRNA, mRNA, lncRNAs); Circular RNAs: structure and functions. Role of circular RNA in cancer, growth and development.

Unit IV (6 Lectures)

Splicing and splice variants; Alternative splicing; Alternative splicing regulation; Nonsense mediated RNA decay; RNA editing.

Unit-V (6 Lectures)

Coding and non-coding sequences; TEs; lincRNAs and lncRNAs; Bacterial RNAs; riboswitches; Introduction to CRISPRs.

VI. Practicals (16 Lectures)

Exploration of databases and tools for identification and characterization of ncRNAs (miRNA, lncRNAs, circular RNAs); Prediction and characterization of ncRNAs from RNA-seq profiles; Structure prediction and validation of ncRNAs; Generation of new ncRNA resources and submission to genomic databases.

VII. Suggested Reading

- Ernesto Picardi Eds. 2015. *RNA bioinformatics*. Springer
- Ruzyo, G. J., and Walter, L., (Eds.) 2014. *RNA sequence, structure and function: computational and bioinformatic methods* –Springer
- Krebs, J. E., Lewin, B., Goldstein, E. S., Kilpatrick, S. T., 2014. *Lewin's Genes XI*- Jones & Bartlett Publishers
- MRS Rao. (ed.). 2017. *Long non-coding RNA biology*, springer
- Darnell J. 2011. *RNA: Life's indispensable molecule* – CSH press
- Krishnarao A. 2008. *MicroRNA-from basic science to disease biology*-Cambridge univ press

I. Course Title : Big Data Analytics

II. Course Code : BI 603

III. Credit Hours : 1+1

IV. Aim of the course

To introduce concepts of Big Data, Handling of unstructured genomic data using Big data analytics based tools.

V. Theory

Unit I (5 Lectures)

Big Data- Concepts, characteristics and relevance; MapReduce – Algorithm and application. Programming Models for Big Data.

Unit II (3 Lectures)

Hadoop framework, Hadoop Distributed File System (HDFS), YARN.

Unit III (5 Lectures)

Big Data SQL: – Hive Data Definition Language, Hive Data Manipulation Language, Hive Analytics: RegexSerDe, Views.

Unit IV (3 Lectures)

Apache Spark: Spark SQL, Spark DataFrame; PIG

VI. Practicals (16 Lectures)

Hadoop environment setup, HDFS, Spark SQL, Hadoop MapReduce, YARN, Hive, PIG.

VII. Suggested Reading

- Zikopoulos, P. C., Eaton, C., DeRoos, D., Deutsch, T., and Lapis, G. 2012. *Understanding big data: Analytics for enterprise class hadoop and streaming data* (p. 176). New York: Mcgraw-hill.
- Gandomi, A., and Haider, M. 2015. *Beyond the hype: Big data concepts, methods, and analytics*. *International Journal of Information Management*, *35*(2), 137-144.
- Akerkar R. (Ed.). 2013. *Big data computing*. CRC Press.
- Prajapati, V. 2013. *Big data analytics with R and Hadoop*. Packt Publishing Ltd.

I. Course Title : Systems Biology

II. Course Code : BI 604

III. Credit Hours : 3+0

IV. Aim of the course

This course provides emphasis on synthetic biology, modeling of genetic networks, cell-cell interactions, and evolutionary dynamics.

V. Theory

Unit I (16 Lectures)

Basic concepts in networks and chemical reactions; Input function of a gene, Michaelis-Menten kinetics, and cooperativity; Autoregulation, feedback and bistability; Introduction to synthetic biology and stability analysis in the toggle switch; Oscillatory genetic networks, Graph properties of transcription networks, Feed-forward loop network motif.

Unit-II (8 Lectures)

Introduction to stochastic gene expression, Causes and consequences of stochastic gene expression, Stochastic modeling—The master equation, Fokker-Planck Equation, and the Gillespie algorithm

Unit III (12 Lectures)

Introduction to microbial evolution experiments, and optimal gene circuit design, Evolution in finite populations, genetic drift, and the theory of neutral molecular evolution; Clonal interference and the distribution of beneficial mutations, Fitness landscapes and sequence spaces.

Unit IV (12 Lectures)

Evolutionary games; Survival in fluctuating environments, Parasites, the evolution of virulence and sex; Interspecies interactions, the Lotka-Volterra model, and predator-prey oscillations; Ecosystem stability, critical transitions, and the maintenance of biodiversity; Dynamics of populations in space, The neutral theory of ecology.

VI. Suggested Reading

- Alon, Uri. 2006. *An Introduction to Systems Biology: Design Principles of Biological Circuits*. Chapman & Hall / CRC. ISBN: 9781584886426.
- Nowak, M. A. 2006. *Evolutionary Dynamics: Exploring the Equations of Life*. Belknap Press, ISBN: 9780674023383.
- Bruce A. 2009. *Essential Cell Biology*. Garland Science, ISBN: 9780815341291.
- Strogatz, Steven H. 2014. *Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry, and Engineering*. Westview Press, ISBN: 9780813349107.
- L. AlberghinaH.V.westerhoff, 2005. *Systems Biology: Definitions and perspectives* Springer.
- A.Kriete, R.Eils,. 2014. *Computational systems biology* Second edition, Academic Press
- E.KlippR.Herwig, A.Kowlad, C.Wierling and H.Lehrach 2005. *Systems Biology in practice: Concepts, Implementation and applications*, WileyInterScience.
- Pengcheng Fu, Panke S. 2009. *Systems Biology and Synthetic Biology* Wiley InterScience.
- Rigoutsos I. and G. Stephanopoulos G. 2007. *Systems Biology* Vol.1: Genomics Oxford University Press Inc., USA.
- Choi S. 2007. *Introduction to Systems Biology*. Humana press Inc, New Jercy, USA.
- A.Kriete, R. Eils 2014. *Computational Systems Biology* (Second edition) Academic Press.

I. Course Title : Comparative and Functional Genomics

II. Course Code : BI 605

III. Credit Hours : 1+1

IV. Theory

Unit 1 (8 Lectures)

Functional elements, Chromosomes and transposons, Organellar Genomes, Symbiosis, Horizontal gene transfer, Gene duplication, Ploidy, Gene fates, Pan and core genomes, Recombination, Transposons, Gene clustering, SNPs and HapMaps, GWAS. Comparative methods for detection of species / organism relationships, Domain evolution, Study of co-evolution: Plant-insect interactions. Host-parasite interactions, viral evolution.

Unit II (8 Lectures)

Pre-and post-genomic era; major advancements in genomic approaches; epigenetics and metagenomics; forward versus reverse genetics, Genome editing approaches and their applications; gene expression analyses and applications. RNAi. DNA chips and their use in transcriptome analysis, qPCR, SAGE, MPSS. Connecting Traits to Genes, and Genes to Functions; protein-protein interaction, and protein networks.

V. Practicals (16 Lectures)

Getting started on the HPC, Regular expressions, Unix and basic sequence statistics Databases, Genome browsers, Blast & HMMER, Short sequence alignments, Distance trees, Maximum likelihood trees, Whole Genome Alignments, DotPlots, CoGeWebTool, AntiSMASHWebTool

VI. Suggested Reading

- Brown TA. 2006. *Genomes. 3rd edition. Garland Science*, New York.
- Sankoff D and Nadeau JH. 2000. *Comparative Genomics: Empirical and Analytical Approaches to Gene Order Dynamics, Map Alignment and the Evolution of Gene Families.* Netherlands, Kluwer Academic Publisher
- Jonathan Pevsner. 2009. *Bioinformatics and Functional Genomics*. Wiley Blackwell
- Wilkins MR, Williams KL, Appel RD, Hochstrasser DF. (Eds) 1997. *Proteome Research: New Frontiers in Functional Genomics*. Springer Verlag Berlin Heidelberg
- Gupta PK and Varshney RK. 2009. *Cereal genomics*.
- Grotewold E. 2006. *Plant Functional Genomics. Methods in Molecular Biology* Vol 236.
- Azuaje F and Dopazo J. 2005. *Data Analysis and Visualization in Genomics and Proteomics*. John Wiley & Sons, US
- Primrose S.B and Twyman R. 2003. *Principles of Genome Analysis and Genomics*. Third Edition.
- Baxevanis. A. D. and Ouellette. B. F. F. (Eds). 2001. *Bioinformatics: A Practical guide to the analysis of genes and proteins.* Wiley Interscience. New York. 470p.
- Hunt and Livesey. 2000. *Functional Genomics: A Practical Approach*. Oxford University Press.
- Jollès P and Jörnvall H. 2000. *Proteomics in Functional Genomics: Protein Structure Analysis*. Birkhäuser.
- Branden. C and J. Troze. 1999. *Introduction to Protein Structure*. Second Edition.
- Brown TA. 2002. *Genomes* IInd Edition. Oxford Wiley Press (ISBN-10: 0-471-25046-5)
- Yun Bi Xu. 2009. *Molecular Plant Breeding*. CABI (ISBN: 978 1 84593 392)

I. Course Title : Phylogenetics

II. Course Code : BI 606

III. Credit Hours : 2+1

IV. Aim of the course

To find out the evolutionary relationship among various species by using different phylogenetic techniques and algorithms.

V. Theory

Unit I (14 Lectures)

Phylogenetic trees and their comparison: Definition and description, various types of trees; Consensus (strict, semi-strict, Adams, majority rule, Nelson); Data partitioning and combination Tree to tree distances, similarity; Phylogenetic analysis algorithms: Maximum Parsimony, Distance based: UPGMA, Transformed Distance, Neighbors-Relation, Neighbor-Joining.

Unit II (18 Lectures)

Probabilistic models of evolution, Maximum likelihood algorithm; Approaches for tree reconstruction: Character optimization; delayed and accelerated transformation, Reliability of trees, Bootstrap, jackknife, decay, randomization tests; Applications of phylogeny analyses: Comparison of Phylogenetic Trees obtained using DNA seq. vs. protein seq. vs. Full genomes. Need for addition of other properties towards total phylogenetic analysis, Comparative methods for detection of species/ organism relationships, Gene duplication, Horizontal transfer, Domain evolution, Study of co-evolution: Plant-insect interactions. Host-parasite interactions, viral evolution.

VI. Practicals (16 Lectures)

Different software for phylogenetic tree construction and evolution of tree such as EMBOSS, MrBayes, PAUP, PHYLIP, PAML, TREE puzzle, Dandogram, cladogram analysis.

VII. Suggested Reading

- Hall, B. G. 2001. *Phylogenetic Tress Made Easy: A How to Manual for Molecular Biologists*. SinauerAss.,USA.
- Nei, M. and Kumar, S. 2000. *Molecular Evolution and Phylogenetics*. Oxford University Press.
- Sankoff, D. & Nadeau JH. 2000. *Comparative Genomics: Empirical and Analytical Approaches to Gene Order Dynamics, Map Alignment and the Evolution of Gene Families*. Netherlands, Kluwer Academic Publisher
- Gustavo Caetano. 2010. *Evolutionary Genomics and Systems Biology*. Wiley-blackwell.
- Mount.D.W.2001. *Bioinformatics: Sequence and Genome Analysis*. Cold Spring Harbor Laboratory Press. New York. 564 pp.
- Nei M and Kumar S. 2000. *Molecular Evolution and Phylogenetics* Oxford University Press.
- Engels J.M.M, RamanathaRao.V, Brown.A.H.D and Jackson.M.T, 2002. *Managing Plant Genetic Diversity*, CABI Publishers, CAB International UK 489pp.

I. Course Title : R and High Dimensional Genome Data

II. Course Code : BI 607

III. Credit Hours : 1+1

IV. Aim of the course

This course mainly aims at teaching R and its packages, programming to the students and make them acquainted with the use of R for data analysis, in general, and genomic data analysis, in particular.

V. Theory

Unit I (8 Lectures)

R programming language: Introduction and basics, R data types- Arithmetic and Logical Operators. R Matrix- Create, Print, add Column, Slice; R Data Frame-Create, Append, Select, Subset, Sort; List in R- Create, Select; R Functions; If, Else, Else If statements in R; For loop and While Loop in R; Data Importing and Exporting; Correlation, Anova, T test , Simple and Linear Regression, Scatter Plot, Bar Chart and Histogram in R; Memory management;

Unit II (8 Lectures)

Applications of R: Univariate and Multivariate phenotypic data analysis; Linear Models – fixed effects model, random effects model, mixed effects model for genetic parameter estimation; GGE Biplot and AMMI for Stability analysis; Gene Expression analysis – Microarray and RNA-Seq data; Genome Wide Association Study (GWAS), Genomic Selection (GS), Sequence analysis; Genome Assembly and Annotation; Machine Learning – ANN, SVM, Random Forest, Deep Learning.

VI. Practicals (16 Lectures)

Matrix Operations In R; R Data Frame, Functions in R, Correlation in R, Simple and Linear Regression in R. ANOVA in R, Other applications of R for crop and animal improvement.

VII. Suggested Reading

- Ihaka R and Gentleman R. 1996. *R: a language for data analysis and graphics*. *Journal of computational and graphical statistics*, *5*(3), 299-314.
- Gentleman R. 2008. *R programming for bioinformatics*. Chapman and Hall/CRC.

I. Course Title : Pharmacogenomics and IPR

II. Course Code : BI 608

III. Credit Hours : 3+1

IV. Theory

Unit I (8 Lectures)

Introduction to Drugs: Sources of drug- plant, animal, microbes, minerals. Drug name – chemical name, brand name or trade name, general name or common name. Drug classification – Chemotherapeutic agents, Pharmacodynamic agents, Miscellaneous agents. Routes of administration – Oral route and Parental route. Drug Absorption, Distribution, Metabolism and Excretion (ADME).

Unit II (8 Lectures)

Drug Response to Genetic Variations: SNP as markers in Pharmacogenomics- Turning SNPs into Useful Markers of Drug Response. Mechanism of drug action – receptor, agonist, ion channel. Inheritance and drug response - Pharmacogenetics of drug metabolism – Phase I metabolism, Phase II metabolism. Pharmacogenomics of Drug Transporters- Organic Anion and Cation Transporter Family, Peptide Transporter Family, Multidrug Resistance-Associated Proteins.

Unit III (6 Lectures)

Case Studies in Pharmacogenomics: Pharmacogenomics of Chemotherapeutic Agents in Cancer Treatment, Pharmacogenomics of Neurodegenerative Diseases: Examples and Perspectives, Pharmacogenomics of Alcoholism, Ethnicity and Pharmacogenomics. Ayugenomics. Pharmacogenomics and pharmaceutical Industries.

Unit IV (8 Lectures)

Basics of Toxicogenomics: Definition, genetic polymorphisms, Comparative toxicogenomics database (CTD) – Chemical gene interaction, chemical – disease association, gene – disease association. Specific applications of toxicogenomics – xenobiotics – insecticide - exposure assessment, hazard screening, variability of susceptibility, mechanistic information, cross-species extrapolation, dose-response relationship, development exposures, mixture.

Unit V (6 Lectures)

Databases for Toxicogenomics: Sample collection and data uniformity. Sharing and distributing data. Building toxicogenomic databases. ToxicogenomicDataRepositories – Standardization, availability, transparency. Data repositories - Stanford Microarray Database, CaBIG, DrugMatrix database, Tox-Express.

Unit VI (12 Lectures)

WTO and TRIPS Agreement: World Trade Organization (WTO)-Globalization-Trade Related Intellectual Property Rights (TRIPs) -General Obligations–substantive requirement of the TRIPS agreement in the WTO –International Union for the Protection of New Varieties of Plants (UPOV)- Multilateral treaties on patent

Forms of IPR and Role of Institutions: Different forms of IPR-Patents, Copyrights, GIs, Trademarks, Industrial Designs and Layouts, Trade secrets – Types of IPR forms-Utility, Design and plant patents, Generic and descriptive trademarks Role of Indian Patent Office (IPO), National Association of Creators, Owners and Users of Intellectual Property (NIPO), Geographical Indications (GI) registry-Multilateral organizations- World Intellectual Property Organization (WIPO), European Patent Office (EPO), US Patent and Trademark Office (USPTO),

Biotechnology and IP Rights: Biotech market in India- Biotech: SWOT – Bioinformatics in India – patent claims in biotechnology – patentable and non-patentable biotech inventions- patenting microorganisms and GMOs - Utility patents for genetic materials-patenting of biotech research tools - Types of bioinformatics patents -Infringement laws at National and International level- Acquisition / licensing of bio-tech patents and trade secrets.

IP Issues in Biotech Research and Development: Research and Development in Biotechnology - Biotechnology and seed policy- Role of Multi-national and Domestic Seed Firms- Moral issues in Patenting Biotechnological inventions- Bio-safety and Bioethics- International bio-safety protocols-cartegena protocols.

IP in Indian Agriculture: Sui-generis system and Status of plant varieties protection in India- Protection of plant genetic resources- protection of Bio-diversity in India- Protection of GIs.

V. Practicals (16 Lectures)

Literature resources: selection and study on a disease, Identification of receptor and ligand involved, search on the drugs at practice, mechanism of their action, toxicity issues-using search engines, Databases on Toxicogenomics- KEGG, chemical databases- Chemfinder, ADME databases, Identification of pharmacophores using databases- retrieving their properties, structure in Smiles notation using Pubchem/ drug bank. Conversion of SMILES, SYBYL, MOL files to PDB format- CORINA, conversion of coordinate file to topology formats- prodrg server, Small molecule generation, evaluation and optimization using Chemsketch, Comparative gene expression analysis on normal and diseased condition, A study on ADME properties- ADME database, calculation of ADME properties- Lipinski rule – Molinspiration tool, High throughput assay to determine a drug toxic effect- ADMEtox, Structural analysis of Protein and Pharmacophores; structural alignment, structural properties- Rasmol/SPDBV, Study of instruments used in experimental Pharmacology, smoking and fixing a kymograph - Handling of laboratory animals - Techniques of drug administrations in animals - Influence of route of administration of drugs on drug response.

VI. Suggested Reading

- Qing Yan. 2006. *Pharmacogenomics in Drug Discovery and Development*. Humana press.
- Licinio, J., and Wong, M.L. 2002. *Pharmacogenomics: The Search for Individualized Therapies*. Wiley-VCH,Verlag GmbH.
- Burcznski, M. E. 2003. *An Introduction to Toxicogenomics*. CRC press.
- Catania MG. 2005. *An A-Z Guide to Pharmacogenomics*, AACC Press.
- Kille P. 2008. *Comparative Toxicogenomics*. Christer Hogstrand. Elsevier Science
- Erbisch FH and Maredia K. 1998. *Intellectual Property Rights in Agricultural Biotechnology*. CABI.
- Anonymous. 2004. *State of Indian Farmer*. Vol. V. Technology, Ministry of Agriculture, Government of India.

- Rothschild M and Scott N. (Ed.). 2003. *Generation and IPR Issues*. Academic Foundation.
- B.L.Wadera. 1996. *Patents, Trade Marks, Copy Right Designs & Geographical Indications*. Universal Law Publishing Co.Pvt.Ltd.
- Narayana PS. 2004. *Intellectual Property Law in India*. K.C.Gogia ,M/S Gogia Law Publication.
- Ganguli P. 2008. *Intellectual Property Rights: Unleashing Knowledge Economy*, McGraw Hill, New Delhi
- Santaniello V, Evenson RE, Zilberman D, Carlson GA. 2000. *Agriculture and Intellectual Property Rights: Economic, Institutional and Implementation Issues in Biotechnology*, CABI Publishing, Wallingford, UK

I. Course Title : Biological Data Integration and Quality Control

II. Course Code : BI 609

III. Credit Hours : 1+1

IV. Aim of the course

To familiarize the techniques of data sources, data curation and integration of data sources

Unit I (5 Lectures)

Curation of genomics, genetic, proteomics, High-throughput screening, array, qPCR data sets; Quality management of data: tools and techniques.

Unit II (6 Lectures)

Biological data sources, Data granularity, Schema modelling, architecture, query design, extraction, transformation and loading, Long term data management, storage and security.

Unit III (5 Lectures)

Bio-chip information system, visualization and reporting, Risk factors for data quality management.

V. Practicals (16 Lectures)

Understanding the data sources, Data granularity, Data modeling and architecture, development of database, Storage, Security, Visualization and reporting.

VI. Suggested Reading

- Kozak, K. 2010. Large Scale Data Handling in Biology. 2010. Ventus Publishing ApS. ISBN 978-87-7681-555-4.
- Harold, E. and Means W.S. 2004. *XML in a Nutshell*, Third Ed. O'Reilly, Sebastopol, CA
- Witten, I.H. and Frank E. 2005. *Data Mining: Practical Machine Learning Tools and Techniques* WEKA, 2nd Ed. San Francisco, Morgan Kaufmann
- Lodish, H. *et al*. 2000. *Molecular Cell Biology*. New York: Freeman & Co.
- Kaneko K. 2006. *Life: An Introduction to Complex Systems Biology*. Springer.

I. Course Title : Quantum Theory and Applications in Biology

II. Course Code : BI 610

III. Credit Hours : 1+1

IV. Aim of the course

This course introduces the concepts of quantum theory with application in molecular biology

V. Theory

Unit I (5 Lectures)

Classical mechanics, Newton, Lagrange and Hamilton's equations, Schrodinger's equation and its complete solution for S.H.O, central force and angular momentum

Unit II (6 Lectures)

Atomic orbital models, the wave equation, molecular orbitals, the LCAO method, the overlap method, coulomb and resonance integrals, the hydrogen molecule, charge distributions, approximate methods

Unit III (5 Lectures)

Absorbance of frequency-specific radiation (photosynthesis), Conversion of chemical energy into motion, Magneto reception in animals, DNA mutation and Brownian motors in many cellular processes

VI. Practicals (16 Lectures)

Classical mechanics, Central force and angular momentum; Atomic orbital model, Wave equation, Resonance integers. DNA mutation and Brownian motors in many cellular processes.

VII. Suggested Reading

- Heisenberg W. 1949. *The Physical Principles of the Quantum T1heory*.
- Bohm D. 1951. *Quantum Theory*.
- Ghatakm AK and Lokanathan S. 2004. *Quantum Mechanics: Theory and Applications.*
- Bittner ER. 2009. *Quantum Dynamics: Applications in Biological and Materials Systems*.
- Blinder SM. 2004. *Introduction to Quantum Mechanics: In Chemistry, Materials Science, and Biology.*

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Biotechnology and Bioinformatics
– Molecular Biology and Biotechnology

Executive Summary
(Molecular Biology and Biotechnology)

There has been a surge of knowledge during the past decades in various streams of science and technology applicable to agriculture, attributed largely to growth in the frontier areas of basic sciences. Plant molecular biology is one such area that has evolved rapidly from conventional genetics, cell biology and tissue culture-based knowledge to the present level of precision genomic selection and genome editing technologies. This has been made possible by a deeper understanding of the basic molecular processes, genome organization, evolution and gene expression at molecular, cellular, organ and finally trait level. Explosion of plant genome and transcriptome data over the past two decades has enrichedour understanding of the vast amounts of genetic information present in the plant species and its role in plant growth and development. This is particularly important for agriculture where breaking the yield barrier has become a real challenge with limited availability of genetic resources for biotic and abiotic stress toleranceto face the global climate change. In such a scenario, plant Molecular Biology and Biotechnology assumes great significance as it has shown the potential for development of products and disruptive technologies with far reaching impact on the Indian agriculture.With this background, the present M.Sc. and Ph.D. syllabi for Molecular Biology and Biotechnology (MBB) is designed to acquaint the students with the basic and applied aspects of Plant Biotechnology. The course contents are structured to provide a complete insight in the subject and ignite the young minds with knowledge and wisdom to take up the challenge of research and teaching of modern Plant Biotechnology. The syllabus has now separate course contents for M.Sc.(500 series courses) and Ph.D.(600 series courses) programme, however a Ph.D. student may take some the M.Sc. courses if required to build the basic understanding in an area not studied during his/ her Master's programme. Following are the key features of the revised MBB course curriculum.

- A set of four courses (total 12 credits) including(i) Fundamentals of Molecular Biology, (ii) Molecular Cell Biology, (iii) Omics and Systems Biology and (iv) Techniques in Molecular Biology I now constitute the major 'Core' for the Masters programme. Additional 8 credits from the major subject will be taken as optional courses which will lead to specialization of the student towards functional genomics, molecular breeding or genetic engineering.
- The technique courses are designed to provide hands on exposure in the experimental procedures. This will prime the students with the basic laboratory skills for moving to diverse advance courses that cater to newer and frontier areas of Plant Biotechnology.
- Genomics is now a full-fledged domain consisting of various components. It combines the power of Bioinformatics to provide the necessary thrust for undertaking advance molecular breeding. A course on Omics and Systems Biology has been developed to address diverse areas including ionomics, metabolomics and proteomics.
- GM technology has now captured the public attention with huge societal impact and students need to prepare to understand its potential. The courses have been deigned to include contents on the latest techniques like genome editing for

developing precisiongenetic engineering.

- Climate change has been ravaging the rainfed agriculture for some time now and particularly abiotic stresses like heat, drought, flooding and salinity have assumed greater importance. Hence, a new course on "Stress Biology and Genomics" has been included to provide the students an insight into various approaches for tackling such crisis.
- Another new course on"Gene Regulation" is now part of the syllabus, its content includes various pathways involved in growth and development.
- Biotechnology is skill oriented with great market potential in the agrarian economy. A new course on "Bio-entrepreneurship" has been included to empower the students with basics of business creation, so that the idea of a "Startup" can be taken up at an early stage.
- Lately, RNAs have attracted immense attention as they assume greater significance in gene regulation. Hence, a new course on "RNA Biology" has been added as an advanced course to provide insights into potential role of non-coding RNAs in various regulatory pathways.
- Keeping in view the importance of plant hormones a new course on "Plant Hormones and Signaling" has been proposed.
- A course on "Plant Microbe Interaction" has been reintroduced as it is now more relevant under the changing soil and climatic conditions and provide a wealth of information through Metagenomics approaches.
- Genomics is incomplete without Bioinformatics and a new advanced course on "Computational and Statistical tools in Biotechnology" has been introduced in the doctorate program.
- Courses on Animal biotechnology have been dropped for providing a focused content exclusive to Plant Biotechnology.

Preamble

Development of cutting-edge technologies and skilled human resource is the need of the hourto put the country's agricultural growth on fast track. Biotechnology one such area which is essentially interdisciplinary in nature incorporating genetics, biochemistry, molecular biology, microbiology, immunology and most recently bioinformatics. It is based on techniques dealing with genes, genomes, nucleic acids and other related macro and micro biomolecules. Agricultural Biotechnology is a rapidly evolving branch of science that is expanding exponentially as an advanced interdisciplinary technology with immense application potential for Agriculture. To cite a few successful examples- banana, orchids and date palm cultivations in parts of India has become possible only because of tissue culture generated planting material. Similarly, Bt-cotton has been a commercial success, with new generation of Bt-cotton coming up to tackle emerging problems, genetically modified crops including brinjal, mustard, potato, tomato and maize have also been developed, awaiting regulatory approval for commercialization. Several varieties developed through of marker-assisted breeding have been already released and notified for commercial cultivation, *e.g.* rice varieties Swarna-Sub-1, Improved Samba Mahsuri, Pusa Basmati 1637, Pusa Basmati 1718, DRR Dhan 50, Ranjit-Sub-1, wheat variety Unnat PBW343, super chickpea variety BGM 10216 and so on. With the availability of high-quality reference genomes of many crop plants it is now possible to dissect the genetics of complex agronomic traits in a precise manner and utilize the information for marker-assisted breeding. With advancing gene editing tools,directed genome modification has now become a reality ushering in a new era of precision plant breeding. Thus, rice plants immune to bacterial leaf blight (BLB) disease have been developed by knocking down three sweet genes which are essential susceptibility factors for BLB infection. Other biotechnological applications include disease diagnostics, DNA bar coding for varietal protection, bio-pesticides, bio-fertilizers, crop residue management, bio-ethanol production, cryopreservation, artificial seed production, exploiting apomixis, male sterility and so on. Biotechnology is an emerging discipline with scope for constant innovations made possible by a deeper understanding of the basic molecular and cellular processes including their genetic basis. It is particularly important forthe agriculture sector where breaking the yield barrier is a challenge, and newsources for biotic and abiotic stress tolerance for adaptation to theglobal climate change are limited. In such a scenario, plant molecular biology and biotechnology assumes enormous significance as it has shown the potential for product development with far reaching impact on the Indian agriculture.

The tremendous impetus received for biotechnological research and education has been due to its direct impact on human and animal health, agricultural productivity and environment issues. Due to increasing acceptance of genetically modified foods and agricultural produce, big pharmaceutical and agribusiness companies are investing huge funds in the biotechnology R&D sector. At present in India the number of companies involved in R&D or product development or production related to biotechnology and life sciences products has grown close to 350. The demand for trained workforce in Biotechnology is ever growing in Research and Industry Sectors. Academic and research sectors require interdisciplinary trained human resource to furtherharness the power of biotechnological revolution. The need of the hour is to design appropriate syllabi that keeps pace with changing times and technology with emphasizes on utilization with in depth elucidation of the technology.With this background, the present syllabus for the Molecular Biology and Biotechnology (MBB) discipline was designed to acquaint the students with a basic and modern outlook of plant biotechnology. The course contents hve been structured to provide a complete insight and ignite the young minds with knowledge and wisdom to take up the dual challenge of research and teaching in modern agriculture.

A set of four courses namely Fundamentals of Molecular Biology, Molecular Cell Biology, Omics and Systems Biologyand Techniques in Molecular Biology I with a total of 12 credit hours constitutes the major core. The student will have to take 8 more credits of optional major courses according to their interest in functional genomics, molecular breeding or genetic engineering to complete the required 20 credit hours of major courses. A minor with total 6 credits needs to be taken from any of the related disciplines such as Genetics & Plant Breeding, Biochemistry, Plant Physiology, Microbiology, Plant Pathology, Plant Genetic Resources, Bioinformatics and others. Total 5 credit hours of courses must be taken from of the basic supporting disciplines including Genetics, Biochemistry, Microbiology, Bioinformatics, Computer Applications and Statistics. One credit of seminar and 30 credits of thesis research make up the total 70 credit hours required for the M.Sc. degree programme. Similarly, the credit hour distribution for Ph.D. courses have been revised to give added emphasis on research component as compared to theoretical courses. The overall requirement for Ph.D. programme is 12 credits for major courses (6 credits of core plus 6 credits of optional courses), 6 credits of minor courses from one of the related disciplines, 5 credits for basic supporting courses, 2 credits of seminar and 75 credits of thesis research, making a total of 100 credit hours.

All courses have been revised and new courses have been introduced keeping in view the recent developments in the MBB discipline. The new courses include: (i) **Omics and System biology** to address all the high throughput areas including genomics, transcriptomics, proteomics, metabolomics and ionomics; (ii) **Stress Biology and Genomics** to provide insights into various approaches for tackling climate change induced stresses; (iii) **Gene Regulation** focusing on various pathways of plant growth and development; (iv) **Bio-entrepreneurship** to empower the students with the basic knowledge of the business of Biotechnology; (v) **RNA Biology**to provide deeper insights into the potential role of non-coding RNAs in various regulatory pathways; (vi) **Plant Hormones and Signaling** to get deeper insights into the role of plant hormones; (vii) **Plant Microbe Interactions**to provide a wealth of information through microbial genomics and metagenomics approaches; and (viii) '**Computational and Statistical Tools in Biotechnology**' to cater for the growing need of the knowledge of Bioinformatics in MBB discipline. Animal biotechnology courses have been deleted to provide a focused content exclusive to Plant Biotechnology.

Thus, the present syllabus provides a proper balance of the advance molecular biology and their biotechnological applications.The restructuring of syllabus and courses has been done anticipating the future needs of Biotechnology Sector with more emphasis on imparting practical knowledge and skills. The main thrust was to makeit compatible with the recent developments in new education policy, research and industrial sectors and imparting an skill-set that will contribute to nation building through dissemination of specialized knowledge and skills in Agricultural Biotechnology.

Course Title with Credit Load
M.Sc. in Molecular Biology and Biotechnology

Course Code	Course Title	Credit Hours
	Major: 20 credits	
	(12 credits of core + 8 credits of optional)	
MBB 501	Principles of Biotechnology	3+0
MBB 502	Fundamentals of Molecular Biology*	3+0
MBB 503	Molecular Cell Biology*	3+0
MBB 504	Techniques in Molecular Biology I*	0+3
MBB 505	Omics and Systems Biology*	2+1
MBB 506	Plant Genetic Engineering	3+0
MBB 507	Techniques in Molecular Biology II	0+3
MBB 508	Introduction to Bioinformatics	2+1
MBB 509	Plant Tissue culture	2+1
MBB 510	Microbial and Industrial Biotechnology	2+1
MBB 511	Molecular Plant Breeding	2+1
MBB 512	IPR, Bio-safety and Bioethics	2+0
MBB 513	Immunologyand Molecular Diagnostics	3+0
MBB 514	Nano Biotechnology	2+1
MBB 515	Environmental Biotechnology	3+0
MBB 516	Bio-entrepreneurship#	1+0
MBB 517	Stress Biology and Genomics#	2+0
MBB 518	Gene Regulation#	2+0
	Minor (8 credits) – from one of the related disciplines	
	Biochemistry	
	Genetics and Plant Breeding	
	Microbiology	
	Plant Physiology	
	Plant Pathology	
	Entomology	
	Bioinformatics	
	Plant Genetic Resources	
	Any other related discipline	

Course Code	Course Title	Credits (L+P)
	Basic Supporting (6 credits) from the following disciplines	
	Biochemistry	
	Microbiology	
	Genetics and Plant Breeding	
	Statistics	
	Bioinformatics	
	Computer Applications	
	Common courses	5
MBB	Seminar	0+1
MBB500	Research	0+30
	Total	**70**

*Core Courses; # New Courses

Course Contents
M.Sc. in Molecular Biology and Biotechnology

I. Course Title : Principles of Biotechnology

II. Course Code : MBB 501

III. Credit Hours : 3+0

IV. Aim of the course

- To understand the basics of Molecular biology, plant and microbial Biotechnology
- Importance and applications in agriculture, case studies and success stories
- Public education, perception, IPR and related issues

V. Theory

Unit I (12 Lectures)

History, scope and importance of Biotechnology; Specializations in Agricultural Biotechnology: Genomics, Genetic engineering, Tissue Culture, Bio-fuel, Microbial Biotechnology, Food Biotechnology etc. Basics of Biotechnology, Primary metabolic pathways, Enzymes and its activities.

Unit II (16 Lectures)

Structure of DNA, RNA and protein, their physical and chemical properties. DNA function: Expression, exchange of genetic material, mutation. DNA modifying enzymes and vectors; Methods of recombinant DNA technology; Nucleic acid hybridization; DNA/RNA libraries; Applications of gene cloning in basic and applied research, Plant transformation: Gene transfer methods and applications of GM crops.

Unit III (8 Lectures)

Molecular analysis of nucleic acids -PCR and its application in agriculture and industry, Introduction to Molecular markers: RFLP, RAPD, SSR, SNP etc, and their applications; DNA sequencing, different methods; Plant cell and tissue culture techniques and their applications.Introduction to genomics, transcriptomics, ionomics, metabolomics and proteomics. Plant cell and tissue culture techniques and their applications.

Unit IV (12 Lectures)

Introduction to Emerging topics: Genome editing, gene silencing, Plant microbial interactions,Success stories in Biotechnology, Careers and employment in biotechnology. Public perception of biotechnology; Bio-safety and bioethics issues; Intellectual property rights in biotechnology.

VI. Suggested Reading

- Watson JD, Baker TA, Bell SP, Gann A, Levine M and Losick R. 2014. *Molecular Biology of the Gene*, 7th edition, Cold Spring Harbor Laboratory Press, New York
- Brown T A. 2010. *Gene Cloning and DNA analysis an Introduction* 6th edition, Wiley Blackwell
- Primrose SB and Twyman R. 2006. *Principles of gene Manipulation* 7th edition, Wiley Blackwell

- Singh BD. 2012. *Biotechnology: Expanding Horizons* 4th edition, Kalyani publisher, New Delhi, India

I. Course Title : Fundamentals of Molecular Biology

II. Course Code : MBB 502

III. Credit Hours : 3+0

IV. Aim of the course

- To understand the basics of DNA, RNA, structure, types and chromatin assembly.
- To get insights into the Central Dogma, basic cellular processes, role of mutation and recombination.
- To understand different levels of gene regulation and the pathways involved.

V. Theory

Unit I (8 Lectures)

Historical developments of molecular biology, Nucleic acids as genetic material, Chemistry and Nomenclature of nucleic acids; Structure of DNA: primary structure; secondary structure, Forms of DNA: A,B, Z and their function; Structure andTypes of RNA Genome organization in prokaryotes and eukaryotes; DNA Topology; DNA re-association kinetics, Types of repeat sequences.

