

Course outline and its distribution as per the recommendation of BSMA 2020

From **Academic Session**

2021-22

at

PG and Ph.D. Level



By

ICAR – Broad Subject Matter Area (BSMA) Committee



College of Agriculture, Kanpur

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Content

SN	Department/Degree programme/course	Page No.
1.	Academic Regulations	4 – 15
2.	Common courses (PGS-501, PGS-502, PGS-503, PGS-504, PGS-505)	16 – 19
3.	<i>Department of Agronomy</i>	
	a) M.Sc. (Ag.) Agronomy	20 – 27
	b) Ph.D. in Agronomy	28 – 33
4.	<i>Department of Soil Science & Agriculture Chemistry</i>	
	a) M.Sc. (Ag.) Soil Science & Agriculture Chemistry	34 – 43
	b) Ph.D. in Soil Science & Agriculture Chemistry	44 – 49
5.	<i>Department of Plant Pathology</i>	
	a) M.Sc. (Ag.) Plant Pathology	50 – 63
	b) Ph.D. in Plant Pathology	64 – 69
6.	<i>Department of Agricultural Biochemistry</i>	
	a) M.Sc. (Ag.) Agril. Biochemistry	70 – 80
	b) Ph.D. in Agril. Biochemistry	81 – 84
7.	<i>Department of Genetics & Plant Breeding</i>	
	a) M.Sc. (Ag.) Genetics & Plant Breeding	85 – 98
	b) Ph.D. in Genetics & Plant Breeding	99 – 105
8.	<i>Department of Agricultural Extension</i>	
	a) M.Sc. (Ag.) Agricultural Extension	106 – 134
	b) Ph.D. in Agricultural Extension	135 – 157
9.	<i>Department of Agricultural Economics & Statistics</i>	
	a) M.Sc. (Ag.) Agril. Economics & Statistics	158 – 169
	b) Ph.D. in Agril. Economics & Statistics	170 – 178

10.	Department of Entomology	
	a) M.Sc. (Ag.) Entomology	179 – 190
	b) Ph.D. in Entomology	191 – 204
11.	Department of Crop Physiology	
	a) M.Sc. (Ag.) Crop Physiology	205 – 234
	b) Ph.D. in Crop Physiology	235 – 258
12.	Department of Seed Science & Technology	
	a) M.Sc. (Ag.) Seed Science & Technology	259 – 274
	b) Ph.D. in Seed Science & Technology	275 – 285
13.	Department of Livestock Production & Management	
	a) M.Sc. (Ag.) Livestock Production & Management	286 – 292
	b) Ph.D. in Livestock Production & Management	293 – 296
14.	Department of Animal Husbandry & Dairying (Dairy Technology)	
	a) M.Sc. (Ag.) Animal Husbandry & Dairying (Dairy Technology)	297 – 304
	b) Ph.D. in Animal Husbandry & Dairying (Dairy Technology)	305 – 308
15.	Department of Soil Conservation & Water Management	
	a) M.Sc. (Ag.) Soil Conservation & Water Management	309 – 314
	b) Ph.D. in Soil Conservation & Water Management	315 – 317
16.	Department of Agri-business Management (ABM)	
	MBA in Agri-business Management	318 – 348

Draft

Academic Regulations for PG and PhD programmes

1. Academic Year and Registration
2. Credit requirements
 - 2.1 Framework of the courses
 - 2.2 Supporting courses
 - 2.3 Syllabus of Common Courses for PG programmes
 - 2.4 Mandatory requirement of seminars
3. Residential requirements
4. Evaluation of course work and comprehensive examination
5. Advisory System
 - 5.1 Advisory Committee
6. Evaluation of research work
 - 6.1 Prevention of plagiarism
7. Learning through online courses
8. Internship during Masters programme
9. Teaching assistantship
10. Registration of project personnel (SRF/RA) for PhD
11. Compliance with the National Education Policy-2020
12. Definitions of academic terms

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 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 approval of the HoD/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	CREDITS
STAT 501	MATHEMATICS FOR APPLIED SCIENCES	2+0
STAT 502	STATISTICAL METHODS FOR APPLIED SCIENCES	3+1
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
BIOCHEM501	BASIC BIOCHEMISTRY	3+1
BIOCHEM505	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).
104

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. Chicago Manual of Style. 14th Ed. 1996. Prentice Hall of India.
2. Collins' Cobuild English Dictionary. 1995.
3. Harper Collins. Gordon HM & Walter JA. 1970. Technical Writing. 3rd Ed.
4. Holt, Rinehart & Winston. Hornby AS. 2000. Comp. Oxford Advanced Learner's Dictionary of Current English. 6th Ed. Oxford University Press.
5. James HS. 1994. Handbook for Technical Writing. NTC Business Books.
6. Joseph G. 2000. MLA Handbook for Writers of Research Papers. 5th Ed. Affiliated East-West Press.
7. Mohan K. 2005. Speaking English Effectively. MacMillan India.
8. Richard WS. 1969. Technical Writing.
9. Barnes & Noble. Robert C. (Ed.). 2005. Spoken English: Flourish Your Language.
10. Abhishek. Sethi J & Dhamija PV. 2004. Course in Phonetics and Spoken English. 2nd Ed. Prentice Hall of India.
11. Wren PC & 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 & 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 & 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 & 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; National Biological Diversity Act, 2003.

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 vaccumets; 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 & 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 & 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 latest developments 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 coursework

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 4th and 6th semester of his/her residence 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 PhD, 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 examination should be based on oral examination by 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.

Advisory System

- **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.

5. Evaluation of research work

- It is highly desirable for Ph.D. programme and this should be done annually as an essential

part of research evaluation. The Student Advisory Committee shall review the progress of research and scrutinize annual progress reports submitted by the student.

- Midterm evaluation of PhD (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.

6. 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 online 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.

7. 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 enhanced partnerships 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 and 10 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

8. 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 PhD 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 of the 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 Vice Chancellor. 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.

9. Registration of project personnel (SRF/RA) for PhD

- A provision may be made to enable the project personnel (SRF/RA) to register for PhD.

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 PhD admission

- The candidates need to submit the declaration stating that the project work shall not be compromised because of PhD 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.

10. 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 Postgraduate 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 hours of 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.

Common courses for PG Programme

SN	Course No.	Name of the course	Credit Semester	Semester	Department
1.	PGS-501	Library And Information Services	1(0+1)	I	Central Library
2.	PGS-502	Technical Writing and Communications Skill	1(0+1)	I	Agril. Extension
3.	PGS-503	Intellectual Property and Its Management in Agriculture	1(0+1)	II	Genetics & Plant Breeding
4.	PGS-504	Basic Concept in Laboratory Techniques	1(0+1)	II	Soil Science & Agril. Chemistry
5.	PGS-505	Agriculture Research, Research Ethics and Rural Development Programmes	1(0+1)	III	Agronomy

PGS-501

Library & Information Services

1(0+1)

Objective

To equip the library users with skills to trace information from libraries efficient, 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 system 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 from reference sources; literature survey; citation techniques/ preparation of bibliography; use of CD-ROM database, online public access catalogue and other computerized library services; use of internet including search engines and its sources; e-resources access methods.

RESOURCES

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

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

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

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

- Erbisch FH & Maredia K.1998. Intellectual Property Rights in Agricultural Biotechnology. CABI.
- Ganguli P. 2001. Intellectual Property Rights: Unleashing Knowledge Economy. McGraw-Hill.

- Intellectual Property Rights: Key to New Wealth Generation. 2001. NRDC & Aesthetic Technologies.
- Ministry of Agriculture, Government of India. 2004. State of Indian Farmer. Vol. V. Technology Generation and IPR Issues. Academic Foundation.
- Rothschild M & Scott N. (Ed.). 2003. Intellectual Property Rights in Animal Breeding and Genetics. CABI.
- 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; National Biological Diversity Act, 2003.

PGS 504 **BASIC CONCEPTS IN LABORATORY TECHNIQUES** **1(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 vaccumets; 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

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

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

PGS 505 **AGRICULTURAL RESEARCH, RESEARCH ETHICS AND RURAL DEVELOPMENT PROGRAMMES** **1(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

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

Department of Agronomy

M.Sc. (Agri.) Agronomy

Semester	Course No.	Credit hour	Course title
Major course			
I	Agron 501*	3(3+0)	Modern Concepts in Crop Production
I	Agron 503*	3(2+1)	Principles and Practices of Weed Management
II	Agron 504*	3(2+1)	Principles and Practices of Water Management
II	Agron 505	2(1+1)	Conservation Agriculture
III	Agron 502*	3(2+1)	Principles and practices of soil fertility and nutrient management
III	Agron 507	3(2+1)	Agronomy of oilseed, fibre and sugar crops
IV	Agron 509	3(2+1)	Agronomy of fodder and forage crops
	Agron-550	1(1+0)	Master's Seminar
	Agron -560	30	Master's research
Minor course			
	SAC 504	3(2+1)	Soil mineralogy, genesis and classification
	SAC 508	3(2+1)	Soil, water and air pollution
	SAC 510	2(0+2)	Analytical technique and instrumental methods in soil & plant analysis.
Supporting course			
	STAT 502	3(2+1)	Statistical method for applied sciences
	STAT 511	3(2+1)	Experimental Design
	Common courses: 5 credit 5 course		
Total credit: 70			

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

Agron 501

MODERN CONCEPTS IN CROP PRODUCTION

3(3+0)

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

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.

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment and class discussion

Learning outcome: Basic knowledge on soil management and crop production

Reading materials:

- Balasubramaniyan P & Palaniappan SP. 2001. *Principles and Practices of Agronomy*. Agrobios.
- Fageria NK. 1992. *Maximizing Crop Yields*. Marcel Dekker.
- Havlin JL, Beaton JD, Tisdale SL & 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 & Mudaliar TV. 1997. *Principles of Agronomy*. The Bangalore Printing & Publ.
- Singh SS. 2006. *Principles and Practices of Agronomy*. Kalyani.
- Alvin, P.T. and Kozlowski, T.T. (ed.) 1976. *Ecophysiology of Tropical Crops*. Academia Pul., New York.
- Gardner, P.P., Pearce, G.R. and Mitchell, R. L. 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, C.P. 1961. *Crop Adaptation and Distribution*. Euresia Pub., New Delhi.

Agron 502

**PRINCIPAL AND PRACTICES OF SOIL FERTILITY AND NUTRIENT
MANAGEMENT**

3(2+1)

Objective: 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.

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.

Practical

1. 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

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment and class discussion

Learning outcome: Basic knowledge on soil fertility and management

Reading Materials:

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

Agron 503

PRINCIPLES AND PRACTICES OF WEED MANAGEMENT

3(2+1)

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

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 of nano-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 combination and 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.

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

Teaching methods/activities: Classroom teaching with AV aids, group discussion, field visit to identify weeds.

Learning outcome: Basic knowledge on weed identification and control for crop production

Reading materials:

- Zimdahl R. L., (ed). 2018. *Integrated Weed Management for Sustainable Agriculture, B. D. Sci. Pub*
- Jugulan, Mithila, (ed). 2017. *Biology, Physiology and Molecular Biology of Weeds*. CRC Press
- T. K. Das. 2008. *Weed Science: Basics and Applications*, Jain Brothers (New Delhi)
- Chauhan Bhagirath and Mahajan Gulshan. 2014. *Recent Advances in Weed Management*. Springer.
- Fennimore, Steven A and Bell, Carl. 2014. *Principles of Weed Control*, 4th Ed, California Weed Sci. Soc.
- Monaco, T. J. Weller, S. C. & Ashton, F. M. 2014. *Weed Science Principles and Practices*, Wiley
- Gupta, O. P. 2007. *Weed Management: Principles and Practices*, 2nd Ed. Walia, U.S. 2006. *Weed Management*, Kalyani.
- Böger, Peter, Wakabayashi, Ko, Hirai, Kenji (Eds.). 2002. *Herbicide Classes in Development. Mode of Action, Targets, Genetic Engineering, Chemistry*. Springer.
- Powles, S. B. and Shaner, D. L. 2001. *Herbicide Resistance and World Grains*, CRC Press.

Agron 504

PRINCIPLES AND PRACTICES OF WATER MANAGEMENT

3(2+1)

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

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.

Practical

1. Determination of Field capacity by field method
2. Determination of Permanent Wilting Point by sunflower pot culture technique
3. Determination of Field capacity and Permanent Wilting Point by Pressure Plate Apparatus
4. Determination of Hygroscopic Coefficient
5. Determination of maximum water holding capacity of soil
6. Measurement of matric potential using gauge and mercury type tensiometer
7. Determination of soil-moisture characteristics curves
8. Determination of saturated hydraulic conductivity by constant and falling head method
9. Determination of hydraulic conductivity of saturated soil below the water table by auger hole method
10. Measurement of soil water diffusivity
11. Estimation of unsaturated hydraulic conductivity
12. Estimation of upward flux of water using tensiometer and from depth ground water table
13. Determination of irrigation requirement of crops (calculations)
14. Determination of effective rainfall (calculations)
15. Determination of ET of crops by soil moisture depletion method
16. Determination of water requirements of crops
17. Measurement of irrigation water by volume and velocity-area method
18. Measurement of irrigation water by measuring devices and calculation of irrigation efficiency
19. Determination of infiltration rate by double ring infiltrometer

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment and field visit

Learning outcome: Basic knowledge on water management for optimization of crop yield

Reading materials:

- Majumdar D.K. 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 & Sandhu BS. 1987. *Irrigation of Food Crops - Principles and Practices*. ICAR.
- Reddy SR. 2000. *Principles of Crop Production*. Kalyani.
- Singh Pratap & Maliwal PL. 2005. *Technologies for Food Security and Sustainable Agriculture*. Agrotech Publ.

Agron 505

CONSERVATION AGRICULTURE

2(1+1)

Objective: To impart knowledge of conservation of agriculture for economic development.

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 agro forestry systems, rainfed / dry land regions

UNIT V

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

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome: Experience on the knowledge of various types of conservation of agriculture.

Reading materials:

1. Muhammad, F. and Kamdambot, H.M.S. (2014). *Conservation Agriculture*. Publisher: Springer Cham Heidelberg, New York Dordrecht London. Doi: 10.1007/978-3-319-11620-4.
2. Bisht, J.K., Meena, V.S., Mishra, P.K. 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.
3. Gracia-Torres, L., Benites, J., Martinez-Vilela, A. and Holgado-Cabera, A. (2003). *Conservation Agriculture- Environment Farmers experiences, innovations Socio- economic policy*.
4. Arakeri HR & Roy D. 1984. *Principles of Soil Conservation and Water Management*. Oxford & IBH.
5. Dhruvanarayana VV. 1993. *Soil and Water Conservation Research in India*. ICAR.
6. FAO. 2004. *Soil and Water Conservation in Semi-Arid Areas*. *Soils Bull.*, Paper 57.
7. Yellamanda Reddy T & Sankara Reddy GH. 1992. *Principles of Agronomy*. Kalyani.

Agron 507

AGRONOMY OF OILSEED, FIBRE AND SUGAR CROPS

3(2+1)

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

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.

Practical

1. Planning and layout of field experiments
2. Cutting of sugarcane setts, its treatment and methods of sowing, tying and propping of sugarcane
3. 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
3. Intercultural operations in different crops
4. Cotton seed treatment
5. Working out growth indices (CGR, RGR, NAR, LAI, LAD, LAR, LWR, SLA, SLW etc)
6. 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)
8. Judging of physiological maturity in different crops and working out harvest index
9. Working out cost of cultivation of different crops
10. Estimation of crop yield on the basis of yield attributes
11. Formulation of cropping schemes for various farm sizes and calculation of cropping and rotational intensities
12. Determination of oil content in oilseeds and computation of oil yield
13. Estimation of quality of fibre of different fibre crops
14. Study of seed production techniques in various crops
15. Visit of field experiments on cultural, fertilizer, weed control and water management aspects
16. Visit to nearby villages for identification of constraints in crop production

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment and class discussion

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

Reading materials:

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 Field Crops*. Oxford & IBH.

Singh SS. 1998. *Crop Management*. Kalyani.

Agron 509

AGRONOMY OF FODDER AND FORAGE CROPS

3(2+1)

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

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/grasses/lime, Napier grass, *Panicum*, *Lasiurus*, *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 poor quality fodder. Fodder production through hydroponics. Azolla cultivation.

UNIT-V: Economics of forage cultivation uses and seed production techniques of important fodder crops.

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.

Teaching methods/activities: Classroom teaching with AV aids, group discussion, assignment and field visit

Learning outcome: acquainted with various fodder and forage crops and their commercial base for developing entrepreneurship.