Unit II (10 Lectures)

Central dogma of Molecular Biology; DNA replication- Classical experiments, Models of DNA replication; DNA replication, Origin and Steps in DNA replication - initiation, elongation and termination; Enzymes and accessory proteins and its mechanisms; Eukaryotic DNA replication in brief. Types of DNA damages and mutations; DNA repair mechanisms, Recombination: Homologous and non-homologous, Genetic consequences.

Unit III (8 Lectures)

Prokaryotic transcription, initiation, elongation and termination, promoters, Structure and function of eukaryotic RNAs and ribosomal proteins. Eukaryotic transcription – RNA polymerase I, II and III, Elongation and Termination, Eukaryotic promoters and enhancers, Transcription factors,Post transcriptional processing, Splicing: Catalytic RNAs, RNA stability and transport, RNA editing.

Unit IV (10 Lectures)

Genetic code and its characteristics,Universal and modified genetic code and its characteristics,Wobble hypothesis; Translational machinery; Ribosomes in prokaryotes and Eukaryotes. Initiation complex formation, Cap dependent and Cap independent initiation in eukaryotes,Elongation: translocation,transpeptidation and termination of translation; Co- and Post-translational modifications of proteins; Translational control; Protein stability -Protein turnover and degradation.

Unit V (12 Lectures)

Gene regulation in prokaryotes, Constitutive and Inducible expression, small molecule regulators; Operon concept: *lac* and *trp* operons, attenuation, anti-termination, stringent control.Gene regulation in eukaryotes– regulatory RNA and RNA interference mechanisms,Silencers, insulators, enhancers, mechanism of silencing and activation; Families of DNA binding transcription factors: Helix-turn-helix, helix-loop-helix etc. Epigenetic regulations

VI. Suggested Reading

- Nelson DL and Cox M.M. 2017. *Lehinger's Principles of Biochemistry*, 7th edition, W H Freeman Publication New York.
- Krebs, J.E., Goldstein, E.S., Kilpatrick, S.T. 2017. *Lewin's Genes* XII 12th edition, Jones & Bartlett Learning publisher, Inc.
- Watson, J.D., Baker, T.A., Bell, S.P., Gann, A., Levine, M and Losick R. 2014. *Molecular Biology of the Gene*, 7th edition, Cold Spring Harbor Laboratory Press, New York.
- Alberts, B. 2017. *Molecular Biology of the Cell* 5th edition, WW Norton & Co, Inc.
- Allison, L.A. 2011. *Fundamentals of Molecular Biology*. 2nd Edition, John Wiley and Sons.

I. Course Title : Molecular Cell Biology

II. Course Code : MBB 503

III. Credit Hours : 3+0

IV. Aim of the course

- To understand the basics structure and function of plant and animal cell
- To get insights into the basic cellular processes, transport, signalling, cell movement, cell division and general regulation mechanisms.

V. Theory

Unit I (8 Lectures)

Origin of life, History of cell biology, Evolution of the cell: endo-symbiotic theory, treeof life, General structure and differences between prokaryotic and eukaryotic cell; Similarities and distinction between plant and animal cells; different kinds of cells inplant and animal tissues.

Unit II (8 Lectures)

Cell wall, cell membrane, structure and composition of bio-membranes, Structure and function of major organelles: Endoplasmic reticulum Ribosomes, Golgi apparatus, Mitochondria, Chloroplasts, Lysosomes, Peroxisomes, Micro-bodies, Vacuoles, Nucleus, Cyto-skeletal elements.

Unit III (12 Lectures)

Membrane transport; Diffusion, osmosis, ion channels, active transport, mechanism of protein sorting and regulation of intracellular transport, transmembrane and vesicular transport - endocytosis and exocytosis; General principles of cell communication: hormones and their receptors,signaling through G-protein coupled receptors, enzyme linked receptors; signal transduction mechanisms and regulation, Cell junctions, Cell adhesion, Cell movement; Extracellular matrix.

Unit IV (10 Lectures)

Chromatin structure, Cell division and regulation of cell cycle; Mechanisms of cell division, Molecular eventsat M phase, mitosis and cytokinesis, Ribosomes in relation to cell growth and division, Extracellular and intracellular Control of Cell Division; abnormal cell division: cancer- hall marks of cancer and role of oncogenes and tumor suppressor genes in cancer development - Programmed cell death (Apoptosis).

Unit V (10 Lectures)

Morphogenetic movements and the shaping of the body plan, Cell diversification, cellmemory, cell determination, and the concept of positional values; Differentiated cells and the maintenance of tissues and organ development; Stem cells: types and applications; Basics of Animal development in model organisms (*C. elegans*; *Drosophila*); Plant development.

VI. Suggested Reading

- Alberts, B. 2017. *Molecular Biology of the Cell* 5th edition, WW Norton & Co, Inc.
- Lodish, H., Berk, A., Kaiser, C.A., Krieger, M., Bretscher, A., Ploegh, H., Amon, A., Martin, K.C., 2016. *Molecular Cell Biology* 8th Edition. W.H. Freeman & Co. New York.
- Alberts, B., Bray, D., Lewis, J., Raff, M., Roberts, K., Hopkin, K., Johnson, A., Walter, P., 2013 *Essential of Cell Biology*, WW Norton & Co, Inc.
- Cooper, G.M. and Hausman, R.E. 2013. *The cell: A Molecular Approach* 6th edition, Sinauer Associates, Inc.

I. Course Title : Techniques in Molecular Biology I

II. Course Code : MBB 504

III. Credit Hours : 0+3

IV. Aim of the course

- To get a basic overview of molecular biology techniques, good lab practices and recombinant DNA technology
- To get a hands on training in chromatography, protein analysis, nucleic acid analysis, bacterial and phage genetics

V. Practicals

- Good lab practices, preparation of buffers and reagents.
- Principle of centrifugation and spectrophotometry.
- Growth of bacterial culture and preparation of growth curve, Isolation of Genomic DNA from bacteria.
- Isolation of plasmid DNA from bacteria.
- Growth of lambda phage and isolation of phage DNA.
- Isolation and restriction of plant DNA (e.g. Rice / Moong / Mango / Merigold).
- Quantification of DNA by (a) Agarose Gel electrophoresis and (b) Spectrophotometry
- PCR using isolated DNA.
- PAGEGel electrophoresis.
- Restriction digestion of plasmid and phage DNA, ligation, Recombinant DNA construction.
- Transformation of *E. coli* and selection of transformants
- Chromatographic techniques
  a. TLC
  b. Gel Filtration Chromatography,
  c. Ion exchange Chromatography,
  d. Affinity Chromatography
- Dot blot analysis, Southern hybridization,Northern hybridization.
- Western blotting and ELISA.
- Radiation safety and non-radio isotopic procedure.

VI. Suggested Reading

- Sambrook, J., and Russell, R.W. 2001. *Molecular Cloning: A Laboratory Manual* 3rd Edition, Cold spring harbor laboratory press, New York.
- Wilson, K., and Walker, J., 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th edition, Cambridge University Press.
- Ausubel FM, Brent R, Kingston RE, Moore DD, Seidman JG, Smith JA and Struhl K. 2002. *Short Protocols in Molecular Biology* 5th edition, Current Protocols publication.

I. Course Title : Omics and Systems Biology

II. Course Code : MBB 505

III. Credit Hours : 2+1

IV. Aim of the course

- To get a basic overview of genomics, proteomics, ionomics and metabolomics
- To get a primary information on the application of omics science across the industry

V. Theory

Unit I (8 Lectures)

Different methods of genome sequencing, principles of various sequencing chemistries, physical and genetic maps, Comparative and evolutionary genomics, Organelle genomics, applications in phylogenetics, case studies of completed genomes, preliminary genome data analysis, basics of ionomics analysis, different methods

Unit II (6 Lectures)

Protein-basics: primary-, secondary- and tertiary structure, Basics of X-ray crystallography and NMR, Principal and Applications of mass spectrometry, Proteomics: Gel based and gel free, Basics of software used in proteomics, MASCOT, PD-Quest, etc., Study of protein interactions, Prokaryotic and yeast-based expression system and purification

Unit III (6 Lectures)

Metabolomics and its applications, Use of 1D/2D NMR and MS in metabolome analysis, Multivariate analysis and identification of metabolite as biomarkers, Study of ionome using inductively coupled plasma – mass spectroscopy (ICP-MS), X-Ray Fluorescence (XRF), Neutron activation analysis (NAA), Data integration using genome, transcriptome, proteome, metabolome and ionome with phenome.

Unit IV (6 Lectures)

Introductory systems Biology - The biochemical models, genetic models and systems model, Molecules to Pathway, Equilibrium binding and cooperatively – Michaelis-Menten Kinetics, Biological oscillators, Genetic oscillators,Quorum Sensing, Cell-cell communication, *Drosophila* Development, Pathways to Network, Gene regulation at a single cell level, transcription network, REGULATORY CIRCUITS, Negative and positive auto-regulation, Alternative Stable States, Bimodal Switches, Network building and analysis

VI. Practical (12)

- Isolation of HMW DNA and brief overview of sequencing, Primary information on genome data analysis.
- BSA Standard curve preparation, Extraction of protein and estimation methods.
- Quantification of proteins from different plant tissues using spectrophotometry.
- 2-D Gel Electrophoresis, 2-D Image analysis.
- Experiments on protein-protein interaction (Yeast 2-hybrid, Split Ubiquitin system).
- Demonstration on MALDI-TOF.
- Demonstration on ICP-MS, AAS, Nitrogen estimation using various methods.

VII. Suggested Reading

- Primrose, S.B. and Twyman, R. 2006. *Principles of Gene Manipulation* 7th edition, Wiley Blackwell
- Wilson, K., and Walker, J. 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th Edition, Cambridge University Press.

I. Course Title : Plant Genetic Engineering

II. Course Code : MBB 506

III. Credit Hours : 3+0

IV. Aim of the course

- To get a basic overview of molecular cloning, vectors and genomic library construction.
- To get anoverview of PCR and its applications, sequencing, gene knockouts, transgenics etc.

V. Theory

Unit I (10 Lectures)

Historical background, Restriction Enzymes; DNA Modifying enzymes, ligase, T4 DNA polymerase, Polynucleotide kinaseetc, Cohesive and blunt end ligation; Labeling of DNA: Nick translation, Random priming, Radioactive and non-radioactive probes, Hybridization techniques: Northern, Southern and Colony hybridization, Fluorescence in situ hybridization; Chromatin Immunoprecipitation; DNA-Protein Interactions: Electromobility shift assay.

Unit II (14 Lectures)

Plasmids; Bacteriophages; M13, Phagemids; Lambda vectors; Insertion and Replacement vectors; Cosmids; Artificial chromosome vectors (YACs; BACs); Animal Virus derived vectors-SV-40; Expression vectors; pMal,pET-based vectors; Protein purification; His-tag; GST-tag; MBP-tag, etc.; Baculovirus vectors system, Plant based vectors, Ti and Ri plasmids as vectors, Yeast vectors, Shuttle vectors. Transformation; Construction of libraries; Isolation of mRNA and total RNA; cDNA and genomic libraries; cDNA and genomic cloning, Jumping and hopping libraries, Protein-protein interactive cloning and Yeast two hybrid system; Phage display; Principles in maximizing gene expression; Codon optimization for heterologous expression. Introduction of DNA into mammalian cells; Transfection techniques

Unit III (12 Lectures)

Principles of PCR, Primer design,DNApolymerases, Types of PCR – multiplex, nested, reverse transcriptase, real time PCR, touchdown PCR, hot start PCR, colony PCR, cloning of PCR products; T- vectors; Applications of PCR in gene recombination, Site specific mutagenesis, in molecular diagnostics; Viral and bacterial detection; Mutation detection: SSCP, DGGE, RFLP, Oligo Ligation Assay.

Unit IV (12 Lectures)

Genetic transformation of plants: DNA delivery – *Agrobacterium* mediated method. Direct DNA delivery – chemical mediated electroporation and particle bombardment. Vectors and transgene design - Promoters and Marker genes. Chloroplast transformation. Development of marker-free plants. Analysis of transgenic plants – molecular and Biochemical assays, genetic analysis - Identification of gene integration site - Advance methods – *cis* genesis, intragenesis and targeted genome modification – ZFN, TALENS and CRISPR. Application of transgenic technology.

VI. Suggested Reading

- Brown, T.A. 2010. *Gene Cloning and DNA Analysis an Introduction.* 6th edition, Wiley Blackwel.
- Primrose, S.B. and Twyman, R. 2006. *Principles of Gene Manipulation* 7th edition, Wiley Blackwell.
- Sambrook, J., and Russell, R.W. 2001. *Molecular cloning: A laboratory manual* 3rd Edition, Cold spring harbor laboratory press, New York.
- Wilson, K., and Walker, J. 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th Edition, Cambridge University Press.

I. Course Title : Techniques in Molecular Biology II

II. Course Code : MBB 507

III. Credit Hours : 0+3

IV. Aim of the course

- To get a basic overview of molecular biology techniques, good lab practices and molecular markers.
- To get a hands on training in RNAi, microarrays, yeast2 hybrid and immunological techniques.

V. Practicals

Construction of gene libraries (cDNA and Genomics).

- Synthesis and cloning of cDNA.
- Real time PCR and interpretation of data.
- Molecular markers
  - i. RAPD.
  - ii. SSR.
  - iii. AFLP / ISSR and their analysis.
- Case study of SSR markers - construction of linkage map.
- QTL analysis using genotypic data based on SSR.
- SNP identification and analysis.
- Microarray studies and use of relevant software.
- Proteomics
  - i. 2D gels,
  - ii. Mass spectrometry
- RNAi - designing of construct, phenotyping of the plant.
- Yeast 1 and 2-hybrid interaction.
- Generation and screening of mutants.
- Transposon mediated mutagenesis.
- Immunology and molecular diagnostics: Ouchterlony double diffusion, Immunoprecipitation, Radiation Immunodiffusion, Immunoelectrophoretic, Rocket Immunoelectrophoretic, Counter Current Immunoelectrophoretic,ELISA, Latex Agglutination, Immunohistochemistry.

VI. Suggested Reading

- Wilson, K., and Walker, J. 2018. *Principles and Techniques of Biochemistry and Molecular Biology* 8th Edition, Cambridge University Press
- Bonifacino, J. S., Dasso, M., Harford, J. B., Liipincott-Schwartz, J., and Yamada, K. M. 2004. *ShortProtocols in Cell Biology*. John Wiley & Sons, New Jersey

- Hawes, C., and Satiat-Jeunemaitre, B. 2001. *Plant Cell Biology: Practical Approach*. Oxford University Press, Oxford
- Sawhney, S.K., Singh, R. 2014. *Introductory Practical Biochemistry*, Alpha science international limited

I. Course Title : Introduction to Bioinformatics

II. Course Code : MBB 508

III. Credit Hours : 2+1

IV. Aim of the course

- To get a basic overview of computational techniques related to DNA, RNA and protein analysis.
- To get a hands on training in software's and programs used to analyse, assemble or annotate genomes, phylogenetics, proteomics etc.

V. Theory

Unit I (8 Lectures)

Bioinformatics basics, scope and importance of bioinformatics; Biological databases for DNA and Protein sequences -PIR, SWISSPROT, GenBank, DDBJ, secondary database, structural databases –PDB,SCOP and CATH, Specialized genomic resources, Microarray database.

Unit II (10 Lectures)

Bioinformatics Tools Facilitate the Genome-Wide Identification of Protein-Coding Genes, Sequence analysis, Sequence submission and retrieval system-SEQUIN, BANKit, SAKURA, Webin, Sequence alignment, pair wise alignment techniques, multiple sequence alignment; Tools for Sequence alignment- BLAST and its variants; Phylogenetic analysis- CLUSTAL X, CLUSTAL W, Phylip, Tcoffee

Unit III (10 Lectures)

Sequencing of protein; Protein secondary structure prediction- Chousfasman, GOR Method, Protein 3DStructure Prediction: Evaluation of models- Structure validation and refinement - Ramachandran plot, Force field calculations, SAVES. Protein function prediction- sequence and domain based, Primer designing- principles and methods.Drug discovery**,** Structure Based Drug Design- Rationale for computer aided drug designing, basic principles, docking, QSAR.

VI. Practical (12 Lectures)

- Usage of NCBI resources
- Retrieval of sequence/structure from databases and submission
- Different Databases, BLAST exercises.
- Assembly of DNA and RNA Seq data
- Annotation of assembled sequences,Phylogenetics and alignment
- Visualization of structures, Docking of ligand receptors
- Protein structure analysis and modeling

VII. Suggested Reading

- Attwood, T.K., and Parry-Smith, D. J. 2004. *Introduction to Bioinformatics*, Pearson Education (Singapore) Pvt. Ltd.
- David Edwards (Ed.) 2007. *Plant Bioinformatics: Methods and Protocols*. Humana Press, New Jersey, USA.

- Mount, D.W. 2004. *Bioinformatics: Sequence and Genome Analysis*. 2nd Revised edition Cold Spring Harbor Laboratory Press, U.S.
- Pevsner J. 2009. *Bioinformatics and Functional Genomics*, 2nd edition, Wiley-Blackwell.

I. Course Title : Plant Tissue Culture

II. Course Code : MBB 509

III. Credit Hours : 2+1

IV. Aim of the course

- To provide insight into principles of plant cell culture and genetic transformation.
- To get a hands on training in basic plant tissue culture techniques, callusing, micropropagation and analysis.

V. Theory

Unit I (12 Lectures)

History of plant tissue culture, principle of Totipotency; Tissue culture media; Plant hormones and morphogenesis; Direct and indirect organogenesis; Direct and indirect somatic embryogenesis; Applications of planttissueculture; National certification and Quality management of TC plants; Genetic Fidelity testing and Virus indexing methods – PCR, ELISA

Unit II (12 Lectures)

Micropropagation of field and ornamental crops; Virus elimination by meristem culture, meristemtip culture and micrografting; Androgenesis and gynogenesis - production of androgenic and gynogenic haploids - diploidization; Protoplast culture - isolation and purification; Protoplast culture; Protoplast fusion; Somatic hybridization - Production of Somatic hybrids and Cybrids;, Wide hybridization - embryo culture and embryo rescuetechniques; Ovule, ovary culture and endosperm culture.

Unit III (12 Lectures)

Large-scalecell suspension culture - Production of alkaloids and other secondary metabolites- techniques to enhance secondary metabolite production, Somaclonal and gametoclonal variations – causes and applications; Callus culture and *in vitro* screening for stress tolerance; Artificial seeds, *In vitro* germplasm storage and cryo-preservation. Commercial Tissue Culture: Case studies and success stories, Market assessment; project planning and preparation, economics, government policies

VI. Practical (12)

- Preparation of stocks - macronutrients, micronutrients, vitamins and hormones, filter sterilization of hormones and antibiotics. Preparation of Murashige and Skoog medium.
- Micro-propagation of plants by nodal and shoot tip culture.
- Embryo culture to overcome incompatibility, Anther culture for haploid production.
- Callus induction in tobacco leaf discs, regeneration of shoots, root induction, role of hormones in morphogenesis.
- Acclimatization of tissue culture plants and establishment in greenhouse.
- Virus indexing in tissue culture plants. (Using PCR and ELISA).
- Plan of a commercial tissue culture unit.

VII. Suggested Reading

- Razdan, M.K. 2003. *Introduction to plant tissue culture*, 2nd edition, Oxford publications group
- Butenko, R.G. 2000. *Plant Cell Culture* University Press of Pacific
- Herman, E.B. 2008. *Media and Techniques for Growth, Regeneration and Storage*, Agritech Publications, New York, USA.
- Bhojwani, S.S and Dantu P. 2013. *Plant Tissue Culture – An Introductory Text*. Springer Publications.
- Gamborg, O.L and G.C. Philips (eds.). 2013. *Plant Cell, Tissue and Organ culture-Lab Manual*. Springer Science & Business media.

I. Course Title : Microbial/ Industrial Biotechnology

II. Course Code : MBB 510

III. Credit Hours : 2-+1

IV. Aim of the course

To familiarize about the various microbialprocesses/systems/activities, which have been used for the development of industrially important products/processes.

V. Theory

Unit (8 Lectures)

Introduction, scope and historical developments; Isolation, screening and genetic improvement (involving classical approaches) of industrially important organisms.

Unit II (8 Lectures)

Primary metabolites, production of industrial ethanol as a case study; Secondary metabolites, bacterial antibiotics and non-ribosomal peptide antibiotics as case study; Recombinant DNA technologies for microbial processes; Strategies for development of industrial microbial strains with scale up production capacities; Metabolic pathway engineering of microbes for production of novel product for industry.

Unit III (8 Lectures)

Microbial enzymes, role in various industrial processes, production of fine chemicals for pharmaceutical industries; Bio-transformations, Bio- augmentation with production of vitamin C as a case study; Bioreactors, their design and types; Immobilized enzymes-based bioreactors; Microencapsulation technologies for immobilization of microbial enzymes.

Unit IV (8 Lectures)

Environmental Biotechnology, biotreatment for pollution control, treatment of industrial and other wastes, biomass production involving single cell protein; Bio-remediation of soil; Production of eco-friendly agricultural chemicals, bio- pesticides, bio-herbicides, bio-fertilizers, bio-fuels, etc.

VI. Practical

- Isolation of industrially important microorganisms, their maintenance and improvement.
- Lab scale production of industrial compounds such as alcohol, beer, citric acid, lactic acid and their recovery.
- Study of bio-reactors and their operations.
- Production of bio-fertilizers.
- Experiments on microbial fermentation processofantibiotics, bio-pigments, dairy products,

harvesting purification and recovery of end products.
- Immobilization of cells and enzymes, studies on its kinetic behavior, growth analysis and biomassestimation.
- Determination of mass transfer coefficient.

VII. Suggested Reading

- Waites, M.J., Morgan, N.L., Rockey, J.S., Higton, G. 2001. *Industrial Microbiology: An Introduction*, Wiley-Blackwell.
- Slater, A., Scott, N.W., & Fowler, M.R. 2003. *The Genetic Manipulation of Plants. Plant Biotechnology Oxford, England: Oxford University Press*.
- Kun, L.Y. (Ed.). 2003. *Microbial biotechnology: principles and applications*. World Scientific Publishing Company.

I. Course Title : Molecular Plant Breeding
II. Course Code : MBB 511
III. Credit Hours : 2-+1

IV. Aim of the course

- To familiarize the students about the use of molecular biology tools in plant breeding.
- To provide a hands on training in data analysis, diversity analysis and mapping of genes and QTLs.

V. Theory

Unit I (8 Lectures)

Inheritance of qualitative and quantitative traits. Heritability – its estimation, Population structure of self- and cross-pollinated species, Factors affecting selection efficiency. Development of different kinds of segregating populations – F_2, F_3, BC_1F_1, BC_1F_2, BC_4F_2, RIL (Recombinant Inbred Lines), AIL (Advanced Intercrossed Lines), DH (Di-haploid population), NIL (Near Isogenic lines), NAM (Nested Association Mapping), MAGIC (Multi-parent Advanced Generation Intercross population).

Unit II (8 Lectures)

Causes of sequence variation and its types, Types of molecular markers and development of sequence based molecular markers – RFLP, AFLP, SCARs, CAPS, SSRs, STMS, SNPsInDel and DARTseq; Inheritance of markers, Linkage analysis using test cross, F_2, F_3, BC_1F_1, RIL. Construction of genetic map, Mapping genes for qualitative traits; Genotyping by sequencing and high-density chip arrays.

Unit III (8 Lectures)

QTL mapping using structured populations; Association mapping using unstructured populations; Genome Wide Association Studies (GWAS),Principle of Association mapping– GWAS-SNP genotyping methods, DART array sequencing, Illumina's Golden Gate Technology, Genotyping by sequencing methods- Fluidigm; GBS, Illumina Hi seq- Nano pore sequencing, Principles and methods of Genomic Selection, Fine mapping of genes/QTL; Development of gene based markers; Allele mining by TILLING and Eco-TILLING.

Unit IV (8 Lectures)

Tagging and mapping of genes. Bulk segregant and co-segregation analysis, Marker assisted selection (MAS); Linked, unlinked, recombinant, flanking, peak markers. Foreground and background selection; MAS for gene introgression and pyramiding: MAS for specific traits with examples. Haplotype concept and Haplotype-based breeding; Genetic variability and DNA fingerprinting. Molecular markers in Plant variety protection, IPR issues, hybrid purity testing, clonal fidelity testing and transgenic testing.

VI. Practical

- Construction of linkage map.
- QTL analysis using the QTL cartographer and other software.
- SNP data analysis using TASEEL.
- Detection of haplotype block using SNP data - pLinksoftware.
- Genotyping by sequencing methods –Illumina genotyping platform.
- Marker assisted breeding – MABB case studies quality traits in rice/maize.
- Genome Assisted Breeding in model crops, Genomic Selection models usingthe morphological and SNP data

VII. Suggested Reading

- Acquaah, G. 2007. *Principles of Plant Genetics and Breeding*, Blackwell Publishing Ltd. USA.
- Weising, K., Nybom, H., Wolff, K., and Kahl, G. 2005. *DNA Fingerprinting in Plants: Principles, Methods and Applications*, 2nd ed. Taylor and Francis Group, Boca Raton, FL.
- Halford, N. 2006. *Plant Biotechnology-Current and future applications of genetically modified crops*, John Wiley and Sons, England.
- Singh, B. D. and Singh, A. K. 2015. *Marker-Assisted Plant Breeding: Principles and Practices* Springer (India) Pvt. Ltd.

5. Boopathi, NM. 2013. *Genetic Mapping and Marker Assisted Selection: Basics, Practice and Benefits*. Springer India. p293.

I. Course Title : IPR, Bio-safety & Bioethics

II. Course Code : MBB 512

III. Credit Hours : 2+0

IV. Aim of the course

- To familiarize the students about ethical and biosafety issues in plant biotechnology.
- To provide a hands-on training in data analysis, diversity analysis and mapping of genes and QTLs.

V. Theory

Unit I (10 Lectures)

IPR: historical background in India; trade secret; patent, trademark, design& licensing; procedure for patent application in India; Patent Cooperation Treaty (PCT); Examples of patents in biotechnology-Case studies in India and abroad; copyright and PVP; Implications of IPR on the commercialization of biotechnology products, ecological implications; Trade agreements- The WTO and other international agreements, and Cross border movement of germplasms.

Unit II (8 Lectures)

Biosafety and bio-hazards; General principles for the laboratory and environmental bio-safety; Biosafety and risk assessment issues; handling and disposal of bio-hazards; Approved regulatory laboratory practice and principles,The Cartagena

Protocol on biosafety; Biosafety regulations in India; national Biosafety Policy and Law; Regulations and Guidelines related to Biosafety in other countries

Unit III (8 Lectures)

Potential concerns of transgenic plants – Environmental safety and food and feed safety. Principles of safety assessment of Transgenic plants – sequential steps in risk assessment. Concepts of familiarity and substantial equivalence. Risk - Environmental risk assessment – invasiveness, weediness, gene flow, horizontal gene transfer, impact on non-target organisms; food and feed safety assessment – toxicity and allergenicity.Monitoring strategies and methods for detecting transgenics.

Unit IV (6 Lectures)

Field trails – Biosafety research trials – standard operating procedures, labeling of GM food and crop,Bio-ethics- Mankind and religion, social, spiritual & environmental ethics; Ethics in Biotechnology, labeling of GM food and crop; Biopiracy

VI. Suggested Reading

- Goel, D. and Parashar, S. 2013. *IPR, biosafety, and bioethics*.
- Joshi, R. 2006. *Biosafety and Bioethics*.
- Nambisan, P. 2017. *An Introduction to Ethical, Safety and Intellectual Property Rights Issues in Biotechnology*.

I. Course Title : Immunology and Molecular Diagnostics

II. Course Code : MBB 513

III. Credit Hours : 3+0

IV. Theory

Unit I (6 Lectures)

Immunity and its classification; Components of innate and acquired immunity; Lymphatic system; Hematopoiesis; Organs and cells of the immune system- primary, secondary and tertiary lymphoid organs Descriptions of Antigens - immunogens, hapten and adjuvants.

Unit II (12 Lectures)

Immunoglobulins-basic structure, classes & subclasses of immunoglobulins, antigenic determinants; Multigene organization of immunoglobulin genes; B-cell receptor; Immunoglobulin superfamily; Principles of cell signaling; Basis of self and non-selfdiscrimination; Kinetics of immune response, memory; B cell maturation, activation and differentiation; Generation of antibody diversity; T-cell maturation, activation and differentiation and T-cell receptors; Functional T Cell Subsets; Cell-mediated immune responses, ADCC; Cluster of Differentiations (CDs), Cytokines-properties, receptors and therapeutic uses.

Unit III (8 Lectures)

Phagocytosis; Complement and Inflammatory responses; Major Histocompatibility Complex - MHC genes, MHC and immune responsiveness and disease susceptibility, HLA typing; Antigen processing and presentation- endogenous antigens, exogenous antigens, non-peptide bacterial antigens and super-antigens; Cell-cell co-operation, Hapten-carrier system

Unit IV (10 Lectures)

Precipitation, agglutination and complement mediated immune reactions; Advanced immunological techniques – RIA, ELISA, Western blotting, ELISPOT assay, immunofluorescence, flow cytometry and immunoelectron microscopy; Surface plasmon resonance, Biosenor assays for assessing ligand –receptor interaction, CMI techniques- lymphoproliferation assay, Mixed lymphocyte reaction, Cell Cytotoxicity assays, Apoptosis, Transgenic mice, Gene knock outs

Unit V (12 Lectures)

Active and passive immunization; Live, killed, attenuated, sub unit vaccines; Vaccine technology- Role and properties of adjuvants, recombinant DNA and protein based vaccines, plant-based vaccines, Antibody genes and antibody engineering- chimeric and hybrid monoclonal antibodies, Immunity to Infection,Bacteria, viral, fungal and parasitic infections, Hypersensitivity – Type I-IV; Autoimmunity; Types of autoimmune diseases, MHC and TCR in autoimmunity; Transplantation, Immunological basis of graft rejection, immunosuppressive therapy; Tumor immunology – Tumor antigens.

V. Suggested Reading

- Owen J.A., Punt, J., & Stranford, S. A. 2013. *Kuby immunology* (p. 692). New York: WH Freeman.
- Kenneth, M., and Weaver, C. 2017. *Janeways Immunobiology*, 9th Edition, New York, USA: Garland Science, Taylor & Francis publisher.
- William, P. 2013. *Fundamental of Immunology*, 7th edition, Lippencott, William and Wilkins publisher.

I. Course Title : Nano Biotechnology

II. Course Code : MBB 514

III. Credit Hours : 2+1

IV. Aim of the course

Understanding the molecular techniques involved in structure and functions of nano-biomolecules in cells such as DNA, RNA and proteins.

V. Theory

Unit I (8 Lectures)

Introduction to Nanotechnology - Nanomaterials - Self-assembly to artificial assembly for creation of useful nanostructures – Bottoms up and Top down approach (Nano rods, nano cages, nanotubes, quantum dots, nanowires, metal/ polymer-based nanostructures) – Preparation and Characterization of nanoparticles (particle size analyzer, microscopy, viz. electron microscopy, atomic force microscopy, etc).

Unit (8 Lectures)

Cell structure – Bio macromolecules: Types, Structure, Dynamics and interaction with water – Cellular nano machines – cellular transducers, membrane channels, membrane transporters, Membrane motors – Creation of bio-nanostructures (Nano liposomes, Nano micelles, Nanomotors, etc).

Unit III (8 Lectures)

Chemical, physical and biological properties of biomaterials and bio response: biomineralization, biosynthesis, and properties of natural materials (proteins, DNA, and polysaccharides), structure-property relationships in polymeric materials (synthetic polymers and structural proteins); Aerosol properties, application and dynamics; Statistical Mechanics in Biological Systems,

Unit (8 Lectures)

Nanoparticular carrier systems; Micro- and Nano-fluidics; Drug and gene delivery system; Microfabrication, Biosensors, Chip technologies, Nano- imaging, Metabolic engineering and Gene therapy.

VI. Practical

- Isolation of enzymes and nucleic acids involved in biosynthesis of nanomaterials
- Synthesis of Gold/silver Nanoparticles by biogenic methods, Synthesis of micelles and inverse micelles
- Synthesis of Carbon Nano-materials by Chemical Vapor Deposition and Sputtering technique
- Preparation ofthiolate silver nanoparticles, Purification and measurement of carbon nano materials
- Zinc selenide quantum dot preparation, Synthesis of Iron Oxide Nanoparticle
- Thin film preparation by spin coating technique, Synthesis of Nickel metal nanoparticle by urea decomposition method
- Synthesis of Zinc Oxide nanoparticle

VII. Suggested Reading

- Nalwa, H.S. 2005. *Handbook of Nanostructured Biomaterials and Their Applications in Nanobiotechnology*. American Scientific Publications.
- Niemeyer C.M. and Mirkin C.A. (Eds) 2005. *Nanobiotechnology: Concepts Applications and Perspectives,* Wiley Inter-science publications.
- Cao, G., and Wang, Y. 2004. *Nanostructures and Nanomaterials: Synthesis, Properties and Applications*, Imperial College Press.

I. Course Title : Environmental Biotechnology

II. Course Code : MBB 515

III. Credit Hours : 3+0

IV. Aim of the course

To apprise the students about the role of biotechnology in environment management for sustainable eco-system and human welfare.

V. Theory

Unit I (8 Lectures)

Basic concepts and environmental issues; types of environmental pollution; problems arising from high-input agriculture; methodology of environmental management; air and water pollution and its control; waste water treatment - physical, chemical and biological processes; need for water and natural resource management.

Unit II (8 Lectures)

Microbiology and use of micro-organisms in waste treatment; biodegradation; degradation of Xenobiotic, surfactants; bioremediation of soil & water contaminated with oils, pesticides and toxic chemicals,detergentsetc; aerobic processes (activated sludge, oxidation ditches, trickling filter, rotating drums, etc); anaerobic processes: digestion, filtration, etc.

Unit III (8 Lectures)

Renewable and non-Renewable resources of energy; energy from solid waste; conventional fuels and their environmental impact; biogas; microbial hydrogen production; conversion of sugar to alcohol; gasohol; biodegradation of lignin and cellulose; biopesticides; biofertilizers; composting; vermiculture etc.

Unit IV (8 Lectures)

Treatment schemes of domestic waste and industrial effluents; food, feed and energy from solid waste; bioleaching; enrichment of ores by microorganisms; global environmental problems: ozone depletion, UV-B, greenhouse effects, and acid rain; biodiversity and its conservation; biotechnological approaches for the management environmental problems.

VI. Suggested Reading

- Evans, G. M. and Furlong, J. C. 2010. *Environmental Biotechnology: Theory and Application*. 2nd edition, Wiley-Blackwell.
- Jordening HJ and Winter J. 2006. *Environmental Biotechnology: Concepts and Applications*. Wiley-VCH Verlag.

I. Course Title : Bio-entrepreneurship

II. Course Code : MBB 516

III. Credit Hours : 1+0

IV. Aim of the course

The objective of this course is to teach students about fundamentals of entrepreneurship, launching a venture or a start up in biotechnology-based theme.

V. Theory

Unit I (4 Lectures)

Scope in biotechnology; types of bio-industries – bio-pharma, bio-agri, bio-services and bio-industrial; Importance of entrepreneurship; introduction to bioentrepreneurship – biotechnology in a global scale; –skills for successful entrepreneur–creativity, leadership, managerial, team building, decision making; opportunities for bio-entrepreneurship- entrepreneurship development programs of public and private agencies (MSME, DBT, BIRAC, Startup & Make in India)

Unit II (4 Lectures)

Business plan preparation; business feasibility analysis by SWOT, socio-economic costs benefit analysis; funds/ support from various agencies; statutory and legal requirements for starting a company/ venture.

Unit III (4 Lectures)

Entry and exit strategy; identifying needs of customers; Market linkages, branding issues; developing distribution channels - franchising; policies, promotion, advertising; branding and market linkages for 'virtual startup company'. Pricing strategy.

Unit IV (4 Lectures)

Knowledge centers e.g., in universities, innovation centres, research institutions (public & private) and business incubators; R&D for technology development and upgradation; assessment of technology development; managing technology transfer;

VI. Suggested Reading

- Adams, D.J. and Sparrow, J.C. 2008. *Enterprise for Life Scientists: Developing Innovation and Entrepreneurship in the Biosciences*. Bloxham: Scion.
- Shimasaki, C.D. 2014. *Biotechnology Entrepreneurship: Starting, Managing, and Leading Biotech Companies*. Amsterdam: Elsevier. Academic Press is an imprint of Elsevier.
- Onetti, A., and Zucchella, A. 2014. *Business Modeling for Life Science and Biotech Companies: Creating Value and Competitive Advantage with the Milestone Bridge*. Routledge.
- Jordan, J. F. 2014. *Innovation, Commercialization, and Start-Ups in Life Sciences*. London: CRC Press.
- Desai, V. 2009. *The Dynamics of Entrepreneurial Development and Management*. New Delhi: Himalaya Pub. House.

I. Course Title : Stress Biology and Genomics

II. Course Code : MBB 517

III. Credit Hours : 2+0

IV. Aim of the course

To provide advanced knowledge on genomics with reference to abiotic stress tolerance and biotic stress resistance in plants tolerance.

V. Theory

Unit I (10 Lectures)

Different kinds of stresses (biotic and abiotic) and adaptation strategies: Plant cell as a sensor of environmental changes; role of cell membranes in signal perception; Ways of signal transduction in cells and whole plants as a response to external factors.Abiotic stresses affecting plant productivity – Drought, salinity, water logging, temperature stresses, light stress and nutrient stress; Drought stress – Effects on plant growth and development; Components of drought resistance; Physiological, biochemical and molecular basis of tolerance mechanisms; Biotic stress (insect and pathogen) resistance mechanism.

Unit II (12 Lectures)

Strategies to manipulate drought tolerance – Osmotic adjustment and Osmoprotectants - synthesis of proline, glycine betaine, poly amines and sugars; ROS and antioxidants; hormonal metabolism - ABA signaling; signaling components – transcription factors. Water logging stress – effects on plant growth and metabolism; adaptation to water logging,tolerance mechanisms -hormones and flooding tolerance. Strategies for improving submergence tolerance. Salinity stress – effects on physiology and metabolism of plants, SOS pathways and ion homeostasis,Strategies to improve salinity tolerance in plants. Water logging stress – effects on plant growth and metabolism; tolerance mechanisms. Physiological and biochemical changes – High & Low temperature tolerance mechanisms - molecular basis of thermo tolerance. Morphological and physiological changes in plants due to high and low light stresses - photo oxidation -plastid development. Characters of heliophytes and sciophytes – solar tracking – sieve effect and light channeling. Heavy metal stress – Al and Cd stress - effects on plant growth and development, biotech Strategies to overcome heavy metal stress Nutrient stress-effects on plant growth and development. Genetic manipulation strategies to overcome the stress effects.

Unit III (10 Lectures)

Genomics; transcriptomes, small RNAs and epigenomes; functional genomics; transfer of tolerance/resistant genes to model plants and validation of gene function. Different techniques for the functional validation of genes.

Signaling pathway related to defense gene expression, R proteins, RNAi approach and genes from pathogens and other sources, coat protein genes, detoxification genes, transgenic and disease management. Bt proteins, resistance management strategies in transgenic crops, ecological impact of field release of transgenic crops. Bioinformatics approaches to determine gene function and network in model plants under stress.

VI. Suggested Reading

- Buchanan, B.B., Gruissem, W. and Jones R. 2015. *Biochemistry and Molecular Biology of Plants*, 2nd edition, Wiley and Blackwell Publications.
- Sarwat, M., Ahmad, A., Abdin, M.Z. 2013. *Stress Signaling in Plants: Genomics and Proteomics Perspective*, Volume 1, Springer.
- Heribert Hirt. 2010. *Plant Stress Biology: From Genomics to Systems Biology*, John Wiley.
- Pandey, G.K. 2015. *Elucidation of Abiotic Stress Signaling in Plants*, Stringer.

I. Course Title : Gene Regulation

II. Course Code : MBB 518

III. Credit Hours : 2+0

IV. Aim of the course

To understand the basics of gene regulation including a wide range of mechanisms that are used by organisms to increase or decrease the production of specific gene products in terms of time, space, conditions or their combinations.

V. Theory

Unit I (8 Lectures)

Transcriptional regulation – Regulatory proteins, Activators and Repressors, Binding of RNA polymerase, Allosteric regulation, DNA looping, Cooperative binding, Anti-termination, Combinatorial control – Regulation of *lac, trp* and *ara* Operons. Gene regulation in Lambda phage – lytic or lysogenic establishment.

Unit II (10 Lectures)

Regulatory sequences – Promoters, Enhancers, Silencers, Insulators, Locus Control Region. Activator proteins and their binding sites, DNA binding domain – Homeodomain, Zinc containing proteins, Leucine Zipper Motif, Helix-Loop-Helix, HMG proteins. Recruitment of RNA polymerase to promoter region, Nucleosomes and their modifiers. Signal integration. Signal transduction and transcriptional regulation. Gene Silencing. Epigenetic gene regulation.

Unit III (10 Lectures)

Regulation by RNA in prokaryotes and eukaryotes, RNA as defense agents. Riboswitches. Gene Silencing by RNA - siRNA & miRNA – synthesis and function. Non-coding RNAs their impact, categories and role in gene regulation, chromatin assembly etc.

Unit IV (4 Lectures)

Negative auto-regulation, Positive auto-regulation, Bistable and Bimodal switch, Oscillating pattern of gene expression.

VI. Suggested Reading

- Nelson, D. L. and Cox, M. M. 2017. *Lehinger's Principles of Biochemistry*, 7th edition, W H Freeman Publication New York
- Krebs, J. E., Goldstein, E. S., Kilpatrick, S. T. 2017. *Lewin's Genes* XII 12th edition, Jones & Bartlett Learning publisher, Inc
- Watson, J. D., Baker, T. A., Bell, S. P., Gann, A., Levine,M., & Lonick, R. 2014. *Molecular Biology of the Gene*, 7th Edition, Cold Spring Harbor Laboratory Press, New York.
- Gardner, E. J., Simmons MJ and Snustad, D.P. 2006. *Principles of Genetics* (2006) eighth Edition. Wiley

Course Title with Credit Load
Ph.D in Molecular Biology and Biotechnology

Course Code	Course Title	Credit Hours
	Major: 12 credits (6 credits of core + 6 credits of optional)	
MBB 601	Plant Molecular Biology*	3+0
MBB 602	Plant GenomeEngineering*	3+0
MBB 603	Plant Omics and Molecular Breeding	3+0
MBB 604	Commercial Plant Tissue Culture	2+0
MBB 605	Plant Microbe interaction#	2+0
MBB 606	RNA Biology#	1+0
MBB 607	Plant Hormones and Signaling#	2+0
MBB 608	Computational and Statistical tools in Biotechnology#	2+1
	Any other appropriate 500 series courses	
	Minor (6 credits) from anyof the following disciplines	
	Biochemistry	
	Genetics and Plant Breeding	
	Microbiology	
	Plant Physiology	
	Plant Pathology	
	Entomology	
	Bioinformatics	
	Plant Genetic Resources	
	Any other related discipline	
	Supporting (5 credits) from the following disciplines	
	Biochemistry	
	Genetics and Plant Breeding	
	Microbiology	
	Bioinformatics	
	Computer Applications	
	Statistics	
	Common Courses	-
MBB	Seminar I	0+1
MBB	Seminar II	0+1
MBB 600	Research	0+75
	Total	**100**

*Core Courses; # New Courses

Course Contents
Ph.D. in Molecular Biology and Biotechnology

I. Course Title : Plant Molecular Biology
II. Course Code : MBB 601
III. Credit Hours : 3+0

IV. Aim of the course
- To provide in depth knowledge of recent developments of plant molecular biology and applications
- To discuss case studies and success stories in agriculture and industry

V. Theory

Unit I (10 Lectures)

Model Systems in Plant Biology (Arabidopsis, Rice, etc.) Forward and Reverse Genetic Approaches. Organization expression and interaction of nuclear, Mitochondrial and Chloroplast Genomes. Cytoplasmic male sterility.

Unit II (12 Lectures)

Transcriptional and Post-transcriptional Regulation of Gene Expression, Isolation of promoters and other regulatory elements, RNA interference, Transcriptional Gene Silencing, Transcript and Protein Analysis.

Unit III (12 Lectures)

Plant Developmental Processes, ABC Model of Floral Development, Role of hormones (Ethylene, Cytokinin, Auxin and ABA, SA and JA) in plant development. Regulation of Flowering, Plant photoreceptors and light signal transduction, vernalization, Circadian Rhythms.

Unit IV (14 Lectures)

Abiotic Stress Responses: Salt, Cold, Heat and Drought.Biotic Stress Responses. Molecular Biology of Plant-pathogen Interactions, Molecular Biology of *Rhizobium* and *Agrobacterium*- Plant interaction. Role of programmed Cell Death in Development and Defense.

VI. Suggested Reading

- Buchanan, B.B., Gruissem, W. and Jones R. 2015. *Biochemistry and Molecular Biology of Plants*, 2nd edition, Wiley and Blackwell Publications.
- Slater, A., Scott, N.W., and Fowler, M.R. 2003. *The Genetic Manipulation of Plants. Plant Biotechnology Oxford, England: Oxford University Press*.
- Walker, J.M., Rapley, R. 2008. *Plant Biotechnology and Genetics: Principles, Techniques and Applications*.

I. Course Title : Plant Genome Engineering

II. Course Code : MBB 602

III. Credit Hours : 3+0

IV. Aim of the course

To discuss the specialized topics and advances in field of genetic engineering and application of molecular tools in breeding of specific crops.

V. Theory

Unit I (14 Lectures)

Conventional versus non-conventional methods for crop improvement; Present status and recent developments on available molecular marker, transformation and genomic tools for crop improvement.Genetic engineering for resistance against abiotic (drought, salinity, flooding, temperature, etc) and biotic (insect pests, fungal, viral and bacterial diseases, weeds, etc) stresses; Genetic Engineering for increasing crop productivity by manipulation of photosynthesis, nitrogen fixation and nutrient uptake efficiency; Genetic engineering for quality improvement (protein, essential amino acids, vitamins, mineral nutrients, etc.); edible vaccines, etc.

Unit II (12 Lectures)

Recent developments in plant transformation strategies; Role of antisense and RNAi-based gene silencing in crop improvement; Regulated and tissue-specific expression of transgenes for crop improvement;

Unit III (12 Lectures)

Gene stacking; Pathway engineering; Marker-free transgenic development strategies; Genome editing: principles and methods, Development of genome edited plants; High throughput phenotyping of transgenic plants.

Unit IV (10 Lectures)

Field studies with transgenic crops; Environmental issues associated with transgenic crops; Food and feed safety issues associated with transgenic crops; Risk assessment of transgenic food crops.

VI. Suggested Reading

- Christou P and Klee H. 2004. *Handbook of Plant Biotechnology*. John Wiley & Sons.
- Stewart Jr, C.N. 2016. *Plant Biotechnology and Genetics: Principles, Techniques, and Applications*. John Wiley & Sons.
- Kirakosyan A and Kaufman PB. 2009. *Recent Advances in Plant Biotechnology* p. 409. Dordrecht: Springer.

I. Course Code : MBB603

II. Course Title : Plant Omics and Molecular Breeding

III. Credit Hours : 3+0

IV. Aim of the course

To discuss the specialized topics and advances in field of genomics and genomics assisted molecular breeding.

V. Theory

Unit I (12 Lectures)

Complex traits and genetic architecture, Mapping genes and QTLs, statistical concepts in QTL mapping, high-throughput genotyping using automated platforms, genetic and physical mapping of genomes, study of population structure and kinship, association genetic analysis of QTL, case studies on QTL mapping using different approaches, map-based of cloning genes and QTLs – case studies.

Unit II (12 Lectures)

Marker Assisted Breeding (MAB): Principles and methods, marker assisted foreground and background selection, marker assisted recurrent selection, whole genome selection, case studies in MAS, requirement for successful marker assisted breeding, cost of MAB.

Unit III (12 Lectures)

Concepts and methods of next generation sequencing (NGS), assembly and annotation of NGS data, genome resequencing, DNA sequence comparison, annotation and gene prediction. Genome-wide insertion mutagenesis and its use in functional genomics, transcriptome profiling using microarrays and deep sequencing, study of methylome and its significance, proteome analysis using mass spectrometry, crystallography and NMR, analysis of proteome data, study of protein- protein interactions.

Unit IV (12 Lectures)

Study of themetabolome, use of 1D/2D NMR and MS in metabolome analysis, multivariate analysis and identification of metabolite as biomarkers, study of ionome using inductively coupled plasma – mass spectroscopy (ICP-MS), correlating the data from genome, transcriptome, proteome, metabolome and ionome with phenome.

VI. Suggested Reading

- Speicher, D.W. (Ed.). 2004. *Proteome analysis: interpreting the genome*. Elsevier.
- Tomita, M. and Nishioka, T. (Eds.). 2006. *Metabolomics: the frontier of systems biology*. Springer Science and Business Media
- Horst, L. and Wenzel, G. (Eds.). 2007. *Molecular marker systems in plant breeding and crop improvement* (Vol. 55). Springer Science and Business Media.
- Stewart C.N. 2008. *Plant Biotechnology and Genetics: Principles, Techniques and Applications*.
- Singh, B.D. and Singh, A.K. 2015. *Marker-Assisted Plant Breeding: Principles and Practices* Springer (India) Pvt. Ltd.

I. Course Title : Commercial Plant Tissue Culture

II. Course Code : MBB 604

III. Credit Hours : 2+0

IV. Aim of the course

- To provide awareness into development of commercial scale plant tissue culture units.
- To provide an insight into the commercial applications of plant tissue culture in agriculture, medicine and industry.
- To educate about biosafety, regulatory as well as entrepreneurship opportunities.

V. Theory

Unit I (8 Lectures)

Micro-propagation of commercially important plant species; plant multiplication, hardening, and transplantation; genetic fidelity; scaling up and cost reduction; bioreactors; synthetic seeds; management and marketing.

Unit II (8 Lectures)

Production of useful compounds via, biotransformation and secondary metabolite production: suspension cultures, immobilization, examples of chemicals being produced for use in pharmacy, medicine and industry.

Unit III (9 Lectures)

Value-addition by transformation; development, production and release of transgenic plants; patent, bio-safety, regulatory, environmental and ethical issues; management and commercialization.

Unit IV (7 Lectures)

Project planning and preparation, economics (entrepreneurship, cost profit ratio), government policies (incubators, different facilitation projects, loan opportunities). Some case studies on success stories on commercial applications of plant tissue culture. Visits to some tissue culture based commercial units/industries.

VI. Suggested Reading

- Honda, H., Liu, C., Kobayashi, T. 2001. *Large-Scale Plant Micropropagation*. In: Zhong J.J. *et al*. (eds) *Plant Cells. Advances in Biochemical Engineering / Biotechnology*, vol 72. Springer, Berlin, Heidelberg.
- Bhojwani SS and Razdan MK. 1986. *Plant tissue culture: theory and practice* (Vol. 5). Elsevier.

I. Course Title : Plant Microbe Interaction

II. Course Code : MBB 605

III. Credit Hours : 2+0

IV. Aim of the course

To discuss the specialized topics and advances in field of plantmicrobe interaction for understanding their potential in enhancing crop growth and development.

V. Theory

Unit I (8 Lectures)

Microbial communities in the soil and atmosphere, Community dynamics and population interactions with particular reference to plant–microbe and microbe-microbe interactions leading to symbiotic, associative, endophytic and pathogenic interactions, effects of microorganisms on plants, effects of plants on microorganisms. Recognition processes and signal exchange, Molecular aspects of Plant Growth Promoting Rhizobacteria (PGPR), Symbiotic diazotrophs: Rhizobia and association with legumes. Mycorrhizal associations: Ectomycorrhizae, Endomycorrhizae with particular emphasis to AM fungi, Ectendomycorrhizae. Biocontrol agents and their action, endophytes associations

Unit II (8 Lectures)

Enzymes, toxins, pili, siderophores, secretion systems of microbes and plants determining soil health, nutrient availability and uptake defense responses in plants: pamp-triggered immunity,effector-triggered susceptibility,qualitative resistance, r genes, structure and function, effector-triggered immunity, regulation of plant cell death, plant hormones in immunity, Plant parasite interactions and its molecular basis and impact on plant functions including photosynthesis, respiration, nitrogen metabolism and translocation

Unit III (8 Lectures)

Quorum sensing in bacteria, understanding microbiome,phytobiomes,dynamics, Applied and ecological aspects of symbioses and pathogen defense, techniques to study plant microbe interaction including microbe tagging, metagenomics and use of organismal databases to identify genes involved in interactions. Industrial application of agriculturally important microbes.

Unit III (8 Lectures)

Resistance mechanisms against attack by plant pathogens, gene-for-gene interactions; induced resistance; non-host resistance. Systemic Acquired Resistance (SAR) and Induced Systemic Resistance (ISR), Plant and microbial gene expression and signal exchange, specific regulators for different interactions including transgenic plants. Recognition mechanism and signal transduction during plant - pathogen interaction

VI. Suggested Reading

- Rangaswamy, G. Bhagyaraj. 1993. *Agricultural Microbiology*, Prentice Hall India.
- Stacey, G., and Keen, N.T. (Eds.). 1996. *Plant-microbe interactions*. Springer Science & Business Media.
- Dickinson M. 2005. *Molecular Plant Pathology*. Bios Scientific Press, Taylor and Francis group.
- Kosuge T and Nester EW. 1989. *Plant-Microbe Interactions: Molecular and Genetic Perspectives.*Vols I-IV. McGraw Hill.
- González MBR and Gonzalez-López J. (Eds.). 2013. *Beneficial plant-microbial interactions: ecology and applications*. CRC press.

I. Course Title : RNA Biology

II. Course Code : MBB 606

III. Credit Hours : 1+0

IV. Aim of the course

To discuss the specialized topics and advances in the field of Plant RNAs, their structure and role in cellular regulation and scope for crop improvement.

V. Theory

Unit I (4 Lectures)

RNA structure, functional evolution: RNA structure, types of RNA and function; Genome evolution- RNA as genetic material to regulatory molecule, Non-Coding RNAs, structure, function and regulation

Unit II (4 Lectures)

RNA synthesis, processing and regulation: transcription and its regulation in prokaryotes and eukaryotes; RNA splicing and editing; Translation and its regulation in prokaryotes and eukaryotes

Unit III (4 Lectures)

Genome regulation: Prokaryotic- attenuation, ribozymes, aptamers, riboswitches, CRISPER-Cas; eukaryotic-Exon skipping, nonsense-mediated decay, RNAi, Long non-coding RNA.

Unit IV (4 Lectures)

Epigenetic regulation. RNA-based gene silencing technologies and their applications for crop improvement

VI. Suggested Reading

- Elliott, D., and Ladomery, M. 2017. *Molecular biology of RNA*. Oxford University Press.
- Rao, M.R.S. (Ed.) 2017. *Long Non-Coding RNA Biology*, Springer,
- Donald, C.R., Hannon, G., Ares, M. and Nilsen, T.W. 2011. *RNA: A Laboratory Manual,* CSHL Press.
- Maas, S. (Ed.). 2013. *RNA Editing: Current Research and Future Trends*. Horizon Scientific Press.

I. Course Title : Plant Hormones and Signaling

II. Course Code : MBB 607

III. Credit Hours : 2+0

IV. Aim of the course

To provide in-depth knowledge of plant hormone and their role in plant growth and development.

V. Theory

Unit I (12 Lectures)

Hormone Biosynthesis, Metabolism and its Regulation: Auxin biosynthesis and metabolism, Gibberellin biosynthesis and Inactivation, Cytokinin biosynthesis and metabolism, Ethylene biosynthesis, Abscisic acid biosynthesis and metabolism, Brassinosteroid biosynthesis and metabolism. Salicylic acid and jasmonate biosynthesis and metabolism.

Unit II (12 Lectures)

Functioning of hormones in plant growth and development: Transport of Auxins, Induction of vascular tissues by Auxin, Hormones and the regulation of water balance, seed development and germination, Hormonal control of day length and senescence.

Unit III (12 Lectures)

Action of Hormones: Hormones in defense against insects and disease; Role of jasmonates, salicylic acids and peptide hormones for defense, growth, development and reproduction; Methods of plant hormone analysis. NPR 1 dependent Salicylic acid signaling, PAMP and effector triggered immunity, systemic acquired resistance and SA signaling.

Unit IV (12 Lectures)

Hormone Signal Transduction: Auxin metabolism, transport and signal transduction, Cytokinin types, synthesis, metabolism, transport and signal transduction, Gibberellin biosynthesis, transport, signal transduction in stem elongation & Leaf Growth, Ethylene metabolism, perception and signaling in seedling growth and development, Ethylene signal transduction in fruits and flowers, Abscisic acid metabolism, transport and signal transduction in nuclear gene expression and stomatal responses. Brassinosteroid biosynthesis, catabolism and signal transduction. Strigalactone biosynthesis, transport and signaling in plant parasitism and symbiosis. Methods of Plant Hormone Analysis**:** Quantitative analysis of plant hormones based on LC/MS.

VI. Suggested Reading

- Davies Jr. F. *et al*. 2017. Hart Mann and KRster's. *Plant Propagation: Principles and Practices*. Pearson.

I. Course Title : Computational and Statistical tools in Biotechnology

II. Course Code : MBB 608

III. Credit Hours : 2+1

IV. Aim of the course

To provide information on basic principles of computational biology and statistical tools used for data analysis

V. Theory

Unit I (8 Lectures)

Basic molecular biology; introduction to the basic principles of structure/function analysis of biological molecules; genome analysis; different types and classification of genome databases (e.g. HTGS, DNA, Protein, EST, STS, SNPs, Unigenes, etc.)

Unit II (8 Lectures)

Statistical Techniques: MANOVA, Cluster analysis, Discriminant analysis, Principal component analysis, Principal coordinate analysis, Multidimensional scaling; Multiple regression analysis; Likelihood approach in estimation and testing; Resampling techniques – Bootstrapping and Jack- knifing; Markov Models. Hidden Markov Models, Bayesian estimation and Gibbs sampling

Unit III (8 Lectures)

DNA sequence retrieval system, various DNA and protein sequence file formats, Basic concepts of similarity searching and sequence alignments, pair wise and multiple sequence alignments, DNA sequence analysis, different gene prediction models and gene annotation tools,

Unit IV (8 Lectures)

Protein sequence analysis and structure prediction, comparative genome analysis, phylogenetic analysis, gene expression analysis tools, programming languages and their applications in bioinformatics

VI. Practical (16)

- Different Types of Databases and Database Search and Retrieval,
- DNA and Protein Sequence Analysis,
- Similarity Searching and Multiple Alignments,
- Gene Annotation,
- Phylogenetic Analysis,
- Sequence Analysis,
- Protein Structure Prediction,

- Analysis of Microarray Data,
- Programming Languages in Bioinformatics.

VII. Suggested Reading

- Xiong J. 2012. *Essential Bioinformatics*, Cambridge University Press.
- Andreas, D.B., and Ouellette B.F.F., (Eds) 2004. *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins* 3rd Edition, Wiley Interscience.
- Mount D. 2004. *Bioinformatics: Sequence and Genome Analysis*, 2nd Edition. By, CSHL Press.
- Augen J. 2004. *Bioinformatics in the Post-Genomic Era: Genome, Transcriptome, Proteome, and Information-Based Medicine*.
- Galperin M.Y. and Koonin E.V. (Eds) 2003. *Frontiers in Computational Genomics*.

Restructured and Revised
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Vol. 2

Statistical Sciences

- Agricultural Statistics
- Computer Application

Contents

Acknowledgements

On behalf of the Broad Subject Matter Area (BSMA) Committee on Statistical Sciences and on our own personal behalf we wish to place on record our deepest sense of gratitude to Dr Arvind Kumar, Chairman, National Core Group and Vice Chancellor, RLBCAU, Jhansi for entrusting us with the responsibility to undertake this challenging but noble cause of revising the course curricula of all the disciplines in Statistical Sciences. This was a herculean task but the leadership of Dr Arvind Kumar, his fresh and fragrant ideas, and his knowledge and wisdom made the job easy for the committee. We would also like to articulate our feelings of indebtedness towards Dr G. Venkateshwarlu, ADG (EQR), Education Division, ICAR in particular, and for the Education Division, ICAR, in general, for providing necessary guidance from time to time and for also extending fullest support in successfully completing this exercise.

We gratefully acknowledge the full support received from Dr SD Sharma, Former Chairman, BSMA Committee (Statistical Sciences) New Delhi, during course of preparation of this report. The logistic support provided by Director and his dedicated team at ICAR-IASRI for holding the meetings of the BSMA committee and the workshop is duly acknowledged.

We have no word to express our most sincere and heartfelt gratefulness to Dr B.V.S. Sisodia, Dr S.P. Singh, Dr S.D. Samantray, and Dr A. Dhandapani members of the BSMA Committee (Statistical Sciences), whose unflinching efforts have culminated in the preparation of this report. The help received from Dr Sukanta Dash, Co-opted members of the BSMA Committee is praise worthy and we would like to express our highest appreciation of his efforts in this formidable work. The help received from Dr H.K. Jain, Head, Department of Agricultural Statistics and Computer application, Rajasthan Agriculture College, and his team members in organizing the meeting at Rajasthan Agriculture University, is held in high esteem. We would also like to express our sincere thanks to all the faculty of the meeting whose valuable suggestions have helped in shaping the course curricula.

The whole exercise started with a rough draft of course curricula prepared by the previous BSMA Committee during 2008 for which the BSMA Committee would like to convey its thankfulness to the entire members of the committee. Their help is also duly acknowledged. Another very important base material for revising the course curricula was the syllabi of the PG Courses of IARI, provided by ICAR-IASRI. The draft on the syllabi was also prepared by various members of the Committee. We very sincerely appreciate the help received from one and all which helped lay the foundation of the success of this phenomenal task.

Lastly, but most importantly, we would articulate our feelings for one and alland would like to reiterate the fact that it has been indeed a great pleasure working with everyone in the committee as well as outside the committee.

L.M. Bhar
Anil Kumar

Preamble

The origin of the discipline of Agricultural Statistics can be traced back to 1930 when the then Imperial Council of Agricultural Research decided setting up a Statistical Section to assist the State Departments of Agriculture and Animal Husbandry in planning their experiments and analysis of data. The activities of this section increased rapidly and acquired International recognition as a centre for research and training in the field of Agricultural Statistics. Training programmes were started in this discipline in 1945. This activity resulted in the conversion of this section to a full-fledged Institute named as Institute of Agricultural Research Statistics (IARS) where subsequently the M.Sc. and Ph.D. degree courses in Agricultural Statistics were started in 1964 in collaboration with Indian Agricultural Research Institute (IARI). With the strengthening of NARS through more SAUs and ICAR Institutes, the demand for trained and qualified manpower in Agricultural Statistics increased rapidly which resulted in starting of M.Sc. and Ph. D. degree courses in Agricultural Statistics in many other State Agricultural Universities (SAUs) and Deemed-to-be Universities (DUs). Throughout the growth of this discipline, the main emphasis was to develop trained manpower in the country in the field of Agricultural Statistics and later on in the field of Computer Application so as to meet the challenges of agricultural research in the newer emerging areas. These disciplines have now become an integrated component of agricultural research and help in making agricultural research globally acceptable.

Use of computers in agricultural research began more than three decades ago. Initially the electronic data processing requirements of agricultural research workers and students in the NARS were catered by ICAR-Indian Agricultural Statistics Research Institute (ICAR-IASRI). Late sixties and seventies saw statisticians - programmers at IASRI shouldering the onerous responsibility of training agricultural research workers in the use of computers. Around the same time a course on Computer Programming was introduced and offered in the curriculum of M.Sc. and Ph.D. students of PG School of IARI and subsequently at many other SAUs. Seventies witnessed an increase in the computing facilities in NARS; there was a great demand for qualified and trained manpower to manage these facilities. During mid-eighties, M.Sc. Course in Computer Application in Agriculture was introduced in the PG programme of IARI. During this time the computing environment started witnessing changes and Mainframe computers were getting replaced by PCs. Concepts like LAN, WAN, Information Technology (IT), Databases, Information Systems, etc., all became bywords among agricultural research workers. PG Programme in Computer Science/Application was also introduced in other SAUs. Computer Application became an important discipline in agricultural research and as such this discipline was introduced in the Agricultural Research Service of the ICAR in 1985. In the present day world, the role of Information Technology has become very important. Together with the discipline of Statistics, it does wonders in agricultural research. The newer areas of research like genomics, geo-informatics, market intelligence, quality management depend very heavily on Statistics and Information Technology. For outreaching the research in the labs to the farmers, information technology plays a vital role. Advisory and consultancy, distance learning, etc. have become possible through IT only. Data warehouses and data mining are the orders of the day.

In view of the importance of Statistical Sciences, it is important that the course curricula framed to initiate the students to conduct research in these areas and to expose them to their applications to agricultural sciences.Courses Syllabi content should have modified as practical oriented and job oriented. All modifications in syllabus are must be focused to Govt. sector and Corporate sector/ Industrial Benefits. Accordingly, a national level core group was constituted to revise the syllabi of agricultural sciences so as to cater to the requirements of the present day world. A Broad Subject Matter Area (BSMA) Committee for statistical sciences was constituted to look into the revision of the course curricula of the disciplines of Agricultural Statistics and ComputerApplication.

A meeting of the BSMA committee was held on 10th August, 2018 at IASRI, New Delhi to initiate the process of course curricula revision. The need for revision of the curricula was discussed and highlighted the importance and scope of statistical sciences due to its high practical applications in basic and applied research in agriculture. It wasalso emphasized about the need to broaden the scope, explore possibilities of collaboration and cooperation in all courses and to introduce technology oriented courses in statistical sciences. It was felt that the revised curricula should include all the necessary courses required to be studied by M.Sc. and Ph.D. students so as to prepare them to initiate the students to conduct research in these areas and to expose them to their applications to agricultural sciences. It was decided to ensure that the curricula mustbe modified as practical oriented and job oriented to handle competitive exam at both National and International level. Further, the course curricula should be such that it is focused to Govt. sector and Corporate sector/ Industrial Benefits. It was also felt that the curricula should be so framed that it includes the courses on newer areas of research. The committee members were then assigned the responsibility of restructuring the course curricula.

Thereafter another meeting of the BSMA committee was held during 24-25 November, 2018 at Rajasthan Agriculture College, MPUAT, Udaipur in which the revised course curricula was discussed. The committee was enlarged by inviting some experienced faculty members so as to take advantage of their experience. Several new courses were introduced. Since there are no Master's degrees of Computer applications in any SAUs except IARI, hence, it was decided to prepare the syllabus of computer applications in a view of IARI course content. Two courses for Ph.D. prgoramme in agricultural statistics have been restructuredand renamed as per modifications such as 'Advanced Statistical Computing' modified as 'Advanced Data Analytics' and 'Statistical Modeling' modified as 'Modeling Techniques for Forecasting'. Also the course 'Advanced Statistical Methods' was partitioned to two different courses as (i) 'Advanced Statistical Methods' and (ii) Linear Models.

A major recommendation from the meeting was to introduce many new course on computer application based on emerging issues in education like (i) IT Informatics-IT in Agriculture, (ii) Internet Technologies, (iii) Introduction to Big Data, (iv) Introduction to IoT, (v) Management Information. Also several courses have been restructuredand renamed as per modifications in computer application for both M.Sc. and Ph.D. programme.

Organization of Course Contents and Credit Requirements

- The current nomenclature of M.Sc. and Ph.D. programme has been finalized as M.Sc. (Ag.) Statistics/ Computer application and Ph.D. (Agricultural Statistics/ Computer Application).
- All courses are divided into two series: 500-series courses pertain to Master's level, and 600-series to Doctoral level. A Ph.D. student must take 500-series courses if not studied during Master's programme.
- Master's programme have a minimum 70 Credit Hours (consisting of 20 from core course, 8 from minorcourse, 6 from supporting course, 5 from common course, 1 credit seminar and 30 research credit hours).
- Similarly, for Ph.D. programme,the members suggested a total of 100 credit hours (including 12 from core course, 6 from minorcourse, 5 from supporting course, 2 credit seminars and 75 credit for research work).
- Maximum of credit load of 20 credit hours and 18 credit hours per semester for M.Sc. and Ph.D. programmes respectively.
- Credit seminar for Master's level is designated by Code no. 591, and the two seminars for Doctoral level are coded as 691 and 692, respectively.
- Similarly, 599 and 699 codes have been given for Master's research and Doctoral research, respectively.

Course Contents

The contents of each course have been organized into:

- Objective – to elucidate the basic purpose.
- Theory units – to facilitate uniform coverage of syllabus for paper setting.
- Suggested Readings – to recommend some standard books as reference material. This does not unequivocally exclude other such reference material that may be recommended according to the advancements and local requirements.
- A list of journals pertaining to the discipline is provided at the end which may be useful as study material for 600-series courses as well as research topics.
- E-Resources - for quick update on specific topics/events pertaining to the subject.
- Broad research topics provided at the end would facilitate the advisors for appropriate research directions to the Students.

Minimum Credit Requirements

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

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

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

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

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

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

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

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Vol. 2

Statistical Sciences
– Agricultural Statistics

Course Title with Credit Load
M.Sc. in Agricultural Statistics

Course Code	Course Title	Credit Hours	Semester
*STAT 552	Probability Theory	2+0	I
*STAT 553	Statistical Methods	2+1	I
*STAT 562	Statistical Inference	2+1	II
*STAT 563	Design of Experiments	2+1	II
*STAT 564	Sampling Techniques	2+1	II
*STAT 565	Statistical Genetics	2+1	II
*STAT 571	Multivariate Analysis	2+1	III
*STAT 572	Regression Analysis	1+1	III
*STAT 573	Statistical Computing	1+1	III
STAT 591	Seminar	0+1	III
STAT 599	Research	0+30	II-IV
STAT 551	Mathematics-I	3+0	I
STAT 554	Actuarial Statistics	2+0	I
STAT 555	Bioinformatics	2+0	I
STAT 556	Econometrics	2+0	I
STAT 561	Mathematics-II	2+0	II
STAT 566	Statistical Quality Control	2+0	II
STAT 567	Optimization Techniques	1+1	II
STAT 574	Time Series Analysis	1+1	III
STAT 575	Demography	2+0	III
STAT 576	Statistical Methods for Life Sciences	2+0	III
STAT 577	Statistical Ecology	2+0	III
	Supporting Courses		
STAT 501	Mathematics for Applied Sciences	2+0	I
STAT 502	Statistical Methods for Applied Sciences	3+1	I
STAT 511	Experimental Designs	2+1	II
STAT 512	Basic Sampling Techniques	2+1	II
STAT 521	Applied Regression Analysis	2+1	III
STAT 522	Data Analysis Using Statistical Packages	2+1	III

*Core Courses

Course Contents
M.Sc. in Agricultural Statistics

I. Course Title : Mathematics for Applied Sciences

II. Course Code : STAT 501

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for students who do not have sufficient background of Mathematics. The students would be exposed to elementary mathematics that would prepare them to study their main courses that involve knowledge of Mathematics. The students would get an exposure to Linear Algebra, differentiation, integration and differential equations etc.

V. Theory

Unit I

Set theory-set operations, finite and infinite sets, operations of set, function.

Unit II

Vectors and vector spaces, Matrices notations and operations, laws of matrix algebra; transpose and inverse of matrix, Eigen values and Eigen vectors. Determinants - evaluation and properties of determinants, Solutions of Linear Equations.

Unit III

Variables and functions, limits and continuity of specific functions. Differentiation: theorems of differentiation, differentiation of logarithmic, trigonometric, exponential and inverse functions, Differentiation of function of a function, derivatives of higher order, partial derivatives. Application of derivatives, determination of points of inflexion, maxima and minima.

Unit IV

Integration, methods of integration, reduction formulae, definite and indefinite integral, Applications of integration in Agriculture, Differential Equations.

VI. Suggested Reading

- Hohn FE. 2013. *Elementary Matrix Algebra*, 3rd Ed., Kindle Edition
- Harville D.A. 1997. *Matrix Algebra from a Statistician's Perspective*. Springer.
- Hohn F.E. 1973. *Elementary Matrix Algebra*. Macmillan.
- Searle S.R. 1982. *Matrix Algebra Useful for Statistics*. John Wiley. Stewart J. 2007. *Calculus*. Thompson.
- Thomas G.B. Jr. and Finney R.L. 1996. *Calculus*. 9th Ed. Pearson Edu.

I. Course Title : Statistical Methods for Applied Sciences

II. Course Code : STAT 502

III. Credit Hours : 3+1

IV. Aim of the course

This course is meant for students who do not have sufficient background of Statistical

Methods. The students would be exposed to concepts of statistical methods and statistical inference that would help them in understanding the importance of statistics. It would also help them in understanding the concepts involved in data presentation, analysis and interpretation. The students would get an exposure to presentation of data, probability distributions, parameter estimation, tests of significance, regression and multivariate analytical techniques.

V. Theory

Unit I

Box-plot, Descriptive statistics, Exploratory data analysis, Theory of probability, Random variable and mathematical expectation.

Unit II

Discrete and continuous probability distributions, Binomial, Poisson, Negative Binomial, Normal distribution, Beta and Gamma distributions and their applications. Concept of sampling distribution: chi-square, t and F distributions. Tests of significance based on Normal, chi-square, t and F distributions.

Unit III

Introduction to theory of estimation and confidence-intervals, Simple and multiple correlation coefficient, partial correlation, rank correlation, Simple and multiple linear regression model, test of significance of correlation coefficient and regression coefficients, Coefficient of determination, Fitting of quadratic models.