Reading materials:

Chatterjee BN. 1989. *Forage Crop Production - Principles and Practices*. Oxford & IBH.

Das NR. 2007. *Introduction to Crops of India*. Scientific Publ. Narayanan TR & Dabadghao PM. 1972. *Forage Crops of India*. ICAR.

Singh P & Srivastava AK. 1990. *Forage Production Technology*. IGFRI, Jhansi.

Singh C, Singh P & Singh R. 2003. *Modern Techniques of Raising Field Crops*. Oxford & IBH.

Tejwani KG. 1994. *Agroforestry in India*. Oxford & IBH.

Department of Agronomy

Ph.D. in Agronomy

Semester	Course No.	Credit hour	Course title
Major course			
I	Agron 601*	3(3+0)	Current trends in Agronomy
I	Agron 604	2(2+0)	Recent trends in weed management
II	Agron 605	2(2+0)	Integrated farming systems for sustainable agriculture
II	Agron 608*	2(2+0)	Research and publication ethics
III	Agron 607	3(2+1)	Stress crop production
	Agron 691	1(1+0)	Doctor's Seminar
	Agron 692	1(1+0)	Doctor's Seminar
	Agron 699	75	Doctors Research
Minor course			
I	SAC 602	2(2+0)	Modern concept in soil fertility
II	SAC 604	2(2+0)	Soil genesis & micro morphology
III	PPY 608	2(2+0)	Seed and fruit growth and their quality improvement
Supporting course			
	STAT 604	3(2+1)	Advanced statistical method
	STAT 612	3(2+1)	Advanced design of experiments
Total credit load		101	

*Indicates core course which is compulsory course for Ph.D.

Agron 601

CURRENT TRENDS IN AGRONOMY

3(3+0)

Objective: To acquaint the students about recent advances in agricultural production.

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 management
Mechanization in crop production: modern agricultural precision tools and technologies, 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.

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation

by students.

Learning outcome: Recent advances in agricultural production

Reading materials:

- Agarwal RL. 1995. *Seed Technology*. Oxford & IBH. Dahiya BS & 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 & Annadurai K. 2006. *Organic Farming - Theory and Practice*. Scientific Publ.
- Sen S & Ghosh N. 1999. *Seed Science and Technology*. Kalyani.
- Tarafdar JC, Tripathi KP & Mahesh Kumar 2007. *Organic Agriculture* Scientific Publ.
- Kumar, Rajeev, Swarnkar Kumar Sushil, Singh Kumar Sunil and Narayan Sumati. 2016. *A Text Book of Seed Technology*. Kalyani Publication.
- Reddy, S.R. and Prabhakara, G. 2015. *Dryland Agriculture*. Kalyani Publishers.
- Gururajan, B. Balasubhranian, 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.

Agron 604

RECENT TRENDS IN WEED MANAGEMENT

2(2+0)

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

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.

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

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

Suggested Readings

- Zimdahl R. L., (ed). 2018. *Integrated Weed Management for Sustainable Agriculture*, B. D. Sci. Pub
- Jugulan, Mithila, (ed). 2017. *Biology, Physiology and Molecular Biology of Weeds*. CRC Press
- T. K. Das. 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.
- Monaco, T. J. Weller, S. C. & Ashton, F. M. 2014. *Weed Science Principles and Practices*, Wiley
- Gupta, O. P. 2007. *Weed Management: Principles and Practices*, 2nd Ed. Walia, U.S. 2006. *Weed Management*, Kalyani.
- Böger, Peter, Wakabayashi, Ko, Hirai, Kenji (Eds.). 2002. *Herbicide Classes in Development. Mode of Action, Targets, Genetic Engineering, Chemistry*. Springer.
- Powles, S. B. and Shaner, D. L. 2001. *Herbicide Resistance and World Grains* , CRC Press.

Agron 605 INTEGRATED FARMING SYSTEMS AND SUSTAINABLE AGRICULTURE 2(2+0)

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

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.

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

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

Reading materials:

- 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.
- Jayanthi C. 2006. *Integrated Farming systems-A way to sustainable Agriculture*. Tamil Nadu Agricultural University, Coimbatore
- A text book of farming system and sustainable agriculture : by Aniket Kalhapure and Madhukar Dhonde
- Edens T. (1984.)Sustainable agriculture and integrated farming system. Michigan State Univ. press,
- Ravisankar D. and Jayanthi C. (2015). *Farming systems: concepts and approaches*. Agrobios,
- Ananthakrishnan TN. (Ed.) 1992. *Emerging Trends in Biological Control of Phytophagous Insects*. Oxford & IBH.
- Balasubramanian P &Palaniappan SP 2006. *Principles and Practices of Agronomy*. Agrobios.
- Joshi M &Parbhakarasetty TK. 2005. *Sustainability through Organic Farming*. Kalyani. Lampin N. 1990. *Organic Farming*. Farming Press Books.
- Palaniappan SP &Anandurai K. 1999. *Organic Farming - Theory and Practice*. Scientific Publ.
- Panda SC. 2004. *Cropping systems and Farming Systems*. Agribios.

Agron 607 STRESS CROP PRODUCTION

3(2+1)

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

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 stress 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.

Practical

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

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome: Experience on the knowledge of various types of stresses in crop production and strategies to overcome these.

Reading materials:

- Baker FWG.1989. *Drought Resistance in Cereals*. Oxon, UK.
- Gupta U.S. (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 &Ojha TP.1981. *Principles of Agricultural Engineering*. Vol II. Jain Bros.
- Nilsen ET &Orcut DM. 1996. *Physiology of Plants under Stress – Abiotic Factors*. John Wiley & Sons.
- Singh K. 2000. *Plant Productivity under Environmental Stress*. Agribios.
- Singh KN & Singh RP. 1990. *Agronomic Research Towards Sustainable Agriculture*. Indian Society of Agronomy, New Delhi.
- Somani LL &Totawat KL. 1992. *Management of Salt-affected Soils and Waters*. Agrotech Publ.
- Virmani SM, Katyal JC, Eswaran H &Abrol IP.1994. *Stressed Ecosystem and Sustainable Agriculture*. Oxford & IBH.

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: Definition, 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

Teaching methods/activities: Classroom teaching with AV aids, group discussion, field practicals and laboratory visit.

Learning outcome: Developed skill for research management, quality publication

Department of Soil Science & Agricultural Chemistry

M.Sc. (Ag.) in Soil Science & Agricultural Chemistry

Sl. No.	Course No.	Course Name	Credit Hrs.	Semester
Major Courses				
1.	SOIL-501	Soil Physics	3(2+1)	I
2.	SOIL-502	Soil Fertility and Fertilizer use	3(2+1)	I
3.	SOIL-503	Soil Chemistry	3(2+1)	II
4.	SOIL-504	Soil Mineralogy, Genesis and Classification	3(2+1)	II
5.	SOIL-506	Soil biology and biochemistry	3(2+1)	III
6.	SOIL-508	Soil, Water and Air Pollution	3(2+1)	III
7.	SOIL-510	Analytical technique and instrumental methods in soil and plant analysis	2(0+2)	IV
Total			20(12+8)	
Minor Courses				
1.	AGRON-502	Principles and practices of soil fertility and nutrient management	3(2+1)	III
2.	AGRON-504	Principles and practices of water management	3(2+1)	II
3.	AGRON-505	Conservation agriculture	2(1+1)	II
4.	ENT-508	Concepts of integrated pest management	2(2+0)	III
5.	PP-505	Hormonal regulation of plant growth and development	3(2+1)	III
Maximum selected credit Hrs.			8	
Supporting Courses				
1.	STAT-511	Experimental Designs	3(2+1)	II
2.	PP-501	Principles of Plant physiology, plant water relations and mineral nutrition	3(2+1)	I
Total			6	
Common Courses				
PGS-501	Library And Information Services (Library)		1(0+1)	I
PGS-502	Technical Writing and Communications Skill (Extension Department)		1(0+1)	I
PGS-503	Intellectual Property and Its Management in Agriculture (Genetics & Plant breeding department)		1(0+1)	II
PGS-504	Basic Concept in Laboratory Techniques (Soil Science & Agril. Chemistry)		1(0+1)	II
PGS-505	Agriculture Research, Research Ethics and Rural Development Programmes (Agronomy)		1(0+1)	III
Total credit Hrs.			5(0+5)	
SOIL-591	Master's Seminar		1(1+0)	III
SOIL-599	Master's Research		30(0+30)	I-IV
Grand Total Credit Hrs.			70	

Objective:

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

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 of hydraulic 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; soil temperature management.

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.

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

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

Suggested Readings

- Baver LD, Gardner WH & Gardner WR. 1972. *Soil Physics*. John Wiley & Sons.
- Ghildyal BP & Tripathi RP. 2001. *Soil Physics*. New Age International. Hanks JR & 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 Physics*. 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 & Powers WL. 1972. *Advanced Soil Physics*. Wiley- Interscience.
- Kohnke H. 1968. *Soil Physics*. McGraw Hill.
- Lal R & Shukla MK. 2004. *Principles of Soil Physics*. Marcel Dekker. Oswal MC. 1994. *SoilPhysics*. Oxford & IBH.

SOIL 502

Soil fertility and fertilizer use

3(2+1)

Objective

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.

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 and alkali soils; factors affecting phosphorus availability in soils; phosphatic fertilizers - behavior in soils and management under field conditions. Potassium - forms, equilibrium in soils and its agricultural significance; mechanism of potassium fixation; management of potassium fertilizers under field conditions.

UNIT V

Sulphur - source, forms, fertilizers and their behavior in soils; role in crops and human 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; speciality fertilizers concept, need and category. Current status of speciality fertilizers use in soils and crops of India;

UNIT IX

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

UNIT X

Definitionandconceptsofsoilhealthandsoilquality;Longtermeffectsoffertilizersandsoilquality.

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)

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome: Experience on the knowledge of soil fertility and fertilizers

Suggested Readings

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

SOIL 503

Soil Chemistry

3(2+1)

Objective

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.

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 specific and non-specific sorption; precipitation-dissolution equilibria; Conceptof quantity/intensity(Q/I) relationship; step and constant-rate K; management aspects.

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

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 and conductivity 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 Δ (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.

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

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

Suggested Readings

- Bear RE. 1964. *Chemistry of the Soil*. Oxford and IBH.
- Bolt GH & Bruggenwert MGM. 1978. *Soil Chemistry*. Elsevier. Greenland DJ & Hayes MHB. 1981. *Chemistry of Soil Processes*. John Wiley & Sons.
- Greenland DJ & Hayes MHB. *Chemistry of Soil Constituents*. John Wiley & Sons.
- McBride MB. 1994. *Environmental Chemistry of Soils*. Oxford Univ. Press. Sposito G. 1981. *The Thermodynamics of Soil Solutions*. Oxford Univ. Press.
- Sposito G. 1984. *The Surface Chemistry of Soils*. Oxford Univ. Press. Sposito G. 1989. *The Chemistry of Soils*. Oxford Univ. Press.
- Stevenson FJ. 1994. *Humus Chemistry*. 2nd Ed. John Wiley & Sons. Van Olphan H. 1977. *Introduction to Clay Colloid Chemistry*. John Wiley & Sons.

SOIL 504

Soil mineralogy, genesis and classification

3(2+1)

Objective

To acquaint students with basic structure of alumino-silicate minerals and genesis of clay minerals; soil genesis in terms 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.

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 crystalline and non-crystalline clay minerals; identification techniques; amorphous soil constituents and other non crystalline silicate mineral sand their identification; clay minerals in Indian soils, role of clay miner als in plant nutrition, interaction of clay with humus, pesticides and heavy metals.

UNIT III

Factors of soil formation, soil formation models; soilforming processes; weathering of rock sand 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.

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 soils using available database in terms of soil quality

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

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

Suggested Readings

- Brady NC & 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 & 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 & Mattox RB. 1960. *Elements of Crystallography and Mineralogy*. Oxford & IBH.
- Wilding LP & Smeck NE. 1983. *Pedogenesis and Soil Taxonomy: II. The Soil Orders*. Elsevier.
- Wilding NE & Holl GF. (Eds.). 1983. *Pedogenesis and Soil Taxonomy*. I. *Concept an*.

SOIL 506

Soil Biology and Biochemistry

3(2+1)

Objective

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.

Theory

UNIT I

Soil biota, soil microbial ecology, types of organisms in different soils; soil microbial biomass; microbial interactions; un-culturable soil biota.

UNIT II

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

UNIT III

Microbial transformations of nitrogen, phosphorus, sulphur, iron and manganese in soil; biochemical composition and biodegradation of soil or ganicmatter and cropresidues, 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 vermi compost.

UNIT VI

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

UNIT VII

Biological indicators of soil quality; bioremediation of contaminated soils; microbial transformations of heavy metals in soil; role of soil organisms in pedogenesis

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, N₂ fixation, S oxidation, P solubilization and mineralization of other micro nutrients

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

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

Reading Materials:

1. Soil Microbiology and Biochemistry...by E.A.Paul and F.E.Clark
2. Soil Biotechnology...by J.M.Lynch
2. Prescott's Microbiology by J.M.Willey, Linda M. Sherwood and C.J.Woolverton.
3. Advances In Agricultural Microbiology by N.S. Subba Rao

SOIL 508

Soil, water and air pollution

2(1+1)

Objective

To make the students aware of the problems of soil, water and air pollution associated with use of soils for crop production.

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, oils pills 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 effect on soil properties/health, and plant growth and human beings; soil as sink for waste disposal.

UNIT IV

Pesticides—their classification, behaviour in soil and effect on 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—carbon dioxide, 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.

Practical

Sampling of sewage waters, sewages ludge, 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 ammonia calnitrogen and phosphorus, heavy metal content ineffluents, Heavy metals in contaminated soils and plants, Management of contaminants in soil and plants to safeguard food safety, Air sampling and determination of particulate matter and oxides of sulphur, **NO₂ and O₂ conc.** Visit to various industrial sites to study the impact of pollutants on soil and plants.

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome: Management of soil and water pollution

Suggested Readings

- Lal R, Kimble J, Levine E & 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 & Pierce 1983. *Environmental Pollution and Control*. Ann Arbor Science Publ.

SOIL 510 Analytical techniques and instrumental methods in soil and plant analysis 2(0+2)

Objective

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.

Practical

UNIT I

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

UNIT II

Determiration 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, ultraviolet and infrareds pectrophotometry, atomic absorption,flame-photometry, inductively coupled plasma spectrometry; chromatographic techniques, masss pectrometry and X-ray defractrometry; 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 soilfor 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) insoils; 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.

Teaching methods/activities: Classroom teaching and laboratory practicals

Learning outcome: Development of confidence for setting soil testing laboratory.

Suggested Readings

- Hesse P. 1971. *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 & Keeney DR. 1982. *Methods of Soil Analysis*. Part II. SSSA, Madison.
- Piper CE. *Soil and Plant Analysis*. Hans Publ.
- Singh D, Chhonkar PK & 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 Waters*. FDCO, New Delhi.
- Vogel AL. 1979. *A Textbook of Quantitative Inorganic Analysis*. ELBS Longman.

Department of Soil Science & Agricultural Chemistry

Ph.D. in Soil Science & Agricultural Chemistry

SN	Course No.	Course Name	Credit Hrs.	Semester
Major Courses				
1.	SOIL-601	Recent Trends in soil physics	2(2+0)	I
2.	SOIL-602	Modern Concept in Soil Fertility	2(2+0)	I
3.	SOIL-603	Physical Chemistry of Soil	2(2+0)	II
4.	SOIL-604	Soil Genesis and Micromorphology	2(2+0)	II
5.	SOIL-605	Biochemistry of Soil Organic Matter	2(2+0)	III
6.	SOIL-607	Modelling of Soil Plant System	2(2+0)	III
Total			12(12+0)	
Minor Courses (Choice based)				
1.	AGRON-605	Integrated farming system for sustainable agriculture	2(2+0)	II
2.	AGRON-607	Stress crop production	3(2+1)	III
3.	BIO CHEM-603	Biochemistry of biotic and abiotic stresses	3(3+0)	III
4.	PP-607	Physiological and molecular aspects of source sink capacity for enhancing yield	3(3+0)	II
Maximum selected credit Hrs.			6	
Supporting Courses				
1.	STAT-604	Advanced statistical methods	3(2+1)	II
2.	PP-606	Global Climate Change and Crop Response	2(2+0)	II
Total credit Hrs.			5(4+1)	
3.	SOIL-691	Doctoral Seminar-I	1(1+0)	III
4.	SOIL-692	Doctoral Seminar-II	1(1+0)	IV
5.	SOIL-699	Doctoral Research	75	
Grand total credit Hrs.			100	

SOIL 601

Recent Trends in Soil Physics

2(2+0)

Objective To provide knowledge of modern concepts in soil physics.