Unit IV

Non-parametric tests – sign, Wilcoxon, Mann-Whitney U-test, Run test for the randomness of a sequence. Median test.

Unit V

Introduction to ANOVA: One way and Two Way, Introduction to Sampling Techniques, Introduction to Multivariate Analysis, Transformation of Data.

VI. Practical

- Exploratory data analysis, fitting of distributions ~ Binomial, Poisson, Negative Binomial, Normal.
- Large sample tests, testing of hypothesis based on exact sampling distributions ~ chi square, t and F.
- Confidence interval estimation and Correlation and regression analysis, fitting of Linear and Quadratic Model.
- Non-parametric tests. ANOVA: One way, Two Way, SRS.

VII. Suggested Reading

- Goon A.M, Gupta M.K and Dasgupta B. 1977. *An Outline of Statistical Theory*. Vol. I. The World Press.
- Goon A.M, Gupta M.K. and Dasgupta B. 1983. *Fundamentals of Statistics*. Vol. I. The World Press.
- Hoel P.G. 1971. *Introduction to Mathematical Statistics*. John Wiley.
- Hogg R.V and Craig T.T. 1978. *Introduction to Mathematical Statistics*. Macmillan.
- Morrison D.F. 1976. *Multivariate Statistical Methods*. McGraw Hill.
- Hogg RV, McKean JW, Craig AT. 2012. *Introduction to Mathematical Statistics* 7th Edition.
- Siegel S, Johan N & Casellan Jr. 1956. *Non-parametric Tests for Behavior Sciences*. John Wiley.
- Anderson TW. 2009. *An Introduction to Multivariate Statistical Analysis*, 3rd Ed . John Wiley

- http://freestatistics.altervista.org/en/learning.php.
- http://www.statsoft.com/textbook/stathome.html.

I. Course Title : Experimental Designs
II. Course Code : STAT 511
III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for students of agricultural and animal sciences other than Agricultural Statistics. Designing an experiment is an integrated component of research in almost all sciences. The students would be exposed to concepts of Design of Experiments so as to enable them to understand the concepts involved in planning, designing their experiments and analysis of experimental data.

V. Theory

Unit I

Need for designing of experiments, characteristics of a good design. Basic principles of designs- randomization, replication and local control.

Unit II

Uniformity trials, size and shape of plots and blocks, Analysis of variance, Completely randomized design, randomized block design and Latin square design.

Unit III

Factorial experiments, (symmetrical as well as asymmetrical). orthogonality and partitioning of degrees of freedom. Concept of confounding.

Unit IV

Split plot and strip plot designs, analysis of covariance and missing plot techniques in randomized block and Latin square designs; Transformations, Balanced Incomplete Block Design, resolvable designs and their applications, Lattice design, alpha design - concepts, randomization procedure, analysis and interpretation of results. Response surfaces. Combined analysis.

VI. Practical

- Uniformity trial data analysis, formation of plots and blocks, Fairfield Smith Law, Analysis of data obtained from CRD, RBD, LSD, Analysis of factorial experiments,
- Analysis with missing data,
- Split plot and strip plot designs.

VII. Suggested Reading

- Cochran WG and Cox GM. 1957. *Experimental Designs*. 2nd Ed. John Wiley.
- Dean AM and Voss D. 1999. *Design and Analysis of Experiments*. Springer.
- Montgomery DC. 2012. *Design and Analysis of Experiments*, 8th Ed. John Wiley.
- Federer WT. 1985. *Experimental Designs*. MacMillan.
- Fisher RA. 1953. *Design and Analysis of Experiments*. Oliver & Boyd.
- Nigam AK and Gupta VK. 1979. *Handbook on Analysis of Agricultural Experiments*. IASRI Publ.
- Pearce SC. 1983. *The Agricultural Field Experiment: A Statistical Examination of Theory and Practice*. John Wiley.
- www.drs.icar.gov.in.

I. Course Title : Basic Sampling Techniques

II. Course Code : STAT 512

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for students of agricultural and animal sciences other than Statistics. The students would be exposed to elementary sampling techniques. It would help them in understanding the concepts involved in planning and designing their surveys, presentation of survey data analysis of survey data and presentation of results. This course would be especially important to the students of social sciences.

V. Theory

Unit I

Concept of sampling, sample survey vs complete enumeration, planning of sample survey, sampling from a finite population.

Unit II

Simple random sampling with and without replacement, sampling for proportion, determination of sample size, inverse sampling, Stratified sampling.

Unit III

Cluster sampling, Multi-stage sampling, systematic sampling; Introduction to PPS sampling,

Unit IV

Use of auxiliary information at estimation, Ratio product and regression estimators. Double Sampling, sampling and non-sampling errors.

VI. Practical

- Random sampling ~ use of random number tables, concepts of unbiasedness, variance, etc.;
- Simple random sampling, determination of sample size, inverse sampling, stratified sampling, cluster sampling and systematic sampling;
- Estimation using ratio and regression estimators;
- Estimation using multistage design, double sampling.

VII. Suggested Reading

- Cochran WG. 1977. *Sampling Techniques*. John Wiley.
- Murthy MN. 1977. *Sampling Theory and Methods*. 2nd Ed. Statistical Publ. Soc., Calcutta.
- Singh D, Singh P and Kumar P. 1982. *Handbook on Sampling Methods*. IASRI Publ.
- Sukhatme PV, Sukhatme BV, Sukhatme S and Asok C. 1984. *Sampling Theory of Surveys with Applications*. Iowa State University Press and Indian Society of Agricultural Statistics, New Delhi.
- Cochran WG. 2007. *Sampling Techniques*, 3rd Edition. John Wiley & Sons Publication

I. Course Title : Applied Regression Analysis

II. Course Code : STAT 521

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for students of all disciplines including agricultural and animal sciences. The students would be exposed to the concepts of correlation and regression. Emphasis will be laid on diagnostic measures such as autocorrelation, multi collinearity and heteroscedasticity. This course would prepare students to handle their data for analysis and interpretation.

V. Theory

Unit I

Introduction to correlation analysis and its measures, Correlation from grouped data, correlation, Rank correlation, Testing of population correlation coefficients; Multiple and partial correlation coefficients and their testing.

Unit II

Problem of correlated errors; Auto correlation; Heteroscedastic models, Durbin Watson Statistics; Removal of auto correlation by transformation; Analysis of collinear data; Detection and correction of multi collinearity, Regression analysis; Method of least squares for curve fitting; Testing of regression coefficients; Multiple and partial regressions.

Unit III

Diagnostic of multiple regression equation; Concept of weighted least squares; regression equation on grouped data; Various methods of selecting the best regression equation.

Unit IV

Concept of nonlinear regression and fitting of quadratic, exponential and power curves; Economic and optimal dose, Orthogonal polynomial.

VI. Practical

- Correlation coefficient, various types of correlation coefficients, partial and multiple, testing of hypotheses;
- Multiple linear regression analysis, partial regression coefficients, testing of hypotheses, residuals and their applications in outlier detection;
- Handling of correlated errors, multi collinearity;
- Fitting of quadratic, exponential and power curves, fitting oforthogonal polynomials.

VII. Suggested Reading

- Kleinbaum DG, Kupper LL, Nizam A. 2007. *Applied Regression Analysis and Other Multivariable Methods* (Duxbury Applied) 4th Ed.
- Draper NR and Smith H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- Ezekiel M. 1963. *Methods of Correlation and Regression Analysis*. John Wiley.
- Koutsoyiannis A. 1978. *Theory of Econometrics*. MacMillan.
- Kutner MH, Nachtsheim CJ and Neter J. 2004. *Applied Linear Regression Models*. 4th Ed. With Student CD. McGraw Hill.

I. Course Title : Data Analysis Using Statistical Packages

II. Course Code : STAT 522

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant for exposing the students in the usage of various statistical packages for analysis of data. It would provide the students a hands on experience in the analysis of their research data. This course is useful to all disciplines.

V. Theory

Unit I

Introduction to various statistical packages: Excel, R, SAS, SPSS. Data Preparation; Descriptive statistics; Graphical representation of data, Exploratory data analysis.

Unit II

Test for normality; Testing of hypothesis using chi-square, t and F statistics and Z-test.

Unit III

Data preparation for ANOVA and ANCOVA, Factorial Experiments, contrast analysis, multiple comparisons, Analyzing crossed and nested classified designs.

Unit IV

Analysis of mixed models; Estimation of variance components; Correlation and regression analysis, Probit, Logit and Tobit Models.

Unit V

Discriminant function; Factor analysis; Principal component analysis; Analysis of time series data, Fitting of non-linear models; Neural networks.

VI. Practical

- Use of software packages for summarization and tabulation of data, obtaining descriptive statistics, graphical representation of data;
- Testing the hypothesis for one sample t-test, two sample t-test, paired t-test, test for large samples - Chi-squares test, F test, one-way analysis of variance;
- Designs for Factorial Experiments, fixed effect models, random effect models, mixed effect models, estimation of variance components;
- Linear regression, Multiple regression, Regression plots;
- Discriminant analysis - fitting of discriminant functions, identification of important variables;
- Factor analysis. Principal component analysis - obtaining principal component.

VII. Suggested Reading

- Anderson C.W. and Loynes R.M. 1987. *The Teaching of Practical Statistics*. John Wiley.
- Atkinson A.C. 1985. *Plots Transformations and Regression*. Oxford University Press.
- Chambers J.M., Cleveland W.S., Kleiner B and Tukey P.A. 1983. *Graphical Methods for Data Analysis*. Wadsworth, Belmount, California.
- Chatfield C. 1983. *Statistics for Technology*. 3rd Ed. Chapman & Hall. Chatfield C. 1995. *Problem Solving: A Statistician's Guide*. Chapman & Hall.
- Cleveland W.S. 1985. *The Elements of Graphing Data*. Wadsworth, Belmont, California.
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- Snell E.J. and Simpson HR. 1991. *Applied Statistics: A Handbook of GENSTAT Analyses*. Chapman and Hall.
- Sprent P. 1993. *Applied Non-parametric Statistical Methods*. 2nd Ed. Chapman & Hall.
- Tufte ER. 1983. *The Visual Display of Quantitative Information*. Graphics Press, Cheshire, Conn.
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- Weisberg S. 1985. *Applied Linear Regression*. John Wiley.
- Wetherill GB. 1982. *Elementary Statistical Methods*. Chapman & Hall.

- Wetherill GB.1986. *Regression Analysis with Applications*. Chapman & Hall.
- Cleveland WS. 1994. *The Elements of Graphing Data*, 2nd Ed., Chapman & Hall
- http://freestatistics.altervista.org/en/learning.php.
  http://freestatistics.altervista.org/en/stat.php.
  http://www.cas.lancs.ac.uk/glossary_v1.1/main.html.
  http://www.stat.sc.edu/~grego/courses/stat706/.
- www.drs.icar.gov.in.

I. Course Title : Mathematics-I

II. Course Code : STAT 551

III. Credit Hours : 3+0

IV. Aim of the course

This course lays the foundation of all other courses of Agricultural Statistics discipline by preparing them to understand the importance of mathematical methods in research. The students would be exposed to the basic mathematical tools of real analysis, calculus, differential equations and numerical analysis. This would prepare them to study their main courses that involve knowledge of Mathematics.

V. Theory

Unit I

Calculus: Limit and continuity, differentiation of functions, successive differentiation, partial differentiation, mean value theorems, Taylor and Maclaurin's series. Application of derivatives, L'hospital's rule.

Unit II

Real Analysis: Convergence and divergence of infinite series, use of comparison tests -D'Alembert's Ratio - test, Cauchy's nth root test, Raabe's test, Kummer's test, Gauss test. Absolute and conditional convergence. Riemann integration, concept of Lebesgue integration, power series, Fourier, Laplace and Laplace -Steiltjes' transformation, multiple integrals.Integration of rational, irrational and trigonometric functions. Application of integration.

Unit III

Differential equation: Differential equations of first order, linear differential equations of higher order with constant coefficient.

Unit IV

Numerical Analysis: Simple interpolation, Divided differences, Numerical differentiation and integration.

VI. Suggested Reading

- Bartle RG. 1976. *Elements of Real Analysis*. John Wiley. Chatterjee SK. 1970. *Mathematical Analysis*. Oxford & IBH.
- Gibson GA. 1954. *Advanced Calculus*. Macmillan.
- Henrice P. 1964. *Elements of Numerical Analysis*. John Wiley.
- Hildebrand FB. 1956. *Introduction to Numerical Analysis*. Tata McGraw Hill.
- Priestley HA. 1985. *Complex Analysis*. Clarenton Press.
- Rudin W. 1985. *Principles of Mathematical Analysis*. McGraw Hill. Sauer T. 2006. *Numerical Analysis With CD-Rom*. Addison Wesley. Scarborough JB. 1976. *Numerical Mathematical Analysis*. Oxford & IBH. Stewart J. 2007. *Calculus*.Thompson.
- Thomas GB Jr. and Finney RL. 1996. *Calculus*. 9th Ed. Pearson Edu.

I. Course Title : Probability Theory

II. Course Code : STAT 552

III. Credit Hours : 2+0

IV. Aim of the course

This is a fundamental course in Statistics. This course lays the foundation of probability theory, random variable, probability distribution, mathematical expectation, etc. which forms the basis of basic statistics. The students are also exposed to law of large numbers and central limit theorem. The students also get introduced to stochastic processes.

V. Theory

Unit I

Basic concepts of probability. Elements of measure theory: class of sets, field, sigma field, minimal sigma field, Borel sigma field in R, measure- probability measure. Axiomatic approach to probability. Properties of probability based on axiomatic definition. Addition and multiplication theorems. Conditional probability and independence of events. Bayes theorem.

Unit II

Random variables: definition of random variable, discrete and continuous, functions of random variables. Probability mass function and Probability density function, Distribution function and its properties. Notion of bivariate random variables, bivariate distribution function and its properties. Joint, marginal and conditional distributions. Independence of random variables. Transformation of random variables (two dimensional caseonly). Mathematical expectation: Mathematical expectation of functions of a random variable. Raw and central moments and their relation, covariance, skewness and kurtosis. Addition and multiplication theorems of expectation. Definition of moment generating function, cumulating generating function, probability generating function and statements of their properties.

Unit III

Conditional expectation and conditional variance. Characteristic function and its properties. Inversion and uniqueness theorems. Chebyshev, Markov, Cauchy-Schwartz, Sequence of random variables and modes of convergence (convergence in distribution in probability, almost surely, and quadratic mean) and their interrelations.

Unit IV

Laws of large numbers: WLLN, Bernoulli and Kintchin's WLLN. Kolmogorov inequality, Kolmogorov's SLLNs.Central Limit theorems: Demoviere- Laplace CLT, Lindberg – Levy CLT and simple applications.

VI. Suggested Reading

- Ash RB. 2000. *Probability and Measure Theory*. 2nd Ed. Academic Press. Billingsley P. 1986. *Probability and Measure*. 2nd Ed. John Wiley.
- Capinski M and Zastawniah. 2001. *Probability Through Problems*. Springer. Dudewicz EJ & Mishra SN. 1988. *Modern Mathematical Statistics*. John Wiley.
- Feller W. 1972. *An Introduction to Probability Theory and its Applications*. Vols. I., II. John Wiley.
- Loeve M. 1978. *Probability Theory*. 4th Ed. Springer.

- Marek C, Tomasz JZ. 2003. *Probability* Through Problems (Problem Books in Mathematics) Corrected Ed.
- Marek F. 1963. *Probability Theory and Mathematical Statistics*. John Wiley.
- Rohatgi VK & Saleh AK Md. E. 2005. *An Introduction to Probability and* Statistics. 2nd Ed. John Wiley.

I. Course Title : Statistical Methods

II. Course Code : STAT 553

III. Credit Hours : 2+1

IV. Aim of the course

This course lays the foundation of probability distributions and sampling distributions and their application which forms the basis of Statistical Inference. Together with probability theory, this course is fundamental to the discipline of Statistics. The students are also exposed to correlation and regression, and order statistics and their distributions. Categorical data analysis is also covered in this course.

V. Theory

Unit I

Descriptive statistics: probability distributions: Discrete probability distributions ~ Bernoulli, Binomial, Poisson, Negative-binomial, Geometric and Hyper Geometric, uniform, multinomial ~ Properties of these distributions and real life examples. Continuous probability distributions ~ rectangular, exponential, Cauchy, normal, gamma, beta of two kinds, Weibull, lognormal, logistic, Pareto. Properties of these distributions. Probability distributions of functions of random variables.

Unit II

Concepts of compound, truncated and mixture distributions (definitions and examples). Sampling distributions of sample mean and sample variance from Normal population, central and non–central chi-Square, t and F distributions, their properties and inter relationships.

Unit III

Concepts of random vectors, moments and their distributions. Bivariate Normal distribution - marginal and conditional distributions. Distribution of quadratic forms. Cochran theorem. Correlation, rank correlation, correlation ratio and intra-class correlation. Regression analysis, partial and multiple correlation andregression.

Unit IV

Sampling distribution of correlation coefficient, regression coefficient. Categorical data analysis, Association between attributes. Variance StabilizingTransformations.

Unit V

Order statistics, distribution of r-th order statistics, joint distribution of several order statistics and their functions, marginal distributions of order statistics.

VI. Practical

- Fitting of discrete distributions and test for goodness of fit;
- Fitting of continuous distributions and test for goodness of fit; Fitting of truncated distribution;

- Computation of simple, multiple and partial correlation coefficient, correlation ratio and intra-class correlation;
- Regression coefficients and regression equations;
- Fitting of Pearsonian curves;
- Analysis of association between attributes, categorical data and log-linear models.

VII. Suggested Reading

- Agresti, A. 2012. *Categorical Data Analysis* 3rd Ed. John Wiley.
- Arnold BC, Balakrishnan N and Nagaraja HN. 1992. *A First Course in Order Statistics*. JohnWiley.
- David HA and Nagaraja HN. 2003. *Order Statistics*. 3rd Ed. John Wiley.
- Dudewicz EJ and Mishra SN. 1988. *Modern Mathematical Statistics*. John Wiley.
- Huber PJ. 1981. *Robust Statistics*. John Wiley.
- Johnson NL, Kotz S and Balakrishnan N. 2000. *Continuous Univariate Distributions*. JohnWiley.
- Johnson NL, Kotz S and Balakrishnan N. 2000. *Discrete Univariate Distributions*. JohnWiley.
- Marek F.1963. *Probability Theory and Mathematical Statistics*. John Wiley.
- Rao CR. 1965. *Linear Statistical Inference and its Applications*. John Wiley.
- Rohatgi VK and Saleh AK Md. E. 2005. *An Introduction to Probability and Statistics*. 2nd Ed. John Wiley.
- Gupta. S.P 2008. *Statistical Methods*. Sultan Chand & sons Educational Publisher

I. Course Title : Actuarial Statistics

II. Course Code : STAT 554

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant to expose to the students to the statistical techniques such as probability models, life tables, insurance and annuities. The students would also be exposed top practical applications of these techniques in computation of premiums that include expenses, general expenses, types of expenses and per policy expenses.

V. Theory

Unit I

Insurance and utility theory, models for individual claims and their sums, survival function, curtate future lifetime, force of mortality.

Unit II

Life table and its relation with survival function, examples, assumptions for fractional ages, some analytical laws of mortality, select and ultimate tables.

Unit III

Multiple life functions, joint life and last survivor status, insurance and annuity benefits through multiple life functions evaluation for special mortality laws. Multiple decrement models, deterministic and random survivorship groups, associated single decrement tables, central rates of multiple decrement, net single premiums and their numerical evaluations.

Unit IV

Distribution of aggregate claims, compound Poisson distribution and its applications.

Unit V

Principles of compound interest: Nominal and effective rates of interest and discount, force of interest and discount, compound interest, accumulation factor, continuous compounding.

Unit VI

Insurance payable at the moment of death and at the end of the year of death-level benefit insurance, endowment insurance, deferred insurance and varying benefit insurance, recursions, commutation functions.

Unit VII

Life annuities: Single payment, continuous life annuities, discrete life annuities, life annuities with monthly payments, commutation functions, varying annuities, recursions, complete annuities-immediate and apportionable annuities-due.

Unit VIII

Net premiums: Continuous and discrete premiums, true monthly payment premiums, apportionable premiums, commutation functions, accumulation type benefits. Payment premiums, apportionable premiums, commutation functions, accumulation type benefits. Net premium reserves: Continuous and discrete net premium reserve, reserves on a semi-continuous basis, reserves based on true monthly premiums, reserves on an apportionable or discounted continuous basis, reserves at fractional durations, allocations of loss to policy years, recursive formulas and differential equations for reserves, commutation functions.

Unit IX

Some practical considerations: Premiums that include expenses-general expenses types of expenses, per policy expenses. Claim amount distributions, approximating the individual model, stop-loss insurance.

VI. Suggested Reading

- Atkinson ME and Dickson DCM. 2000. *An Introduction to Actuarial Studies*. Elgar Publ.
- Bedford T and Cooke R. 2001. *Probabilistic Risk Analysis*. Cambridge.
- Booth PM, Chadburn RG, Cooper DR, Haberman, S and James DE.1999. Modern *Actuarial Theory and Practice*. Chapman & Hall.
- Borowiak Dale S. 2003. *Financial and Actuarial Statistics: An Introduction*. Marcel Dekker.
- Bowers NL, Gerber HU, Hickman JC, Jones DA and Nesbitt CJ.1997. *Actuarial Mathematics*. 2nd Ed. Society of Actuaries, Ithaca, Illinois.
- Dale SB, Arnold FS. 2013. *Financial and Actuarial Statistics: An Introduction*, 2nd Ed. (Statistics: A Series of Textbooks and Monogrphs)
- Daykin CD, Pentikainen T and Pesonen M. 1994. *Practical Risk Theory for Actuaries*. Chapman & Hall.
- Klugman SA, Panjer HH, Willmotand GE and Venter GG. 1998. *Loss Models: From data to Decisions*. John Wiley.
- Medina PK and Merino S. 2003. *Mathematical Finance and Probability: A Discrete Introduction*. Basel, Birkhauser.
- Melnikov, A. 2011. *Risk Analysis in Finance and Insurance* (Chapman & Hall/Crc Financial Mathematics Series) 2nd Ed.
- Neill A. 1977. *Life Contingencies*. Butterworth-Heinemann.
- Rolski T, Schmidli H, Schmidt V and Teugels J. 1998. *Stochastic Processes for Insurance and Finance*. John Wiley.
- Rotar VI. 2006. *Actuarial Models. The Mathematics of Insurance. Chapman*& Hall/CRC.
- Spurgeon ET. 1972. *Life Contingencies*. Cambridge Univ. Press.

I. Course Title : Bioinformatics

II. Course Code : STAT 555

III. Credit Hours : 2+0

IV. Aim of the course

Bioinformatics is a new emerging area. It is an integration of Statistics, Computer applications and Biology. The trained manpower in the area of Bioinformatics is required for meeting the new challenges in teaching and research in the discipline of Agricultural Sciences. This course is meant to train the students on concepts of basic biology, statistical techniques and computational techniques for understanding bioinformatics principals.

V. Theory

Unit I

Basic Biology: Cell, genes, gene structures, gene expression and regulation, Molecular tools, nucleotides, nucleic acids, markers, proteins and enzymes, bioenergetics, single nucleotide polymorphism, expressed sequence tag. Structural and functional genomics: Organization and structure of genomes, genome mapping, assembling of physical maps, strategies and techniques for genome sequencing and analysis.

Unit II

Computing techniques: OS and Programming Languages – *Linux, perl, bioperl*,*python, biopython*,*cgi*, *MySQL*, *phpMyAdmin*; Coding for browsing biological databases on web, parsing & annotation of genomic sequences; Database designing; Computer networks – Internet, World wide web, Web browsers– EMBnet, NCBI; Databases on public domain pertaining to Nucleic acid sequences, protein sequences, SNPs, etc.; Searching sequence databases, Structural databases.

Unit III

Statistical Techniques: MANOVA, Cluster analysis, Discriminant analysis, Principal component analysis, Principal coordinate analysis, Multidimensional scaling; Multiple regression analysis; Likelihood approach in estimation and testing; Resampling techniques – Bootstrapping and Jack-knifing; Hidden Markov Models; Bayesian estimation and Gibbs sampling;

Unit IV

Tools for Bioinformatics: DNA Sequence Analysis – Features of DNA sequence analysis, Approaches to EST analysis; Pairwise alignment techniques: Comparing two sequences, PAM and BLOSUM, Global alignment (The Needleman and Wunsch algorithm), Local Alignment (The Smith-Waterman algorithm), Dynamic programming, Pairwise database searching; Sequence analysis– BLAST and other related tools, Multiple alignment and database search using motif models, ClustalW, Phylogeny; Databases on SNPs; EM algorithm and other methods to discover common motifs in biosequences; Gene prediction based on Neural Networks, Genetic algorithms, Computational analysis of protein sequence, structure and function; Design and Analysis of microarray/ RNAseqexperiments.

VI. Suggested Reading

- Baldi P. and Brunak S. 2001. *Bioinformatics: The Machine Learning Approach.* 2nd Ed. (Adaptive Computation and Machine Learning). MIT Press.
- Baxevanis A.D. and Francis B.F. (Eds.). 2004. *Bioinformatics: A Practical Guide to the*

Analysis of Genes and Proteins. John Wiley.
- Bergeron B.P. 2002. *Bioinformatics Computing*. Prentice Hall.
- Duda R.O, Hart P.E and Stork D.G. 1999. *Pattern Classification*. John Wiley.
- Ewens W.J and Grant G.R. 2001. *Statistical Methods in Bioinformatics: An Introduction* (*Statistics for Biology and Health*). Springer.
- Graham B. Zweig, J. Buffett, WE. 2006.*The Intelligent Investor: The Definitive Book on Value Investing*. A Book of Practical Counsel, Revised Edition
- Hunt S and Livesy F. (Eds.). 2000. *Functional Genomics: A Practical Approach* (*The Practical Approach Series, 235*). Oxford Univ. Press.
- Jones N.C. and Pevzner P.A. 2004. *An Introduction to Bioinformatics Algorithims*. MIT Press.
- Koski T and Koskinen T. 2001. *Hidden Markov Models for Bioinformatics*. Kluwer.
- Krane D.E. and Raymer M.L. 2002. *Fundamental Concepts of Bio-informatics*. Benjamin / Cummings.
- Krawetz S.A and Womble D.D. 2003. *Introduction to Bioinformatics: A Theoretical and Practical Approach*. Humana Press.
- Lesk A.M. 2002. *Introduction to Bio-informatics*. Oxford Univ. Press.
- Percus J.K. 2001. *Mathematics of Genome Analysis*. Cambridge Univ. Press.
- Sorensen D and Gianola D. 2002. *Likelihood, Bayesian and MCMC Methods in Genetics*. Springer.
- Tisdall J.D. 2001. *Mastering Perl for Bioinformatics*. O'Reilly & Associates.
- Wang J.T.L., Zaki M.J., Toivonen H.T.T. and Shasha D. 2004. *Data Mining in Bioinformatics*. Springer.
- Wu C.H. and McLarty J.W. 2000. *Neural Networks and Genome Informatics*. Elsevier.
- Wunschiers R. 2004. *Computational Biology Unix/Linux, Data Processing and Programming*. Springer.

I. Course Title : Econometrics

II. Course Code : STAT 556

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for training the students in econometric methods and their applications in agriculture. This course would enable the students in understanding the economic phenomena through statistical tools and economics principles.

V. Theory

Unit I

Representation of Economic phenomenon, relationship among economic variables, linear and non-linear economic models, single equation general linear regression model, basic assumptions, Ordinary least squares method of estimation for simple and multiple regression models; summary statistics correlation matrix, co-efficient of multiple determination, standard errors of estimated parameters, tests of significance and confidence interval estimation. BLUE properties of Least Squares estimates. Chow test, test of improvement of fit through additional regressors. Maximum likelihood estimation.

Unit II

Heteroscedasticity, Auto-correlation, Durbin Watson test, Multi-collinearity. Stochastic regressors, Errors in variables, Use of instrumental variables in regression analysis. Dummy Variables. Distributed Lag models: Koyck's Geometric Lag scheme, Adaptive Expectation and Partial Adjustment Mode, Rational Expectation Models and test for rationality.

Unit III

Simultaneous equation model: Basic rationale, Consequences of simultaneous relations, Identification problem, Conditions of Identification, Indirect Least Squares, Two-stage least squares, K-class estimators, Limited Information and Full Information Maximum Likelihood Methods, three stage least squares, Generalized least squares, Recursive models, SURE Models. Mixed Estimation Methods, use of instrumental variables, pooling of cross-section and time series data, Principal Component Methods.

Unit IV

Problem and Construction of index numbers and their tests; fixed and chain based index numbers; Construction of cost of living index number.

Unit V

Demand analysis – Demand and Supply Curves; Determination of demand curves from market data. Engel's Law and the Engel's Curves, Income distribution and method of its estimation, Pareto's Curve, Income inequality measures.

VI. Suggested Reading

- Croxton F.E. and Cowden D.J. 1979. *Applied General Statistics*. Prentice Hall of India.
- James H.S. and Mark W.W. 2017. Introduction to Econometrics, 3rd Ed. John Wiley
- Johnston J. 1984. *Econometric Methods*. McGraw Hill.
- Judge G.C., Hill R.C., Griffiths W.E., Lutkepohl H and Lee T.C. 1988. *Introduction to the Theory and Practice of Econometrics*. 2nd Ed. John Wiley.
- Kmenta J. 1986. *Elements of Econometrics*. 2nd Ed. University of Michigan Press.
- Koop G. 2007. *Introduction to Econometrics*. John Wiley.
- Maddala G.S. 2001. *Introduction to Econometrics*. 3rd Ed. John Wiley.
- Pindyck R.S. and Rubinfeld D.L. 1998. *Econometric Models and Economic Forecasts*. 4th Ed. McGraw Hill.
- Verbeek M. 2008. *A Guide to Modern Econometrics*. 3rd Ed. John Wiley.

I. Course Title : Mathematics-II

II. Course Code : STAT 561

III. Credit Hours : 2+0

IV. Aim of the course

This is another course that supports all other courses in Agricultural Statistics. The students would be exposed to the advances in Linear Algebra and Matrix theory. This would prepare them to study their main courses that involve knowledge of Linear Algebra and Matrix Algebra.

V. Theory

Unit I

Linear Algebra: Group, ring, field and vector spaces, Sub-spaces, basis, Gram Schmidt's orthogonalization, Galois field - Fermat's theorem and primitive elements. Linear transformations. Graph theory: Concepts and applications.

Unit II

Matrix Algebra: Basic terminology, linear independence and dependence of vectors.

Row and column spaces, Echelon form. Determinants, Trace of matrices rank and inverse of matrices. Special matrices – idempotent, symmetric, orthogonal. Eigen values and eigen vectors, Spectral decomposition of matrices.

Unit III

Unitary, Similar, Hadamard, Circulant, Helmert's matrices. Kronecker and Hadamard product of matrices, Kronecker sum of matrices. Sub-matrices and partitioned matrices, Permutation matrices, full rank factorization, Grammian root of a symmetric matrix. Solutions of linear equations, Equations having many solutions.

Unit IV

Generalized inverses, Moore-Penrose inverse, Applications of g-inverse. Inverse and Generalized inverse of partitioned matrices, Differentiation and integration of vectors and matrices, Quadratic forms.

VI. Suggested Reading

- Aschbacher M. 2000. *Finite Group Theory*. Cambridge University Press.
- Deo N. 1984. *Graph Theory with Application to Engineering and Computer Science*. Prentice Hall of India.
- Gentle JE. 2007. *Matrix Algebra: Theory, Computations and Applications in Statistics*. Springer.
- Graybill FE.1961. *Introduction to Matrices with Applications in Statistics*. Wadsworth Publ.
- Hadley G. 1969. *Linear Algebra*. Addison Wesley.
- Harville DA. 1997. *Matrix Algebra from a Statistician's Perspective*. Springer.
- Rao CR. 1965. *Linear Statistical Inference and its Applications*. 2^{nd} Ed. John Wiley.
- Robinson DJS. 1991. *A Course in Linear Algebra with Applications*. World Scientific.
- Searle SR. 2006. *Matrix Algebra Useful for Statistics* John Wiley, 2^{nd} Ed.
- Seber GAF. 2008. *A Matrix Handbook for Statisticians*. John Wiley.

I. Course Title : Statistical Inference

II. Course Code : STAT 562

III. Credit Hours : 2+1

IV. Aim of the course

This course lays the foundation of Statistical Inference. The students would be taught the problems related to point and confidence interval estimation and testing of hypothesis. They would also be given the concepts of nonparametric and sequential test procedures and elements of decision theory.

V. Theory

Unit I

Concepts of point estimation: unbiasedness, consistency, efficiency and sufficiency. Statement of Neyman's Factorization theorem with applications. MVUE, Rao-Blackwell theorem, completeness, Lehmann- Scheffe theorem. Fisher information, Cramer-Rao lower bound and its applications.

Unit II

Moments, minimum chi-square, least square and maximum likelihood methods of estimation and theirproperties.Interval estimation-Confidence level, shortest length CI. CI for the parameters of Normal, Exponential, Binomial and Poisson distributions.

Unit III

Fundamentals of hypothesis testing-statistical hypothesis, statistical test, critical region, types of errors, test function, randomized and non- randomized tests, level of significance, power function, most powerful tests: Neyman-Pearson fundamental lemma, MLR families and UMP tests for one parameter exponential families. Concepts of consistency, unbiasedness and invariance of tests. Likelihood Ratio tests, asymptotic properties of LR tests with applications (including homogeneity of means and variances).Relation between confidence interval estimation and testing of hypothesis.

Unit IV

Sequential Probability ratio test, Properties of SPRT.Termination property of SPRT, SPRT for Binomial, Poisson, Normal and Exponential distributions. Concepts of loss, risk and decision functions, admissible and optimal decision functions, estimation and testing viewed as decision problems, conjugate families, Bayes and Minimax decision functions with applications to estimation with quadratic loss.

Unit V

Non-parametric tests: Sign test, Wilcoxon signed rank test, Runs test for randomness, Kolmogorov – Smirnov test for goodness of fit, Median test and Wilcoxon-Mann-Whitney U-test. Chi-square test for goodness of fit and test for independence of attributes. Spearman's rank correlation and Kendall's Tau tests for independence.

VI. Practical

- Methods of estimation - Maximum Likelihood, Minimum c^2 and Moments;
- Confidence Interval Estimation;
- MP and UMP tests;
- Large Sample tests;
- Non-parametric tests, Sequential Probability Ratio Test;
- Decision functions.

VII. Suggested Reading

- Box G.E.P. and Tiao G.C. 1992. *Bayesian Inference in Statistical Analysis*.John Wiley.
- Casela G and Berger R.L. 2001. *Statistical Inference*. Duxbury Thompson Learning.
- Christensen R. 1990. *Log Linear Models*. Springer.
- Conover W.J. 1980. *Practical Nonparametric Statistics*. John Wiley.
- Dudewicz EJ and Mishra SN. 1988. *Modern Mathematical Statistics*. JohnWiley.
- Gibbons J.D. 1985. *Non Parametric Statistical Inference*. 2nd Ed. Marcel Dekker.
- Kiefer J.C. 1987. *Introduction to Statistical Inference*. Springer.
- Lehmann EL. 1986. *Testing Statistical Hypotheses*. John Wiley.
- Lehmann EL. 1986. *Theory of Point Estimation*. John Wiley.
- Randles R.H and Wolfe D.S. 1979. *Introduction to the Theory of Nonparametric Statistics*. John Wiley.
- Rao C.R. 2009. *Linear Statistical Inference and Its Applications*, 3rdEd. John Wiley.
- Rohatgi V.K. and Saleh A.K. Md. E. 2005. *An Introduction to Probability and Statistics*. 2nd Ed. John Wiley.
- Rohtagi V.K. 1984. *Statistical Inference*. John Wiley
- Sidney S and Castellan N.J. Jr. 1988. *Non Parametric Statistical Methods for Behavioral Sciences*. McGraw Hill.
- Wald A. 2004. *Sequential Analysis*. Dover Publ.
- Michael J.Panik. 2012. *Statistical Inference*. A John Wiley & Sons, INC, publication

I. Course Title : Design of Experiments

II. Course Code : STAT 563

III. Credit Hours : 2+1

IV. Aim of the course

Design of Experiments provides the statistical tools to get maximum information from least amount of resources. This course is meant to expose the students to the basic principles of design of experiments. The students would also be provided with mathematical background of various basic designs involving one-way and two-way elimination of heterogeneity and their characterization properties. This course would also prepare the students in deriving the expressions for analysis of experimental data.

V. Theory

Unit I

Elements of linear estimation, Gauss Markoff Theorem, relationship between BLUEs and linear zero-functions. Aitken's transformation, test of hypothesis, Analysis of Variance, Partitioning of degrees of freedom.

Unit II

Orthogonality, contrasts, mutually orthogonal contrasts, analysis of covariance; Basic principles of design of experiments, uniformity trials, size and shape of plots andblocks, Randomization procedure.

Unit III

Basic designs - completely randomized design, randomized complete block design and Latin square design; Construction of orthogonal Latin squares, mutually orthogonal Latin squares (MOLS), Youden square designs, Graeco Latin squares.

Unit IV

Balanced Incomplete Block (BIB) designs – general properties and analysis without and with recovery of intra block information, construction of BIB designs. Partially balanced incomplete block designs with two associate classes - properties, analysis and construction, Lattice designs, alpha designs, cyclic designs, augmented designs.

Unit V

Factorial experiments, confounding in symmetrical factorial experiments ($2^n$and 3^nseries), partial and total confounding, asymmetrical factorials.

Unit VI

Cross-over designs. Missing plot technique; Split plot and Strip plot design; Groups of experiments.Sampling in field experiments.

VI. Practical

- Determination of size and shape of plots and blocks from uniformity trials data;
- Analysis of data generated from completely randomized design, randomized complete block design;
- Latin square design, Youden square design; Analysis of data generated from a BIB design, lattice design, PBIB designs;
- 2^n, 3^n factorial experiments without and with confounding;
- Split and strip plot designs, repeated measurement design;
- Missing plot techniques,

- Analysis of covariance;
- Analysis of Groups of experiments,
- Analysis of clinical trial experiments.

VII. Suggested Reading

- Chakrabarti M.C. 1962. *Mathematics of Design and Analysis of Experiments*. Asia Publ.House.
- Cochran W.G. and Cox D.R. 1957. *Experimental Designs*. 2nd Ed. John Wiley.
- Dean A.M. and Voss D. 1999. *Design and Analysis of Experiments*. Springer.
- Dey A and Mukerjee R. 1999. *Fractional Factorial Plans*. John Wiley.
- Dey A 1986. *Theory of Block Designs*. Wiley Eastern. Hall M Jr. 1986. *Combinatorial Theory*. John Wiley.
- John J.A. and Quenouille M.H. 1977. *Experiments: Design and Analysis*. Charles & Griffin.
- Kempthorne, O. 1976. Design and Analysis of Experiments. John Wiley. Khuri AI & Cornell JA. 1996. *Response Surface Designs and Analysis*. 2nd Ed. Marcel Dekker.
- Kshirsagar A.M. 1983. *A Course in Linear Models*. Marcel Dekker.
- Montgomery D.C. 2013. *Design and Analysis of Experiments*. John Wiley & Sons
- Raghavarao D. 1971. *Construction and Combinatorial Problems in Design of Experiments*. John Wiley.
- Searle S.R. 2006. *Linear Models*. John Wiley.
- Street A.P. and Street D.J. 1987. *Combinatorics of Experimental Designs*. Oxford Science Publ.
- Design Resources Server. *Indian Agricultural Statistics Research Institute (ICAR), New Delhi-110 012, India*. Hyperlink "http: //www.iasri.res.in/design" www.drs.icar.gov.in.

I. Course Title : Sampling Techniques

II. Course Code : STAT 564

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant to expose the students to the techniques of drawing representative samples from various populations and then preparing them on the mathematical formulations of estimating the population parameters based on the sample data. The students would also be exposed to the real life applications of sampling techniques and estimation of parameters.

V. Theory

Unit I

Sample survey vs complete enumeration, probability sampling, sample space, sampling design, sampling strategy; Determination of sample size; Confidence-interval; Simple random sampling, Estimation of population proportion, Stratified random sampling, Proportional allocation and optimal allocation, Inverse sampling.

Unit II

Ratio, Product and regression methods of estimation, Cluster sampling, Systematic sampling, Multistage sampling with equal probability, Separate and combined ratio estimator, Double sampling, Successive sampling –two occasions. Unbiased ratio type estimators

Unit III

Non-sampling errors – sources and classification, Non-response in surveys, Randomized response techniques, Response errors/ Measurement error – interpenetrating sub-sampling.

Unit IV

PPS Sampling with and without replacement, Cumulative method and Lahiri's method of selection, Horvitz-Thompson estimator, Ordered and unordered estimators, Sampling strategies due to Midzuno-Sen and Rao-Hartley-Cochran. Inclusion probability proportional to size sampling.

VI. Practical

- Determination of sample size and selection of sample;
- Simple random sampling, Inverse sampling, Stratified random sampling, Cluster sampling, systematic sampling;
- Ratio and regression methods of estimation;
- Double sampling, multi-stage sampling, Imputation methods;
- Randomized response techniques;
- Sampling with varying probabilities.

VII. Suggested Reading

- Cassel C.M., Sarndal C.E. and Wretman J.H. 1977. *Foundations of Inference in Survey Sampling*. John Wiley.
- Chaudhari A and Stenger H. 2005. *Survey Sampling Theory and Methods*. 2nd Ed. Chapman & Hall.
- Chaudhari A and Voss J.W.E. 1988. *Unified Theory and Strategies of Survey Sampling*. North Holland.
- Cochran W.G. 1977. *Sampling Techniques*. John Wiley.
- Hedayat A.S. and Sinha B.K. 1991. *Design and Inference in Finite Population Sampling*. John Wiley.
- Kish L. 1965. *Survey Sampling*. John Wiley.
- Mukhopadhyay, P. 2008.
- *Theory and Methods of Survey Sampling*, John Wiley & Sons
- Murthy M.N. 1977. *Sampling Theory and Methods*. 2nd Ed. Statistical Publ. Society, Calcutta.
- Sukhatme P.V., Sukhatme B.V., Sukhatme S and Asok C. 1984. *Sampling Theory of Surveys with Applications*. Iowa State University Press and Indian Society of Agricultural Statistics, New Delhi.
- Thompson SK. 2000. *Sampling*. John Wiley.
- Kochran WG. 2007. *Sampling Techniques*. A John Wiley & Sons *Publication*

I. Course Title : Statistical Genetics

II. Course Code : STAT 565

III. Credit Hours : 2+1

IV. Aim of the course

This course is meant to prepare the students in applications of statistics in quantitative genetics and breeding. The students would be exposed to the physical basis of inheritance, detection and estimation of linkage, estimation of genetic parameters and development of selection indices.

V. Theory

Unit I

Physical basis of inheritance. Analysis of segregation, detection and estimation of linkage for qualitative characters. Amount of information about linkage, combined estimation, disturbed segregation.

Unit II

Gene and genotypic frequencies, Random mating and Hardy -Weinberg law, Application and extension of the equilibrium law, Fisher's fundamental theorem of natural selection. Disequilibrium due to linkage for two pairs of genes, sex-linked genes, Theory of path coefficients.

Unit III

Concepts of inbreeding, Regular system of inbreeding. Forces affecting gene frequency - selection, mutation and migration, equilibrium between forces in large populations, Random genetic drift, Effect of finite populationsize.

Unit IV

Polygenic system for quantitative characters, concepts of breeding value and dominance deviation. Genetic variance and its partitioning, Effect of inbreeding on quantitative characters, Multipleallelism in continuous variation, Sex-linked genes, Maternal effects - estimation of their contribution.

Unit V

Correlations between relatives, Heritability, Repeatability and Genetic correlation. Response due to selection, Selection index and its applications in plants and animals' improvement programmes, Correlated response to selection.

Unit VI

Restricted selection index. Variance component approach and linear regression approach for the analysis of GE interactions. Measurement of stability and adaptability for genotypes. Concepts of general and specific combining ability. Diallel and partial diallel crosses - construction and analysis.

VI. Practical

- Test for the single factor segregation ratios, homogeneity of the families with regard to single factor segregation;
- Detection and estimation of linkage parameter by different procedures;
- Estimation of genotypic and gene frequency from a given data.
- Hardy-Weinberg law;
- Estimation of changes in gene frequency due to systematic forces, inbreeding coefficient, genetic components of variation, heritability and repeatability coefficient, genetic correlation coefficient;
- Examination of effect of linkage, epistasis and inbreeding on mean and variance of metric traits;
- Mating designs;
- Construction of selection index including phenotypic index, restricted selection index. Correlated response to selection.

VII. Suggested Reading

- Agarwal BL and Agarwal SP. 2007. *Statistical Analysis of Quantitative Genetics*. New Age International Publisher.
- Bailey NTJ. 1961. *The Mathematical Theory of Genetic Linkage*.Clarendon Press.
- Balding DJ, Bishop M and Cannings C. 2001. *Hand Book of Statistical Genetics*. John Wiley.
- Crow JF and Kimura M. 1970. *An Introduction of Population Genetics Theory*. Harper and Row.
- Dahlberg G. 1948. *Mathematical Methods for Population Genetics*. Inter Science Publ.
- East EM and Jones DF. 1919. *Inbreeding and Outbreeding*.
- Lippincott JB & Co. Ewens WJ. 1979. *Mathematics of Population Genetics*. Springer.

- Falconer DS. 1985. *Introduction to Quantitative Genetics*. ELBL.
- Fisher RA. 1949. *The Theory of Inbreeding*. Oliver & Boyd.
- Fisher RA. 1950. *Statistical Methods for Research Workers*. *Oliver*& Boyd.
- Fisher RA. 1958. *The Genetical Theory of Natural Selection*. *Dover* Publ.
- Kempthorne O. 1957. *An Introduction to Genetic Statistics*. The Iowa State Univ. Press.
- Lerner IM. 1950. *Population Genetics and Animal Improvement*.Cambridge Univ. Press.
- Lerner IM. 1954. *Genetic Homeostasis*. Oliver & Boyd.
- Lerner IM. 1958. *The Genetic Theory of Selection*. John Wiley.
- Li CC. 1982. *Population Genetics*. The University of Chicago Press.
- K & Jinks JL. 1977. *Introduction to Biometrical Genetics*.Chapman & Hall.
- Mather K and Jinks JL. 1982. *Biometrical Genetics*. Chapman & Hall.
- Mather K. 1949. *Biometrical Genetics*. Methuen.
- Mather K. 1951. *The Measurement of Linkage in Heredity*.
- Methuen. N. P. 1990. *Statistical Genetics*. Wiley Eastern.

I. Course Title : Statistical Quality Control

II. Course Code : STAT 566

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for exposing the students to the concepts of Statistical Quality Control and their applications in agribusiness and agro- processing industries. This course would enable the students to have an idea about the statistical techniques used in quality control. Students who do not have sufficient background of Statistical Methods.

V. Theory

Unit I

Introduction to Statistical Quality Control; Control Charts for Variables – Mean, Standard deviation and Range charts; Statistical basis; Rational subgroups.

Unit II

Control charts for attributes- ‘np’, ‘p’ and ‘c’ charts.

Unit III

Fundamental concepts of acceptance, sampling plans, single, double and sequential sampling plans for attributes inspection.

Unit IV

Sampling inspection tables for selection of single and double sampling plans.

VI. Suggested Reading

- Cowden D.J. 1957. *Statistical Methods in Quality Control*. Prentice Hall of India.
- Dodge H.F. and Romig H.G. 1959. *Sampling Inspection Tables*. John Wiley.
- Duncan A.J. 1986. *Quality Control and Industrial Statistics*. 5th Ed. Irwin Book Co.
- Grant E.L. and Leavenworth R.S. 1996. *Statistical Quality Control*. 7th Ed. McGraw Hill.
- Montgomery D.C. 2008. *Introduction to Statistical Quality Control*. 6th Ed. John Wiley.
- Wetherhil G.B. 1977. *Sampling Inspection and Quality Control*. Halsted Press.

I. Course Title : Optimization Techniques

II. Course Code : STAT 567

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant for exposing the students to the mathematical details of the techniques optimization techniques. They will be taught numerical methods of optimization, linear programming techniques, nonlinear programming and multiple objective programming. Students will also be exposed to practical applications of these techniques.

V. Theory

Unit I

Classification of optimization problems, Classical optimization techniques: single variable optimization, multivariable optimization techniques with no constraints, multivariable optimization techniques with equality constraints, multivariable optimization techniques with inequality constraints.

Unit II

Linear programming: simplex method, duality, sensitivity analysis, Karmarkar's method, transportation problem.

Unit III

Nonlinear programming Unconstrained optimization techniques: direct search methods such as random search, grid search, Hooke and Jeeves' method, Powel's method. Descent methods such as gradient method, steepest descent method, conjugate gradient method, Newton's method, Marquardt method.

Unit IV

Quadratic programming, integer linear programming, integer nonlinear programming, geometric programming, dynamic programming, stochastic programming, multiobjective optimization, optimal control theory, genetic algorithms, simulated annealing, neural network based optimization,

VI. Practical

- Problems based on classical optimization techniques, optimization techniques with constraints, minimization problems using numerical methods.
- Linear programming (LP) problems through graphical method, simplex method, simplex two-phase method, primal and dual method.
- Sensitivity analysis for LP problem, LP problem using Karmarkar's method.
- Problems based on Quadratic programming, integer programming, dynamic programming, stochastic programming.
- Problems based on Pontryagin's maximum principle.
- Problems based on multiobjective optimization.

VII. Suggested Reading

- Antunes C.H., Alves, M.J., Climaco J. 2016. *Multi objective Linear and Integer Programming* (EURO Advanced Tutorials on Operational Research)
- Nocedal, J. and Wright, S.J. 1999. *Numerical Optimization*. Springer.
- Rao, S.S. 2007. *Engineering Optimization: Theory and Practice*. New Age International Publishers.
- Rustagi, J.S. 1994. *Optimization Techniques in Statistics*. Academic Press.

- Taha, H.A. 2007. *Operations Research: Introduction with CD*. Pearson Education.
- Xu, H, Teo, K.L. Zhang Y. 2016. *Optimization and Control Techniques and Applications* (Springer Proceedings in Mathematics & Statistics)
- Zeleny, M. 1974. *Linear Multi objective Programming*. Springer.

I. Course Title : Multivariate Analysis

II. Course Code : STAT 571

III. Credit Hours : 2+1

IV. Aim of the course

This course lays the foundation of Multivariate data analysis. Most of the data sets in agricultural sciences are multivariate in nature. The exposure provided to multivariate data structure, multinomial and multivariate normal distribution, estimation and testing of parameters, various data reduction methods would help the students in having a better understanding of agricultural research data, its presentation and analysis.

V. Theory

Unit I

Concept of random vector, its expectation and Variance-Covariance matrix. Marginal and joint distributions. Conditional distributions and Independence of random vectors. Multinomial distribution. Multivariate Normal distribution, marginal and conditional distributions. Sample mean vector and its distribution. Maximum likelihood estimates of mean vector and dispersion matrix. Tests of hypothesis about mean vector.

Unit II

Wishart distribution and its simple properties. Hotelling's T^2 and Mahalanobis D^2 statistics. Null distribution of Hotelling's T^2. Rao's U statistics and its distribution. Wilks' λ criterion and its properties. Concepts of discriminant analysis, computation of linear discriminant function, classification between k (≥ 2) multivariate normal populations based on LDF and Mahalanobis D^2.

Unit III

Principal Component Analysis, factor analysis. Canonical variables and canonical correlations. Cluster analysis: similarities and dissimilarities of qualitative and quantitative characteristics, Hierarchical clustering. Single, Complete and Average linkage methods. K-means cluster analysis.

Unit IV

Path analysis and computation of path coefficients, introduction to multidimensional scaling, some theoretical results, similarities, metric and non-metric scaling methods.

VI. Practical

- Maximum likelihood estimates of mean-vector and dispersion matrix;
- Testing of hypothesis on mean vectors of multivariate normal populations;
- Cluster analysis, Discriminant function, Canonical correlation, Principal component analysis, Factor analysis;
- Multivariate analysis of variance and covariance, multidimensional scaling.

VII. Suggested Reading

- Abdelmonem A, Virginia AC and Susanne M. 2004. *Computer Aided Multivariate Analysis*. Chapman & Hall/CRC.
- Anderson TW. 1984. *An Introduction to Multivariate Statistical Analysis*. 2nd Ed. John Wiley.
- Arnold SF. 1981. *The Theory of Linear Models and Multivariate Analysis*. John Wiley.
- Giri NC. 1977. *Multivariate Statistical Inference*. Academic Press.
- Johnson RA and Wichern DW. 1988. *Applied Multivariate Statistical Analysis*. Prentice Hall.
- Kshirsagar AM. 1972. *Multivariate Analysis*. Marcel Dekker.
- Muirhead RJ. 1982. *Aspects of Multivariate Statistical Theory*. John Wiley. Muirhead, RJ. (2005) *Aspects of Multivariate Statistical Theory*. 2nd Ed. John Wiley.
- Rao CR. 1973. *Linear Statistical Inference and its Applications*. 2nd Ed. John Wiley.
- Rencher AC. 2012. *Methods of Multivariate Analysis*. 3rd Ed. John Wiley.
- Srivastava MS and Khatri CG. 1979. *An Introduction to Multivariate Statistics*. North Holland.

I. Course Title : Regression Analysis

II. Course Code : STAT 572

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant to prepare the students in linear and non-linear regression methods useful for statistical data analysis. They would also be provided a mathematical foundation behind these techniques and their applications in agricultural data.

V. Theory

Unit I

Simple and Multiple linear regressions: Least squares fit, Properties and examples. Polynomial regression: Use of orthogonal polynomials.

Unit II

Assumptions of regression; diagnostics and transformations; residual analysis ~ Studentized residuals, applications of residuals in detecting outliers, identification of influential observations. Lack of fit, Pure error. Test of normality, test of linearity,Testing homoscedasticity and normality of errors, Durbin-Watson test. Test of goodness of fit for the model evaluation and validation.Concept of multi-collinearity

Unit III

Weighted least squares method: Properties, and examples. Box-Cox family of transformations. Use of dummy variables, Over fitting and under fitting of model, Selection of variables: Forward selection, Backward elimination. Stepwise and Stagewise regressions.

Unit IV

Introduction to non-linear models, nonlinear estimation: Least squares for nonlinear models.

VI. Practical

- Multiple regression fitting with three and four independent variables;
- Estimation of residuals, their applications in outlier detection, distribution of residuals;

- Test of homoscedasticity, and normality, Box-Cox transformation;
- Restricted estimation of parameters in the model, hypothesis testing, Step wise regression analysis;
- Least median of squares norm, Orthogonal polynomialfitting.

VII. Suggested Reading

- Barnett V and Lewis T. 1984. *Outliers in Statistical Data*. John Wiley.
- Belsley DA, Kuh E and Welsch RE. 2004. *Regression Diagnostics-Identifying Influential Data and Sources of Collinearity*. John Wiley.
- Chatterjee S and Hadi AS. 2013. *Regression Analysis* by *Example*. A John Wiley & sons Publication.
- Draper NR and Smith H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- McCullagh P and Nelder JA. 1999. *Generalized Linear Models*. 2nd Ed.*Chapman* & Hall.
- Montgomery DC, Peck EA and Vining GG. 2003. *Introduction to Linear Regression Analysis*. 3rd Ed. John Wiley.
- Rao CR. 1973. *Linear Statistical Inference and its Applications*. 2nd*Ed*. John Wiley.

I. Course Title : Statistical Computing

II. Course Code : STAT 573

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant for exposing the students in the concepts of computational techniques. Various statistical packages would be used for teaching the concepts of computational techniques.

V. Theory

Unit I

Introduction to statistical packages and computing: data types and structures, Use of Software packages like, SAS, SPSS or "R: The R Project for Statistical Computing". Data analysis principles and practice, Summarization and tabulation of data, Exploratory data analysis; Graphical representation of data.Statistical Distributions: Fitting and testing the goodness of fit of discrete and continuous probability distributions;

Unit II

ANOVA, regression and categorical data methods; model formulation, fitting, diagnostics and validation; Matrix computations in linear models. Analysis of discrete data. Multiple comparisons, Contrast analysis.

Unit III

Numerical linear algebra, numerical optimization, graphical techniques, numerical approximations, Time Series Analysis.

Unit IV

Analysis of mixed models; Estimation of variance components, Analysis of Covariance, Fitting of non-linear model, Discriminant function; Principal component analysis. techniques in the analysis of survival data and longitudinal studies, Approaches to handling missing data, and meta-analysis

VI. Practical

- Data management, Graphical representation of data, Descriptive statistics;

- General linear models ~ fitting and analysis of residuals, outlier detection;
- Fitting and testing the goodness of fit of probability distributions;
- Testing the hypothesis for one sample *t*-test, two sample *t*-test, paired *t*-test, test for large samples - Chi-squares test, F test, One way analysis of variance, contrast and its testing, pairwise comparisons;
- Mixed effect models, estimation of variance components;
- Categorical data analysis, dissimilarity measures, similarity measures;
- Analysis of discrete data, analysis of binary data;
- Numerical algorithms;
- Spatial modeling, cohort studies;
- Clinical trials, analysis of survival data;
- Handling missing data.Analysis of time series data - fitting of ARIMA models.

VII. Suggested Reading

- Agresti A. 2013. *Categorical Data Analysis*. 3rd Ed. John Wiley.
- Everitt BS and Dunn G. 1991. *Advanced Multivariate Data Analysis*. 2nd Ed. Arnold.
- Geisser S. 1993. *Predictive Inference: An Introduction*. Chapman & Hall.
- Gelman A & Hill J. 2006. *Data Analysis Using Regression and Multilevel/Hierarchical Models*. Cambridge Univ. Press.
- Gentle JE, Härdle W and Mori Y. 2012. *Handbook of Computational Statistics - Concepts and Methods*. 2nd Ed. Springer.
- Han J and Kamber M. 2000. *Data Mining: Concepts and Techniques*. Morgan.
- Hastie T, Tibshirani R and Friedman R. 2001. *The Elements of Statistical Learning: Data Mining, Inference and Prediction*. Springer.
- Kennedy WJ & Gentle JE. 1980. *Statistical Computing*. Marcel Dekker.
- Miller RG Jr. 1986. *Beyond ANOVA, Basics of Applied Statistics*. John Wiley.
- Rajaraman V. 1993. *Computer Oriented Numerical Methods*. Prentice-Hall.
- Ross S. 2000. *Introduction to Probability Models*. Academic Press.
- Ryan BF and Joiner BL. 1994. *MINITAB Handbook*. 3rd Ed. Duxbury Press.
- Simonoff JS. 1996. *Smoothing Methods in Statistics*. Springer.
- Singh, AK. 2016. *Practical R-Book by Examples for Agricultural Statistics*. Deptt. Of Ag. Statistics, IGKV. Raipur
- Snell EJ. 1987. *Applied Statistics: A Handbook of BMDP Analyses*. Chapman & Hall.
- Thisted RA. 1988. *Elements of Statistical Computing*. Chapman & Hall.
- Venables WN and Ripley BD. 1999. *Modern Applied Statistics With S-Plus*. 3rd Ed. Springer.
- http: //www.r-project.org/
- http: //www.stat.sc.edu/~grego/courses/stat706/.
- Design Resources Server: www.drs.icar.gov.in.

I. Course Title : Time Series Analysis

II. Course Code : STAT 574

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant to teach the students the concepts involved in time series data. They would also be exposed to components of time series, stationary models and forecasting/ projecting the future scenarios based on time series data. It would also help them in understanding the concepts involved in time series data presentation, analysis and interpretation.

V. Theory

Unit I

Components of a time-series. Autocorrelation and Partial autocorrelation functions, Correlogram and periodogram analysis.

Unit II

Linear stationary models: Autoregressive, moving average and Mixed processes. Linear non-stationary models: Autoregressive integrated moving average processes.

Unit III

Forecasting: Minimum mean square forecasts and their properties, Calculating and updating forecasts.

Unit IV

Model identification: Objectives, Techniques, and Initial estimates. Model estimation: Likelihood function, Sum of squares function, Least squares estimates. Seasonal models. Intervention analysis models and Outlier detection.

VI. Practical

Time series analysis, autocorrelations, correlogram and periodogram; Linear stationary model; Linear non-stationary model; Model identification and model estimation; Intervention analysis and outlier detection.

VII. Suggested Reading

- Box GEP, Jenkins GM and Reinsel GC. 2007. *Time Series Analysis: Forecasting and Control*. 3rd Ed. Pearson Edu.
- Brockwell PJ and Davis RA. 2002. *Introduction to Time Series and Forecasting*. 2nd Ed. Springer.
- Chatterjee S, Hadi A and Price B.1999. *Regression* Analysis by Examples.John Wiley.
- Draper NR and Smith H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- Jenkins, GM, Reinsel, GC, Greta M. L,George E.P.B. 2015. *Time Series Analysis: Forecasting and Control*, Wiley Series in Probability and Statistics
- Johnston J. 1984. *Econometric Methods*. McGraw Hill.
- Judge GG, Hill RC, Griffiths WE, Lutkepohl H and Lee TC. 1988. *Introduction to the Theory and Practice of Econometrics*. 2nd Ed. John Wiley.
- Montgomery DC and Johnson LA. 1976. *Forecasting and Time Series Analysis*. McGraw Hill.
- Montgomery DC, Jennings CA and Kulahci M. 2015. *Introduction to Time Series Analysis and Forecasting*, Wiley Series in Probability and Statistics
- Shumway RH and Stoffer DS. 2006. *Time Series Analysis and its Applications: With R Examples*. 2nd Ed. Springer.

I. Course Title : Demography

II. Course Code : STAT 575

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for training the students in measures of demographic indices, estimation procedures of demographic parameters. Students would also be exposed to population projection techniques and principle involved inbioassays.

V. Theory

Unit I

Introduction to vital statistics, crude and standard mortality and morbidity rates, Estimation of mortality, Measures of fertility and mortality, period and cohort measures.

Unit II

Life tables and their applications, methods of construction of abridged life tables, Increment-Decrement Life Tables.

Unit III

Stationary and stable populations, Migration and immigration. Application of stable population theory to estimate vital rates, migration and its estimation. Demographic relations in Nonstable populations. Measurement of population growth, Lotka's model (deterministic) and intrinsic rate of growth, Measures of mortality and morbidityPeriod.

Unit IV

Principle of biological assays, parallel line and slope ratio assays, choice of doses and efficiency in assays quantal responses, probit and logit transformations, epidemiological models.

VI. Suggested Reading

- Cox DR. 1957. *Demography*. Cambridge Univ. Press.
- Charles Griffin. Fleiss JL. 1981. *Statistical Methods for Rates and Proportions*. John Wiley.
- Finney DJ. 1981. *Statistical Methods in Biological Assays*.
- Grow A, Bavel JV. 2016. *Agent-Based Modelling in Population Studies: Concepts, Methods, and Applications* (The Springer Series on Demographic Methods and Population Analysis)
- Lawless JF. 1982. *Statistical Models and Methods for Lifetime Data*. John Wiley.
- MacMahon B and Pugh TF. 1970. *Epidemiology- Principles and Methods.*Little Brown, Boston.
- Mann NR, Schafer RE and Singpurwalla ND. 1974. *Methods for Statistical Analysis of Reliability and Life Data*. John Wiley.
- Newell C. 1988. *Methods and Models in Demography*. Guilford Publ.
- Preston S, Heuveline P and Guillot M. 2001. *Demography: Measuring and Modeling Population Processes*. Blackwell Publ.
- Rowland DT. 2004. *Demographic Methods and Concepts*. Oxford Press.
- Siegel JS and Swanson DA. 2004. *The Methods and Material ofDemography*. 2nd Ed. Elsevier.
- Woolson FR. 1987. *Statistical Methods for the Analysis of Biomedical Data*. JohnWiley.
- Yakovlev AY, Klebanov L and Gaile D. 2013. *Statistical Methods for Microarray Data Analysis: Methods and Protocols* (Methods in Molecular Biology)

I. Course Title : Statistical Methods for Life Sciences

II. Course Code : STAT 576

III. Credit Hours : 2+0

IV. Aim of the course

This course focuses on statistical methods for discrete data collected in public health, clinical and biological studies including survival analysis. This would enable the students to understand the principles of different statistical techniques useful in public health and clinical studies conducted.

V. Theory

Unit I

Proportions and counts, contingency tables, logistic regression models, Poisson regression and log-linear models, models for polytomous data and generalized linear models.

Unit II

Computing techniques, numerical methods, simulation and general implementation of biostatistical analysis techniques with emphasis on data applications. Analysis of survival time data using parametric and non- parametric models, hypothesis testing, and methods for analyzing censored (partially observed) data with covariates. Topics include marginal estimation of a survival function, estimation of a generalized multivariate linear regression model (allowing missing covariates and/or outcomes).

Unit III

Proportional Hazard model: Methods of estimation, estimation of survival functions, time-dependent covariates, estimation of a multiplicative intensity model (such as Cox proportional hazards model) and estimation of causal parameters assuming marginal structural models.

Unit IV

General theory for developing locally efficient estimators of the parameters of interest in censored data models. Rank tests with censored data. Computing techniques, numerical methods, simulation and general implementation of bio-statistical analysis techniques with emphasis on data applications.

Unit V

Newton, scoring, and EM algorithms for maximization; smoothing methods; bootstrapping; trees and neural networks; clustering; isotonic regression; Markov chain Monte Carlomethods.

VI. Suggested Reading

- Biswas S. 2007. *Applied Stochastic Processes. A Biostatistical and Population Oriented Approach*. Wiley Eastern Ltd.
- Collett D. 2003. *Modeling Survival Data in Medical Research*. Chapman & Hall.
- Cox D.R. and Oakes D. 1984. *Analysis of Survival Data*. Chapman & Hall.
- Hosmer DW Jr. and Lemeshow S. 1999. *Applied Survival Analysis: Regression Modeling or Time to Event*. John Wiley.
- Klein J.P. and Moeschberger M.L. 2003. *Survival Analysis: Techniques for Censored and Truncated Data*. Springer.
- Kleinbaum D.G. and Klein M 2005. *Survival Analysis. A Self Learning Text*. Springer.
- Kleinbaum D.G. and Klein M. 2005. *Logistic Regression*. 2nd Ed. Springer.
- Lee ET. 1992. *Statistical Methods for Survival Data Analysis*.
- John Wiley and Miller RG. 1981. *Survival Analysis*. John Wiley.
- Therneau T.M. and Grambsch P.M. 2000. *Modeling Survival Data: Extending the Cox Model*.Springer.

I. Course Title : Statistical Ecology

II. Course Code : STAT 577

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for exposing the students to the importance and use of statistical methods in collections of ecological data, species-abundance relations, community classification and community interpretation.

V. Theory

Unit I

Ecological data, Ecological sampling; Spatial pattern analysis: Distribution methods, Quadrant-variance methods, Distancemethods.

Unit II

Species-abundance relations: Distribution models, Diversity indices; Species affinity: Niche-overlap indices, interspecific association, interspecificcovariation.

Unit III

Community classification: Resemblance functions, Association analysis, Cluster analysis; Community Ordination: Polar Ordination, Principal Component Analysis, Correspondence analysis, Nonlinear ordination.

Unit IV

Community interpretation: Classification Interpretation and Ordination Interpretation.

VI. Suggested Reading

- Gotelli N.J. and Ellison A.M. 2004. *A Primer of Ecological Statistics*
- Pielou E.C. 1970. *An introduction to Mathematical Ecology*. John Wiley.
- Reynolds J.F. and Ludwig J.A. 1988. *Statistical Ecology: A Primer on Methods and Computing*. JohnWiley.
- Young L.J., Young J.H. and Young J. 1998. *Statistical Ecology: A Population Perspective.* Kluwer.

Course Title with Credit load
Ph.D. in Agricultural Statistics

Course Code	Course Title	Credit Hours	Semester
*STAT 601	Advanced Data Analytics	1+2	I
*STAT 602	Simulation Techniques	1+1	I
*STAT 603	Linear Models	2+0	I
*STAT 604	Advanced Statistical Methods	2+1	I
*STAT 611	Baysian Inference	2+0	II
STAT 691	Seminar I	0+1	I
STAT 692	Seminar II	0+1	II
STAT 699	Research	0+75	II-VI
STAT 605	Modeling Techniques for Forecasting	2+1	I
STAT 606	Stochastic Processes	2+0	I
STAT 607	Survival Analysis	2+0	I
STAT 608	Spatial Statistics	1+1	I
STAT 612	Advanced Design of Experiments	2+1	II
STAT 613	Advanced Sampling Techniques	2+1	II
STAT 614	Advanced Statistical Genetics	2+1	II
STAT 615	Advanced Time Series Analysis	2+0	II
STAT 616	Advanced Bioinformatics	2+0	II
STAT 617	Advanced Econometrics	2+0	II
STAT 618	Recent Advances in the Field of Specialization	1+0	II

*Core Courses

Course Contents
Ph.D. in Agricultural Statistics

I. Course Title : Advanced Data Analytics
II. Course Code : STAT 601
III. Credit Hours : 1+2

IV. Aim of the course

This is an advanced course in Statistical Computing that aims at describing some advanced level topics in this area of research with a very strong potential of applications. This course also prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to agricultural sciences and use of statistical packages.

V. Theory

Unit I

Measures of association. Structural models for discrete data in two or more dimensions.
Estimation in complete tables. Goodness of fit, choice of a model. Generalized Linear Model for discrete data, Poisson and Logistic regression models. Log-linearmodels.

Unit II

Elements of inference for cross-classification tables. Models for nominal and ordinal response.

Unit III

Computational problems and techniques for robust linear regression, nonlinear and generalized linear regression problem, tree-structured regression and classification, cluster analysis, smoothing and function estimation, robust multivariate analysis.

Unit IV

Analysis of incomplete data: EM algorithm, single and multiple imputations. Markov Chain, Monte Carlo and annealing techniques, Neural Networks, Association Rules and learning algorithms.

Unit V

Linear mixed effects models, generalized linear models for correlated data (including generalized estimating equations), computational issues and methods for fitting models, and dropout or other missing data.

Unit VI

Multivariate tests of linear hypotheses, multiple comparisons, confidence regions, prediction intervals, statistical power, transformations and diagnostics, growth curve models, dose-response models.

VI. Practical

- Analysis of qualitative data;
- Generalized linear for correlated data;
- Generalized linear models for discrete data;
- Robust methods of estimation and testing of non-normal data;
- Robust multivariate analysis;
- Cluster analysis;
- Analysis of Incomplete data;
- Classification and prediction using artificial neural networks;
- Markov Chain;
- Analysis of data having random effects using Linear mixed effects models;
- Analysis of data with missing observations;
- Applications of multiple comparison procedures;
- Building Simultaneous confidence intervals;
- Fitting of growth curve models to growth data;
- Fitting of dose-response curves and estimation of parameters.

Suggested Reading

- Everitt B.S. and Dunn G. 1991. *Advanced Multivariate Data Analysis*. 2nd Ed. Arnold.
- Geisser S. 1993. *Predictive Inference: An Introduction*. Chapman & Hall.
- Gentle J.E., Härdle W and Mori Y. 2004. *Handbook of Computational Statistics-Concepts and Methods*. Springer.
- Han J and Kamber M. 2000. *Data Mining: Concepts and Techniques*. Morgan.
- Hastie T, Tibshirani R and Friedman R. 2017. *The Elements of Statistical Learning: Data Mining, Inference and Prediction*. Springer. 2nd Ed.
- Kennedy W.J. and Gentle J.E. 1980. *Statistical Computing*. Marcel Dekker.
- Miller R.G. Jr. 1986. *Beyond ANOVA, Basics of Applied Statistics*. John Wiley.
- Rajaraman V. 1993. *Computer Oriented Numerical Methods*. Prentice-Hall.
- Robert C.P. and Casella G. 2004. *Monte Carlo* Statistical *Methods*. 2nd Ed. Springer.
- Ross S. 2000. *Introduction to Probability Models*. Academic Press.
- Simonoff J.S. 1996. *Smoothing Methods in Statistics*. Springer.
- Thisted R.A. 1988. *Elements of Statistical Computing*. Chapman & Hall.
- Venables W.N. and Ripley B.D. 1999. *Modern Applied Statistics With S-Plus*. 3rd Ed. Springer.
- Free Statistical Softwares: http: //freestatistics.altervista.org/en/stat.php.
- Design Resources Server: www.drs.icar.gov.in.

I. Course Title : Simulation Techniques

II. Course Code : STAT 602

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant for students who have a good knowledge in Statistical Inference and Statistical Computing. This course would prepare students for undertaking research in the area of simulation techniques andtheir applications to agricultural sciences.

V. Theory

Unit I

Uses and purposes of simulation; Classification of models. Generation and testing of random numbers, Review of simulation methods; Implementation of simulation methods - for Discrete and continuous probability distribution, sampling and resampling methods: theory and application of the jackknife and thebootstrap.

Unit II

Randomization tests, analysis using computer software packages. Simulating multivariate distributions, MCMC methods and Gibbs sampler.

Unit III

Simulation of generalized linear models and time series models, Simulated data sets to be analyzed using popular computer software packages.

Unit IV

Stochastic simulation: Markov Chain, Monte Carlo, Hastings-Metropolis algorithms, critical slowing-down and remedies, auxiliary variables, simulated tempering, reversible- jump MCMC and multi-grid methods.