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

UNIT III

Theories of horizontal and vertical infiltration under different boundary conditions.

UNIT IV

Movement of salts in soils, models for miscible-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 heat flow, 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 evapo transpiration 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.

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

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

Suggested Readings

- Baver LD, Gardner WH & 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 Physics*. Academic Press.
- Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
- Kirkham D & Powers WL. 1972. *Advanced Soil Physics*. Wiley Interscience.
- Lal R & Shukla MK. 2004. *Principles of Soil Physics*. Marcel Dekker. Oswal MC.1994. *SoilPhysics*. Oxford & IBH.

SOIL 602

Modern concept in soil fertility

2(2+0)

Objective

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

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 equilibria) involving nutrientions in soils, particularly in submerged soils; Kinetic studies of nutrients in soils.

UNIT IV

Modern concepts offer tilizer evaluation, nutrient use efficiency and nutrient budgeting.

UNIT V

Modern concepts 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-anutrient central to soil fertility; carbon cycle in nature, stocks, pools and fluxes; green house effect and climate change; carbon sequestration vis-à-vis sustenance of soil quality and crop productivity.

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome: Experience on the knowledge of soil fertility and fertilizers

Suggested Readings

- Barber SA. 1995. *Soil Nutrient Bioavailability*. John Wiley & Sons.
- Barker V Allen & Pilbeam David J. 2007. *Handbook of Plant Nutrition*. CRC / Taylor & Francis.
- Brady NC & 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 & Govindarajan K. 2004. *Biofertilizers Technology*. Scientific Publ.
- Mortvedt JJ, Shuman LM, Cox FR & Welch RM. (Eds.). 1991. *Micronutrients in Agriculture*. 2nd Ed. Soil Science Society of America, Madison.
- Prasad R & Power JF. 1997. *Soil Fertility Management for Sustainable Agriculture*. CRC Press.
- Stevenson FJ & 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 & 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.

SOIL 603

Physical chemistry of soil

2(2+0)

Objective

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

UNIT I

Colloidal chemistry of inorganic 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 mineralogy 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 inorganic surfaces and organic surfaces of soil materials (citation of utility in agricultural system).

UNIT V

Common solubility equilibria- carbonates, iron oxide and hydroxides, aluminum silicate, aluminum-phosphate; electro chemical properties of clays (citation of examples from agricultural use).

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

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

Suggested Readings

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

SOIL 604

Soil genesis and micromorphology

2(2+0)

Objective

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

Theory

UNIT I

Pedogenic evolution of soils; soil composition and characterization.

UNIT II

Weather in 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.

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

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

Suggested Readings

- Brady NC & 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 & 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 & Mattox RB. 1960. *Elements of Crystallography and Mineralogy*. Oxford & IBH.

SOIL 605

Biochemistry of soil organic matter

2(2+0)

Objective

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

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; trace metal 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.

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

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

Reading Materials:

1. Soil Microbiology and Biochemistry...by E.A. Paul and F.E.Clark
2. Soil Biotechnology...by J.M.Lynch
3. Prescott's Microbiology.....by J.M. Willey, Linda M. Sherwood and C.J.Woolverton.
4. Advances In Agricultural Microbiology by N.S. Subba Rao

Objective

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

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

Teaching methods/activities: Classroom teaching with AV aids, group discussion, oral presentation by students.

Learning outcome: Experience on soil modelling concept for forecasting productivity

Suggested reading

- Theory and Principles of Simulation Modeling in Soil-Plant System. S.C. Datta, Capital Publishing Company, New Delhi, 2008.
- Modeling Carbon and Nitrogen Dynamics for Soil Management. 2001, Edited by M.J. Shaffer, L. Ma and S. Hansen, Lewis Publishers, Boca Raton, Fl Mathematical Models in Agriculture - A Quantitative approach to problems in agriculture and related science. J. Frame and J.H.M Thornley, Butterworth and Co. Ltd., 1984
- Modeling Plant and Soil System. J. Hanks and J.T. Richie (Eds.) Agronomy Bulletin No.31, ASA, SSSA Madison, Wisconsin, USA.
- Simulation of Accumulation and Leaching in Soils. M.I.Frissel, and P. Reinger Oxford and IBM Pub.Co. New Delhi 1974.
- Regression Methods - A tool for data Analysis, R.J. Freud and P.D. Minton, Marcel Dekker Inc., New York.
- Schaum's Outline Series- Theory and Problems of programming with Fortran. S. Lipschutz and A. Poe., McGraw-Hill Book Co., Singapore.
- Simulation of ecophysiological processes of growth in several annual crops. F.W.T Penning de Vries, D.M. Jansen, H.F.M. Ten Berge and A, Baker, PUDOC, Wageningen 1989.

Department of Plant Pathology

M.Sc. (Ag.) in Plant Pathology

Course code	Course Title	Credits	Semester
Major Courses			
PL PATH 501	Mycology	3(2+1)	I
PL PATH 502	Plant Virology	3(2+1)	II
PL PATH 503	Plant Pathogenic Prokaryotes	3(2+1)	I
PL PATH 504	Plant Nematology	3(2+1)	III
PL PATH 505	Principles of Plant Pathology	3(2+1)	II
PL PATH 506	Techniques in Detection and Diagnosis of Plant Diseases	2(0+2)	I
PL PATH 515	Diseases of Field and Medicinal Crops	3(2+1)	II
Total		20	
Minor Courses			
ENT-509	Pest of Field Crops	3(2+1)	II
ENT-506	Toxicology of Insecticides	3(2+1)	II
ENT-508	Concepts of IPM	2(2+0)	III
ENT-511	Post-harvest Entomology	2(1+1)	III
Total		8	
Supporting Courses (To be taken 06 credit only) STAT-511 is compulsory			
STAT-511	Experimental Design	3(2+1)	II
*PL PATH 507	Principles of Plant Disease Management	3(2+1)	IV
*PL PATH 511	Chemicals and Botanicals in Plant Disease Management	3(2+1)	IV
*PL PATH 517	Diseases of Vegetable and Spices Crops	3(2+1)	IV
*PL PATH 509	Disease Resistance in Plants	2(2+0)	IV
*PL PATH 513	Biological Control of Plant Diseases	2(1+1)	IV
*PL PATH 508	Epidemiology and Forecasting Of Plant Diseases	1(1+0)	IV
*PL PATH 514	Integrated Disease Management	3(2+1)	IV
*PL PATH 519	Plant Quarantine and Regulatory Measures	1(1+0)	IV
*PL PATH 516	Diseases of Fruits, Plantation and Ornamental Crops	3(2+1)	IV
Total		6	
Common courses			
PGS-501	Library And Information Services	1(0+1)	I
PGS-502	Technical Writing and Communications Skill	1(0+1)	I
PGS-503	Intellectual Property and Its Management in Agriculture	1(0+1)	II
PGS-504	Basic Concept in Laboratory Techniques	1(0+1)	II
PGS-505	Agriculture Research, Research Ethics and Rural Development Programmes	1(0+1)	III
Total		5	
Others courses			
PL PATH-591	Master's Seminar	1(1+0)	III
PL PATH-5021	Research work [M.Sc. Thesis]	30(0+30)	
Total		31	

* Minimum 5 students must be taken to run the course(s) in the concerned semester. Otherwise student should be opted another course.

Objective

To study the nomenclature, classification and characters of fungi.

Theory

UNIT I

Introduction, definition of different terms, basic concepts. Importance of mycology in agriculture, relation of fungi to human affairs. History of mycology. Importance of culture collection and herbarium of fungi. Somatic characters and reproduction in fungi. Modern concept of nomenclature and classification, Classification of kingdom fungi: Stramenopila and Protists.

UNIT II

The general characteristics of protists and life cycle in the Phyla Plasmodiophoromycota, Dictyosteliomycota, Acrasiomycota and Myxomycota. Kingdom Stramenopila: characters and life cycles of respective genera under Hypochytriomycota, Oomycota and Labyrinthulomycota.

UNIT III

Kingdom fungi: General characters, ultrastructure and life cycle patterns in representative genera under Chytridiomycota, Zygomycota, Ascomycota; Archiascomycetes, Ascomycetous yeasts, Pyrenomycetes, Plectomycetes, Discomycetes, Loculoascomycetes, Erysiphales and anamorphs of ascomycetous fungi.

UNIT IV

Basidiomycota; general characters, mode of reproduction, types of basidiocarps and economic importance of Hymenomycetes. Uridinales and Ustilaginales; variability, host specificity and life cycle pattern in rusts and smuts. Mitosporic fungi; status of asexual fungi, their teliomorphic relationships, Molecular characterization of plant pathogenic fungi.

Practical

Detailed comparative study of different groups of fungi; Collection of cultures and live specimens. Saccardoan classification and classification based on conidiogenesis. Vegetative structures and different types of fruiting bodies produced by slime molds, stramenopiles and true fungi. Myxomycotina: Fructification, plasmodiocarp, sporangia, plasmodium and aethalia. Oomycota; somatic and reproductive structures of *Pythium*, *Phytophthora*, downy mildews and Albugo, Zygomycetes: Sexual and asexual structures of *Mucor*, *Rhizopus*, General characters of VAM fungi. Ascomycetes; fruiting structures, Erysiphales, and Eurotiales; general identification characters of Pyrenomycetes, Discomycetes, Loculoascomycetes and Laboulbeniomyces, Basidiomycetes; characters, ultrastructures and life cycle patterns in Ustilaginomycetes and Teliomycetes, Deuteromycetes; characters of Hyphomycetes and Coelomycetes and their teliomorphic and anamorphic states, Collection, preservation, culturing and identification of plant parasitic fungi. Application of molecular approaches and techniques for identification of fungal pathogens.

Suggested Readings:

- Ainsworth GC, Sparrow FK & Susman HS. 1973. *The Fungi – An Advanced Treatise*. Vol. IV (A & B). Academic Press, New York.
- Alexopoulos CJ, Mims CW & Blackwell M. 2000. *Introductory Mycology*. 5th Ed. John Wiley & Sons, New York.
- Maheshwari R 2016. *Fungi: Experimental Methods in Biology* 2nd edn. CRC Press, US. Mehrotra RS & Arneja KR. 1990. *An Introductory Mycology*. Wiley Eastern, New Delhi. Sarbhoy AK. 2000. *Text book of Mycology*. ICAR, New Delhi.
- Singh RS. 1982. *Plant Pathogens – The Fungi*. Oxford & IBH, New Delhi.

- Webster J. 1980. *Introduction to Fungi*. 2nd Ed. Cambridge Univ. Press, Cambridge, New York.

PL PATH 502

PLANT VIROLOGY

3(2+1)

Objective

To acquaint with the structure, virus- vector relationship, biology and management of plant viruses.

Theory

UNIT I

History and economic significances of plant viruses. General and morphological characters, composition and structure of viruses. Myco-viruses, arbo and baculo viruses, satellite viruses, satellite RNAs, phages, viroids and prions. Origin and evolution of viruses and their nomenclature and classification.

UNIT II

Genome organization, replication in selected groups of plant viruses and their movement in host. Response of the host to virus infection: biochemical, physiological, and symptomatic changes. Transmission of viruses and virus-vector relationship. Isolation and purification of viruses.

UNIT III

Detection and identification of plant viruses by using protein and nucleic acid based diagnostic techniques. Natural (R-genes) and engineering resistance to plant viruses.

UNIT IV

Virus epidemiology and ecology (spread of plant viruses in fields, host range and survival). Management of diseases caused by plant viruses.

Practical

Study of symptoms caused by plant viruses (followed by field visit). Isolation and biological purification of plant virus cultures. Bioassay of virus cultures on indicator plants and host differentials. Transmission of plant viruses (Mechanical, graft and vector and study of disease development). Plant virus purification (clarification, concentration, centrifugation, high resolution separation and analysis of virions), Electron microscopy for studying viral particle morphology. Antisera production, Detection and diagnosis of plant viruses with serological (ELISA), nucleic acid (Non-PCR–LAMP, Later flow micro array & PCR based techniques. Exposure to basic bio-informatic tools for viral genome analysis and their utilization in developing detection protocols and population studies (BLASTn tool, Primer designing software, Bioedit tool, Clustal X/W, MEGA Software).

Suggested Readings

- Bos L. 1964. *Symptoms of Virus Diseases in Plants*. Oxford & IBH., New Delhi.
- Brunt AA, Krabtree K, Dallwitz MJ, Gibbs AJ & Watson L. 1995. *Virus of Plants: Descriptions and Lists from VIDE Database*. CABI, Wallington.
- Gibbs A & Harrison B. 1976. *Plant Virology - The Principles*. Edward Arnold, London. Hull R. 2002.
- *Mathew's Plant Virology*. 4th Ed. Academic Press, New York.
- Noordam D. 1973. *Identification of Plant Viruses, Methods and Experiments*. Oxford & IBH, New Delhi.
- Wilson C, 2014. *Applied Plant Virology*. CABI Publishing England.

Objective

To acquaint with plant pathogenic prokaryote (procarya) and their structure, nutritional requirements, survival and dissemination.

Theory

UNIT I

Prokaryotic cell: History and development of Plant bacteriology, history of plant bacteriology in India. Evolution of prokaryotic life, Prokaryotic cytoskeletal proteins. Structure of bacterial cell. Structure and composition of gram negative and gram positive cell wall; synthesis of peptidoglycan; Surface proteins; Lipopolysaccharide structure; Membrane transport; fimbriae and pili (Type IV pili); Mechanism of flagellar rotatory motor and locomotion, and bacterial movement; Glycocalyx (S-layer; capsule); the bacterial chromosomes and plasmids; Operon and other structures in cytoplasm; Morphological feature of fastidious bacteria, spiroplasmas and Phytoplasmas.

UNIT II

Growth and nutritional requirements. Infection mechanism, role of virulence factors in expression of symptoms. Survival and dispersal of phytopathogenic prokaryotes.

UNIT III

Taxonomy of phytopathogenic prokarya: Taxonomic ranks hierarchy; Identification, Classification and nomenclature of bacteria, phytoplasma and spiroplasma. The codes of Nomenclature and characteristics. Biochemical and molecular characterization of phytopathogenic prokaryotes.

UNIT IV

Variability among phytopathogenic prokarya: general mechanism of variability (mutation); specialized mechanisms of variability (sexual like process in bacteria-conjugation; transformation; transduction); and horizontal gene transfer.

UNIT V

Bacteriophages, L form of bacteria, plasmids and bdellovibrios: Structure; Infection of host cells; phage multiplication cycle; Classification of phages, Use of phages in plant pathology/bacteriology, Lysogenic conversion; H Plasmids and their types, plasmid borne phenotypes. Introduction to bacteriocins. Strategies for management of diseases caused by phytopathogenic prokaryotes.

Practical

Study of symptoms produced by phytopathogenic prokaryotes. Isolation, enumeration, purification, identification and host inoculation of phytopathogenic bacteria. Stains and staining methods. Biochemical and serological characterization. Isolation of genomic DNA plasmid. Use of antibacterial chemicals/antibiotics. Isolation of fluorescent *Pseudomonas*. Preservation of bacterial cultures. Identification of prokaryotic organisms by using 16S rDNA, and other gene sequences. Diagnosis and management of important diseases caused by bacteria and mollicutes.

Suggested Readings

- Goto M. 1990. *Fundamentals of Plant Bacteriology*. Academic Press, New York.
- Jayaraman J & Verma JP. 2002. *Fundamentals of Plant Bacteriology*. Kalyani Publ., Ludhiana.
- Mount MS & Lacy GH. 1982. *Phytopathogenic Prokaryotes*. Vols. I, II Academic Press, New York.
- Salle AJ 1979. *Fundamental Principles of Bacteriology 7th edn*.
- Verma JP, Varma A & Kumar D. (Eds). 1995. *Detection of Plant Pathogens and their Management*. Angkor Publ., New Delhi.

Objective

To project the importance of nematodes in agriculture and impart basic knowledge on all aspects of plant nematology.

Theory

UNIT I

Characteristics of Phylum Nematoda and its relationship with other related phyla, history and growth of Nematology; nematode habitats and diversity- plant, animal and human parasites; useful nematodes; economic importance of nematodes to agriculture, horticulture and forestry.

UNIT II

Gross morphology of plant parasitic nematodes; broad classification, nematode biology, physiology and ecology.

UNIT III

Types of parasitism; nature of damage and general symptomatology; interaction of plant-parasitic nematodes with other organisms.

UNIT IV

Plant nematode relationships, cellular responses to infection by important phytonematodes; physiological specialization among phytonematodes.