VI. Practical

- Simulation from various probability models;
- Resampling methods, jackknife and the bootstrap;
- Randomization tests;
- Simulating multivariate distributions, MCMC methods and Gibbs sampler;
- Simulated data sets to be analyzed using popular computer software packages;
- Markov Chain, Monte Carlo, Gibbs' sampling;
- Reversible- jump MCMC and multi-grid methods.

VII. Suggested Reading

- Averill M.L. 2017. *Simulation, Modeling and Analysis*. Tata McGraw Hill.
- Balakrishnan N, Melas V.B. and Ermakov S. (Ed.). 2000. *Advances in Stochastic Simulation Methods*. Basel-Birkhauser.
- Banks J. (Ed.). 1998. *Handbook of Simulation: Principles, Methodology, Advances, Applications and Practice*. John Wiley.
- Brately P, Fox B.L. and Scharge L.E. 1987. *A Guide to Simulation*. Springer. Davison A.C. and Hinkley D.V. 2003. *Bootstrap Methods and their Application*. Cambridge Univ. Press.
- Gamerman D, Lopes H.F. and Lopes H.F. 2006. *Markov Chain* Monte *Carlo: Stochastic Simulation for Bayesian Inference*. CRC Press.
- Gardner F.M. and Baker J.D. 1997. *Simulation Techniques Set*. John Wiley. Gentle J.E. 2005. *Random Number Generation and Monte Carlo Methods*. Springer.
- Janacek G and Louise S. 1993. *Time Series: Forecasting, Simulation, Applications*. Ellis Horwood Series in Mathematics and its Applications.
- Kleijnen J and Groenendaal W.V. 1992. *Simulation: A Statistical Perspective*. John Wiley.
- Kleijnen J. 1974 (Part I), 1975 (Part II). *Statistical Techniques in Simulation*. Marcel Dekker.
- Law A and Kelton D. 2000. *Simulation Modeling and Analysis*. McGraw Hill.
- Press W.H., Flannery B.P., Tenkolsky S.A. and Vetterling W.T. 1986. *Numerical Recipes*. Cambridge Univ.Press.
- Ripley B.D. 1987. *Stochastic Simulation*. John Wiley. Ross SM. 1997. *Simulation*. John Wiley.

I. Course Title : Linear Models

II. Course Code : STAT 603

III. Credit Hours : 2+0

IV. Aim of the course

The students would be exposed to the theory of linear models, estimation of variance components for unbalanced data and advanced techniques for analysis of data in agriculture.

V. Theory

Unit I

General Gauss Markoff set up, Gauss-Markoff's theorem, Aitken's transformation. Theory of linear estimation, test of hypothesis in linear models. Analysis of variance, partitioning of degrees of freedom. Restricted least squares. Special cases of one and two way classifications (including disproportionate cell frequencies and interaction, cross and nested classifications).

Unit II

Analysis of covariance. Variance components models, estimation of variance components from unbalanced data. Unified theory of least-squares, MINQUE, MIVQUE. Mixed models. LAR, LASSO.

VI. Suggested Reading

- Bapat, R.B. 2012. *Linear Algebra and Linear Models*. Springer-Verlag.
- Graybill, F. A. 1976. *Theory and Application of the Linear Model*. Duxbury, North Scituate.
- Joshi, D.D. 1987. *Linear Estimation and Design of Experiments*. Wiley Eastern.
- Rao, C. R. 2001. *Linear Inference and its Application*. Wiley Eastern.
- Searle, S. R. 1998. *Variance Components*. John Wiley.
- Searle, S.R. 1971. *Linear Models*. John Wiley.
- Seber, G.A. F. 1996. *The Linear Hypothesis: A General Theory*. Griffin, Charles and Co. Ltd.
- Sheffe, H. 1999. *Analysis of Variance*. John Wiley.

I. Course Title : Advanced Statistical Methods

II. Course Code : STAT 604

III. Credit Hours : 2+1

IV. Aim of the course

This is an advanced course in Statistical Methods that aims at describing some advanced level topics in this area of research with a very strong potential of applications. This course also prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to agriculturalsciences.

V. Theory

Unit I

Truncated and compound distributions. Fitting of orthogonal polynomials. Pearsonian curves.Categorical data analysis - loglinear models, Association between attributes. Variance stabilizingtransformations.

Unit II

Sampling distribution of correlation coefficient, regression coefficient, correlation ratio, intra class correlation coefficient.

Unit III

Non-central t, χ^2 and F distributions. Distribution of quadratic forms. Cochran's theorem. Tests for normality. Large sample tests. Tests of significance based on t, χ^2 and F distributions. Order statistics, distribution of r^{th} order statistics, joint distribution of several order statistics andtheir functions, marginal distributions of order statistics, distribution of range, median, etc.

Unit IV

Fitting of a generalized linear model, mixed model and variance components estimation, MINQUE, MIVQUE, REML.

VI. Practical

- Fitting of truncated distribution,
- Fitting of Pearsonian curves,
- Analysis of association between attributes, categorical data.
- Fitting of non-central t, χ^2 and F distributions.
- Computation of Tests of significance based on t, χ^2 and F distributions.
- Order statistics.

VII. Suggested Reading

- Chatterjee S, Hadi A and Price B. 2013. *Regression Analysis by Examples*. 5th Ed. John Wiley.
- Draper N.R. and Smith H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- Rao C.R. 2009. *Linear Statistical Inference and its Applications*. 2nd Ed. John Wiley.
- Searle S.R, Casella G and McCulloch C.E. 1992. *Variance Components*. John Wiley.
- Searle S.R. 1971. *Linear Models*. John Wiley.

I. Course Title : Modeling Techniques for Forecasting

II. Course Code : STAT 605

III. Credit Hours : 2+1

IV. Aim of the course

This is an advanced course in Statistical Methods that aims at describing some advanced level topics in this area of research with a very strong potential of applications. This course also prepares students for undertaking research in the area of empirical and mechanistic models and nonlinear estimation and the replications in different disciplines of agricultural sciences.

V. Theory

Unit I

Empirical and mechanistic models. Nonlinear growth models: monomolecular, logistic, Gompertz, Richards. Applications in agriculture and fisheries.

Unit II

Nonlinear estimation: Least squares for nonlinear models, Methods for estimation of parameters like Linearization, Steepest, and Levenberg- Marquardt's Parameterization.

Unit III

Two-species systems. Lotka-Volterra, Leslie-Gower and Holling-Tanner non-linear prey-predator models. Volterra's principle and its applications. Gauss competition model.

Unit IV

Compartmental modelling - First and second order input-output systems, Dynamics of a multivariable system.

Unit V

Forecasting techniques with special reference to agriculture. Forecast based on time series data: exponential smoothing, Box – Jenkins approach and non-linear models. Forecast models using weather parameters, crop-weather relationships and their use in yield forecast. Forecast using plant characters.

Unit VI

Forecast surveys, between-year models (regression model, Markov chain probability model and group method of data handling) and within-year models. Agro-meteorological models: climatic water balance model and crop yield assessment. Forewarning of crop pests and diseases. Application of remote sensing techniques in forecasting. Use of ANN in forecasting.

VI. Practical

- Fitting of mechanistic non-linear models;
- Application of Schaefer and Fox non-linear models;
- Fitting of compartmental models.Fitting of forecast models using weather parameters.
- Time series analysis: plots, decomposition, stationarity tests, exponential smoothing. •Univariate Box – Jenkins ARIMA models and seasonal ARIMA models.
- Forecast models using plant characters,
- Agrometeorological models for crop forecasting, Markov chain models and ANN models.

VII. Suggested Reading

- Draper, N.R. and Smith, H. 1998. *Applied Regression Analysis*. 3rd Ed. John Wiley.
- Efromovich S. 1999. *Nonparametric Curve Estimation*. Springer.
- Fan, J. and Yao, Q. 2003. *Nonlinear Time Series-Nonparametric and Parametric Methods*. Springer.
- France, J. and Thornley, J.H.M. 1984. *Mathematical Models in Agriculture*. Butterworths.
- Harvey, A.C. 1996. *Forecasting, Structural Time Series Models and the Kalman Filter*. Cambridge Univ. Press.
- Makridakis, S., Wheelwright, S.C. and Hyndman, R.J. 1998. *Forecasting: Methods and Applications*. John Wiley.
- Pankratz, A. 1983. *Forecasting with Univariate Box Jenkins Models: Concepts and Cases.* John Wiley.
- Thornley, J. and France J. 2006. *Mathematical Models in Agriculture: Quantitative Methods for the Plant, Animal and Ecological Sciences* (Cabi) 2nd Ed.

I. Course Title : Stochastic Processes

II. Course Code : STAT 606

III. Credit Hours : 2+0

IV. Aim of the course

This is a course on Stochastic Processes that aims at describing some advanced level topics in this area of research with a very strong potential of applications. This course also prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to agricultural sciences.

V. Theory

Unit I

Introduction to stochastic process - classification according to state space and time domain. Finite and countable state Markov chains; time- homogeneity; Chapman-Kolmogorov equations, marginal distribution and finite dimensional distributions. Classification of Markov chain. Canonical form of transition probability matrix of a Markov chain. Fundamental matrix; probabilities of absorption from transient states into recurrent classes in a finite Markov chain, mean time for absorption. Ergodic state and Ergodic chain. Stationary distribution of a Markov chain, existence and evaluation of stationary distribution. Random walk and gamblers ruin problem.

Unit II

Discrete state continuous time Markov process: Kolmogorov difference – differential equations. Birth and death process, pure birth process (Yule- Fury process). Immigration-Emigration process. Linear growth process, pure death process.

Unit III

Renewal process: renewal process when time is discrete and continuous. Renewal function and renewal density. Statements of Elementary renewal theorem and Key renewal theorem.

Unit IV

Stochastic process in biological sciences: Markov models in population genetics, compartmental analysis. Simple deterministic and stochastic epidemic model. General epidemic models-Karmack and McKendrick's threshold theorem. Recurrent epidemics.

Unit V

Elements of queueing process; the queuing model M/M/1: steady state behaviors. Birth and death process in queuing theory- Multi channel models. Network of Markovian queuing system.

Unit VI

Branching process: Galton-Watson branching process. Mean and variance of size of nth generation, probability of ultimate extinction of a branching process. Fundamental theorem of branching process and applications.

Unit VII

Wiener process- Wiener process as a limit of random walk. First passage time for Wiener process. Kolmogorov backward and forward diffusion equations and their applications.

VI. Suggested Reading

- Adke SR and Manjunath SM. 1984. *Finite Markov Processes*. John Wiley.
- Bailey NTJ. 1964. *Elements of Stochastic Processes with Applications to the Natural Sciences*. Wiley Eastern.
- Bartlett MS. 1955. *Introduction to Stochastic Processes*. Cambridge Univ. Press.
- Basawa IV and Prakasa Rao BLS. 1980. *Statistical Inference for Stochastic Processes*. Academic Press.
- Bharucha-Reid AT. 2012. *Elements of the Theory of Markov Processes and their Applications*. McGraw Hill.
- Bhat BR. 2000. *Stochastic Models; Analysis and Applications*. New Age.

- Draper NR and Smith H. 1981. *Applied Regression Analysis*. Wiley Eastern. France J &Thornley JHM. 1984. *Mathematical Models in Agriculture*. Butterworths.
- Lawler GF. 2006. *Introduction to Stochastic Processes*. Chapman & Hall. 2nd Ed.
- Medhi J. 2001. *Stochastic Processes*. 2nd Ed. Wiley Eastern.
- Prakasa Rao BLS and Bhat BR.1996. *Stochastic Processes and Statistical Inference*. New Age.
- Ratkowsky DA. 1983. *Nonlinear Regression Modelling: a Unified Practical Approach*. Marcel Dekker.
- Ratkowsky DA. 1990. *Handbook of Nonlinear Regression Models*. Marcel Dekker.
- Seber GAF and Wild CJ. 1989. *Non-linear Regression*. John Wiley.

I. Course Title : Survival Analysis

II. Course Code : STAT 607

III. Credit Hours : 2+0

IV. Aim of the course

The course deals with the study of demographic profiles and survival times. In-depth statistical properties and analysis is an important component of this course.

V. Theory

Unit I

Measures of Mortality and Morbidity: Ratios and proportions, rates of continuous process, rates of repetitive events crude birth rate, Mortality measures used in vital statistics relationships between crude and age specific rates, standardized mortality ratios evaluation of person-year of exposed to risk in long term studies, prevalence and incidence of a disease, relative risk and odds ratio. Survival Distribution: Survival functions, hazard rate, hazard function, review of survival distributions: exponential, Weibull, Gamma, Rayleigh, Pareto, Lognormal~ IFR and TFRA, Gompertz and Makeham. Gompertz and logistic distributions. Parametric (m.l.e) estimation. Types of Censoring: Type I, Type II, random and other types of censoring, right and left truncated distributions. Expectation and variance of future life time, series and parallel system of failures. Life Tables: Fundamental and construction.

Unit II

Complete Mortality data, Estimation of Survival Function: Empirical survival function, estimation of survival function from grouped mortality data, joint distribution of the number of deaths, distribution of the estimation P_i covariance of estimate, estimation of curves of deaths and central death rate and force of mortality rate. Incomplete Mortality data (non-parametric models): Actuarial method, m.1.e method, moment and reduced sample method of estimation and their comparison. Product limit (Kaplan-Meier) method and cumulative hazard function (CHF) of estimation of survival function.

Unit III

Fitting Parametric Survival Distribution: Special form of survival function cumulative hazard function (CHF) plots, Nelson's method of ungrouped data, construction of the likelihood function for survival data, least squares fitting, fitting a Gompertz distribution to grouped data. Some tests of Goodness of fit: Graphical, Kolmogorov-Smirnov statistics for complete, censored and truncated data, Chi-Square test and Anderson- Darling A^2-statistics. Comparison of Mortality

Experiences: Comparison of two life tables, some distribution- free methods (two samples) for ungrouped data, Two samples Kolmogorov-Smirnov test, Wilcoxon test for complete data and modified Wilcoxon test for incomplete data .Gilbert and Gehan's test, mean and variance of Wilcoxon statistics, generalization of Gehan's test. Testing for Consistent Differences in Mortality: Mantel-Haenszel and log rank test. Generalized Mantel-Haenszel test (k-sample).

Unit IV

Concomitant Variables: General parametric model for hazard function with observed concomitant variables. Additive and multiplicative models of hazard rate functions. Estimating multiplicative models, selection of concomitant variables. Logistic linear model, Concomitant Variable regarded as random variable. Age of onset distributions: Models of onset distributions and their estimation. Gompertz distribution, parallel system and Weibull distribution, Fatal short models of failure. Two component series system.

Unit V

Interval Censoring Competing Risk Theory: Indices for measurement of probability of death under competing risks and their inter-relations.Concept of COX regression Stochastic Epidemic Models: Simple epidemic models, general epidemic model definition and concept (without derivation). Duration of an epidemic.

VI. Suggested Reading

- Anderson B. 1990. *Methodological Errors in Medical Research*. Blackwell.
- Armitage P and Berry G. 1987. *Statistical* Methods *in Medical Research*. Blackwell.
- Biswas, S. 2007. *Applied Stochastic Processes*: *A Biostatistical and Population Oriented Approach*, 2nd Ed., New Central Book Agency.
- Collett D. 2014. *Modeling Survival Data in Medical Research*. Chapman & Hall. 3rd Ed.
- Cox D.R. and Oakes D. 1984. *Analysis of Survival Data*. Chapman & Hall.
- Elandt-Johnson R.C. and Johnson N.L. 1980. Survival *Models and Data Analysis*. John Wiley.
- Everitt B.S. and Dunn G. 1998. *Statistical Analysis of Medical Data*. Arnold. Hosmer D.W. Jr. and Lemeshow S. 1999. *Applied Survival Analysis: Regression Modeling or Time to Event*. John Wiley.
- Indrayan, A. 2008. *Medical Biostatistics*, 2nd Ed. Chapman and Hall/CRC.
- Lee E.T. 1980. *Statistical Methods for Survival Data Analysis*. Lifetime Learning Publ.
- Kalbfleisch J.D. and Prentice. R.L. 2002. *The Statistical Analysis of Failure Time Data*. John Wiley.
- Klein J.P. and Moeschberger M.L. 2003. *Survival Analysis: Techniques for Censored and Truncated Data*. Springer.
- Kleinbaum D.G. and Klein M. 2002. *Logistic Regression*.Springer.
- Kleinbaum D.G. and Klein M. 2005. *Survival Analysis*. Springer.

I. Course Title : Spatial Statistics

II. Course Code : STAT 608

III. Credit Hours : 1+1

IV. Aim of the course

This is a course on Spatial statistics aims at exposing the students to some advanced level spatial methods and their applications to agricultural situations.

V. Theory

Unit I

Spatial Analysis and types of spatial data; Visualizing Spatial Data – Exploratory data Analysis.

Unit II

Spatial Relationship- Random forest, spatially autocorrelated data, weight matrix, measures of spatial Auto-correlation – Moran's I & Geary's C; Measuring of autocorrelation of spatially continuous data.

Unit III

Spatial Sampling – Methods and procedures, Statistical Analysis of Spatial Point Process – homogenous Poisson Process, Spatial interpolation – non-statistical methods; Variogram modelling; Spatial Prediction – Simple Kriging, Co-kriging;

Unit IV

Modelling Areal data – Autoregressive and spatial regression models and model diagnostics. Examples of Spatial Data analysis in Agriculture– Disease Mapping; Incorporating spatial effects in Agricultural Field experiments

VI. Practical

- Spatial Data – Import, export;
- Spatial Classes in R;
- Visualizing Spatial Data;
- Spatial Auto-correlation;
- Spatial Sampling, Spatial Interpolation, Spatial Autoregressive Models, Spatial Regression Model

VII. Suggested Reading

- Cressie, N.A.C. 1993.*Statistics for Spatial Data*. Revised Edition. JohnWiley
- Richard E.P. 2018. *Spatial Data Analysis in Ecology and Agriculture Using R*, 2nd Ed.
- Roger S. Bivand, E Pebesma J. and Rubio B.G. 2008. *Applied Spatial Data Analysis using R*. Springer-Verlog.

I. Course Title : Baysian Inference

II. Course Code : STAT 611

III. Credit Hours : 2+0

IV. Aim of the course

This course aims at describing the advanced level topics in statistical methods and statistical inference. This course would prepare students to have a strong base in basic statistics that would help them in undertake basic and applied research in Statistics.

V. Theory

Unit I

Introduction and history and criticism of Bayesian Approach; Subjective interpretation of Probability, Review of Bayes Theorem, Sufficiency, Likelihood Principle.

Unit II

Subjective Prior distribution of a parameter; Posterior Distribution of parameters using Bayes Theorem

Unit III

Informative and non-informative priors for Location and scale; Conjugate families –Discrete and Continuous and interpretation of Hyper-parameters of conjugates.

Unit IV

Non-informative, improper and invariant priors for location and scale and in general settings.

Unit V

Bayesian Point Estimation – squared error loss, absolute error loss etc. Bayesian Interval Estimation – Credible Interval, interpretation and comparison with frequentist confidence Intervals

Unit VI

Bayesian Hypothesis Testing - Specification of the appropriate form of the prior distribution for a Bayesian testing of hypothesis problem. Prior odds, Posterior odds, Bayes factor for various types of testing hypothesis problems

Unit VII

Bayesian Prediction; Numerical and Monte-Carlo Integrations

Unit VIII

Applications of Bayesian Inference - Bayesian Data Analysis

VI. Suggested Reading

- Berger, J.O. 1985. *Statistical Decision Theory and Bayesian Analysis*, Springer Verlag.
- Box, G.P. and Tiao, G.C. 1992. *Bayesian Inference in StatisticalAnalysis*,Addison – Wesley
- Pilon C.D. 2015. *Bayesian Methods for Hackers: Probabilistic Programming and Bayesian Inference* (Addison-Wesley Data and Analytics)

I. Course Title : Advanced Design of Experiments

II. Course Code : STAT 612

III. Credit Hours : 2+1

IV. Aim of the course

This is an advanced course in Design of Experiments that aims at describing some advanced level topics for students who wish to pursue research in Design of Experiments. This course prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to agricultural sciences.

V. Theory

Unit I

General properties and analysis of block designs. Balancing criteria. *m*- associate PBIB designs, and their association schemes including lattice designs - properties and construction, Designs for test treatment – control(s) comparisons; Nested block designs, Mating designs.Structurally Incomplete block designs

Unit II

General properties and analysis of two-way heterogeneity designs, Youden type designs, generalized Youden designs, Pseudo Youdendesigns., Designs for two sets of treatments.

Unit III

Balanced factorial experiments - characterization and analysis (symmetrical and asymmetrical factorials). Factorial experiments with extra treatment(s). Orthogonal arrays, Mixed orthogonal arrays, balanced arrays, Fractional replication, Resolution plans, Regular and irregular fractions.

Unit IV

Response surface designs - Symmetrical and asymmetrical factorials, Response optimization and slope estimation, Blocking, Canonical analysis and ridge analysis, CCD, Box-Jenkins, Experiments with mixtures: design and analysis. Experiments with qualitative cum quantitative factors.

Unit V

Optimality criteria and optimality of designs, robustness of designs against loss of data, outliers, etc. Diagnostics in design of experiments.

VI. Practical

Analysis of block designs, Analysis of Latin square type designs, group divisible designs, triangular designs, lattice designs. Analysis of fractional replications of factorial experiments, analysis of asymmetrical factorials and block designs with factorial structure. Analysis of second order response surface designs.

VII. Suggested Reading

- Chakraborti M.C. 1962. *Mathematics of Design and Analysis of Experiments*. Asia Publ.House.
- Dean A.M. and Voss D. 1999. *Design and Analysis of Experiments*.
- pringer. Dey A and Mukerjee R. 1999. *Fractional Factorial Plans*. John Wiley.
- Dey A 1986. *Theory of Block Designs*. Wiley Eastern.
- Hall M Jr. 1986. *Combinatorial Theory*. John Wiley.
- Hedayat A.S., Sloane N.J.A. and Stufken J. 1999. *Orthogonal Arrays: Theory and Applications*. Springer.
- John J.A. and Quenouille M.H. 1977. *Experiments: Design and Analysis*. Charles and Griffin.
- Khuri A.I. and Cornell J.A. 1996. *Response Surface Designs and Analysis*. 2nd Ed. Marcel Dekker.
- Montgomery D.C. 2005. *Design and Analysis of Experiments*. John Wiley.
- Ogawa J. 1974. *Statistical Theory of the Analysis of Experimental Designs*. Marcel Dekker.
- Parsad R, Gupta V.K., Batra P.K., Satpati S.K. and Biswas P. 2007. *Monograph on a-designs*. IASRI, New Delhi.
- Raghavarao D. 1971. *Construction and Combinatorial Problems in Design of Experiments*. John Wiley.
- Shah K.R. and Sinha B.K. 1989. *Theory of Optimal Designs. Lecture notes in Statistics*. Vol. 54. Springer.
- Sharma M.K. 2012. *Design and Analysis of Experiments*. Kindle Ed. 1st Ed.
- Street A.P. and Street D.J. 1987. *Combinatorics of Experimental Designs*.Oxford Science Publ.
- Design Resources Server: www.drs.icar.gov.in.

I. Course Title : Advanced Sampling Techniques

II. Course Code : STAT 613

III. Credit Hours : 2+1

IV. Aim of the course

This is an advanced course in Sampling Techniques that aims at describing some advanced level topics for students who wish to pursue research in Sampling Techniques. This course prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to Statistical System in thecountry.

V. Theory

Unit I

Optimum Stratification, two-way stratification, collapsed strata, Controlled selection, Use of combinatorics in controlled selection, Systematic sampling in two dimensions. Sampling with varying probabilities without replacement, Horvitz – Thompson estimator

Unit II

Variance estimation in complex surveys. Taylor's series linearization, balanced repeated replication, Jackknife and bootstrap methods.Ordered and unordered estimators, Sampling strategies, Midzuno-Sen, Rao-Hartley-Cochran,ðPS Sampling: procedures such as Brewer, Durbin and Sampford,

Unit III

Unified theory of sampling from finite populations. UMV - Non-existence theorem and existence theorem under restricted conditions. Concept of sufficiency and likelihood in survey sampling. Admissibility and hyper- admissibility.

Unit IV

Post-stratified estimator, imperfect frames, multiple frames, randomized response techniques. Inference under super population models - concept of designs and model unbiasedness, prediction approach. Regression analysis and categorical data analysis with data from complex surveys. Domain estimation. Small area estimation. Longitudinal survey.

VI. Practical

- Sampling with varying probability,
- Ordered and un-ordered estimators,
- Sampling strategies due to Horvitz-Thompson, Midzuno-Sen, Rao-Hartley-Cochran and PPS sampling: procedures such as Brewer, Durbin and Sampford, etc.
- Imperfect frames, Randomized response technique.
- Small area estimation.

V. Suggested Reading

- Berger J.O. 1993. *Statistical Decision Theory and Bayesian Analysis*. Sringer.
- Bolfarine H and Zacks S. 1992. *Prediction Theory for Finite Population Sampling*. Springer.
- Cassel C.M., Sarndal C.E and Wretman J.H. 1977. *Foundations of Inference in Survey Sampling*. John Wiley.
- Des Raj and Chandhok P. 1998. *Sample Survey Theory*. Narosa Publ.
- House. Ghosh M and Meeden G. 1997. *Bayesian Method for Finite Population*
- *Sampling. Monograph on Statistics and Applied Probability*. Chapman and Hall.

- Mukhopadhyay P. 1998. *Theory and Methods of Survey Sampling*. Prentice Hall of India.
- Rao J.N.K. 2003. *Small Area Estimation*. John Wiley.
- Sarndal C.E., Swensson B and Wretman J.H. 1992. *Model Assisted Survey Sampling*. Springer.

I. Course Title : Advanced Statistical Genetics

II. Course Code : STAT 614

III. Credit Hours : 2+1

IV. Aim of the course

This is an advanced course in Statistical Genetics that aims at describing some advanced level topics for students who wish to pursue research in Statistical Genetics. This course prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject in plant and animal breeding.

V. Theory

Unit I

Hardy-Weinberg law with multiple allelic systems, auto-tetraploids and self-sterility alleles. Complex cases of selection with two or more loci.

Unit II

Different approaches to study inbreeding process, methods of path co- efficient, probability and generation matrix. Fisher's approach to inbreeding. Stochastic process of gene frequency change, transition matrix approach using finite Markov chains, diffusion approximation, Steady decay and distribution of gene frequency, Probability of fixation of a gene, Conditional process - Markov chains and diffusion approaches, Distribution of time until fixation, random fluctuations in selection intensity, stationary distribution of gene frequency. Effective population size.

Unit III

Prediction and estimation of genetic merit. Best linear unbiased prediction, Use of mixed model methodology in analysis of animal and plant breeding experiments. Newer reproductive technology and its effect in genetic evaluation of individual merit. Estimation of genetic parameters - problems relating to computational aspects of genetic variance components, parameter estimation in variance component models for binary response data.

Unit IV

Identification of genes with large effects, Use of molecular markers (RFLP, PCR-AFLP, RAPD and SSR), Gene mapping and Quantitative trait loci. Molecular manipulation for genetic variability.

Unit V

Variance component approach and linear regression approach for the analysis of GE interactions.Measurement of stability and adaptability for genotypes. Concepts of general and specific combining ability, diallel and partial diallel crosses: construction and analysis.

VI. Practical

- Hardy-Weinberg law,
- Estimation of genetic load and random genetic drift.
- Effect of finite population size.
- Estimation of path coefficients.
- Detection and estimation of multiple allelism in continuous variation, sexlinked genes, maternal effects.
- Analysis of G × E interaction, measurement of stability and adaptability.
- Analysis of data of diallel and partial diallel crosses.

VII. Suggested Reading

- Crow J.F. and Kimura M. 1970. *An Introduction of Population Genetics Theory*. Harper & Row.
- Ewens W.J. 1979. *Mathematical Population Genetics*. Springer.
- Falconer D.S. 1985. *Introduction to Quantitative Genetics*. ELBL.
- Fisher R.A. 1949. *The Theory of Inbreeding*. Oliver & Boyd.
- Fisher R.A. 1958. *The Genetical Theory of Natural Selection*. Dover Publ.
- Haldane J.B.S. 1932. *The Causes of Evolution*. Harper & Bros.
- Kempthorne O. 1957. *An Introduction to Genetic Statistics*. The Iowa State Univ. Press.
- Lerner I.M. 1950. *Population Genetics and Animal Improvement*. Cambridge Univ. Press.
- Lerner I.M. 1958. *The Genetic Theory of Selection*. John Wiley.
- Li C.C. 1982. *Population Genetics*. The University of Chicago Press.
- Mather K and Jinks J.L. 1982. *Biometrical Genetics*. Chapman & Hall.
- Mather K. 1951. *The Measurement of Linkage in Heredity*.
- Methuen. Nagilaki T. 1992. *Introduction to Theoretical PopulationGenetics*.Springer.
- Narain P. 1990. *Statistical Genetics*. Wiley Eastern.
- Nielsen R, Montgomery S. 2013. *An Introduction to Population Genetics: Theory and Applications* 1st Ed.

I. Course Title : Advanced Time Series Analysis

II. Course Code : STAT 615

III. Credit Hours : 2+0

IV. Aim of the course

This is an advanced course in Time Series Analysis that aims at describing some advanced level topics in this area of research with a very strong potential of applications. This course also prepares students for undertaking research in this area. This also helps prepare students for applications of this important subject to agriculturalsciences.

V. Theory

Unit I

Multivariate time series: modelling the mean, stationary VAR models: properties, estimation, analysis and forecasting, VAR models with elements of nonlinearity, Non-stationary multivariate time series: spurious regression, co-integration, Vector Error Correction Model (VECM).

Unit II

Volatility: The class of ARCH and GARCH models; Extensions of GARCH models: TGARCH, IGARCH, PGARCH, EGARCH, GJR-GARCH, ARCH and GARCH model with-t distributed error; ARCD (Auto-Regressive Conditional Density), Multivariate GARCH model: estimation, analysis and forecasting, stochastic volatility.

Unit III

Structural time-series modelling: State space models, Kalman filter, Local level model, Local linear trend model, Seasonal models, Cyclical models. Threshold and Functional coefficient autoregressive models, Structural Break in time series.

Unit IV

Fuzzy time series models, Artificial Neural Network (ANN) methodology, Support vector machines, Wavelets for time series analysis, combinations of time series models.

VI. Suggested Reading

- Box G.E.P., Jenkins G.M. and Reinsel G.C. 2015. *Time Series Analysis: Forecasting and Control*. 5th Ed. John Wiley.
- Brockwell P.J. and Davis R.A. 1991. *Time Series: Theory and Methods*. 2nd Ed. Springer.
- Chatfield C. 2004. *The Analysis of Time Series: An Introduction*. 6th Ed. Chapman& Hall/ CRC.
- Johnston J. 1984. *Econometric Methods*. McGraw Hill.
- Singh, P. 2016. *Applications of Soft Computing in Time Series Forecasting: Simulation and Modeling Techniques*. Springer International Publishing AG
- Tong H. 1995. *Nonlinear Time Series: A Dynamical System Approach*.Oxford Univ. Press.
- Vapnik, V. N. (2000). *The Nature of Statistical Learning Theory*. Springer- Verlag, New York.
- Percival, D.B. and Walden, A.T. 2000. *Wavelet Methods for Time-Series Analysis.* Cambridge University Press, U.K.

I. Course Title : Advanced Bioinformatics

II. Course Code : STAT 616

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on Bioinformatics that aims at exposing the students to some advanced statistical and computational techniques related to bioinformatics. This course would prepare the students in understanding bioinformatics principles and their applications.

V. Theory

Unit I

EM algorithm and other statistical methods to discover common motifs in biosequences. Concepts in phylogeny. Gene prediction based on codons, Decision trees, Clustering Techniques, Classificatory analysis, Neural Networks, Genetic algorithms, Pattern recognition, Hidden Markov models.

Unit II

Computational analysis of protein sequence, structure and function. Expression profiling by microarray/ gene chip/ RNAseq, proteomics etc., Multiple alignment of protein sequences, Modelling and prediction of structure of proteins, Designer proteins, Drug designing.

Unit III

Analysis of one DNA sequence (Modeling signals in DNA; Analysis of patterns; Overlaps and Generalizations), Analysis of multiple DNA or protein sequences (Alignment algorithms – Gapped global comparisons and Dynamic programming;

use of linear gap models; protein sequences and substitution matrices – BLOSUM, PAM; Multiple sequences), BLAST (Comparison of two aligned sequences – Parameter calculation; Choice of a score; Bounds for P-value; Normalized and Bit scores, Karlin – Altschul sum statistic; comparison of two unaligned sequences; Minimum significance Lengths).

Unit IV

Markov Chains (MC with no absorbing states, higher order Markov dependence, patterns insequences, Markov Chain Monte Carlo – Hastings-Metropolis algorithm, simulated annealing,MC with absorbing States). Bayesian techniques and use of Gibbs Sampling. Advanced topicsin design and analysis of DNA microarray experiments.

Unit V

Modeling protein families; Multiple sequence alignments; Pfam; Gene finding), Computationally intensive methods (Classical estimation methods; Bootstrap estimation and Confidence Intervals; Hypothesis testing; Multiple Hypothesis testing), Evolutionary models (Models of Nucleotide substitution; Discrete time models – The Jukes-Cantor Model, The Kimura Model, The Felsenstein Model; Continuous-time models)

Unit VI

Phylogenetic tree estimation (Distances; Tree reconstruction – Ultrametric and Neighbor-Joining cases; Surrogate distances; Tree reconstruction; Parsimony and Maximum Likelihood; Modeling, Estimation and Hypothesis Testing;) Neural Networks (Universal Approximation Properties; Priors and Likelihoods, Learning Algorithms – Backpropagation; Sequence encoding and output interpretation; Prediction of Protein Secondary Structure; Prediction of Signal Peptides and their cleavage sites; Application for DNA and RNA Nucleotide Sequences), Analysis of SNPs and Haplotypes.

VI. Practical

- Genomic databases and analysis of high-throughput data sets, BLAST and related sequence comparison methods.
- Statistical methods to discover common motifs in biosequences.
- Multiple alignment and database search using motif models, clustalw, classificatory analysis, neural networks, genetic algorithms, pattern recognition,
- Hidden Markov models.
- Computational analysis of protein sequence.
- Expression profiling by microarray/ gene chip, proteomics.
- Modelling and prediction of structure of proteins.
- Bayesian techniques and use of Gibbs Sampling.
- Analysis of DNA microarray experiments.
- Analysis of one DNA sequence, multiple DNA or protein sequences.
- Computationally intensive methods, multiple hypothesis testing,
- Phylogenetic tree estimation,
- Analysis of SNPs and haplotypes.

VII. Suggested Reading

- Baldi P and Brunak S. 2001. *Bioinformatics: The Machine Learning Approach*. MIT Press.
- Baxevanis AD and Francis BF. (Eds.). 2004. *Bioinformatics: A Practical Guide to the Analysis*

of Genes and Proteins. John Wiley.
- Duda RO, Hart PE and Stork DG. 1999. *Pattern Classification*. John Wiley.
- Ewens WJ and Grant GR. 2001. *Statistical Methods in Bioinformatics*.Springer.
- Jones NC and Pevzner PA. 2004. *Introduction to Bioinformatics Algorithms*. The MIT Press.
- Koskinen T. 2001. *Hidden Markov Models for Bioinformatics*. Kluwer.
- Krane DE and Raymer ML. 2002. *Fundamental Concepts of Bio-informatics*.
- Benjamin/ Cummings.
- Krawetz SA &Womble DD. 2003. *Introduction to Bioinformatics: A Theoretical and Practical Approach*. Humana Press.
- Lesk AM. 2002. *Introduction to Bio-informatics*. Oxford Univ. Press.
- Linder E and Seefeld K. 2005. *R for Bioinformatics*. O'Reilly and Associates.
- Percus JK. 2001. *Mathematics of Genome Analysis*. Cambridge Univ. Press.
- Sorensen D and Gianola D. 2002. *Likelihood, Bayesian and MCMC Methods in Genetics*. Springer.
- Tisdall J.D. 2001. *Mastering Perl for Bioinformatics*. O'Reilly & Associates.
- Wang J.T.L., Zaki M.J., Toivonen H.T.T. and Shasha D. 2004. *Data Mining in Bioinformatics*. Springer.
- Wu C.H. and McLarty J.W. 2000. *Neural Networks and Genome Informatics*. Elsevier.
- Wunschiers R. 2004. *Computational Biology Unix/Linux, Data Processing and Programming*. Springer.
- Yang M.C.C. 2000. *Introduction to Statistical Methods in Modern Genetics*. Taylor & Francis.

I. Course Title : Advanced Econometrics

II. Course Code : STAT 617

III. Credit Hours : 1+1

IV. Aim of the course

This is a course on Econometrics aims at exposing the students to some advanced level econometric methods and their applications to agricultural situations.