UNIT V

Principles and practices of nematode management; integrated nematode management.

UNIT VI

Emerging nematode problems, Importance of nematodes in international trade and quarantine.

Practical

Studies on kinds of nematodes- free-living, animal, insect and plant parasites; nematode extraction from soil; extraction of migratory endoparasites, staining for sedentary endoparasites; examination of different life stages of important plant parasitic nematodes, their symptoms and histopathology.

Suggested Readings

- Dropkin VH. 1980. *An Introduction to Plant Nematology*. John Wiley & Sons, New York. Maggenti AR. 1981. *General Nematology*. Springer-Verlag, New York.
- Perry RN & Moens M. 2013. *Plant Nematology*. 2nd Ed. CABI Publishing: Wallingford, UK. Perry RN, Moens M, & Starr, JL. 2009. *Root-knot nematodes*, CABI Publishing: Wallingford, UK.
- Sikora RA, Coyne D, Hallman J and Timper P, 2018. *Plant Parasitic Nematodes in Subtropical and Tropical Agriculture*. 3rd edn. CABI Publishing, England.
- Thorne G. 1961. *Principles of Nematology*. McGraw Hill, New Delhi.
- Walia RK & Bajaj HK. 2003. *Text Book on Introductory Plant Nematology*. ICAR, New Delhi. Walia RK. & Khan MR. 2018. *A Compendium of Nematode Diseases of Crop Plants*, ICAR- AICRP (Nematodes), IARI, New Delhi.

Objective

To introduce the subject of Plant Pathology, its concepts and principles.

Theory

UNIT I

Importance, definitions and concepts of plant diseases, history and growth of plant pathology, biotic and abiotic causes of plant diseases.

UNIT II

Growth, reproduction, survival and dispersal of important plant pathogens, role of environment and host nutrition on disease development.

UNIT III

Host parasite interaction, recognition concept and infection, symptomatology, disease development- role of enzymes, toxins, growth regulators; defense strategies- oxidative burst; Phenolics, Phytoalexins, PR proteins, Elicitors. Altered plant metabolism as affected by plant pathogens.

UNIT IV

Genetics of resistance; 'R' genes; mechanism of genetic variation in pathogens; molecular basis for resistance; marker-assisted selection; genetic engineering for disease resistance.

Practical

Basic plant pathological techniques. Isolation, inoculation and purification of plant pathogens and proving Koch's postulates. Techniques to study variability in different plant pathogens. Purification of enzymes, toxins and their bioassay. Estimation of growth regulators, phenols, phytoalexins in resistant and susceptible plants.

Suggested Readings

- Agrios GN. 2005. *Plant Pathology*. 5th Ed. Academic Press, New York.
- Heitefuss R & Williams PH. 1976. *Physiological Plant Pathology*. Springer Verlag, Berlin, New York.
- Mehrotra RS & Aggarwal A. 2003. *Plant Pathology*. 2nd Ed. Oxford & IBH, New Delhi.
- Singh RS 2017. *Introduction to Principles of Plant Pathology*. 5th edn. MedTech, New Delhi.
- Singh RP 2012. *Plant Pathology* 2nd edn. Kalyani Publishers, New Delhi.
- Singh DP & Singh A. 2007. *Disease and Insect Resistance in Plants*. Oxford & IBH, New Delhi.
- Upadhyay RK & Mukherjee KG. 1997. *Toxins in Plant Disease Development and Evolving Biotechnology*. Oxford & IBH, New Delhi.

Objective

To impart training on various methods/techniques/instruments used in the study of plant diseases/pathogens

Practical

Detection of plant pathogens 1. based on visual symptoms, 2. Biochemical test 3. Using microscopic techniques, 4. Cultural studies; (use of selective media to isolate pathogens). 5. Biological assays

(indicator hosts, differential hosts) 6. Serological assays 7. Nucleic acid based techniques (Non-PCR–LAMP, Later flow microarray & PCR based- multiplex, nested, qPCR, immune capture PCR, etc.). Phenotypic and genotypic tests for identification of plant pathogens. Molecular identification (16S rDNA and 16s-23S rDNA intergenic spacer region sequences-prokaryotic organisms; and eukaryotic organism by ITS region) and whole genome sequencing. Volatile compounds profiling by using GC-MS and LC-MS. FAME analysis, Fluorescence in-situ Hybridization (FISH), Flow Cytometry, Phage display technique, biosensors for detection of plant pathogens. Genotypic tools such as genome/specific gene sequence homology comparison by BLAST (NCBI and EMBL) and electron microscopy techniques of plant virus detection and diagnosis.

Suggested readings

- Baudoin ABAM, Hooper GR, Mathre DE & Carroll RB. 1990. *Laboratory Exercises in Plant Pathology: An Instructional Kit*. Scientific Publ., Jodhpur.
- Dhingra OD & Sinclair JB. 1986. *Basic Plant Pathology Methods*. CRC Press, London, Tokyo. Fox RTV. 1993. *Principles of Diagnostic Techniques in Plant Pathology*, CABI Wallington.
- Mathews REF. 1993. *Diagnosis of Plant Virus Diseases*. CRC Press, Boca Raton, Tokyo. Pathak VN. 1984. *Laboratory Manual of Plant Pathology*. Oxford & IBH, New Delhi.
- Forster D & Taylor SC. 1998. *Plant Virology Protocols: From Virus Isolation to Transgenic Resistance. Methods in Molecular Biology*. Humana Press, Totowa, New Jersey.
- Matthews REF. 1993. *Diagnosis of Plant Virus Diseases*. CRC Press, Florida.
- Noordam D. 1973. *Identification of Plant Viruses, Methods and Experiments*. Cent. Agric. Pub. Doc. Wageningen.
- Trigiano RN, Windham MT & Windham AS. 2004. *Plant Pathology-Concepts and Laboratory Exercises*. CRC Press, Florida. Chakravarti BP. 2005. *Methods of Bacterial Plant Pathology*. Agrotech, Udaipur.

PL PATH 507

PRINCIPLES OF PLANT DISEASE MANAGEMENT

3(2+1)

Objective

To acquaint with different strategies for management of plant diseases.

Theory

UNIT I

Principles of plant disease management by cultural, physical, biological, chemical, organic amendments and botanicals methods of plant disease control, integrated control measures of plant diseases. Disease resistance and molecular approach for disease management.

UNIT II

History of fungicides, bactericides, antibiotics, concepts of pathogen, immobilization, chemical protection and chemotherapy, nature, properties and mode of action of antifungal, antibacterial and antiviral chemicals. Label claim of fungicides.

UNIT III

Application of chemicals on foliage, seed and soil, role of stickers, spreaders and other adjuvants, health *vis-a-vis* environmental hazards, residual effects and safety measures.

Practical :

Phytopathometry. Methods of in vitro evaluation of chemicals, antibiotics, bio agents against plant pathogens. Field evaluation of chemicals, antibiotics, bio agents against plant pathogens. Soil solarisation, methods of soil fumigation under protected cultivation. Methods of application of chemicals and bio control agents. ED and MIC values, study of structural details of sprayers and dusters. Artificial epiphytotic and screening of resistance.

Suggested Readings

Fry WE. 1982. *Principles of Plant Disease Management*. Academic Press, New York.

Hewitt HG. 1998. *Fungicides in Crop Protection*. CABI, Wallington. Marsh RW. 1972. *Systemic Fungicides*. Longman, New York.

Nene YL & Thapliyal PN. 1993. *Fungicides in Plant Disease Control*. Oxford & IBH, New Delhi. Palti J. 1981. *Cultural Practices and Infectious Crop Diseases*. Springer Verlag, New York.

Vyas SC. 1993 *Handbook of Systemic Fungicides*. Vols. I-III. Tata McGraw Hill, New Delhi.

PL PATH 508

EPIDEMIOLOGY AND FORECASTING OF PLANT DISEASES

1(1+0)

Objective

To acquaint with the principles of epidemiology and its application in disease forecasting.

Theory

UNIT I

Epidemic concepts, simple interest and compound interest disease, historical development. Elements of epidemics and their interaction. Structures and patterns of epidemics. Modelling, system approaches and expert systems in plant pathology.

UNIT II

Genetics of epidemics. Models for development of plant disease epidemics. Common and natural logarithms, function fitting, area under disease progress curve and correction factors, inoculum dynamics. Population biology of pathogens, temporal and spatial variability in plant pathogens.

UNIT III

Epidemiological basis of disease management. Survey, surveillance and vigilance. Remote sensing techniques and image analysis. Crop loss assessment.

UNIT IV

Principles and pre-requisites of forecasting, systems and factors affecting various components of forecasting, some early forecasting and procedures based on weather and inoculum potential, modelling disease growth and disease prediction. Salient features of important forecasting models.

Suggested Readings

- Campbell CL & Madden LV. 1990. *Introduction to Plant Disease Epidemiology*. John Wiley & Sons, New York
- Cooke B, Jones DM and Gereth KB 2018 *The Epidemiology of Plant Diseases*. Springer Publications. Cowling EB & Horsefall JG. 1978. *Plant Disease*. Vol. II. Academic Press, New York.
- Laurence VM, Gareth H & Frame Van den Bosch (Eds.). *The Study of Plant Disease Epidemics*. APS, St. Paul, Minnesota.
- Nagarajan S & Murlidharan K. 1995. *Dynamics of Plant Diseases*. Allied Publ., New Delhi.
- Thresh JM. 2006. *Plant Virus Epidemiology*. Advances in Virus Research 67, Academic Press, New York.
- Van der Plank JE. 1963. *Plant Diseases Epidemics and Control*. Academic Press, New York.
- Zadoks JC & Schein RD. 1979. *Epidemiology and Plant Disease Management*. Oxford Univ. Press, London.

Objective

To acquaint with the disease resistance mechanisms.

Theory**UNIT I**

Introduction and historical development, dynamics of pathogenicity, process of infection, variability in plant pathogens, gene centres as sources of resistance, disease resistance terminologies. Disease escape, non-host resistance and disease tolerance.

UNIT II

Genetic basis of disease resistance, types of resistance, identification of physiological races of pathogen, disease progression in relation to resistance, stabilizing selection pressure in plant pathogens. UNIT III

Host defence system, morphological and anatomical resistance, pre-formed chemicals in host defence, post-infectious chemicals in host defence, phytoalexins, hypersensitivity and its mechanisms. Genetic basis of relationships between pathogen and host, Gene-for-gene concept, protein-for-protein and immunization basis, management of resistance genes. Strategies for gene deployment.

Suggested Readings

- Deverall BJ. 1977. *Defence Mechanisms in Plants*. Cambridge Univ. Press, Cambridge, New York. Mills Dallice *et al.* 1996. *Molecular Aspects of Pathogenicity and Resistance: Requirement for Signal Transduction*. APS, St Paul, Minnesota.
- Parker J. 2008. *Molecular Aspects of Plant Diseases Resistance*. Blackwell Publ. Robinson RA. 1976. *Plant Pathosystems*. Springer Verlag, New York.
- Singh BD. 2005. *Plant Breeding – Principles and Methods*. 7th Ed. Kalyani Publ., Ludhiana Van der Plank JE. 1975. *Principles of Plant Infection*. Academic Press, New York.
- Van der Plank JE. 1978. *Genetic and Molecular Basis of Plant Pathogenesis*. Springer Verlag, New York.
- Van der Plank JE. 1982. *Host Pathogen Interactions in Plant Disease*. Academic Press, New York. Van der Plank JE. 1984. *Disease Resistance in Plants*. Academic Press, New York.

Objective

To provide knowledge on the concepts, principles and judicious use of chemicals and botanicals in plant disease management.

Theory**UNIT I**

History and development of chemicals; definition of pesticides and related terms; advantages and disadvantages of chemicals and botanicals.

UNIT II

Classification of chemicals used in plant disease management and their characteristics.

UNIT III

Chemicals in plant disease control, viz., fungicides, bactericides, nematocides, antiviral chemicals and botanicals. Issues related to label claim.

UNIT IV

Formulations, mode of action and application of different fungicides; chemotherapy and phytotoxicity of fungicides.

UNIT V

Handling, storage and precautions to be taken while using fungicides; compatibility with other agrochemicals, persistence, cost-benefit ratio, factor affecting fungicides. New generation fungicides and composite formulations of pesticides.

UNIT VI

Efficacy of different botanicals used and their mode of action. Important botanicals used against diseases. General account of plant protection appliances; environmental pollution, residues and health hazards, fungicidal resistance in plant pathogens and its management.

Practical

Acquaintance with formulation of different fungicides and plant protection appliances. Formulation of fungicides, bactericides and nematicides; *in vitro* evaluation techniques, preparation of different concentrations of chemicals including botanical pesticides against pathogens; persistence, compatibility with other agro-chemicals; detection of naturally occurring fungicide resistant mutants of pathogen; methods of application of chemicals.

Suggested Readings:

- Bindra OS & Singh H. 1977. *Pesticides - And Application Equipment*. Oxford & IBH, New Delhi. Nene YL & Thapliyal PN. 1993. *Fungicides in Plant Disease Control*. 3rd edn. Oxford & IBH, New Delhi.
- Torgeson DC (Ed.). 1969. *Fungicides*. Vol. II. An Advanced Treatise. Academic Press, New York. Vyas SC. 1993. *Handbook of Systemic Fungicides*. Vols. I-III. Tata McGraw Hill, New Delhi

PL PATH 513

BIOLOGICAL CONTROL OF PLANT PATHOGENS

2(1+1)

Objective

To study principles and application of ecofriendly and sustainable management strategies of plant diseases.

Theory

UNIT I

Concept of biological control, definitions, importance, principles of plant disease management with bioagents, history of biological control, merits and demerits of biological control.

UNIT II

Types of biological interactions, competition: mycoparasitism, exploitation for hypovirulence, rhizosphere colonization, competitive saprophytic ability, antibiosis, induced resistance, mycorrhizal associations, operational mechanisms and its relevance in biological control.

UNIT III

Factors governing biological control, role of physical environment, agroecosystem, operational mechanisms and cultural practices in biological control of pathogens, pathogens and antagonists and their relationship, biocontrol agents, comparative approaches to biological control of plant pathogens by resident and introduced antagonists, control of soil-borne and foliar diseases. Compatibility of bioagents with agrochemicals and other antagonistic microbes.

UNIT IV

Commercial production of antagonists, their delivery systems, application and monitoring, biological

control in IDM, IPM and organic farming system, biopesticides available in market. Quality control system of biocontrol agents.

Practical

Isolation, characterization and maintenance of antagonists, methods of study of antagonism and antibiosis, application of antagonists against pathogen *in vitro* and *in vivo* conditions. Preparation of different formulations of selected bioagents and their mass production. Quality parameters of biocontrol agents. One week exposure visit to commercial biocontrol agents production unit.

Suggested Readings :

- Campbell R. 1989. *Biological Control of Microbial Plant Pathogens*. Cambridge Univ. Press, Cambridge.
- Cook RJ & Baker KF. 1983. *Nature and Practice of Biological Control of Plant Pathogens*. APS, St. Paul, Minnesota.
- Fokkema MJ. 1986. *Microbiology of the Phyllosphere*. Cambridge Univ. Press, Cambridge.
- Gnanamanickam SS (Eds). 2002. *Biological Control of Crop Diseases*. CRC Press, Florida.
- Heikki MT & Hokkanen James M (Eds.). 1996. *Biological Control - Benefits and Risks*. Cambridge Univ. Press, Cambridge.
- Mukerji KG, Tewari JP, Arora DK & Saxena G. 1992. *Recent Developments in Biocontrol of Plant Diseases*. Aditya Books, New Delhi.

PL PATH 514

INTEGRATED DISEASE MANAGEMENT

3(2+1)

Objective

To emphasize the importance and the need of IDM in the management of diseases of important crops. **Theory**

UNIT I

Introduction, definition, concept and tools of disease management, components of integrated diseasemanagement- their limitations and implications.

UNIT II

Development of IDM-basic principles, biological, chemical and cultural disease management.

UNIT III

IDM in important crops- rice, wheat, cotton, sugarcane, chickpea, rapeseed and mustard, pearl millet, pulses, vegetable crops, fruit, plantation and spice crops.

Practical

Application of physical, biological and cultural methods, Use of chemical and biocontrol agents, their compatibility and integration in IDM. Demonstration of IDM and multiple disease management in crops of regional importance as project work.

Suggested Readings:

- Gupta VK & Sharma RC. (Eds). 1995. *Integrated Disease Management and Plant Health*. Scientific Publ., Jodhpur.
- Mayee CD, Manoharachary C, Tilak KVBR, Mukadam DS & Deshpande Jayashree (Eds.). 2004. *Biotechnological Approaches for the Integrated Management of Crop Diseases*. Daya Publ. House, New Delhi.
- Sharma RC & Sharma JN. (Eds). 1995. *Integrated Plant Disease Management*. Scientific Publ., Jodhpur.