V. Theory

Unit I

Quantile regression, binary quantile regression, extreme values, copula, loss functions, Point and interval forecasting, unconditional and conditional forecasting, forecasting with serially correlated errors, bootstrap: asymptotic expansion, bootstrap consistency, asymptotic refinement, recent developments for dependent timeseries. Co integration analysis.

Unit II

Multivariate time series: modelling the mean, stationary VAR models: properties, estimation, analysis and forecasting, VAR models with elements of nonlinearity, Non-stationary multivariate time series: spurious regression, co-integration, common trends; Volatility: Modelling the variance, The class of ARCH models: properties, estimation, analysis and forecasting, stochastic volatility, realized volatility.

Unit III

Basic Concepts of Bayesian Inference, Probability and Inference, Posterior Distributions and Inference, Prior Distributions. The Bayesian linear model and autoregressive (AR) processes; Model selection with marginal likelihoods and fractional priors, Comparison of Bayesian Methods with Classical approaches, Bayes risk and their applications, and Sample Selection Monte Carlo integration, importance sampling and Gibbs sampling, The Regression Model with General

Error Covariance Matrix, Qualitative Choice Models, Bayesian information criterion (BIC), Markov Chain Monte Carlo (MCMC) Model Composition and stochastic search variable selection, BUGS [Bayesian Inference Using Gibbs Sampling], BUCC [Bayesian Analysis, Computation and Communication].

VI. Practical

Fitting of equation with serially correlated errors, ordinary least-squares and generalized least squares methods of estimation. Non-stationary multivariate time series analysis. Fitting of The Regression Model with General Error Covariance Matrix, Qualitative Choice Models, Bayesian information criterion (BIC), Markov Chain Monte Carlo (MCMC) Model Composition and stochastic search variable selection, BUGS Fitting of ARCH model.

VII. Suggested Reading

- Banerjee A, Dolado J, Galbraith J and Hendry D.F. 1993. *Co-integration, Error Correction, and the Econometric Analysis of Nonstationary Data*. Oxford Univ. Press.
- Bauwens L, Lubrano M. and Richard J.F. 1999. *Bayesian Inference in Dynamics of Econometric Models*. Oxford Univ. Press.
- Carlin B.P. and Louis T.A. 2008. *Bayes and Empirical Bayes Methods for Data Analysis*. Chapman & Hall.
- Gilks W.R., Richardson S and Spiegelhalter D. 1996. *MCMC in Practice*.Chapman & Hall.
- Greenberg E. 2012. *Introduction to Bayesian Econometrics*. Cambridge Univ. Press.
- Hamilton J.D. 1994. *Time Series Analysis*. Princeton Univ. Press.
- Judge G.G., Griffith W.E., Hill R.C., Lee C.H. and Lutkepohl H. 1985. *The Theory and Practice of Econometrics*. 2nd Ed. JohnWiley.
- Koop G, Poirier D and Tobias J. 2007. *Bayesian Econometric Methods*.Cambridge Univ. Press.
- Koop G. 2003. *Bayesian Econometrics*. John Wiley.
- Lancaster A. 2004. *An Introduction to Modern Bayesian Econometrics*. Blackwell.
- Pindyck R.S. and Rubinfeld D.L. 1981. *Econometric Models and Economic Forecasts*. McGraw Hill.

I. Course Title : Recent Advances in the Field of Specialization

II. Course Code : STAT 618

III. Credit Hours : 1+0

IV. Aim of the course

To familiarize the students with the recent advances in the areas of their specialization to prepare them for undertaking research.

V. Theory

Recent advances in the field of specialization - sample surveys / design of experiments /statistical genetics / statistical modeling / econometrics / statistical inference, etc. will be covered by various speakers from the University / Institute as well as from outside the University / Institute in the form of seminar talks.

VI. Suggested Reading

Recent journals related to the research works.

Restructured and Revised
Syllabi of Post-graduate Programmes

Vol. 2

Statistical Sciences
– Computer Application

Course Title with Credit Load
M.Sc. (Ag) in Computer Application

Course Code	Course Title	Credit Hours	Semester
*MCA 513	Mathematics for Applied Sciences	2+0	I
*MCA 514	Statistical Computing	1+1	III
*MCA 551	Mathematical Foundations in Computer Science	3+0	I
*MCA 552	Object Oriented Programming	2+1	I
*MCA 553	Design And Analysis of Algorithms	2+1	I
*MCA 561	Data Structures	2+1	II
*MCA 562	System Software and Programming	2+1	II
*MCA 563	Internet Technologies	1+1	II
*MCA 571	Database Management Systems	2+1	III
*MCA 572	Software Engineering	2+0	III
MCA 591	Master's Seminar	0+1	I/II/III
MCA 599	Master's Research	0+30	II-IV
MCA 554	Information Security	2+0	I
MCA 555	Web Technologies and Applications	1+1	I
MCA 556	Computer Networks	2+0	I
MCA 564	Bioinformatics Computing	1+1	II
MCA 565	Soft Computing Techniques	1+1	II
MCA 573	Operating System	2+1	III
MCA 574	Compiler Construction	2+1	III
MCA 575	Data Warehousing and Data Mining	2+1	III
	Supporting Courses		
MCA 501	Computers Fundamentals and Programming	2+1	I
MCA 502	Computer Organization Andarchitecture	2+0	I
MCA 511	Introduction Tocommunication Technologies, Computer Networking and Internet	1+1	II
MCA 512	Information Technology in Agriculture	2+0	II

*Core Courses

Course Contents
M.Sc. (Ag) in Computer Application

I. Course Title : Computer Fundamentals and Programming

II. Course Code : MCA 501

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on Computer Fundamentals and Programming that aims at exposing the students to understand how computer works, analytical skills to solve problems using computers. andto write computer programs using C.

V. Theory

Unit I

Functional units of computer, I/O devices, primary and secondary memories. Number systems: decimal, octal, binary and hexadecimal; Representation of integers, fixed and floating point numbers, Operator precedence, character representation; ASCII, Unicode.

Unit II

Programming Fundamentals with C - Algorithm, techniques of problem solving, flowcharting, stepwise refinement; Constants and variables; Data types: integer, character, real, data types; Arithmetic expressions, assignment statements, logical expressions. Control flow

Unit III

Arrays and structures. Pointers, dynamic memory allocations

Unit IV

Program Structures – functions, subroutines

Unit V

I/O operations, Program correctness; Debugging and testing of programs.

VI. Practical

- Conversion of different number types;
- Creation of flow chart, conversion of algorithm/flowchart to program;
- Mathematical operators, operator precedence;
- Sequence, control and iteration;
- Arrays and string processing;
- Matrix operations, Sorting, Pointers and File processing – Reading and writing text files.

VII. Suggested Reading

- Balaguruswamy E. 2019. *Programming with ANSI C*. Tata McGraw Hill.
- Gottfried B. 2017. *Programming with C, Schaum Outline Series*. Tata McGraw Hill.
- Kanetkar Y. 1999. *Let Us C*. BPB Publ.

- Malvino A.P. and Brown J.A.. 2017. *Digital Computer Electronics*. Tata McGrawHill.
- Mano M.M. 1999. *Digital Logic and Computer Design*. Prentice Hall of India.

I. Course Title : Computer Organization and Architecture
II. Course Code : MCA 502
III. Credit Hours : 2+0

IV. Aim of the course

This is a course on Computer Organization and Architecture that aims at exposing the students to understand basic knowledge of how computer works.

V. Theory

Unit I

Number systems; Boolean algebra - minimization of Boolean function using KarnaughMap.

Unit II

Logic Gates, Combinational circuits – multiplexer, de-multiplexer, encoder, decoder; Sequential circuits: Flip-flops, Half and Full adder, Shift register, Counters.

Unit III

Organization of CPU, Control Unit- Instruction and Execution cycle in CPU, Register Organization, The Instruction Cycle, Instruction Pipelining.

Unit IV

Memory organization - Internal memory: Semiconductor Main Memory (RAM, ROM, EPROM), Cache Memory, Advanced DRAM Organization; External Memory - Magnetic Disks, RAID, Optical Memory, Magnetic Tape.

Unit V

Basic structure of computer hardware and system software - Addressing methods and machine programme sequencing; Input-output organizations - accessing I/O devices - direct memory access (DMA) – interrupts.

Unit VI

Introduction to microprocessors – CISC and RISC Architecture, Study of functional units of microprocessors.

VI. Suggested Reading

- Gear C.W. 1974. *Computer Organization and Programming*. McGraw Hill.
- Hayes J.P. 1988. *Computer Architecture and Organisation*. McGraw Hill.
- Malvino A.P and Brown J.A. 1999. *Digital Computer Electronics*. Tata McGraw Hill.
- Mano M.M. 1999. *Digital Logic and Computer Design*. Prentice Hall of India.
- Mano M.M. 2007. *Computer System Architecture*. Prentice Hall of India.
- Stallings W. 2016. *Computer Organization and Architecture: Designing for Performance*. Pearson Edu.

I. Course Title : Introduction to Networking and Internet Applications
II. Course Code : MCA 511
III. Credit Hours : 1+1

IV. Aim of the course

This is a course on Introduction to Networking and Internet Applications that aims at exposing the students to understand Computer networking and web applications development.

V. Theory

Unit I

Networking fundamentals, types of networking, network topology; Introduction to File Transfer Protocol (FTP), Telnet, Simple Mail Transfer Protocol (SMTP), Internet Protocol v4 & v6. Network infrastructure and Security-switches, routers, firewall, intranet, internet, Virtual Private Network

Unit II

World Wide Web (www), working with Internet; Web pages, web sites, web servers; Web Applications.

Unit III

Hyper Text Markup Language (HTML), DHTML, web based application development. Static websites, dynamic websites. Client Side processing – scripting languages, Jquery. Server Side processing ASP.NET/JSP

VI. Practical

- Network and mail configuration;
- Using Network Services;
- Browsing of Internet;
- Creation of web pages;
- Creation of websites using HTML and scripting languages.

VII. Suggested Reading

- Cox V, Wermers L and Reding E.E. 2006. *HTML Illustrated Complete*. 3rd Ed. Course Technology.
- Niederst J. 2001. *Web Design in a Nutshell*. O'Reilly Media.
- Tanenbaum A.S. 2003. Computer Networks. *Prentice* Hall of India.

I. Course Title : Information Technology in Agriculture

II. Course Code : MCA 512

III. Credit Hours : 2+0

IV. Aim of the course

This is a course on Introduction to Networking and Internet Applications that aims at exposing the students to understand analogy of computer, basic knowledge of MS Office. Also to understand Internet and WWW, use of IT application and different IT tools in Agriculture

V. Theory

Unit I

Introduction to Computers, Anatomy of computer, Operating Systems, definition and types, Applications of MS Office for document creation & Editing, Data presentation, interpretation and graph creation, statistical analysis, mathematical expressions,

Unit II

Database, concepts and types, uses of DBMS in Agriculture, World Wide Web

(WWW): Concepts and components, Introduction to computer programming languages, concepts and standard input/output operations. e-Agriculture, concepts and applications,

Unit III

Use of ICT in Agriculture, Computer Models for understanding plant processes. IT application for computation of water and nutrient requirement of crops, Computer-controlled devices (automated systems) for Agri-input management, Smartphone Apps in Agriculture for farm advises, market price, postharvest management etc.,

Unit IV

Geospatial technology for generating valuable agri-information. Decision support systems, concepts, components and applications in Agriculture, Agriculture Expert System, Soil Information Systems etc. for supporting Farm decisions, Preparation of contingent crop-planning using IT tools.

VI. Suggested Reading

- Vanitha G. 2011. *Agro-informatics*
- http://www.*agrimoon*.com
- http://www.agriinfo.in
- http://www.eagri.org
- http://www.agriglance.com
- http://agritech.tnau.ac.in

I. Course Title : Mathematics for Applied Sciences

II. Course Code : MCA 513

III. Credit Hours : 2+0

IV. Aim of the course

This course is meant for students who do not have sufficient background of Mathematics. The students would be exposed to elementary mathematics that would prepare them to study their main courses that involve knowledge of Mathematics. The students would get an exposure to Linear Algebra, differentiation, integration and differential equations etc.

V. Theory

Unit I

Set theory-set operations, finite and infinite sets, operations of set, function.

Unit II

Vectors and vector spaces, Matrices notations and operations, laws of matrix algebra; transpose and inverse of matrix, Eigen values and Eigen vectors. Determinants - evaluation and properties of determinants, Solutions of Linear Equations.

Unit III

Variables and functions, limits and continuity of specific functions. Differentiation: theorems of differentiation, differentiation of logarithmic, trigonometric, exponential and inverse functions, Differentiation of function of a function, derivatives of higher order, partial derivatives. Application of derivatives, determination of points of inflexion, maxima and minima.

Unit IV

Integration, methods of integration, reduction formulae, definite and indefinite integral, Applications of integration in Agriculture, Differential Equations.

VI. Suggested Reading

- Hohn FE. 2013. *Elementary Matrix Algebra*, 3rdEd., Kindle Edition
- Harville DA. 1997. *Matrix Algebra from a Statistician's Perspective*. Springer.
- Searle SR. 1982. *Matrix Algebra Useful for Statistics*. John Wiley.
- Stewart J. 2007. *Calculus*. Thompson.
- Thomas GB. Jr. and Finney RL. 1996. *Calculus*. 9th Ed. Pearson Edu

I. Course Title : Statistical Computing

II. Course Code : MCA 514

III. Credit Hours : 1+1

IV. Aim of the course

This course is meant for exposing the students in the concepts of computational techniques. Various statistical packages would be used for teaching the concepts of computational techniques.

V. Theory

Unit I

Introduction to statistical packages and computing: data types and structures, Use of Software packages like, SAS, SPSS or "R: The R Project for Statistical Computing". Data analysis principles and practice, Summarization and tabulation of data, Exploratory data analysis; Graphical representation of data.Statistical Distributions: Fitting and testing the goodness of fit of discrete and continuous probability distributions;

Unit II

ANOVA, regression and categorical data methods; model formulation, fitting, diagnostics and validation; Matrix computations in linear models. Analysis of discrete data. Multiple comparisons, Contrast analysis

Unit III

Numerical linear algebra, numerical optimization, graphical techniques, numerical approximations, Time Series Analysis

Unit IV

Analysis of mixed models; Estimation of variance components, Analysis of Covariance, Fitting of non-linear model, Discriminant function; Principal component analysis. techniques in the analysis of survival data and longitudinal studies, Approaches to handling missing data, and meta-analysis

VI. Practical

- Data management, Graphical representation of data, Descriptive statistics
- General linear models ~ fitting and analysis of residuals, outlier detection
- Fitting and testing the goodness of fit of probability distributions
- Testing the hypothesis for one sample *t*-test, two sample *t*-test, paired *t*-test, test for large samples - Chi-squares test, F test
- One way analysis of variance, contrast and its testing, pairwise comparisons

- Mixed effect models, estimation of variance components
- Categorical data analysis, dissimilarity measures, similarity measures
- Analysis of discrete data, analysis of binary data
- Numerical algorithms
- Spatial modeling, cohort studies
- Clinical trials, analysis of survival data
- Handling missing data
- Analysis of time series data - fitting of ARIMA models.

VII. Suggested Reading

- Agresti A. 2013. *Categorical Data Analysis*. 3rd Ed. John Wiley.
- Everitt B.S. and Dunn G. 1991. *Advanced Multivariate Data Analysis*. 2nd Ed. Arnold.
- Geisser S. 1993. *Predictive Inference: An Introduction*. Chapman & Hall.
- Gelman A and Hill J. 2006. *Data Analysis Using Regression and Multilevel/Hierarchical Models*. Cambridge Univ. Press.
- Gentle J.E., Härdle W and Mori Y. 2012. *Handbook of Computational Statistics - Concepts and Methods*. 2nd Ed. Springer.
- Han J and Kamber M. 2000. *Data Mining: Concepts and Techniques*. Morgan.
- Hastie T, Tibshirani R and Friedman R. 2001. *The Elements of Statistical Learning: Data Mining, Inference and Prediction*. Springer.
- Kennedy W.J. and Gentle J.E. 1980. *Statistical Computing*. Marcel Dekker.
- Miller RG Jr. 1986. Beyond ANOVA, *Basics of Applied Statistics*. John Wiley.
- Rajaraman V. 1993. *Computer Oriented Numerical Methods*. Prentice-Hall.
- Ross S. 2000. *Introduction to Probability Models*. Academic Press.
- Ryan B.F. and Joiner B.L. 1994. *Minitab Handbook*. 3rd Ed. Duxbury Press.
- Simonoff J.S. 1996. *Smoothing Methods in Statistics*. Springer.
- Singh, AK. 2016. *Practical R-Book by Examples for Agricultural Statistics*. Deptt. of Ag. Statistics, IGKV. Raipur
- Snell E.J. 1987. Applied Statistics: A Handbook of BMDP Analyses. Chapman & Hall.
- Thisted R.A. 1988. Elements of Statistical Computing. Chapman & Hall.
- Venables W.N. and Ripley B.D. 1999. Modern Applied Statistics With S-Plus. 3rd Ed. Springer.
- http://www.r-project.org/
- http://www.stat.sc.edu/~grego/courses/stat706/.
- Design Resources Server: www.drs.icar.gov.in.

I. Course Title : Mathematical Foundations in Computer Science

II. Course Code : MCA 551

III. Credit Hours : 3+0

IV. Aim of the course

This is a course on Mathematical Foundations in Computer Science that aims at exposing the students to provide basic foundations in Mathematics for problem solving.

V. Theory

Unit I

Mathematical Logic: Propositions – Simple and complex; Validity of Proposition-Truth Tables; Use of Propositions in computer programming.

Unit II

Mathematical data types: Sets, Functions, Bijective functions, pigeon-hole principle, Boolean functions, permutation functions, Boolean algebra, recursion relations.

Unit III

Number Theory: Binary arithmetic, exponentiation, induction, sequences, big-oh notation, GCD, Euclidean algorithm, partially ordered sets, congruence and equivalence relation, encryption scheme, Fibonacci sequence, linear homogenous recurrence relations with constant coefficients.

Unit IV

Matrix Algebra Basic operations on matrices, Rank and inverse of matrices. System of linear equations, Characteristic roots and equations, Eigen values and eigen vectors;

Unit V

Graph Theory: Graphs, trees, LAN, Eulerian cycles, Hamiltonian cycles, graph coloring, graph algorithms.

VI. Suggested Reading

- Abertson M.O. and Hutchinson J.P. 1988. *Discrete Mathematics with Algorithms*. John Wiley.
- Deo N. 1984. *Graph Theory with Application to Engineering and Computer Science*. Prentice Hall of India.
- Knuth D.E. 2011. *Art of Computer Programming*. Vol. I. *Fundamental Algorithms*. Addison Wesley.
- Tremblay J.P. and Manohar R.P. 2017. *Discrete Mathematical Structures with Applications to Computer Science*. McGraw Hill.

I. Course Title : Object Oriented Programming

II. Course Code : MCA 552

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on Java that aims at exposing the students to understand basic concepts of object oriented design and to write computer programs for problem solving using object oriented.

V. Theory

Unit I

Introduction to Objected Oriented Programming(OOP), Introduction to C++, data types in C++, Compilation and execution of C++; data types, control flow, input/output operations, interaction with file systems – reading, writing and appending.

Unit II

Strings, string manipulations, Arrays, functions, scope of variables, structures in C++.

Unit III

Classes, data members, member functions, this Pointer, Friends, Friend Functions, Friend Classes, Constructors, destructors.

Unit IV

Operator Overloading, dynamic binding, parametric polymorphism. Inheritance, inheritance and dynamic binding, multiple inheritance.

Unit V

New Approaches to programming – Model-View-Controller (MVC) architecture, Single page applications.

VI. Practical

- Case studies using object oriented analysis and design (OOAD);
- Creation of classes with features - overloading, inheritance, data abstraction, polymorphism and Implementation of a case study.

VII. Suggested Reading

- Arnold K and Gosling J. 1996. *The Java Programming Language. The Java Series*. Addison Wesley.
- Bergin J. 1994. *Data Abstraction: The Object-Oriented Approach Using C++*. McGraw Hill.
- Holzner S. 1997. *The Visual C++ Programming Language*. Prentice Hall of India.
- Johnsonbaugh R and Kalin M. 1995. *Object Oriented Programming in C++*. Prentice Hall.
- Khoshafian S and Abnous R. 1995. *Object Orientation Concepts, Languages, Databases, User Interfaces*. JohnWiley.
- Sengupta S and Korobkin C.P. 1994. *C++ Object Oriented Data Structures*.Springer.
- Stroustrup B. 1997. *The C++ Programming Language*. Addison Wesley.
- Troelsen A. 2005. *Pro C# 2005 and the .NET 2.0 Platform*. 3rd Ed. Apress.
- Kothari D.P. 2013. *Object Oriented Approach using C++*

I. Course Title : Design and Analysis of Algorithms

II. Course Code : MCA 553

III. Credit Hours : 2+1

IV. Aim of the course

This course provides a theoretical foundation in designing algorithms. The focus is on the advanced analysis of algorithms and on how the selections of different data structures affect the performanceof algorithms.

V. Theory

Unit I

Algorithm Analysis – Time Space Tradeoff – Asymptotic Notations – Conditional asymptotic notation – Removing condition from the conditional asymptotic notation - Properties of big-Oh notation – Recurrence equations – Solving recurrence equations – Analysis of linear search.

Unit II

Divide and Conquer: General Method – Binary Search – Finding Maximum and Minimum –Merge Sort – Greedy Algorithms: General Method – Container Loading – Knapsack Problem.

Unit III

Dynamic Programming: General Method – Multistage Graphs – All-Pair shortest paths – Optimal binary search trees – 0/1 Knapsack – Travelling salesperson problem.

Unit IV

Backtracking: General Method – 8 Queens problem – sum of subsets – graph coloring – Hamiltonian problem – knapsack problem.

Unit V

Graph Traversals – Connected Components – Spanning Trees – Biconnected components – Branch and Bound: General Methods (FIFO & LC) – 0/1 Knapsack problem – Introduction to NP-Hard and NP-Completeness.

VI. Practical

- Solving recurrence equations, Analysis of linear search,
- Programming Divide and Conquer Algorithms and their analysis,
- Programming Greedy Algorithms and their analysis,
- Implementing Dynamic Programming and their analysis,
- Implementing Backtracking examples,
- Implementing Graph Traversals,
- Implementing Spanning Trees.

VII. Suggested Reading

- Alfred V. Aho, John E. Hopcroft and Jeffrey D. Ullman. 1999. *The Design and Analysis of Computer Algorithms*. Pearson Education.
- Cormen, T.H., C.E. Leiserson, R.L. Rivest, and C. Stein. 2003. *Introduction to Algorithms*. Prentice Hall of India, New Delhi.
- Horowitz E, Sahni S and Rajasekaran S. 2007. *Computer Algorithms/ C++*. Universities Press.

I. Course Title : Information Security

II. Course Code : MCA 554

III. Credit Hours : 2+0

IV. Aim of the course

This course provides exposure to challenges and techniques for securing the information in servers and Web enabled systems. The course deals with theoretical as well as practical issues of Information Security.

V. Theory

Unit I

General introduction to security, Cryptographic techniques: classical cryptography, conventional cryptography (DES), public-key cryptography (RSA), and digital signatures (DSA), steganography.

Unit II

Security services: message integrity, confidentiality and authentication, certification and key management (PKI).

Unit III

Network security applications: IP security (IPsec), Web security (SSL, TLS, SET), Electronic mail security (PGP, S/MIME), and SNMP security.

Unit IV

Access control in computer networks: authentication protocols and services (Kerberos), firewalls and Virtual Private Networks (VPNs).

Unit V

System security: intrusion detection, viruses. E-commerce securities: e-payment systems, fair data exchange.

VI. Suggested Reading

- Amoroso E. 1994. *Fundamentals of Computer Security Technology*. Prentice-Hall.
- Bhushan M. 2017. *Fundamentals of Cyber Security* Prentice Hall
- Chapman B and Zwicky E.D. 2000. *Building Internet Firewalls*. O'Reilly.
- Ford W. 1994. *Computer Communications Security*. Prentice Hall. Pfleeger CP. 2006. *Security in Computing*. Prentice Hall.
- Stallings W. 2003. *Cryptography and Network Security: Principles and* Practice. Prentice-Hall.

I. Course Title : Web Technologies and Applications
II. Course Code : MCA555
III. Credit Hours : 1+1

IV. Aim of the course

The main objective of the course is to introduce the whole range of web technologies. Through the various examples, the course will describe how to design a specific page, dynamic web pages, forms and frames and interaction with adatabase.

V. Theory

Unit I

Survey of contemporary Internet Technologies - Role, use and implementation of currenttools.

Unit II

Application Layer Services and protocols - Domain name services, network management protocol, electronic mail and file transfer protocol.

Unit III

World Wide Web – Web pages, Web Sites, Web Servers; Intranet andxtranet Concepts; Web Application Architectures.

Unit IV

Hyper Text Markup Language (HTML); Building static and dynamic web pages.

Unit V

Scripting Languages - Client side and server side scripting; Interaction with database.

Unit VI

Latest trends in programming on the emerging technologies relating to web based software development.

VI. Practical

- Designing static website with features like tables, hyperlink among pages, pictures, frames and layers;
- Client side scripting for user interface validation;
- Server side scripting for database interaction;
- Designing of a information system.

VII. Suggested Reading

- Ayers D, Bergsten H, Bogovich M, Diamond J, Ferris M, Fleury M, Halberstadt A, Houle P, Mohseni P, Patzer A, Philips R, Li S, Vedati K, Wilcox M and Zeiger S. 1999. *Professional Java Server Programming*. Wrox Press Ltd.

- Boudreaux 2005. PHP 5: *Your Visual Blueprint for Creating Open Source, Server-side Content*. (Visual Blueprint). Visual.
- Ellis M.D. 2007. *ASP.NET AJAX Programming Tricks*. Magma Interactive.
- Esposito D 2007. *Introducing Microsoft ASP. NET AJAX (Pro Developer)*. Microsoft Press.
- Evjen B, Hanselman S and Rader D. 2008. *Professional ASP.NET 3.5: In C# and VB* (*Programmer to Programmer*). Wrox Press Ltd.
- Haefel-Monson R. 2003. *Enterprise JavaBeans*. O'Reilly & Associates.
- Naughton P and Schildt H. 2001.*The Complete Reference, Java 2*. TataMcGraw Hill.
- Neimke D. 2006. *ASP.NET 2.0 Web Parts in Action: Building Dynamic Web Portals (In Action)*. Manning Publ.
- Walther S. 2008. ASP.NET 3.5 Unleashed. Sams.

I. Course Title : Computer Networks

II. Course Code : MCA 556

III. Credit Hours : 2+0

IV. Aim of the course

This course addresses the principles, architectures and protocols that have gone into the development of the Internet and modern networked applications. The course examines network design principles, underlying protocols, technologies and architectures such as naming, data transport, routing and algorithms for networked applications including messaging, encryption and authentication.

V. Theory

Unit I

The importance of Networking, Types of Networking, Network Topology, Transmission Media, Data communication: Concepts of data, signal, channel, bandwidth, bit-rate and baud-rate; Maximum data-rate of channel; Analog and digital communications, asynchronous and synchronous transmission.

Unit II

Network adapters card, Multiplexer (FDM, TDM, STDM), Hub, Repeater. Network References Models: Layered architecture, protocol hierarchies, interface and services.

Unit III

ISO-OSI references model, TCP/IP reference model; Data link layer function and protocols: Framing, error-control, flow control; sliding window protocol; HDLC, SLIP and PPP protocol.

Unit IV

Network layer - routing algorithms, congestion control algorithms; Internetworking: bridges and gateway; Transport layer - connection management, addressing; Flow control and buffering, multiplexing.

Unit V

Session layer – RPC; Presentation layer - abstract syntax notation.

Unit VI

Application layer - File Transfer Protocol (FTP), Telnet, Simple Mail Transfer Protocol (SMTP); World Wide Web(WWW) - Wide Area Indexed Servers (WAIS), WAP; Network Security; Data compression and cryptography.

VI. Suggested Reading

- Arick MR. 1994. *The TCP/IP Companion - A Guide for Common User*. Shroff Publ.
- Freer J. 1990. *Computer Communication and Networks*. Affiliated East West Press.
- Hayes J. 2001. *Modelling and Analysis of Computer Communication Networks*. KhannaPubl.
- Tanenbaum AS. 2003. *Computer Networks*. Prentice Hall of India.

I. Course Title : Data Structures
II. Course Code : MCA 561
III. Credit Hours : 2+1

IV. Aim of the course

This is a course on Data Structures that aims at exposing the students tounderstand data structures and their use in problem solving and to analyze different algorithms

V. Theory

Unit I

Algorithms and analysis of Algorithms, Big Oh notation. Arrays, Linked Lists, Elementary List Processing. Memory Allocation for Lists. Strings. Compound Data Structures.

Unit II

Recursive algorithms, Divide and conquer, Dynamic programming, Trees, different tree traversal algorithms, graph traversal.

Unit III

Sorting, Selection Sort. Insertion Sort. Bubble Sort. Performance Characteristics of Elementary Sorts. Shellsort. Sorting Other Types of Data. Index and Pointer Sorting. algorithms.

Unit IV

Quick sort, merging, merge sort, Heap structure, algorithm on heap structure, Queues, priority queues, Search Algorithms

VI. Practical

Implementation of various types of structures - linked lists, doubly linked lists, circular linked lists, queue, dequeue, stack and tree; String processing; Searching and sorting techniques; Graph and geometric algorithms and Casestudies

VII. Suggested Reading

- Aho A.V., Hopcroft J.E. and Ullman J.D. 1983. *Data Structures and Algorithms*. Addison Wesley.
- Cormen T.H., Leiserson CE, Rivest R.L. and Stein C. 2006. *Introduction toAlgorithms*. Prentice Hall of India.
- Goodrich M.T., Tamassia R and Mount D. 2004. *Data Structures and Algorithms in C^{++}*. John Wiley.
- Horowitz E and Sahani S. 1983. *Fundamentals of Data Structures*. Galgotia Publ.
- Jain H. 2018. *Problem Solving in Data Structures and Algorithms Using Java.*
- Kleinberg J and Tardos E. 2006. *Algorithm Design*. Pearson Edu.
- Knuth D.E. 1968. *Art of Computer Programming*. Vol. I. *Fundamental Algorithms*. Addison Wesley.
- Knuth D.E. 1973. *Art of Computer Programming*. Vol. III. *Sorting and Searching*. Addison Wesley.

- Kruse R.L. and Ryba A.J. 1998. *Data Structures and Program Design in C^{++}*. Prentice-Hall.
- Langsam Y, Augenstein M.J. and Tanenbum A.S. 1999. *Data Structures Using C and C^{++}*. Prentice Hall of India.
- Tremblay J.P. and Sorenson P.G. 2017. *An Introduction to Data Structures with Applications*. McGrawHill.
- Weiss M.A. 1994. *Data Structures and Algorithm Analysis in C^{++}*. Benjamin/Cummings.

I. Course Title : System Software and Programming

II. Course Code : MCA 562

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on System Software and Programming that aims at exposing the students to understand operating systems and its functions and to design and write simple low level programming.

V. Theory

Unit I

Systems software-introduction, system specific features; Operating Systems and its functions – device management, process management, memory management, file system management, security.

Unit II

Users, directory, files, file access rights; Terminal Controls and signals; Modularization and program assembly – Interfaces, APIs, header files, libraries, shared objects, dynamic and static links.

Unit III

Input/output at System Level – sequential and random access; indexes.

Unit IV

Memory Management –Allocating and deallocating memory; Threads, spawning processes, network access, sleep, Inter Process communications – pipes, shared memory, sockets, secured sockets, Certificates.

Unit V

Object oriented software design; Generic and reusable classes, Debugging and testing of programs

VI. Practical

- Low Level programming for input/output interface, memory, threads, listening and responding,
- Programming constructs, control statements: branching and looping, file operations,
- Creation of classes with features - overloading, inheritance, data abstraction, polymorphism and a case study using and Object oriented language.

VII. Suggested Reading

- Ken A and Gosling, J. 1996. *The Java Programming Language*. The Java Series. Addison Wesley.
- Balaguruswamy, E. 2019. *Programming with ANSI C*. Tata McGraw Hill, New Delhi.
- Balaguruswamy, E. 2017. *Programming with Object Oriented Programming using C++*. Tata McGraw Hill, New Delhi.

- Bergin, J. 1994. *Data Abstraction: The Object-Oriented Approach Using C++*. McGraw Hill.
- Sethi, R. 1996. *Programming Language Concepts*. Addison Wesley.
- Stroustrup, B. 1997. *The C++ Programming Language*. Addison Wesley.

I. Course Title : Internet Technologies

II. Course Code : MCA 563

III. Credit Hours : 1+1

IV. Aim of the course

The main objective of the course is to introduce the whole range of web technologies. Through the various examples, the course will describe how to design a specific page, dynamic web pages, forms and frames and interaction with adatabase.

V. Theory

Unit I

World Wide Web – Web pages, Web Sites, Web Servers; Intranet and Extranet Concepts; Hyper Text Markup Language (HTML); Building static dynamic web pages.

Unit II

Web application architecture – (ASP.NET/Java) – Web Forms, Server Side Controls, handling events, Validation, JQuery

Unit III

Database Connectivity, read, write, update databases using web forms; data bound controls, sessions, session handling

Unit IV

Authentication of users, Personalization, Roles, role based access

Unit V

Using external libraries/ controls; Ajax, Jquery; Data Exchange – XML, JSON; Creating web services

VI. Practical

- Designing static website with features like tables, hyperlink among pages, pictures, frames and layers;
- Client side scripting for user interface validation;
- Server side scripting for database interaction;
- Designing of information system.

VII. Suggested Reading

- Ayers D, Bergsten H, Bogovich M, Diamond J, Ferris M, Fleury M, Halberstadt A, Houle P, Mohseni P, Patzer A, Philips R, Li S, Vedati K, Wilcox M and Zeiger S. 1999. *Professional Java Server Programming*. Wrox Press Ltd.
- Buest C and Allamaraju S. 2007. *Professional Java Server Programming*: J2EE 3rd Ed.
- Boudreaux 2005. PHP 5: *Your Visual Blueprint for Creating Open Source, Server-side Content*. (Visual Blueprint). Visual.
- Ellis M.D. 2007. *ASP.NET AJAX Programming Tricks*. Magma Interactive.
- Esposito D. 2007. *Introducing Microsoft ASP.NET AJAX* (*Pro-Developer*). Microsoft Press.
- Evjen B, Hanselman S and Rader D. 2008. *Professional ASP.NET 3.5: In C# and VB* (*Programmer to Programmer*). Wrox Press Ltd.
- Haefel-Monson R. 2003. *Enterprise Java Beans*. O'Reilly & Associates.

- Naughton P and Schildt H. 2001. *The Complete Reference, Java 2.* Tata McGraw Hill.
- Neimke D. 2006. *ASP.NET 2.0 Web Parts in Action: Building Dynamic Web Portals* (*In Action*). Manning Publ.
- Walther S. 2008. *ASP.NET 3.5 Unleashed*. Sams.

I. Course Title : Bioinformatics Computing

II. Course Code : MCA 564

III. Credit Hours : 1+1

IV. Aim of the course

The aim of the course is to introduce modern computational practices in bioinformatics at the algorithmic level that will train the students to complement researchers with biological background.

V. Theory

Unit I

The Central Dogma, Review and Utilization of Biological Databases.

Unit II

Overview of Algorithms: Pattern Matching, Biological Motivation Naïve Algorithm.

Unit III

Pre-processing: Suffix trees Time and Space Considerations. Approximate Pattern Matching: Sequence Comparisons, Dot Plots. Sequence Alignment: Dynamic Programming, Global and Local Alignments Scoring Matrices, BLAST, FASTA Parameters.

Unit IV

Similarity and Distance: PAM & BLOSUM matrices, Heuristic Approaches.

Unit V

Exhaustive Search Fragment Assembly: DNA Sequencing, Greedy Algorithms, Sequencing by Hybridization Fragment Assembly.

Unit VI

Graph Algorithms, Overlap Graphs, and Hamiltonian Path Wrap-up.

VI. Practical

- Suffix trees: Time and Space Considerations;
- Approximate Pattern Matching: Sequence Comparisons, Dot Plots;
- Sequence Alignment: Dynamic Programming, Global and Local Alignments Scoring Matrices, BLAST, FASTA Parameters;
- Similarity and Distance: PAM & BLOSUM matrices,
- Heuristic Approaches and Exhaustive Search Fragment Assembly: DNA Sequencing, Greedy Algorithms, Sequencing by Hybridization Fragment Assembly,
- Graph Algorithms, Overlap Graphs, and Hamiltonian PathWrap-up.