PL PAT 515

DISEASES OF FIELD AND MEDICINAL CROPS

3(2+1)

Theory

UNIT I

Diseases of Cereal crops- Rice, wheat, barley, pearl millet, sorghum and maize.

UNIT II

Diseases of Pulse crops- gram, urdbean, mungbean, lentil, pigeonpea, soybean and cowpea.

UNIT III

Diseases of Oilseed crops- rapeseed and mustard, sesame, linseed, sunflower, groundnut, castor.

UNIT IV

Diseases of Cash crops- cotton, sugarcane.

UNIT V

Diseases of Fodder legume crops- berseem, oats, guar, lucerne,

UNIT VI

Medicinal crops- plantago, liquorice, *mulathi*, rosagrass, sacred basil, mentha, *ashwagandha*, *Aloe vera* 71

Practical

Detailed study of symptoms and host parasite relationship of important diseases of above mentioned crops. Collection and dry preservation of diseased specimens of important crops.

Suggested Readings

- Joshi L M, Singh D.V & Srivastava K. D. 1984. *Problems and Progress of Wheat Pathology in South Asia*. Malhotra Publ. House, New Delhi.
- Rangaswami G. 1999. *Diseases of Crop Plants in India*. 4th Ed.. Prentice Hall of India, New Delhi. Ricanel C, Egan BT, Gillaspie Jr AG & Hughes CG. 1989. *Diseases of Sugarcane, Major Diseases*. Academic Press, New York.
- Singh RS. 2017. *Plant Diseases*. 10th Ed. Medtech, New Delhi.
- Singh US, Mukhopadhyay AN, Kumar J & Chaube HS. 1992. *Plant Diseases of International Importance*. Vol. I. *Diseases of Cereals and Pulses*. Prentice Hall, Englewood Cliffs, New Jersey.

PL PATH 516

DISEASES OF FRUITS, PLANTATION AND ORNAMENTAL CROPS

3(2+1)

Objective

To acquaint with diseases of fruits, plantation, ornamental plants and their management.

Theory

UNIT I

Introduction, symptoms and etiology of different fruit diseases. Factors affecting disease development in fruits like apple, pear, peach, plum, apricot, cherry, walnut, almond, strawberry, citrus, mango, grapes, guava, *ber*, banana, pineapple, papaya, fig, pomegranate, date palm custard apple and their management.

UNIT II

Symptoms, mode of perpetuation of diseases of plantation crops such as tea, coffee, rubber and coconut and their management.

UNIT III

Symptoms and life cycle of pathogens. Factors affecting disease development of ornamental plants such as roses, gladiolus, tulip, carnation, gerbera orchids, marigold, chrysanthemum and their management.

Practical

Detailed study of symptoms and host parasite relationship of representative diseases of plantation crops. Collection and dry preservation of diseased specimens of important crops.

Suggested Readings:

- Gupta V. K. & Sharma S. K. 2000. *Diseases of Fruit Crops*. Kalyani Publ., New Delhi. Pathak V. N. 1980. *Diseases of Fruit Crops*. Oxford & IBH, New Delhi.
- Singh R. S. 2000. *Diseases of Fruit Crops*. Oxford & IBH, New Delhi. Walker J. C. 2004. *Diseases of Vegetable Crops*. TTPP, India.

PL PATH 517

DISEASES OF VEGETABLE AND SPICES CROPS

3(2+1)

Objective:

To impart knowledge about symptoms, epidemiology of different diseases of vegetables and spices and their management.

Theory

UNIT I

Nature, prevalence, factors affecting disease development of tuber, bulb, leafy vegetable, crucifers, cucurbits and solanaceous vegetables. Diseases of crops under protected cultivation.

UNIT II

Symptoms and management of diseases of different root, tuber, bulb, leafy vegetables, crucifers, cucurbits and solanaceous vegetable crops.

UNIT III

Symptoms, epidemiology and management of diseases of different spice crops such as black pepper, nutmeg, saffron, cumin, coriander, turmeric, fennel, fenugreek and ginger. Biotechnological approaches in developing disease resistant transgenics.

Practical

Detailed study of symptoms and host pathogen interaction of important diseases of vegetable and spice crops.

Suggested Readings

- Chaube HS, Singh US, Mukhopadhyay AN & Kumar J. 1992. *Plant Diseases of International Importance*. Vol. II. *Diseases of Vegetable and Oilseed Crops*. Prentice Hall, Englewood Cliffs, New Jersey.
- Gupta VK & Paul YS. 2001. *Diseases of Vegetable Crops*. Kalyani Publ., New Delhi
- Sherf AF & McNab AA. 1986. *Vegetable Diseases and their Control*. Wiley InterScience, Columbia. Singh RS. 1999. *Diseases of Vegetable Crops*. Oxford & IBH, New Delhi.
- Gupta SK & Thind TS. 2006. *Disease Problem in Vegetable Production*. Scientific Publ., Jodhpur. Walker JC. 1952. *Diseases of Vegetable Crops*. McGraw-Hill, New York.

PL PATH 519

PLANT QUARENTINE AND REGULATIONS

1(1+0)

Objective

To acquaint the learners about the principles and the role of plant quarantine in containment of pests and diseases, plant quarantine regulations and set-up.

Theory

UNIT I

Historical development in plant quarantine, Definitions of pest, and transgenics as per Govt.

notification; Organizational set up of plant quarantine in India. relative importance; quarantine – domestic and international. Quarantine restrictions in the movement of agricultural produce, seeds and planting material; case histories of exotic pests/diseases and their status.

UNIT II

Acts related to registration of pesticides and transgenics. History of quarantine legislations, Salient features of PQ Order 2003. Environmental Acts, Industrial registration; APEDA, Import and Export of bio-control agents.

UNIT III

Identification of pest/disease free areas; contamination of food with toxigens, microorganisms and their elimination; Symptomatic diagnosis and other techniques to detect pest/pathogen infestations; VHT and other safer techniques of disinfestation/salvaging of infected material.

UNIT IV

WTO regulations; non-tariff barriers; Pest risk analysis, good laboratory practices for pesticide laboratories; pesticide industry; Sanitary and Phytosanitary measures. Visit to plant quarantine station and PEQ facilities.

Suggested Readings:

- Rajeev K & Mukherjee RC. 1996. *Role of Plant Quarantine in IPM*. Aditya Books.
- Rhower GG. 1991. Regulatory Plant Pest Management. In: *Handbook of Pest Management in Agriculture*. 2nd Ed. Vol. II. (Ed. David Pimental). CRC Press.

Department of Plant Pathology

Ph.D. in Plant Pathology

Course code	Course Title	Credits	Semester
Major Courses			
PL PATH 604	Molecular Basis Of Host-Pathogen Interaction	3(2+1)	I
PL PATH 601	Advances in Mycology	3(2+1)	I
PL PATH 602	Advances in Virology	3(2+1)	II
PL PATH 603	Advances in Plant Pathogenic Prokaryotes	3(2+1)	II
	Total credit	12	
Minor Courses			
ENT-604	Bio-inputs for Pest Management	3(2+1)	II
ENT-606	Insects Toxicology Residues	3(2+1)	II
ENT-603	Insect Ecology and Diversity	3(2+1)	I
	Total credit	06	
Supporting Courses			
STAT-604	Advanced Statistical Methods	3(2+1)	II
**STAT-612	Advances Design of Experiments	3(2+1)	II
PL PATH 605	Principles and Procedures of Certification	1(1+0)	III
PL PATH 606	Plant Biosecurity and Biosafety	2(2+0)	III
	Total	05	
PL PATH 691	Doctoral Seminar-I	1(0+1)	IV
PL PATH 692	Doctoral Seminar-II	1(0+1)	V
PL PATH 699	Doctoral Research	75(0+75)	
	Grand Total Credit	100	

***STAT 612 course is compulsory*

Objective

To acquaint with the advances in mycology

Theory**UNIT I**

General introduction, historical development and advances in mycology. Recent taxonomic criteria, morphological criteria for classification. Serological, chemical (chemotaxonomy), molecular and numerical (computer based assessment) taxonomy. Interaction between groups: Phylogeny, Micro conidiation, conidiogenesis and sporulating structures of fungi imperfecti.

UNIT II

Population biology, pathogenic variability/ vegetative compatibility. Heterokaryosis and parasexual cycle. Sex hormones in fungi. Pleomorphism and speciation in fungi. Mechanism of nuclear inheritance. Mechanism of extra-nuclear inheritance. Biodegradation.

UNIT III

Ultra structures and chemical constituents of fungal cells, functions of cell organelles. Mitosis, meiosis, gene action and regulation. Effects of fungal interaction with host plants and other microorganisms; parasitism, symbiosis and commensalism.

UNIT IV

Genetic Improvement of Fungal strains. Fungal biotechnology. Fungi mediated synthesis of nano particles - characterization process and application. Mycotoxins problems and its management.

Practical

Isolation, purification and identification of cultures, spores and mating type determination. Study of conidiogenesis-Phialides, porospores, arthrospores. Study of fruiting bodies in Ascomycotina. Identification of fungi up to species level. Study of hyphal anastomosis. Morphology of representative plant pathogenic genera from different groups of fungi. Molecular characterization of fungi.

Suggested Readings:

- Alexopoulos CJ, Mims CW & Blackwell M. 1996. *Introductory Mycology*. John Wiley & Sons, New York.
- Dube HC. 2005. *An Introduction to Fungi*. 3rd Ed. Vikas Publ. House, New Delhi.
- Kirk PM, Cannon PF, David JC & Stalpers JA. (Eds.). 2001. *Ainsworth and Bisby's Dictionary of Fungi*. 9th Ed., CABI, Wallington.
- Maheshwari R 2016. *Fungi: Experimental Methods in Biology* 2nd edn. CRC Press, US. Ulloa M & Hanlin RT. 2000. *Illustrated Dictionary of Mycology*. APS, St. Paul, Minnesota. Webster J & Weber R. 2007. *Introduction to Fungi*. Cambridge Univ. Press, Cambridge.

Objective

To educate about the advanced techniques and new developments in plant virology.

Theory**UNIT I**

Origin, evolution and interrelationship with animal viruses. Virus morphology, structure, architecture, replication (overview of host and viral components required), assembly and virus specific cytological effects in infected plant cells. Mechanisms leading to the evolution of new

viruses/strains: mutation, recombination, pseudo-recombination, component re-assortment etc.

UNIT II

Major vector groups of plant viruses and their taxonomy, virus-vector relationship, molecular mechanism of virus transmission by vectors. Terminologies used in immunology and serology. Classification, structure and functions of various domains of Immunoglobulins. Production of Polyclonal and monoclonal antibodies for detection of viruses. Immuno/serological assays (Slide agglutination tests, Test tube precipitation test, Double agar diffusion test, ELISA (DAC, DAS, TAS), Dot Immuno Binding Assay, and nucleic acid based assays for detection of plant viruses.

UNIT III

Polymerase Chain Reaction based (PCR, reverse transcriptase PCR, multiplex PCR, Nested PCR, Real time/q PCR) and non PCR based: LAMP, Fluorescent *in situ* hybridization (FISH), dot blot hybridization. Plant virus genome organization (General properties of plant viral genome-information content, coding and non-coding regions), replication, transcription and translational strategies of pararetroviruses, geminiviruses, tobamo-, poty-, bromo, cucumo, ilar, tospoviruses, satellite viruses and satellite RNA.

UNIT IV

Gene expression, regulation and viral promoters. Genetic engineering with plant viruses, viral suppressors, RNAi dynamics and resistant genes. Virus potential as vectors, genetically engineered resistance, transgenic plants. Techniques and application of tissue culture for production of virus free planting materials. Phylogenetic grouping system based on partial/complete sequences of virus genomes and using of next generation sequencing technology in plant virus discovery.

Practical:

Purification of viruses, SDS-PAGE for molecular weight determination, production of polyclonal antiserum, purification of IgG and conjugate preparation. Acquaintance with different serological techniques (i) DAC- ELISA (ii) DAS-ELISA (iii) DIBA (iv) Western blots (v) (ab) 2-ELISA. Nucleic acid isolation, DOT-blot, southern hybridization, probe preparation, and autoradiography. PCR application and viral genome cloning of PCR products, plasmid purification, enzyme digestion, sequencing, annotation of genes, analysis of viral sequences (use of gene bank, blast of viral sequences and phylogeny). Bioinformatics analysis tools for virology (ORF finder, Gene mark, Gene ontology, BLAST, Clustal X/W, Tm pred and Phylogeny programs).

Suggested Readings:

- Davies 1997. *Molecular Plant Virology: Replication and Gene Expression*. CRC Press, Florida. Fauquet et al. 2005. *Virus Taxonomy*. VIII Report of ICTV. Academic Press, New York.
- Gibbs A & Harrison B. 1976. *Plant Virology - The Principles*. Edward Arnold, London.
- Jones P, Jones PG & Sutton JM. 1997. *Plant Molecular Biology: Essential Techniques*. John Wiley & Sons, New York.
- Khan J. A. & Dijkstra. 2002. *Plant Viruses as Molecular Pathogens*. Howarth Press, New York. Maramorosch K, Murphy FA & Shatkin AJ. 1996. *Advances in Virus Research*. Vol. 46. Academic Press, New York.
- Pirone T. P. & Shaw JG. 1990. *Viral Genes and Plant Pathogenesis*. Springer Verlag, New York. Roger Hull 2002. *Mathew's Plant Virology (4th Ed.)*. Academic Press, New York.
- Thresh J. M. 2006. *Advances in Virus Research* Academic Press, New York.

PL PATH 603

ADVANCES IN PLANT PATHOGENIC PROKARYOTES

3(2+1)

Objective

To learn about the latest developments in all the plant pathogenic prokaryotes as a whole.

Theory

UNIT I

Prokaryotic cell: Molecular basis for origin and evolution of prokaryotic life, RNA world, prokaryotic cytoskeletal proteins. Flagella structure, assembly and regulation. Structure and composition (bacteria) cell wall/envelop, Types of secretion systems (TI to TIV) and their molecular interaction, fimbriae and pili (Type IV pili), Bacterial chromosomes and plasmids, other cell organelles. Growth, nutrition and metabolism in prokaryotes (Embden Meyerhof pathway, Phosphoketolase Pathway and Entner Doudoroff Pathway).

UNIT II

Current trends in taxonomy and identification of phytopathogenic prokaryotes: International code of nomenclature, Polyphasic approach, New/special detection methods for identification of bacterial plant pathogens. Taxonomic ranks hierarchy; Identification, Advances in classification and Nomenclature.

UNIT III

Bacterial genetics: General mechanism of variability (mutation), specialized mechanisms of variability. Transposable genetic elements in bacteria-integron and prophages, Mechanism of gene transfer. Pathogenicity islands, horizontal gene transfer, Bacterial Pan-Genome.

UNIT IV

Bacteriophages: Composition, structure and infection. Classification and use of phages in plant pathology/bacteriology. Host pathogen interactions: Molecular mechanism of pathogenesis: Pathogenicity factors of soft rot, necrosis, wilt, canker etc. Immunization, induced resistance/ Systemic Acquired Resistance, Quorum sensing. Bacterial pathogenicity and virulence: Molecular mechanism of virulence and pathogenesis, bacterial secretion systems, pathogenicity of bacterial enzymes that degrade the cell walls, Role of hrp/hrc genes and TALE effectors. Synthesis and regulation of EPSs.

UNIT V

Beneficial Prokaryotes-Endophytes, PGPR, Phylloplane bacteria and their role in disease management. Endosymbionts for host defence. Advances in management of diseases caused by prokaryotes: genetic engineering, RNA silencing; CRISPR cas9.

Practical

Pathogenic studies and race identification, plasmid profiling of bacteria, fatty acid profiling of bacteria, RFLP profiling of bacteria and variability status, Endospore, Flagella staining, Test for secondary metabolite production, cyanides, EPS, siderophore, specific detection of phytopathogenic bacteria using species/pathovar specific primers. Basic techniques in diagnostic kit development, Molecular tools to identify phytoendosymbionts. Important and emerging diseases and their management strategies.

Suggested Reading

- Dale JW & Simon P. 2004. *Molecular Genetics of Bacteria*. John Wiley & Sons, New York. Garrity GM, Krieg NR & Brenner DJ. 2006. *Bergey's Manual of Systematic Bacteriology: The Proteobacteria*. Vol. II. Springer Verlag, New York.
- Gnanamanickam SS. 2006. *Plant-Associated Bacteria*. Springer Verlag, New York.
- Mount MS & Lacy GH. 1982. *Plant Pathogenic Prokaryotes*. Vols. I, II. Academic Press, New York. Sigeo DC. 1993. *Bacterial Plant Pathology: Cell and Molecular Aspects*. Cambridge Univ. Press, Cambridge.
- Starr MP. 1992. *The Prokaryotes*. Vols. I – IV. Springer Verlag, New York.

PL PATH 604

MOLECULAR BASIS OF HOST-PATHOGEN INTERACTION

3(2+1)

Objective

To understand the concepts of molecular biology and biotechnology in relation to host plant-pathogen interactions.

Theory

UNIT I

History of host plant resistance and importance to Agriculture. Importance and role of biotechnological tools in plant pathology. Basic concepts and principles to study host pathogen relationship. Molecular genetics, imaging and analytical chemistry tools for studying plants, microbes, and their interactions.

UNIT II

Different forms of plant-microbe interactions and nature of signals/effectors underpinning these interactions. Plant innate immunity: PAMP/DAMP. Molecular basis of host-pathogen interaction-fungi, bacteria, viruses and nematodes; recognition system, signal transduction.

UNIT III

Induction of defence responses- HR, Programmed cell death, reactive oxygen species, systemic acquired resistance, induced systemic resistance, pathogenesis related proteins, phytoalexins and virus induced gene silencing. Molecular basis of gene-for-gene hypothesis; R-gene expression and transcription profiling, mapping and cloning of resistance genes and marker-aided selection, pyramiding of R genes. Gene for gene systems: Background, genetics, phenotypes, molecular mechanisms, races, breakdown of resistance (boom-and-bust cycles), Coevolution-arms race and trench warfare models, Metapopulations, cost of resistance, cost of unnecessary virulence, GFG in agricultural crops vs. natural populations, Durability of resistance, erosion of quantitative resistance.

UNIT IV

Pathogen population genetics and durability, viruses vs cellular pathogens. Gene deployment, cultivar mixtures. Disease emergence, host specialization. Circadian clock genes in relation to innate immunity. Biotechnology and disease management; development of disease resistance plants using genetic engineering approaches, different methods of gene transfer, biosafety issues related to GM crops.

Practical

Protein, DNA and RNA isolation, plasmid extraction, PCR analysis, DNA and Protein electrophoresis, bacterial transformation. Gene mapping and marker assisted selection. Development and use of molecular markers in identification and characterization of resistance to plant pathogens and their management.

Suggested Reading

- Chet I. 1993. *Biotechnology in Plant Disease Control*. John Wiley & Sons, New York.
- Gurr SJ, McPohersen MJ & Bowlos DJ. (Eds.). 1992. *Molecular Plant Pathology - A Practical Approach*. Vols. I & II, Oxford Univ. Press, Oxford.
- Mathew JD. 2003. *Molecular Plant Pathology*. Bios Scientific Publ., UK.
- Ronald PC. 2007. *Plant-Pathogen Interactions: Methods in Molecular Biology*. Humana Press, New Jersey.
- Stacey G & Keen TN. (Eds.). 1996. *Plant Microbe Interactions*. Vols. I-III. Chapman & Hall, New York; Vol. IV. APS Press, St. Paul, Minnesota.

PL PATH 605

PRINCIPLES AND PROCEDURES OF CERTIFICATION

1(1+0)

Objective

To acquaint with the certification procedures of seed and planting material.

Theory

UNIT I

Introduction to certification. International scenario of certification and role of ISTA, EPPO, OECD etc. in certification and quality control. Case studies of certification systems of USA and Europe. National Regulatory mechanism and certification system including seed certification, minimum seed certification standards. National status of seed health in seed certification. Methods for testing genetic identity, physical purity, germination percentage, seed health etc. Fixing tolerance limits for diseases and insect pests in certification and quality control programmes.

UNIT II

Methods used in certification of seeds, vegetative propagules and *in vitro* cultures. Accreditation of seed testing laboratories. Role of seed/planting material health certification in national and international trade.

Reference Books

- Association of Official Seed Certifying Agencies. <http://www.aosca.org/index.htm>. Hutchins D & Reeves JE. (Eds.). 1997.
- Seed Health Testing: Progress Towards the 21st Century. CABI, UK. ISHI-veg Manual of Seed Health Testing Methods. http://www.worldseed.org/enus/international_seed/ishi_vegetable.html
- ISHI-F Manual of Seed Health Testing Methods. http://www.worldseed.org/en-us/international_seed/ishi_f.html
- ISTA Seed Health Testing Methods. <http://www.seedtest.org/en/content--1--1132--241.html> Tunwar NS & Singh SV. 1988. Indian Minimum Seed Certification Standards. Central Seed
- Certification Board, Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi. US National Seed Health System. <http://www.seedhealth.org>

PL PATH 606

PLANT BIOSECURITY AND BIOSAFETY

2(2+0)

Objective

To facilitate deeper understanding on plant biosecurity and biosafety issues in agriculture.

Theory

UNIT I

History of biosecurity, Concept of biosecurity, Components of biosecurity, Quarantine, Invasive Alien Species, Biowarfare, Emerging / resurgence of pests and diseases. Introduction and History of biosecurity and its importance.

UNIT II

National Regulatory Mechanism and International Agreements/Conventions viz., Agreement on Application of Sanitary and Phytosanitary (SPS) Measures. World Trade Organization (WTO), Convention on Biological Diversity (CBD), International Standards for Phytosanitary Measures, pest risk analysis, risk assessment models, pest information system, early warning and forecasting system, use of Global Positioning System (GPS) and Geographic Information System (GIS) for plant biosecurity, pest/disease and epidemic management, strategies for combating risks and costs associated with agroterrorism event, mitigation planning, integrated approach for biosecurity.

UNIT III

Biosafety, policies and regulatory mechanism, Cartagena Protocol on Biosafety and its implications, Issues related to release of genetically modified crops. Emerging/resurgence of pests and diseases in the changing scenario of climatic conditions. Issues related to release of genetically modified crops.

Department of Agricultural Biochemistry

M.Sc.(Ag) in AGRICULTURAL BIOCHEMISTRY

COURSE CODE	COURSE TITLE	CREDITS	SEMESTER
MAJOR COURSES		20	
BIOCHEM-501*	Basic Biochemistry	4(3+1)	I
BIOCHEM -502*	Intermediary metabolism	3(3+0)	I
BIOCHEM -503*	Enzymology	3(2+1)	II
BIOCHEM -504	Molecular Biology	3(2+1)	III
BIOCHEM -505*	Techniques in Biochemistry	4(2+2)	II
BIOCHEM -507	Plant Biochemistry	3(2+1)	III
MINOR COURSES		8	
SS-506	Soil Biology and Biochemistry	3(2+1)	III
GPB-506	Molecular Breeding and Bio informatics	3(2+1)	II
PP-502	Metabolic Process and Growth Regulators	3(2+1)	I
FN-502	Public health and Nutrition	3(2+1)	I
FN-508	Nutritional Counseling	2(0+2)	III
SUPPORTING COURSES		6	
STAT-511	Experimental Designs	3(2+1)	II
PP-505	Hormonal Regulation of plant Growth and Development	3(2+1)	III
FN-509	Food Safety and Standard	3(2+1)	III
COMMON COURSES		5	
PGS-501	Library and Information services	1(0+1)	I (Library)
PGS-502	Technical writing and communication skill	1(0+1)	I (Ag. Extension)
PGS-503	Intellectual Property and its management in Agriculture	1(1+0)	II(GPB)
PGS-504	Basic concepts in Laboratory techniques	1(0+1)	II(Soil Chemistry)
PGS-505	Agricultural Research, research ethics and Rural Development Programme	1(1+0)	III (Agron)
OTHERS COURSES		31	
BIOCHEM -591	Master's Seminar	1(1+0)	III
BIOCHEM -599	Research Work [M.Sc. Thesis]	30	IV

* Core Course

Semester Wise Distribution

COURSE CODE	COURSE TITLE	CREDIT
FIRST SEMESTER		
BIOCHEM -501*	Basic Biochemistry	4(3+1)
BIOCHEM -502*	Intermediary Metabolism	3(3+0)
SECOND SEMESTER		
BIOCHEM -505*	Techniques In Biochemistry	4(2+2)
BIOCHEM -503*	Enzymology	3(2+1)
THIRD SEMESTER		
BIOCHEM -504	Molecular Biology	3(2+1)
BIOCHEM -507	Plant Biochemistry	3(2+1)
BIOCHEM -591	Master's Seminar	1(1+0)
FOURTH SEMESTER		
BIOCHEM -599	Research Work [M.Sc. Thesis]	30

**SYLLABUS
FOR
M.Sc. (AG) Agricultural Biochemistry**

BIOCHEM-501

BASIC BIOCHEMISTRY

4(3+1)

BLOCK 1: INTRODUCTION TO BIOCHEMISTRY

Unit 1: Scope and importance of biochemistry (One lecture)

Biochemistry as modern science and its various divisions, Scope and importance of biochemistry in agriculture and allied sciences.

Unit 2: Foundation of life(Two lectures)

Fundamental principles governing life, supramolecular structures, significance of weak non covalent interactions in biology

Unit 3: Water(Three lecture)

Structure of water, ionization of water, acid base concept, pH and buffers, significance of structure-function relationship

Unit 4: Physical techniques for structure determination(Two lectures)

General introduction to physical techniques for determination of structure of biopolymers

BLOCK 2: STRUCTURE AND FUNCTION OF BIOMOLECULES

Unit 1: Biomolecules(Ten lectures)

Structure, classification, properties and function of carbohydrates, amino acids, proteins, lipids and nucleic acids.

Unit 2: Immunoglobulin's and PR proteins(Two lectures)

Structure, formation and different forms of immunoglobulin's, PR proteins and their classification

Unit 3: Plant secondary metabolites(Three lectures)

Structure, classification and function of plant secondary metabolites

BLOCK 3: METABOLISM – THE BASICS

Unit 1: Molecules aiding metabolism(Two 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(Two lectures)

Fundamentals of thermodynamic principles applicable to biological processes, Bioenergetics.

BLOCK 4: CATABOLISM AND ITS REGULATION

Unit 1: molecules(Catabolism of energy Five lectures)

Important and basic degradative metabolic pathways of carbohydrates, lipids and proteins and their regulation

Unit 2: ATP formation (Three 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(Four lectures) Overview of replication, transcription and translation

Unit 2: Recombinant DNA technology(Three lectures) Restriction enzymes, DNA cloning,

applications of cloning, transgenics

PRACTICALS

1. Preparation of standard and buffer solutions
2. Detection of carbohydrates, amino acids and proteins
3. Extraction and estimation of sugars
4. Extraction and estimation of amino acids
5. Extraction and estimation of proteins
6. Estimation of acid value of fat/oil
7. Estimation of peroxide value of fat/oil
8. Estimation of saponification value in fats and oils
9. Fatty acid composition in fat/oil by GC
10. Estimation of DNA and RNA by spectroscopic methods
11. Estimation of Ascorbic acid
12. Separation of biomolecules by TLC and Paper chromatography
13. Estimation of alpha amylase activity Qualitative tests for secondary plant metabolites

TEACHING METHODS / ACTIVITIES

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz

READING SUGGESTIONS

- 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
- 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*. 4th edition 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
- Conn E. E., Stumpf, P. K., Bruening, G. and Doi, R. H. (2006). *Outlines of Biochemistry*. 5th edition. Wiley

BIOCHEM -502

INTEMDIATORY METABOLISM 3(3+0)

BLOCK 1: INTRODUCTION TO METABOLISM

Unit 1: Overview of metabolism (Four lectures)

The living cell - a unique chemical system, biochemical reaction types, bioenergetics, bioavailability of nutrients, transport mechanism, signal transduction.

Unit 2: Metabolic pathways (Five 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(Five lectures)**

Major catabolic and anabolic pathways of carbohydrate metabolism, the glyoxylate pathway

Unit 2: Lipid metabolism(Five lectures)

Fatty acid oxidation, ketone bodies, fatty acid biosynthesis, synthesis of triacylglycerols, cholesterol, eicosanoids

Unit 3: Protein metabolism(Three 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(Four lectures)

Mechanisms of energy transduction, electron transport system, oxidative phosphorylation, control of ATP production

BLOCK 3.SULPHUR AND NUCLEOTIDE METABOLISM**Unit 1: Sulphur metabolism(Five lectures)**

Sulphate reduction and incorporation of sulphate into amino acids

Unit 2: Nucleotide metabolism(Three lectures)

Synthesis and degradation of purine and pyrimidine nucleotides

BLOCK 4: METABOLIC REGULATION AND DEFECTS IN METABOLISM**Unit 1: Regulation of metabolic pathways (Four lectures)**

Regulation of carbohydrate, lipid, protein, nucleotide metabolism and oxidative phosphorylation

Unit 2: Defects in metabolism(Four lectures)

Disorders of carbohydrates, lipids, amino acids and nucleic acid metabolism, and inborn errors of metabolism. Metabolic pathway engineering.

TEACHING METHODS / ACTIVITIES

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

READING SUGGESTIONS

- 14. Essential Biochemistry. 3rd Edition. Wiley
- Moorthy, K. 2007. Fundamentals of Biochemical Calculations. 2nd edition. CRC Press 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. 6th edition 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. 4th edition . John Wiley.
- Pratt, C. W. and Cornely, K. 20

PRACTICALS

1. Soluble protein estimation
2. Enzyme assay by taking any model enzyme
3. Isolation and purification of any model enzyme
4. Study of the effect of enzyme and substrate concentrations on enzyme activity
5. Determination of K_m and V_{max}
6. Determination of pH and temperature optima
7. Effect of inhibitors on enzyme activity
8. Determination of pH and temperature stability of enzyme
9. Electrophoretic analysis of isozymes.

TEACHING METHODS / ACTIVITIES

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

READING SUGGESTIONS

- Palmer, T. and Bonner, P. L. 2007. Enzymes: Biochemistry, Biotechnology, Clinical Chemistry. 2nd edition. Woodhead Publishing
- Okotore, R. O. 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, T. D. H. 2012. Introduction to Enzyme and Coenzyme Chemistry, 3rd Edition. WILEY
- Guo, Y. 2014. Enzyme Engineering. Science Press
- Bisswanger, H. 2011. Practical Enzymology. Wiley-Blackwell

BIOCHEM -504

MOLECULAR BIOLOGY

3(2+1)

BLOCK 1: INTRODUCTION TO NUCLEIC ACIDS

Unit 1: History(One lecture)

Historical development of molecular biology, nucleic acids as genetic material

Unit 2: Properties of nucleic acid(Two 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(Three 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(Three 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(Three 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 (Two lectures)

Ribosomes structure and function, organization of ribosomal proteins and RNA genes, genetic code, aminoacyl tRNA synthases

Unit 2: Mechanism of protein synthesis(Two lectures)

Initiation, chain elongation and termination of translation, energetics, inhibitors of translation

Unit 3:Post-translational events(Two 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(Three lectures)

Importance, Sanger method,High-Throughput Sequencing (HTS) techniques, applications of DNA sequencing.

Unit 2: Recombinant DNA technology(Four 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(Three lectures)

Polymerase chain reaction (PCR), expression cloning, gel electrophoresis, molecular markers, macromolecule blotting and probing, arrays (DNA array and protein array) – principles and application

PRACTICALS

1. Isolation and purification of DNA and RNA
2. To check the purity of isolated DNA and RNA
3. Restriction fragmentation of genomic DNA
4. Separation of oligos by agarose gel electrophoresis
5. Southern blotting experiments
6. Northern blotting experiments
7. Cloning of DNA fragment in vector
8. Selection of recombinant

9. SSR analysis of DNA
10. cDNA synthesis using RT-PCR
11. Basic tools in bioinformatics analysis

TEACHING METHODS / ACTIVITIES

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

READING SUGGESTIONS

- 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, T. A., Bell, S. P., Gann, A., Levine, M. and Losick, R. 2014. *Molecular biology of the gene 7th edition*, Pearson

BIOCHEM -505

[TECHNIQUE IN BIOCHEMISTRY]

CREDIT-4(2+2)

BLOCK 1: SEPARATION TECHNIQUES

Principles and applications of separation techniques

Unit 1: Chromatography techniques(Four lectures)

Principles and applications of paper, thin layer, gel filtration, ion-exchange, affinity, column & HPTLC, GC, HPLC and FP

Unit 2: Electrophoretic technique(Two lectures)

General principles, paper and gel electrophoresis, native and SDS-PAGE, 2D-PAGE, capillary electrophoresis

Unit 3: Hydrodynamic methods(Two lectures)

Hydrodynamic methods of separation of biomolecules such as viscosity and sedimentation velocity, - their principles

Unit 4: Centrifugation(Two lectures)

Basic principles of sedimentation, type, care and safety aspects of centrifuge preparative and analytical centrifugation,

BLOCK 2: SPECTROSCOPIC TECHNIQUES

Unit 1: Spectrophotometry(Three lectures)

Principles and applications of UV-visible, Fluorescence, IR and FTIR, Raman, NMR and FTNMR, ESR and X-Ray spectroscopy

Unit 2: Mass spectroscopy(Three lectures)

MS/MS, LC-MS, GC-MS, MALDI-TOF, applications of mass spectrometry in biochemistry

Unit 3: Atomic absorption spectrophotometry(Two lectures)

Principle, function and instrumentation of atomic absorption spectrophotometry

BLOCK 3. MICROSCOPY

Unit 1: Microscopic techniques(Two 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(Two lectures)

Tracer techniques in biology: concept of radioactivity, radioactivity counting methods with principles of different types of counters, concept of α , β and γ emitters, scintillation counters, γ -ray spectrometers, autoradiography, applications of radioactive tracers in biology.