VII. Suggested Reading

- Bryan B. 2002. *Bioinformatics Computing*. Prentice Hall.
- Duda R.O., Hart P.E. and Stork D.G. 1999. *Pattern Classification*. John Wiley.
- Ewens W.J. and Grant G.R. 2001. *Statistical Methods in Bioinformatics*. Springer.
- Jones N.C. and Pavel A.P. 2004. *Introduction to Bioinformatics Algorithms*. MIT Press.
- Koskinen T. 2001. *Hidden Markov Models for Bioinformatics*. Kluwer.

- Krane D.E. & Raymer M.L. 2002. *Fundamental Concepts of Bioinformatics*. Benjamin / Cummings.
- Krawetz S.A. and Womble D.D. 2003. *Introduction to Bioinformatics: A Theoretical and Practical Approach*. Humana Press.
- Lesk A.M. 2002. *Introduction to Bioinformatics*. Oxford Univ. Press.
- Shortliffe E.H. and Cimino J.J. 2006. *Biomedical Informatics: Computer Applications in Health Care and Biomedicine* (*Health Informatics*). Springer.
- Wang J.T.L., Zaki M.J., Toivonen H.T.T. and Shasha D. 2004. *Data Mining in Bioinformatics*. Springer.

I. Course Title : Soft Computing Techniques

II. Course Code : MCA 565

III. Credit Hours : 1+1

IV. Aim of the course

This course introduces the soft computing techniques and their applications in solving real world problems. The course is dealt with the perspective of using soft computing techniques in machine learning.

V. Theory

Unit I

Introduction to soft-computing tools – Fuzzy Logic, Genetic Algorithm, Neural Networks and Probabilistic Reasoning, Rough Sets.

Unit II

Applications of Fuzzy Logic concepts in Knowledge Management.

Unit III

Optimization problem solving using genetic algorithm.

Unit IV

Neuron as a simple computing element, the perceptron, multilayer neural networks, Neural network approaches in data analysis, design and diagnostics problems; Applications of probabilistic reasoning approaches.

VI. Practical

Classification using Fuzzy Logic, Genetic Algorithm, Neural Networks

VII. Suggested Reading

- Goldberg D.E. 2008. *Genetic Algorithms in Search, Optimization, and Machine Learning*. Addison Wesley.
- Haykin S. 1998. *Neural Networks: A Comprehensive Foundation*. Prentice Hall.
- Jang J.R., Sun C and Mizutani E. 1996. *Neuro-Fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence*. Prentice Hall.
- Kecman V and Kecman V. 2001. *Learning and Soft Computing: Support Vector Machines, Neural Networks, and Fuzzy Logic Models*. MIT Press.
- Lee K.H. 2005. *First Course on Fuzzy Theory and Applications*. Springer.
- Mitra S and Acharya T. 2003. *Data Mining: Multimedia, Soft Computing, and Bioinformatics*. John Wiley.

I. Course Title : Database Management System

II. Course Code : MCA 571

III. Credit Hours : 2+1

IV. Aim of the course

Database systems are backbone of any information system, enterprise resource planning, research activities and other activity that require permanence of data storage. This course provides the basic introduction to database system technologies; design, concurrency, security and backup/recovery issues of database management systems. The major focus in this course is the Relational database model.

V. Theory

Unit I

Database system - Operational Data, Characteristics of database approach, architecture.

Unit II

Overview of DBMS; Data associations - Entities, Attributes and Associations, Relationship among Entities, Representation of Associations and Relationship, Data Model classification.

Unit III

Entity Relationship model; Relational Data Structure- Relations, Domains and Attributes, Relational Algebra and Operations, Retrieval Operations.

Unit IV

Relational Database Design - Anomalies in a Database, Normalization Theory, and Normal forms; Query processing.

Unit V

Distributed Databases- concepts, architecture, design; Structured Query Language (SQL) - Data Definition Language (DDL), Data Manipulation Language (DML).

Unit VI

PL/SQL - Stored procedure, Database triggers; Relational Data Base Management Package.

VI. Practical

E-R diagram construction; SQL - Command Syntax, Data types, DDL Statements, DML Statements, integrity constraints; Triggers, creating stored procedures/ functions; Normalization of database and Case study on a database design andimplementation.

VII. Suggested Reading

- Date C.J. 2000. *Introduction to Database System*. Addison Wesley.
- Desai B.C. 2000. *Introduction to Database Systems*. Galgotia Publ.
- Elmasri and Navathe. 2006. *Fundamentals of Database Systems*. 4th Ed. Addison Wesley.
- Garcia-Molina H., Ullman J.D. and Widom J. 2013. *Database Systems: The Complete Book*. Prentice Hall.
- Rob P. and Coronel C. 2006. *Database Systems: Design, Implementation and Management*. 7^{th} Ed. Thomson Learning.
- Silberschartz A, Korth H.F. and Sudarshan S. 1997. *Database Systems Concepts*. Tata McGraw Hill.

I. Course Title : Software Engineering

II. Course Code : MCA 572

III. Credit Hours : 2+0

IV. Aim of the course

The objective of the course is to make the learner efficiently work as software engineer so as to acquaint them with all the phases of Software Development Life Cycle.

V. Theory

Unit I

Software engineering definition; Software Development: Phases, Process models, Project structure, Project team structure, Role of metrics, Measurement, Software quality factors.

Unit II

Planning and Software Project: Requirement analysis, Cost estimation, Project Scheduling, Quality Assurance Plan, and Project Monitoring Plans, Gantt charts, PERT and CPM.

Unit III

System Design: Design Objectives, Design Principles, Design Tools, and Techniques, Prototyping.

Unit IV

Structured Programming Coding: Programming Practices, Verification, Monitoring and Control.

Unit V

Testing: Testing Fundamentals, Functional Testing, Structural Testing, Test Plan activities, Unit testing, IntegrationTesting.

Unit VI

Reliability: Concept of Software Reliability, Reliability Models, Limitations of Reliability Models, Software Maintenance. CASE tools.

VI. Suggested Reading

- Aggarwal K.K. and Singh Y. 2006. *Software Engineering*. 2nd Ed. New Age.
- Awad E.M. 1993. *System Analysis and Design*. Galgotia Publ.
- Fairley R. 2017. *Software Engineering Concepts*. Tata McGraw Hill.
- Jalote P. 2005. *An Integrated Approach to Software Engineering*. 3rd Ed. Narosa.
- Kerzner H. 1998. *Project Management: A System Approach to Planning, Scheduling and Controlling*. CBS.
- Mall R. 2006. *Fundamentals of Software Engineering*. 2nd Ed. Prentice- Hall ofIndia.
- Pressman R.S. 2017. *Software Engineering: A Practitioner's Approach*. 6th Ed. McGraw Hill.
- Sommerville I. 2004. *Software Engineering*. 6thEd. Pearson Edu.

I. Course Title : Operating System

II. Course Code : MCA 573

III. Credit Hours : 2+1

IV. Aim of the course

The main objective of this course is to provide core knowledge of Operating Systems features,functions and techniques.

V. Theory

Unit I

Operating system overview: operating system as an extended machine and resource manager; Operating system classifications; Operating system modes and system calls.

Unit II

Operating system architecture; Process model, Process synchronization, Concurrent processes,Process scheduling criterion and algorithms.

Unit III

Problem of mutual exclusion; Deadlock and prevention; Race conditions; Semaphores; Monitors; Process allocation.

Unit IV

Memory management; Multi-programming with fixed and variable number of tasks; Continuousallocation; Paging, Demand paging, Page fault; Virtual memory; Fragmentation; Segmentedmemory management, shared segments; Segmented and demand paged management, Overlaysand swapping, Thrashing.

Unit V

Multi-processor system, Master slave scheduling; Homogeneous scheduling; Device managementsystem; Dedicated share and virtual devices.

Unit VI

File Management System- Input-Output file protection; Remote Procedure Call; Distributedoperating system (Course to be taught in accordance to the Unix Operating System).

VI. Practical

- Problems using system calls for process management, signaling, file management, directorymanagement, protection;
- Critical section problem; Solution to mutual exclusion by Peterson method;
- Producer consumer problem with fatal race conditions;
- Comparison of various CPU scheduling algorithms and Paging, segmentation and demand paging.

VII. Suggested Reading

- Bach, M.J. 2015. *Design of the UNIX Operating System*. Pearson Education.
- Deitel, H.M. 1990. *An Introduction to Operating System*. Addison Wesley.
- Dhamdhere, D.M. 2007. *Operating Systems: A Concept Based Approach*. Tata McGraw Hill, NewDelhi.
- Kernighan, B.W. and Pike, R. 1996. *The UNIX Programming Environment*. Prentice Hall of India,New Delhi.
- Peterson, J. and Silberschatz, A. 1991. *Operating System*. Addison Wesley.
- Stallings, W. 2006. *Operating Systems: Internals and Design Principals*. Prentice Hall of India, New Delhi.
- Silberchatz, A., Galvin, P.B. and Gagne, G. 2006. *Operating System Principals*. Wiley India.
- Tanenbaum, A.S. 2001. *Modern Operating Systems*. Prentice Hall of India, New Delhi.

I. Course Title : Compiler Construction

II. Course Code : MCA 574

III. Credit Hours : 2+1

IV. Aim of the course

The purpose of the course is to acquaint various phases of compiler writing which will help anapplication/system programmer working on other projects besides compilers.

V. Theory

Unit I

Introduction to Compiler, Compilation Process, Compiler Structure.

Unit II

Programming Language Grammars, Elements of a Formal Language Grammar, Derivation,Reduction and Syntax Trees, Ambiguity Regular Grammar & Regular Expression – Context FreeGrammar.

Unit III

Introduction to Finite Automata, Deterministic Finite Automata.

Unit IV

Non-deterministic Finite Automata; Scanning & Parsing Techniques – The Scanner, RegularGrammar and FSA, Top Down Parsing, Parsing Algorithm, Top Down Parsing WithoutBacktracking, Predictive Parsers, Bottom Up Parsing, Parsing, LR Parsers, Shift Reduce Parsing; Symbol Table.

Unit V

Organization, Memory Allocation – Static & Dynamic Memory Allocation, Compilation Control Transfer, Procedure Calls, Conditional Execution, Iteration Control Construct; Lexical Syntax Errors, Semantic, Major Issues in Optimization, Optimizing.

Unit VI

Transformations, Local Optimization, Program Flow Analysis, Global Optimization.

VI. Practical

- Design of a lexical analyser for regular expression;
- Design of a finite state machine;
- Program for - magic squares, context free grammar, shift reduce parsing, operator precedence parsing, recursive decent parsing, predictive parser, simple LR parser and Post fix form for intermediate code.

VII. Suggested Reading

- Aho, A.V. and Ullman, J.D. 1993. *Principles of Compiler Design Theory*. NarosaPublishing House,New Delhi.
- Galles, G. 2007. *Modern Compiler Design*. Pearson Education.
- Holab, A. 2006. *Compiler Design in C.* Prentice-Hall of India, New Delhi.
- Lewis, P.M., Rosenkrantz, D.J. and Stearns, R.E. 1978. *Compiler Design Theory*. Addison Wesley.
- Tremblay, J.P. and Sorenson, P.G. 1985. *The Theory and Practice of Compiler Writing*. McGraw Hill.
- Raghavan V. 2017. *Principles of Compiler Design*. Addison Wesley

I. Course Title : Data Warehousing and Data Mining

II. Course Code : MCA 575

III. Credit Hours : 2+1

IV. Aim of the course

The basic objective of this course is to familiarize students about this state of art of setting datawarehouse for business intelligence in relation to agricultural research, development and planning.

V. Theory

Unit I

Concepts and principles of data warehousing; Project management and requirements. Introduction to Data Mining and its Tasks, Data Pre-processing, Data Discretization

Unit II

Dimensional modelling; Data warehousing architecture; System process and process architecture. Classification and Prediction, Decision Tree, Naive Bayes' Classifier.

Unit III

Data warehousing design; Database schema; Data staging. Output and Knowledge Representation, Evaluation and Credibility, Association Rule Mining.

Unit IV

Partitioning strategy; Aggregations; Data marts; Meta data management; OLAP Modelling, Querymanagement. Clustering: Similarity measures, Hierarchical Clustering, k-Means Clustering.

Unit V

Data warehouse security; Backup and recovery; Building end-user Applications; Capacity planning; Testing the warehouse.

Unit VI

Implementation and maintenance of data warehouse; Case study.

V. Practical

- Data warehouse design, selection of schema;
- Normalization and renormalization;
- Query planstrategy;
- Performance tuning, backup and recovery of data warehouse;
- Dynamic reports and OLAP Reports.
- Introduction to Data Mining software,
- Data Pre-processing, Discretization, Decision Tree: D3,Naïve Bayes' Classifier,
- Association Rule Mining: Apriori Algorithm,
- Clustering: Hierarchical Clustering, K-Means.

VI. Suggested Reading

- Gupta, G.K. 2014. *Introduction to Data Mining with Case Studies*. Prentice Hall of India, New Delhi.
- Han, J and Kamber, M. 2006. *Data Mining: Concepts and Techniques*. Morgan Kaufman.
- Inmon, B. 2005. *Building the Data Warehouse*. John Wiley.
- Kelly, S. 1997. *Data Warehousing in Action*. John Wiley.
- Kimball, R. 2000. *The Data Webhouse Toolkit: Building the Web-Enabled Data Warehouse*. John Wiley.

- Kimball, R. 2002. *The Data Warehouse Toolkit: The Complete Guide to Dimensional Modeling*. John Wiley.
- Kimball, R. 2004. *The Data Warehouse ETL Toolkit: Practical Techniques for Extracting, Cleaning, Conforming, and Delivering Data*. John Wiley.
- Kimball, R. 2005. *The Microsoft Data Warehouse Toolkit: With SQL Server 2005 and the Microsoft Business Intelligence Toolset*. John Wiley.
- Kimball, R. 2008. *The Data Warehouse Lifecycle Toolkit: Practical Techniques for Building Data Warehouse and Business Intelligence Systems.* John Wiley.
- Kimball, R and Ross M. 2013. *The Data Warehouse Toolkit: The Complete Guide to Dimensional Modeling*, John Wiley
- Lee, K.H. 2005. First Course on Fuzzy *Theory and Applications*. Springer.

Course Title with Credit Load
Ph.D. in Computer Application

Course Code	Course Title	Credit Hours	Semester
*MCA 601	Spatial Informatics, GIS and Remote Sensing	1+1	I
*MCA 602	Introduction to Computer Graphics	1+1	I
*MCA 611	Computer Oriented Numerical Analysis	2+1	II
*MCA 612	Artificial Intelligence and Machine Learning	2+1	II
*MCA 615	Bioinformatics Computing	2+0	II
MCA 691	Seminar I	0+1	I/II
MCA 692	Seminar II	0+1	I/II
MCA 699	Research	0+75	II-VI
MCA 603	Simulation and Modeling	1+1	I
MCA 604	Introduction to Big Data	2+1	I
MCA 605	Introduction to Iot	2+1	I
MCA 606	Management Information Systems	2+0	I
MCA 613	Multimedia And its Applications	1+1	II
MCA 614	Knowledge Based Systems for Semantic Web	1+1	II

*** Core Course**

Course Contents
Ph.D. in Computer Application

I. Course Title : Spatial Informatics, GIS and Remote Sensing Techniques

II. Course Code : MCA 601

III. Credit Hours : 1+1

IV. Aim of the course

The basic objective of this course is to teach concepts of GIS and remote sensing with specific applications in agriculture related statistics.

V. Theory

Unit I

Introduction to Geographical Information System (GIS); Introduction- maps and spatial information, components of a GIS; GIS Internals - data representation-raster and vector data structures and analysistechniques.

Unit II

Digital Elevation Models; Data input, verification, storage and output.

Unit III

Spatial modelling- manual and automatic digitizing process; Data errors in GIS; Classification methods-multivariate analysis and classification.

Unit IV

Spatial interpolation; Current and potential uses of GIS in agricultural planning; Software components used in GIS; GIS in India.

Unit V

Physics of remote sensing, atmospheric effects and remote sensing sensors; Spectral signatures of earth surface features, spectral characteristics of vegetation, soil and water.

Unit VI

Data acquisition system, satellite image acquisition; Data collections: pre- processing and data storage; Visual and digital image interpretation; Digital image processing.

VI. Practical

- Digitization of a map with the help of a digitizer;
- Map editing;
- Geo- referencing and map projections;
- Creation of attribute database and linking with spatial data;
- General analysis of the data with the help software;
- Applications of digital elevation models using GIS;
- Spatial interpolations using GIS;
- Visual interpretations of remote sensing data;

- Geometric corrections of remote sensing digital data;
- Methods for improving quality of digital data and Techniques of image classifications.

VII. Suggested Reading

- Annadurai S and Shanmugalakshmi R. 2007. *Fundamentals of Digital Image Processing*. Pearson Edu.
- Burrough P.A. 1986. *Principles of Geographic Information System for Land Resources Assessment*. Oxford Univ. Press.
- Curran P.J. 1985. *Principles of Remote Sensing*. Longman.
- Jensen J.R. 2017. *Introductory Digital Image Processing*. 4th Ed. Prentice Hall.
- Lillesand T.M. and Kiefer R.W. 1987. *Remote Sensing and Image Interpretation*. John Wiley.
- Peuquet D.J. and Marble D.F. 1990. *Introductory Readings in Geographic Information System*. Taylor & Francis.

I. Course Title : Introduction to Computer Graphics

II. Course Code : MCA 602

III. Credit Hours : 1+1

IV. Aim of the course

This course examines the principles of computer graphics, with a focus on the mathematics and theory behind 2D and 3D graphics rendering.

V. Theory

Unit I

Introduction, Application of Graphics, Elements of Graphics Workstation, Graphics I/P Devices; Development of computer graphics: Basic graphics system and standards.

Unit II

Raster scan and random scan graphics; Continual refresh and storages displays; Display processors and character generators; Colour display techniques.

Unit III

Frame buffer and bit operations, Concepts in raster graphics; Points, Lines and Curves; Scan conversion; Line-drawing algorithms; Circle and ellipse generation; Polygon filling; Conic-section generation.

Unit IV

Antialiasing; Two-dimensional viewing: Basic transformations; Co- ordinate systems; Windowing and clipping; Segments; Interactive picture- construction techniques; Interactive input/output devices.

Unit V

Three-dimensional concepts: 3-D representations and transformations; 3-D viewing; Algorithm for 3-D volumes, Spline curves and surfaces.

Unit VI

Fractals; Quadtree and Octree data structures; Hidden line and surface rendering and animation.

VI. Practical

- Implementation of algorithms for drawing geometrical figures, rotation, charts;

- Pixel handling on screen;
- Clipping – Line clipping – Polygon Clipping, Windowing;
- Use of primitive transformations and/or their combinations;
- Implementation of 3D Object Representation and Fractal programming and animation.

VII. Suggested Reading

- Hearn D and Baker M.P. 2004. *Computer Graphics*. Prentice Hall of India. Marshal G. 1983. *Programming with Graphics*. Granada Publ.
- Newman W.M. and Sproull R.F. 1981. *Principles of Interactive Computer Graphics*. McGrawHill.
- Prince D.M. 1979. *Interactive Graphics for Computer Aided Design* (*CAD*). Addison Wesley.
- Rogers D.F. 2001. *Procedural Elements in Computer Graphics*. McGraw Hill.
- Shalini G.P. 2010. *Principles of Computer Graphics: Theory and Practice Using OpenGL and Maya*. McGraw Hill.

I. Course Title : Simulation and Modeling

II. Course Code : MCA 603

III. Credit Hours : 1+1

IV. Aim of the course

The courses aim at teaching simulation and modeling technique for conducting experiments on models that describe the behaviour, uncertainty and structure of real world systems. This course will help in simulation of agricultural research problems and systems.

V. Theory

Unit I

Uses and purposes of simulation; Classification of models.

Unit II

Generation and testing of random numbers.

Unit III

Simulation of stochastic events and processes, Discrete event simulation.

Unit IV

Design of simulation experiments. Analysis of data generated by simulation experiments. Verification and validation of simulation models.

Unit V

Simulation languages.

Unit VI

Simulation of agricultural problems and systems.

VI. Practical

- Generation of random numbers;
- Testing randomness of generated random numbers;
- Generation of random variates following Normal, Beta, Gamma, Exponential, Chi-square, Student's-t, F, Weibull, Binomial, Poisson distributions with the given parameters;

- Discrete event simulation and Simulation from specific models applicable in agriculture.

VII. Suggested Reading

- Averill M.L. and Kelton D. 2005. *Simulation, Modelling and Analysis*. Tata McGraw Hill.
- Banks J. 1998. *Handbook of Simulation*. John Wiley.
- Brately P, Fox B.L. and Scharge LE. 1987. *A Guide to Simulation*. Springer.
- Deo N. 1987. *System Simulation with Digital Computer*. Prentice Hall of India.
- Gentle G.E. 2005. *Random Number Generation and Monte Carlo Methods*. Springer.
- Gordan G. 2007. *System Simulation*. Pearson Edu.
- Kennedy W.J. and Gentle J.E. 1980. *Statistical Computing*. Marcel Dekker.
- Press W.H., Flannery B.P., Tenkolsky S.A. and Vetterling W.T. 1986. *Numerical Recipes: The Art of Scientific Computing*. Cambridge Univ. Press.
- Ripley B.D. 1987. *Stochastic Simulation*. John Wiley.
- Taha H.A. 2003. *Operations Research: An Introduction*. Prentice Hall of India.

Course Title : Introduction to Big Data
Course Code : MCA 604
Credit Hours : 2+1

Aim of the course

This course provides exposure to different aspects of use of big data in agriculture and industrial research. It helps in providing information about the analysis procedure for Big data.

Theory

Unit I

Introduction to Big Data; Big Data Foundations, Components of big data infrastructure; Hadoop; Spark 2.0, installation, Hadoop Distributed File System, reading and processing Big data

Unit II

Introduction to MapReduce, Algorithms for common problems; NoSQL, Scripting

Unit III

Data visualization and mining big data

Unit IV

Processing streaming data, text and natural language processing

Suggested Reading

- Davenport T.H. 2016. *Big Data at Work: Dispelling the Myths, Uncovering the Opportunities*. Kindle Ed.
- Maheshwari A. 2018. *Data Analytics Made Accessible*. Kindle Ed.
- Simon P. 2018. *Too Big to Ignore: The Business Case for Big Data*, Wiley and SAS Business Series
- Schönberger V.M. and Cukier K. 2015. *Big Data: A Revolution That Will Transform How We Live, Work, and Think,*Kindle Ed.

I. Course Title : Introduction to Internet of Things
II. Course Code : MCA 605
III. Credit Hours : 2+1

IV. Aim of the course

This course provides exposure to different aspects of research, implementation, and business with IoT. It also deals withchallenges and techniques for building different IoT solutions. IoT-based applications such as innovative shopping system, infrastructure management in both urban and rural areas, remote health monitoring and emergency notification systems, and transportation systems.

V. Theory

Unit I

Introduction to IoT: Sensing, Actuation, Basics of Networking, Communication Protocols, Sensor Networks, Machine-to-Machine Communications

Unit II

Interoperability in IoT, Introduction to Arduino Programming, Integration of Sensors and Actuators with Arduino, Introduction to Python programming, Introduction to Raspberry, Implementation of IoT with Raspberry.

Unit III

Introduction to SDN, SDN for IoT, Data Handling and Analytics, Cloud Computing, Sensor-Cloud.

Unit IV

Fog Computing, Smart Cities and Smart Homes, Connected Vehicles, Smart Grid, Industrial IoT.

VI. Practical

- Case Study: Agriculture, Healthcare, Activity Monitoring

VII. Suggested Reading

- Raj P. and Raman A.C. 2017. *The Internet of Things: Enabling Technologies, Platforms, and Use Cases*, CRC Press.
- Bahga A. and Madisetti V. 2017. *Internet of Things: A Hands-on Approach*, Universities Press.

I. Course Title : Management Information System

II. Course Code : MCA 606

III. Credit Hours : 2+0

IV. Aim of the course

This course provides exposure to challenges and techniques for management Information Systems. The course deals with theoretical aspects on how to manage the information systems.

V. Theory

Unit I

Information Systems in Global Business – Role of Information Systems in Business; Emergence of Digital Firms, Perspectives on Information Systems.

Unit II

Business Processes and Information Systems; how Information Systems improve Businesses; Types of Information Systems – Transaction Processing Systems; Management Information Systems; Decision Support Systems; Executive Information System.

Unit III

Organizations and Information Systems – Impact of Information System on organization –Economic, Organization and behavioral impacts; Competitive Advantages using Information Systems.

Unit IV

Enterprise wide Applications – ERP, CRM, Business Intelligence, Collaboration Tools and its use; E-Commerce; Social Media; Ethical Issues, privacy and regulations.

VI. Suggested Reading

- Amoroso E. 1994. *Fundamentals of Computer Security Technology*. Prentice-Hall.
- Bhushan M. 2017. *Fundamentals of Cyber Security* Prentice Hall.
- Chapman B & Zwicky ED. 2000. *Building Internet Firewalls*. O'Reilly.

I. Course Title : Computer Oriented Numerical Methods

II. Course Code : MCA 611

III. Credit Hours : 2+1

IV. Aim of the course

This is a course on computer oriented numerical methods that aims at exposing the students to introduce numerical algorithms and to solve mathematical problems using numerical approximations

V. Theory

Unit I

Errors in computations: Basic concepts: Floating point number system, Implication of finite precision, Rounding off errors

Unit II

Finite Differences, Interpolation: Polynomial interpolation, Inverse interpolation, Spline interpolation; Numerical integration: Trapezoidal rule, Simpson's 1/3rd and 3/8th rules; Ordinary differential equations: Runge-Kutta methods, Predictor -correctormethods.

Unit III

Linear system of equations: Gaussian's elimination, Operation counts, Implementation including pivoting and scaling, Direct factorization methods, Iterative techniques and their analysis.

Unit IV

Linear Difference equations; Non-linear equations: Bisection, Newton Raphson, false positions, Secant methods, Iterative methods.

Unit V

Inverse of Matrices; Computation of Eigen values and Eigen vectors: Error estimates, the power methods – Jaccobi and Householder Method.

VI. Practical

- Solving polynomial and algebraic equations using numerical approximations, finding minimum and maximum of functions;
- Inversion of matrices, rank of a matrix,

- Choleskey Decompositions,
- Structural Value Decomposition and Eigen Values.

VII. Suggested Reading

- Atkinson K.E. and Han W. 2003. *Elementary Numerical Analysis*. 3rd Ed. John Wiley.
- Atkinson K.E. 1978. *An Introduction to Numerical Analysis*. John Wiley.
- Jain M.K., Iyengar S.R.K. and Jain R.K. 2007. *Numerical Methods for Scientific and* Engineering *Computation*. 7th Ed. New Age.
- Kennedy W.J. and Gentle J.E. 1980. *Statistical Computing*. Marcel Dekker.
- Krishnamurthi E.V. and Sen S.K. 1986. *Computer-Based Numerical Algorithms*. East West Publ.
- MacMillan. C. 2012. *Elementary Numerical Analysis An Algorithmic Approach:* John Wiley

I. Course Title : Artificial Intelligence and Machine Learning

II. Course Code : MCA 612

III. Credit Hours : 2+1

IV. Aim of the course

The primary objective of this course is to provide an introduction to the basic principles and applications of Artificial Intelligence that includes problem solving, knowledge representation, reasoning, decision making, planning, perception & action, and learning.

V. Theory

Unit I

Introduction to Artificial Intelligence (AI); Scope of AI: Games, theorem proving, natural language processing, robotics, expert system.

Unit II

Knowledge: General concept of knowledge, Knowledge based system, Representation of knowledge, Knowledge organization and manipulation, Acquisition of knowledge.

Unit III

Symbolic approach: Syntax and Semantics for Prepositional Logic (PL) and First order predicates logic (FOPL), Properties of well-formed formulas (wffs), Conversion to clausal form, Inference rules, Resolution principle, Non deductive inference methods.

Unit IV

Search and Control strategies: Blind search, Breadth- first search, Depth – First search, Hill climbing method, Best – First search, Branch and Bound search.

Unit V

Learning: Concept of learning, learning automation, genetic algorithms, learning by induction.

Unit VI

Expert System: Introduction to expert system, Characteristics features of expert system, Applications, Importance of Expert system, Rule based system architecture.

VI. Practical

- Search and Control strategies: Blind search, Breadth- first search, Depth – First search, Hill climbing method, Best – First search, Branch and Bound search;

- Learning by induction;
- Genetic algorithms;
- Case study of a rule based expert system and Construction of Decision tree.

VII. Suggested Reading

- Akerkar R. 2005. *Introduction to Artificial Intelligence*. Prentice-Hall of India.
- Giarratano J. and Riley G. 1998. *Expert Systems - Principles and Programming*. 3rd Ed. PWS Publ.
- Gonzalez A. and Dankel D. 2004. *The Engineering of Knowledge-Based Systems*. Prentice Hall.
- Hill E.F. 2003. *Jess in Action*. Manning Publ.
- Jackson P. 1999. *Introduction to Expert Systems*. Addison Wesley.
- Nilson N.J. 2014. *Artificial Intelligence: A New Synthesis*. Maurgan Kaufman.
- Nilson N.J. 2001. *Principles of Artificial Intelligence*. Narosa.
- Rich E. and Knight K. 2002. *Artificial Intelligence*. Tata McGraw Hill.
- Russell S. and Norvig P. 2003. *Artificial Intelligence: A Modern Approach*. Prentice Hall.

I. Course Title : Multimedia and Applications

II. Course Code : MCA 613

III. Credit Hours : 1+1

IV. Aim of the course

This course introduces students to current practices, technologies, methodologies, and authoring systems in the design and implementation of systems that incorporate text, audio, images, animation and full-motion video.

V. Theory

Unit I

Introduction to Multimedia Technology - Computers, communications and entertainment; Framework for multimedia systems.

Unit II

M/M devices, presentation devices and the user interface, M/M presentation and authoring.

Unit III

Digital representation of sound and transmission; Brief survey of speech recognition and generation; Digital video and image compression; JPEG image compression standard; MPEG motion video compression.

Unit IV

DVD technology, Time based media representation and delivery; M/M software environment; Limitation of workstation operating systems.

Unit V

M/M systems services; OS support for continuous media applications; Media stream protocol; M/M file system and information representation.

Unit VI

Data models for M/M and Hypermedia information.

VI. Practical

- Script Writing and Story Boards;

- Hot Spots and Buttons, Layouts and designing of visuals, Basics of colors;
- Working with text, presentations, charts and putting animations;
- Creating interactive presentations;
- Adobe Photoshop – Introduction, Working with images, Image editing and cleaning;
- Macromedia Flash - Introduction, Creating shapes, Inserting text, Concepts of colors, layers, frames and timelines;
- Creating Animation - Creating scenes, creating movie, testing and playing movie;
- Adobe Acrobat – Overview, Creating Adobe PDF e-Books;
- Macro Media Director Basics.

VII. Suggested Reading

- Furhet B. 1998. *Multimedia Technologies and Applications for the 21st Century*. Kluwer.
- Gibbs S.J. and Tsischritziz D.C. 1995. *Multimedia Programming - Objects, Environment & Framework*. Addison-Wesley.
- Kerman P. 2002. *Teach Yourself Macromedia Flash MX*. Sams Publ. Luther AC. 1994. *Authoring Interactive Multimedia*. Academic Press. Parekh R. 2006. *Principles of Multimedia*. TataMcGraw-Hill.
- Vaughan T. 2017. *Multimedia-Making it Work*.McGraw-Hill.

List of Journals

Agricultural Statistics

- *American Statistician*
- *Annals of Institute of Statistical Mathematics*
- *Annals of Statistics*
- *Australian and New Zealand Journal of Statistics*
- *Biometrical Journal*
- *Biometrics*
- *Biometrika*
- *Bulletin of Calcutta StatisticalAssociation*
- *Canadian Journal of Statistics*
- *Communication in Statistics (Simulation and Computation)*
- *Communication in Statistics (Theory and Methods)*
- *Experimental Agriculture*
- *Institute of Mathematical Statistics Bulletin (IMSB)*
- *Journal of American Statistical Association*
- *Journal of Applied Statistics*
- *Journal of the Indian Society of Agricultural Statistics*
- *Journal of the International Statistical Review*
- *Journal of Statistical Planning and Inference*
- *Journal of Statistical Theory andPractice*
- *Journal of Statistics, Computer and Applications*
- *Journal of Royal Statistical Society, Series A*
- *Journal of Royal Statistical Society, Series B*
- *Journal of Royal Statistical Society, Series C*
- *Metrika*
- *Metron*
- *Scandinavian Journal of Statistics (Theory & Applied)*
- *Sankhya*
- *Statistica*
- *Statistical Science*
- *Statistics and Probability Letters*
- *Technometrics*
- *Utilitas Mathematica*

Computer Application

- *ACM Transactions on Knowledge Discovery from Data*
- *Applied Intelligence–The International Journal of Artificial Intelligence, Neural Networks, and Complex Problem-Solving Technologies*
- *Computational Statistics and Data Analysis, Elsevier Inc.*
- *Computers and Electronics in Agriculture, Elsevier Inc.*
- *Data Mining and Knowledge Discovery: An International Journal (DMKD)*
- *Expert Systems with Applications, Elsevier Inc.*
- *IEEE Transactions on Knowledge and Data Engineering*
- *IEEE Transactions on Neural Networks*
- *IEEE Transactions on Pattern Analysis and Machine Intelligence*
- *International Journal of Computing and Information Sciences*
- *International Journal of Information and Management Sciences*
- *International Journal of Information Technology*
- *Journal of Artificial Intelligence Research*
- *Journal of Combinatorics, Information and System Sciences*
- *Journal of Computer Sciences and Technology*
- *Journal of Computer Society of India*
- *Journal of Indian Society of Agricultural Statistics*
- *Journal of Intelligent Information Systems - Integrating Artificial Intelligence and Database Technologies*
- *Journal of Machine Learning Research*
- *Journal of Statistics, Computer and Applications*
- *Journal of Systems and Software*
- *Journal of Theoretical and Applied Information Technology*
- *Knowledge and Information Systems: An International Journal (KAIS)*
- *Lecture Notes in Computer Science, Springer Verlag.*
- *Machine Learning*
- *Transactions on Rough Set*

e-Resources

- Design Resources Server. *Indian Agricultural Statistics Research Institute (ICAR), New Delhi 110 012, India.*www.drs.icar.gov.in.
- Free Encyclopedia on Design of Experiments
- http: //en.wikipedia.org/wiki/Design_of_experiments
- Statistics Glossaryhttp: //www.cas.lancs.ac.uk/glossary_v1.1/main.html.
- Electronic Statistics Text Book: http://www.statsoft.com/textbook/stathome.html.
- Hadamard Matriceshttp: //www.research.att.com/~njas/hadamard;
- Hadamard Matrices http: //www.uow.edu.au/~jennie/WILLIAMSON/williamson.html.
- Course on Experimental design: http://www.stat.sc.edu/~grego/courses/stat706/.
- Learning Statistics: http: //freestatistics.altervista.org/en/learning.php.
- Free Statistical Softwares: http://freestatistics.altervista.org/en/stat.php.
- Statistics Glossaryhttp: //www.cas.lancs.ac.uk/glossary_v1.1/main.html.
- Statistical Calculators: http: //www.graphpad.com/quickcalcs/index.cfm
- SAS Online Doc 9.1.3: http: //support.sas.com/onlinedoc/913/docMainpage.jsp

Suggested Broad Topics for Research Agricultural Statistics

- Design and analysis of multi-response experiments
- Design and analysis of micro-array experiments
- Design and analysis of experiments for precision agriculture
- Design and analysis of agroforestry experiments
- Designs for computer experiments.
- Bayesian designing of experiments, Bayesian optimality and Bayesian analysis of experimental data

- Computer aided search of efficient experimental designs for various experimental settings
- Fractional factorials including search designs, supersaturated designs, computer experiments, etc.
- Statistical techniques in bioinformatics, biotechnology, microbiology, genomics, etc.
- Optimality aspects and robustness of designs against several disturbances under various experimental settings (single factor, multi-factor, nested classifications, etc.)
- Small area estimation
- Computer intensive techniques in sample surveys
- Analysis of survey data, regression analysis, categorical data analysis, analysis of complex survey data
- Assessment and impact survey methodologies, valuation of natural resources, its degradation, depletion, etc.
- Linear and non-linear modeling of biological and economical phenomena
- Non-linear time series modeling
- Non-linear stochastic modeling
- Forecast models for both temporal and spatial data
- Innovative applications of resampling techniques
- Applications of remote sensing, GIS, ANN, etc. in modeling various phenomena
- Econometric models for risk, uncertainty, insurance, market analysis, technical efficiency, policy planning, etc.
- Statistical studies on value addition to crop produce

Computer Application

- Web solutions inagriculture
- Decision Support/ Expert Systems/ Information Management Systems in Agriculture
- Software for Statistical DataAnalysis
- Modelling and Simulation of Agricultural Systems
- Application Software for GIS and Remote Sensing
- Office Automation and Management System

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