Unit 2: Imaging techniques(Two lectures)

Principles and applications of phosphor imager, MRI and CT scan.

Unit 3: Immunochemical technique(Two lectures)

Production of antibodies, immunoprecipitation, immunoblotting, immunoassays, RIA and ELISA

Unit 4: Other techniques(Two lectures)

Cryopreservation, polymerase chain reaction (PCR), FACS

PRACTICALS

1. Expression of concentration in terms of dilution, molarity, normality, percent expression
2. pH measurement and buffer preparation
3. Determination of absorption maxima of biomolecules
4. Estimation of biomolecules through spectrophotometry and other methods
5. Separation of carbohydrates and amino acids by paper chromatography
6. Separation and analysis of fatty acids/lipids by GC
7. Separation/estimation of biomolecules through HPLC and FPLC
8. Separation of proteins using ion exchange, gel filtration and affinity chromatography
9. Electrophoretic separation of proteins and nucleic acids
10. Centrifugation- differential and density gradient
11. $(\text{NH}_4)_2\text{SO}_4$ precipitation and dialysis
12. Use of radioisotopes in metabolic studies
13. PCR
14. ELISA
15. Western blotting/ Dot blotting

TEACHING METHODS / ACTIVITIES

- Classroom lectures (oral + audio-visual)

- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

READING SUGGESTIONS

- 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 & 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, J. W. (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

BIOCHEM -507

[PLANT BIOCHEMISTRY]

CREDITS-3(2+1)

BLOCK 1: PHOTOSYNTHESIS

Unit 1: Photosynthetic machinery (Three 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(Four lectures)

Carbon reduction in C₃, C₄ and CAM plants, photorespiration, sucrose-starch interconversion

BLOCK 2: CONVERSION OF PHOTOSYNTHATES

Unit 1: Synthesis of major biomolecules(Three lectures)

Biosynthesis of structural carbohydrates, storage proteins and lipids.

Unit 2: Nitrogen and sulphur metabolism(Five 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 DEVELOPMENT

Unit 1: Germination and fruit ripening(Four 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 (Three lectures)

classes of phytohormones, their biosynthesis and mode of action

Different

BLOCK 4: SECONDARY METABOLITES

Unit 1: Biochemistry of plant secondary metabolites(Six 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.

PRACTICALS

1. Fractionation of cell organelles,
2. Estimation of starch,
3. Assay of ADPG pyrophosphorylase/starch synthase,
4. Assay of PAL/SOD
5. Assay of PPO/LOX,
6. Estimation of individual amino acids,
7. Qualitative tests of secondary metabolites (alkaloids, sterols etc.)
8. Content and composition of carotenoids, anthocyanin and chlorophylls
9. Determination of polyphenols/phenolics
10. Fractionation of storage proteins
11. Estimation of glucosinolates
12. Estimation of cyanogenic compounds.

TEACHING METHODS / ACTIVITIES

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

READING SUGGESTIONS

- Buchanan, B.B., 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 & Mercer EI. 2005. *Introduction to Plant Biochemistry*. 2nd edition. CBS
- Heldt, H-W. and Piechulla, B. 2010. *Plant Biochemistry*. 4th Edition. Elsevier
- Harinda, Makkeand Klaus. 2007. *Plant Secondary Metabolites*. Springer
- Leland J. Cseke, Ara Kirakosyan, Peter B. Kaufman, Sara Warber, James A. Duke, Harry L. Brielmann. 2006. *Natural Products from Plants*. 2nd Edition. CRC Press

AGRICULTURAL BIOCHEMISTRY
Ph.D. (Ag) in AGRICULTURAL BIOCHEMISTRY

COURSE CODE	COURSE TITLE	CREDITS	SEMESTER
MAJOR COURSE		<u>12</u>	
BIOCHEM-601*	Advance Enzymology	3(2+1)	I
BIOCHEM -607*	Application of Technique in Biochemistry	3(1+2)	I
BIOCHEM -602	Advance Molecular Biology	3(3+0)	II
BIOCHEM -603	Biochemistry of Biotic and Abiotic Stresses	3(3+0)	III
MINOR COURSE		<u>7</u>	
PP-607	Physiological and Molecular Aspects of source sink Capacity per enhancing Yield	3(3+0)	II
SS-605	Biochemistry and soil organic matter	2(2+0)	III
SST-606	Advances in Seed Science	2(2+0)	II
FN-604	Global Nutritional Problem	2(2+0)	
SUPPORTING COURSE		<u>5</u>	
STAT-612	Advance Design of Experiment	3(2+1)	II
AGRON-608	Research and Publication Ethics	2(2+0)	II
FN-603	Nutrition and agriculture interface	3(2+1)	
OTHER COURSE		<u>77</u>	
BIOCHEM -691	Doctoral seminar I	1(1+0)	II
BIOCHEM -692	Doctoral seminar II	1(1+0)	III
BIOCHEM -699	Doctoral Research (PhD Thesis)	75	

* Core Course

SEMESTER WISE BREAKUP:-

COURSE CODE	COURSE TITLE	CREDIT
Ist SEMESTER		
BIOCHEM-601*	Advance Enzymology	3(2+1)
BIOCHEM -607*	Application of Technique in Biochemistry	3(1+2)
IIInd SEMESTER		
BIOCHEM -602	Advance Molecular Biology	3(3+0)
BIOCHEM -691	Doctoral seminar I	1(1+0)
IIIrd SEMESTER		
BIOCHEM -603	Biochemistry of Biotic and Abiotic Stresses	3(3+0)
BIOCHEM -692	Doctoral seminar II	1(1+0)
IVth TO VIth SEMESTER		
BIOCHEM -699	Doctoral Research (PhD Thesis)	75

SYLLABUS
FOR
Ph.D. (AG) AGRICULTURAL BIOCHEMISTRY

BIOCHEM-601

[ADVANCE ENZYMOLOGY]

CREDIT-3(2+1)

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(Seven 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(Seven 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(Seven 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.

PRACTICALS

1. Purification and characterization of some model enzymes (peroxidase, α -amylase, lipase)
2. Study kinetics of inhibited and un inhibited enzyme catalysed reactions
3. Determination of K_m values of single substrate reactions
4. Determination of enzyme activity by coupled assay
5. Electrophoretic separation of isozymes
6. Enzyme immobilization.

TEACHING METHODS / ACTIVITIES

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

READING SUGGESTIONS

- 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

BIOCHEM -602

[ADVANCE MOLECULAR BIOLOGY]

CREDITS-3(3+0)

BLOCK 1:GENOME ORGANISATION AND MANIPULATION

Unit 1: Concepts of gene and genome(Five 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(Six lectures)

Prokaryotic and eukaryotic gene regulation, transcriptional and posttranscriptional regulation; regulation at genome level, role of histones, riboswitches.

Unit 3: Techniques in genome analysis(Six 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(Six 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 interference; 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(Five 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

TEACHING METHODS / ACTIVITIES

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

READING SUGGESTIONS

- 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 Manipulation*. 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

BIOCHEM -603

[BIOCHEMISTRY OF BIOTIC AND ABIOTIC STRESS]

CREDIT-3(3+0)

BLOCK 1: BIOCHEMISTRY OF BIOTIC AND ABIOTIC STRESSES

Unit 1: Plant-pathogen interaction and disease development(Four 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(Seven 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(Four lectures)

Plant viruses, host-virus interactions, disease induction, virus movement, and host range determination; viroids.

Unit 4: Biochemical basis of abiotic stresses(Seven 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(Six 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.

TEACHING METHODS / ACTIVITIES

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

READING SUGGESTIONS

- 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

BIOCHEM -607 [APPLICATION OF TECHNIQUE IN BIOCHEMISTRY] CREDITS-3(1+2)

BLOCK 1: APPLICATION OF TECHNIQUES IN BIOCHEMISTRY

Unit 1: Isolation, purification and analysis of metabolites(Three 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(Three 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 (Two lectures)

Isolation of chloroplast and mitochondria by differential centrifugation and their purification by density gradient centrifugation.

Unit 4: Enzyme techniques(three lectures)

Isolation, purification and characterization of enzymes, isozymic analysis and enzyme immobilization

Unit 5: Molecular biology and immunochemical techniques(Three lectures)

Application of PCR, yeast 2 hybrid system, Antigen-Antibody interaction, ELISA, Chromatin immunoprecipitation, gel based and gel free proteasome tools.

TEACHING METHODS / ACTIVITIES

- Classroom lectures (oral + audio-visual)
- Demonstration and hands on training
- Exposure visit to institutions equipped with modern facilities

READING SUGGESTIONS

- 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

Department of Genetics & Plant Breeding

M.Sc. (Ag.) in Genetics & Plant Breeding

Major Courses (20 Credits)

Sl. No.	Course Code	Course Title	Credits	Semester
1.	GPB-501*	Principles of Genetics	3(2+1)	I
2.	GPB-502*	Principles of Plant Breeding	3(2+1)	I
3.	GPB-503*	Fundamentals of Quantitative Genetics	3(2+1)	II
4.	GPB-504	Varietal Development and Maintenance Breeding	2(1+1)	IV
5.	GPB-506*	Molecular Breeding and Bioinformatics	3(2+1)	II
6.	GPB-511	Crop Breeding I (Kharif crops)	3(2+1)	III
7.	GPB-512	Crop Breeding II (Kharif crops)	3(2+1)	II
Total			20	

Minor Courses

Sl. No.	Course Code	Course Title	Credits	Semester
1.	FSC-504	Breeding of Fruit Crops	3(2+1)	II
2.	VSC- 506	Breeding of cross pollinated Vegetable crops	3(2+1)	I
3.	SST- 503*	Seed Production Principles and Techniques in Field crops	3(2+1)	I
4.	PLPATH506	Techniques in detection and diagnosis of plant diseases	2(0+2)	I
5.	ENT-507	Concepts of Integrated pest management	2(2+0)	III
6.	PPY-507	Photosynthetic process, crop, productivity and concepts of crop modelling	3(2+1)	II
Total			08	

Supporting Courses

Sl. No.	Course Code	Course Title	Credits	Semester
1.	SST-509	Seed Quality Testing and Enhancement		II
2.	STAT-511*	Experimental Designs	3(2+1)	II
3.	BIOCHEM-507	Plant Biochemistry	3(2+1)	III
4.	SST-507	Seed Legislation and Certification	3(2+1)	II
Total			06	

Compulsory e-courses:

The following courses will be offered to all students undergoing Master's degree programme:

Sl. No.	Course Code	Course Title	Credits	Semester
1.	PGS-501	Library and Information Services	1(0+1)	
2.	PGS-502	Technical writing and communications skills	1(0+1)	
3.	PGS-503	Intellectual property and its management in agriculture	1(1+0)	II
4.	PGS-504	Basic concepts in laboratory techniques	1(0+1)	
5.	PGS-505	Agricultural research, research ethics and rural development programmes	1(1+0)	
Total			5	

Other

	GPB-591	Seminar (Two)	1(0+1)	IV
	GPB -599	Research	30(0+30)	IV
Total			31 (0+31)	
Grand Total			70	

Why this course?

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

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

Theory**Unit I**

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

Practical:

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

Teaching methods:

- Power point presentation,

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

Learning outcome:

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

Suggested reading:

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

GPB 502

Principles of Plant Breeding

3(2+1)

Why this course?

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

Aim of the course: To impart theoretical knowledge and practical skills about plant breeding objectives, genetic consequences, breeding methods for crop improvement.

Theory

UNIT I

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

UNIT II

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

UNIT III

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

to diallel selective mating; Transgressive breeding.

UNIT IV

Breeding methods in cross pollinated crops; Population breeding: mass selection and ear-to-row methods; S₁ and S₂ progeny testing, progeny selection schemes, recurrent selection schemes for intra and inter-population improvement and development of synthetics and composites. Hybrid breeding: genetical and physiological basis of heterosis and inbreeding, production of inbreds, breeding approaches for improvement of inbreds, predicting hybrid performance; seed production of hybrid and their parent varieties/inbreds. Self-incompatibility, male sterility and apomixes in crop plants and their commercial exploitation.

UNIT V

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

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

UNIT VII

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

Practical:

- Floral biology in self and cross pollinated species,
- Selfing and crossing techniques.
- Selection methods in segregating populations and evaluation of breeding material;
- Analysis of variance (ANOVA);
- Estimation of heritability and genetic advance;
- Maintenance of experimental records;
- Learning techniques in hybrid seed production using male-sterility in field crops.
- Prediction of performance of double cross hybrid.

Teaching methods:

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

Learning outcome:

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

Resources:

- Allard RW. 1981. Principles of Plant Breeding. John Wiley & Sons.
- Chahal GS and Gossal, SS. 2002. Principles and Procedures of Plant Breeding Biotechnological and Conventional approaches. Narosa Publishing Chopra
- VL. 2004. Plant Breeding. Oxford & IBH.
- George A. 2012. Principles of Plant Genetics and Breeding. John Wiley & Sons. Gupta SK. 2005. Practical Plant Breeding. Agribios.
- Jain HK and Kharakwal MC. 2004. Plant Breeding and –Mendelian to Molecular Approach, Narosa Publications New Delhi

- Roy D. 2003. Plant Breeding, Analysis and Exploitation of Variation. Narosa Publ. House.
- Sharma JR. 2001. Principles and Practice of Plant Breeding. Tata McGraw-Hill. Sharma JP. 2010. Principles of Vegetable Breeding. Kalyani Publ, New Delhi.
- Simmonds NW. 1990. Principles of Crop Improvement. English Language Book Society. Singh BD. 2006. Plant Breeding. Kalyani Publ.
- Singh S & Pawar IS. 2006. Genetic Bases and Methods of Plant Breeding. CBS.

GPB 503

Fundamentals of Quantitative Genetics

3(2+1)

Why this course?

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

Aim of the course:

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

Theory:

UNIT I

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

UNIT II

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

UNIT III

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

UNIT IV

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

UNIT V.

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

Practical:

- Analysis and interpretation of variability parameters, Analysis and interpretation of Index score and Metroglyph,
- Clustering and interpretation of D^2 analysis.
- Genotypic and phenotypic correlation analysis and interpretation,
- Path coefficient analysis and interpretation, Estimation of different types of heterosis, inbreeding depression and interpretation.
- A, B and C Scaling test,

- L x T analysis and interpretation, QTL analysis,
- Use of computer packages.
- Diallel analysis,
- GxE interaction and stability analysis

Teaching methods:

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

Learning outcome:

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

Resources:

- Bos I & Caligari P. 1995. Selection Methods in Plant Breeding. Chapman & Hall.
- Falconer DS and Mackay J. 1998. Introduction to Quantitative Genetics (3rd Ed.). ELBS/Longman, London.
- Mather K & Jinks JL. 1985. Biometrical Genetics (3rd Ed.). Chapman and Hall, London.
- Nandarajan N & Gunasekaran M. 2008. Quantitative Genetics and Biometrical Techniques in Plant Breeding. Kalyani Publ.
- Naryanan SS & Singh P. 2007. Biometrical Techniques in Plant Breeding. Kalyani Publ.
- Roy D. 2000. Plant Breeding: Analysis and Exploitation of Variation. Narosa Publishing House, New Delhi.
- Sharma J R. 2006. Statistical and Biometrical Techniques in Plant Breeding. New Age International Pvt. Ltd.
- Singh P & Narayanan SS. 1993. Biometrical Techniques in Plant Breeding. Kalyani Publ.
- Singh R.K. & Chaudhary B.D. 1987. Biometrical Methods in Quantitative Genetic analysis. Kalyani Publ.
- Weir DS. 1990. Genetic Data Analysis. Methods for Discrete Population Genetic Data. Sinauer Associates.
- Wricke G & Weber WE. 1986. Quantitative Genetics and Selection in Plant Breeding.
- Walter de Gruyter. www.iasri.icar.gov.in www.hau.ac.in /OPstat

GPB 504

Varietal Development and Maintenance Breeding

2(1+1)

Why this course?

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

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

Theory:

UNIT I

Variety Development systems and Maintenance; Definition- variety, cultivar, extant variety,

essentially derived variety, independently derived variety, reference variety, farmers' variety, landraces, hybrid, and population; Variety testing, release and notification systems and norms in India and abroad.

UNIT II

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

UNIT III

Maintenance of varieties in self and cross pollinated crops, isolation distance; Principles of seed production; Methods of nucleus and breeder seed production;

Generation system of seed multiplication -nucleus, breeders, foundation, certified.

UNIT IV

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

UNIT V

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

Practical :

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

Teaching methods:

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

Learning outcome:

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

Resources:

- Agarwal RL. 1997. Seed Technology. 2nd Ed. Oxford & IBH. Kelly AF. 1988. Seed Production of Agricultural Crops. Longman.
- McDonald MB Jr & Copeland LO. 1997. Seed Production: Principles and Practices.

- Chapman & Hall.
- Poehlman JM & Borthakur D. 1969. Breeding Asian Field Crops. Oxford & IBH. Singh BD. 2005. Plant Breeding: Principles and Methods. Kalyani. 2015 Thompson JR. 1979. An Introduction to Seed Technology. Leonard Hill

GPB 506

Molecular Breeding and Bioinformatics

3(2+1)

Why this course?

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

Aim of the course:

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

Theory:

UNIT I

Genotyping; Biochemical and Molecular markers; Morphological, biochemical and DNA-based markers (RFLP, RAPD, AFLP, SSR, SNPs, ESTs etc.), Functional markers; Mapping populations (F₂s, back crosses, RILs, NILs and DH); Molecular mapping and tagging of agronomically important traits; Statistical tools in marker analysis.

UNIT II

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

UNIT III

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

UNIT IV

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

Practical:

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

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

Teaching methods:

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

Learning outcome:

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

Resources:

- Azuaje F & Dopazo J. 2005. Data Analysis and Visualization in Genomics and Proteomics. John Wiley & Sons.
- Brown TA. 1991. Essential Molecular Biology: a practical Approach. Oxford university press ,2002, 2nd edition
- Chawala H.S. 2000. Introduction to Plant Biotechnology. Oxford & IBH Publishing Co.Pvt. Ltd.
- Chopra VL & Nasim A. 1990. Genetic Engineering and Biotechnology: Concepts, Methods and Applications. Oxford & IBH.
- Gupta PK. 1997. Elements of Biotechnology. Rastogi Publ.
- Hackett PB, Fuchs JA & Messing JW. 1988. An Introduction to Recombinant DNA Technology - Basic Experiments in Gene Manipulation. 2nd Ed. Benjamin Publ. Co. Jollès P & Jörnvall H. 2000. Proteomics in Functional Genomics: Protein Structure Analysis. Birkhäuser.
- Lewin B. 2017. Genes XII. Jones & Bartlett learning, 2017
- Robert NT and Dennis JG. 2010. Plant Tissue Culture, Development, and Biotechnology. CRC Press
- Sambrook J & Russel D. 2001. Molecular Cloning - a Laboratory Manual. 3rd Ed. Cold Spring Harbor Lab. Press.
- Singh BD. 2005. Biotechnology, Expanding Horizons. Kalyani Publ. Watson J .2006. Recombinant DNA. Cold Spring harbor laboratory press

Why this course?

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

Aim of the course:

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

Theory:

UNIT-I

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

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

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

UNIT-II

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

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

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

UNIT-III

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

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

UNIT-IV

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

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

UNIT-V

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

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

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

Practical:

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

Teaching methods:

- Power point presentation,
- Chalk and Board
- Smart board
- Lectures,
- Assignments, quiz,
- Group tasks, student's presentations IX. Learning outcome:

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

Resources:

- Agarwal RL. 1996. Identifying Characteristics of Crop Varieties. Oxford & IBH.
- Bahl PN & Salimath PM. 1996. Genetics, Cytogenetics and Breeding of Crop Plants. Vol. Pulses and Oilseeds. Oxford & IBH.
- Chandraratna MF. 1964. Genetics and Breeding of Rice. Longmans.
- Chopra VL & Prakash S. 2002. Evolution and Adaptation of Cereal Crops. Oxford & IBH. Gill KS. 1991. Pearl Millet and its Improvement. ICAR.
- IRRI. 1964. Rice Genetics and Cytogenetics. Elsevier.
- IRRI. 1986. Rice Genetics. Proc. International Rice Genetics Symposium. IRRI, Los Banos, Manila, Philippines.
- IRRI. 1991. Rice Genetics II. Proc. International Rice Genetics Symposium. IRRI, Los Banos, Manila, Philippines.
- IRRI. 1996. Rice Genetics III. Proc. International Rice Genetics Symposium. IRRI, Los Banos, Manila, Philippines.
- IRRI. 2000. Rice Genetics IV. Proc. International Rice Genetics Symposium. IRRI, Los Banos, Manila, Philippines.
- Jennings PR, Coffman WR & Kauffman HE. 1979. Rice Improvement. IRRI, Los Banos, Manila, Philippines.
- Kannaiyan S, Uthamasamy S, Theodore RK & Palaniswamy S. 2002. New Dimensions and Approaches for Sustainable Agriculture. Directorate of Extension Education, TNAU, Coimbatore.
- Murty DS, Tabo R & Ajayi O. 1994. Sorghum Hybrid Seed Production and Management. ICRISAT, Patancheru, India.
- Nanda JS. 1997. Manual on Rice Breeding. Kalyani Publishers.
- Parthasarathy VA .2017. Spices and Plantation Crops Vol.1 (Part A) Breeding of Horticultural Crops Vol.1 (Part-B), Today and Tomorrow Printers and Publishers Poehlman, JM .1987. Breeding of Field Crops. AVI Publishing Co. Inc. East Post Connecticut, USA
- Ram HH & Singh HG. 1993. Crop Breeding and Genetics. Kalyani.
- Sharma, A K .2005. Breeding Technology of Crop Plant. Yesh Publishing House, Bikaner
- Singh HG, Mishra SN, Singh TB, Ram HH & Singh DP. (Eds.). 1994. Crop Breeding in India. International Book Distributing Co.
- Slafer GA. (Ed.). 1994. Genetic Improvement of Field Crops. Marcel Dekker. Walden DB. 1978. Maize Breeding and Genetics. John Wiley & Sons

GPB 512

Crop Breeding-II (Rabi Crops)

3(2+1)

Why this course?

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

Aim of the course:

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

Theory:

UNIT-I

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

Oats: Origin, evolution, mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress

resistance etc., breeding approaches, introgression of alien gene(s) (if required), biotic and abiotic stress resistance, released varieties, examples of MAS used for improvement.

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

UNIT-II

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

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

UNIT-III

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

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

UNIT-IV

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

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

UNIT-V

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

Practical:

- Floral biology, emasculation and pollination techniques in wheat, oats, barley, chickpea, rajma, rapeseed mustard, sunflower;
- Study of range of variation for yield and yield components;
- Study of segregating populations in cereal, pulses and oilseed crops;

- Use of descriptors for cataloguing; Learning on the crosses between different species ;
- Trait based screening for stress resistance
- Learning on the Standard Evaluation System (SES) and descriptors;
- Use of software for database management and retrieval.

Teaching methods:

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

Learning outcome:

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

Resources:

- Agarwal RL. 1996. Identifying Characteristics of Crop Varieties. Oxford & IBH.
- Bahl PN & Salimath PM. 1996. Genetics, Cytogenetics and Breeding of Crop Plants. Vol. Pulses and Oilseeds. Oxford & IBH.
- Gupta SK. 2012. Technological Innovations in Major World Oil crops. Vol. I. Springer, USA
- Gupta SK. 2012. Technological Innovations in Major World Oil crops. Vol. II. Springer, USA
- Gupta, S.K. 2016. Breeding of Oilseed Crops for Sustainable Production. Academic Press, USA
- Kannaiyan S, Uthamasamy S, Theodore RK & Palaniswamy S. 2002. New Dimensions and Approaches for Sustainable Agriculture. Directorate of Extension Education, TNAU, Coimbatore.
- Parthasarathy VA .2017. Spices and Plantation Crops Vol.1 (Part A) Breeding of Horticultural Crops Vol.1 (Part-B)
- Poehlman JM .1987. Breeding of Field Crops. AVI Publishing Co. Inc. East Post Connecticut, USA
- Ram HH & Singh HG. 1993. Crop Breeding and Genetics. Kalyani Publisher, New-Delhi Sharma AK .2005. Breeding Technology of Crop Plant. Yesh Publishing House, Singh HG, Mishra SN, Singh TB, Ram HH & Singh DP. (Eds.). 1994. Crop Breeding in India. International Book Distributing Co.
- Slafer GA. (Ed.). 1994. Genetic Improvement of Field Crops. Marcel Dekker. Walden DB. 1978. Maize Breeding and Genetics. John Wiley & Sons.

Department of Genetics & Plant Breeding

Ph. D. in Genetics & Plant Breeding

Major Courses (20 Credits)

Sl. No.	Course Code	Course Title	Credits	Semester
1.	GPB 601*	Advances in Plant Breeding System	3(2+0)	I
2.	GPB 605*	Genomics in Plant Breeding	3(3+0)	I
3.	GPB 606	Population Genetics	2(2+0)	II
4.	GPB 607	Crop Evolution	3(3+0)	III
5.	GPB 609*	IPR and Regulatory Mechanism (e-course)	1(1+0)	II
8.		Sub Total	12	

Minor Courses: Any two of the following

Sl. No.	Course Code	Course Title	Credits	Semester
1.	SST 601	Hybrid Seed Production Technology	3(2+1)	I
2.	FSC 601	Innovative Approaches in Fruit Breeding	3(2+1)	I
3.	VSC 602	Advances in Breeding of Vegetable Crops	3(3+0)	II
4.	VSC 607	Biotechnological Approaches in Vegetable Crops	3(3+0)	III
5.	PPY 607	Physiological and Molecular Aspects of Source Sink Capacity for Enhanced Yield	3(2+1)	II
		Sub Total	06	

Supporting Courses

Sl. No.	Course Code	Course Title	Credits	Semester
1.	STAT 604	Advanced Statistical Methods	3(2+1)	II
2.	SST 606	Advances in Seed Science	2(2+0)	III
3.	PPY 606	Global Climatic Change and Crop Response	3(2+1)	II
4.	SST 602	Organic Seed Production	2(1+1)	II
		Sub Total	05	
1.	GPB 691	Seminar I	01	
2.	GPB 692	Seminar II	01	
3.	GPB 699	Thesis/Research	75	
		Sub Total	100	
Comprehensive (Pre-qualifying) Examination		(Non-credit of 100 marks)	Satisfactory/ Not satisfactory	

GPB 601

Advances in Plant Breeding Systems

3(3+0)

Why this course?

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

Aim of the course:

To impart theoretical knowledge about advances in plant breeding.

Theory:

UNIT I

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

governing anthesis and bottlenecks for gene transfer.

UNIT II

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

UNIT III

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

UNIT IV

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

UNIT V

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

UNIT VI

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

UNIT VII

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

Teaching methods:

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

Learning outcome:

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

Resources:

- Agarwal RL. 1996. Fundamentals of Plant Breeding and Hybrid Seed Production. Oxford & IBH.
- Allard RW. 1966. Principles of Plant Breeding. John Wiley & Sons. Briggs FN & Knowles PF. 1967. Introduction to Plant Breeding. Reinhold.
- Fehr WR. 1987. Principles of Cultivar Development: Theory and Technique. Vol I. Macmillan.
- Hayes HK, Immer FR & Smith DC. 1955. Methods of Plant Breeding. McGraw-Hill. Kang MS and Priyadarshan PM (Edit.). 2007. Breeding Major Food Staples. Blackwell Publishing.
- Kole C. 2013. Genomics and Breeding for Climate-Resilient Crops. Springer. Volume 2 Target Traits.
- Mandal AK, Ganguli PK & Banerji SP. 1995. Advances in Plant Breeding. Vol. I, II. CBS.
- Richards AJ. 1986. Plant Breeding Systems. George Allen & Unwin.
- Sharma JR. 1994. Principles and Practice of Plant Breeding. Tata McGraw-Hill. Simmonds NW. 1979. Principles of Crop Improvement. Longman.
- Singh BD. 1997. Plant Breeding: Principles and Methods. 5th Ed., Kalyani Publ. Singh P. 1996. Essentials of Plant Breeding. Kalyani Publ.
- Welsh JR. 1981. Fundamentals of Plant Genetic and Breeding. John Wiley.

GPB 605**Genomics in Plant Breeding****3(3+0)****Why this course?**

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

Aim of the course:

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

Theory:

UNIT I

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

UNIT II

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

UNIT III

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

Concept of allele mining; Diversity array technology: concepts and applications.

UNIT IV

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

PCR and molecular beacon.

UNIT V

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

UNIT VI

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

Teaching methods:

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

Learning outcome:

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

Resources:

- Alonso JM, Stepanova AN. (2015). Plant Functional Genomics: Methods and Protocols. Springer
- Chopra VL, Sharma RP, Bhat SR and Prasanna BM. (2007) Search for New Genes. Academic Foundation, New Delhi
- Hackett PB, Fuchs JA & Messing JW. 1988. An Introduction to Recombinant DNA Technology - Basic Experiments in Gene and Manipulation. 2nd Ed. Benjamin Publication Co.
- Primose SB & Twyman RM. 2006. Principles of Gene Manipulation and Genomics. 7th Ed. Wiley-Blackwell Publishing
- Sambrook J & Russel D. 2001. Molecular Cloning - a Laboratory Manual. 3rd Ed. ColdSpring Harbor Laboratory Press.
- Singh BD. 2005. Biotechnology: Expanding Horizons. Kalyani Publ.
- Somers DJ, Langridge P, Gustafson JP. (2009). Plant Genomics: Methods and Protocols. Springer
<http://gramene.org> <https://www.arabidopsis.org> <https://wheat.pw.usda.gov>
<http://ncbi.nlm.nih.gov> <http://www.maizegenetics.net>

GPB 606

Population Genetics

2(2+0)

Why this course?

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

Aim of the course:

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

Theory:

UNIT I

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

UNIT II

Hardy-Weinberg equilibrium, Hardy-Weinberg law, Proof and applications of the HardyWeinberg law, Test of Hardy-Weinberg equilibrium; Mating frequencies: Nondominance, Codominance, Snyder's ratio, importance and its effect over randommating in succeeding generations.

UNIT III

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

UNIT IV

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

Teaching methods:

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

Learning outcome:

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

Resources:

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

GPB 607

Crop Evolution

3(4+0)

Why this course?

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

Aim of the course:

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

Theory:

UNIT I

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

UNIT II

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

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

UNIT IV

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

Teaching methods:

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

Learning outcome:

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

Resources:

- Hancock JF. 2004. Plant Evolution and the Origin of Crop Species. 2nd Ed. CABI. Ladizinsky G. 1999. Evolution and Domestication. Springer.
- Miller AJ. 2007. Crop Plants: Evolution. John Wiley & Sons.
- Smartt J & Simmonds NW. 1995. Evolution of Crop Plants. Blackwell.

GPB 609**IPR and Regulatory Mechanism (e-course)****1(1+0)****Why this course?**

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

Aim of the course:

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.

Teaching methods:

- Power point presentation,
- Smart board
- Assignments, quiz,
- Group tasks, student's presentations

Learning outcome:

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

Resources:

- Erbisch FH & Maredia K. 1998. Intellectual Property Rights in Agricultural Biotechnology. CABI.
- Ganguli P. 2001. Intellectual Property Rights: Unleashing Knowledge Economy. McGraw-Hill.
- Intellectual Property Rights: Key to New Wealth Generation. 2001. NRDC & Aesthetic Technologies.
- Ministry of Agriculture, Government of India. 2004. State of Indian Farmer. Vol. V. Technology Generation and IPR Issues. Academic Foundation.

Department of Agricultural Extension

M.Sc. (Ag.) in Agricultural Extension

A. Major Courses

Sl. No.	Course Code	Course Title	Credits	Semester
1.	EXT-501	Extension Landscape	2(2+0)	I
2.	EXT-502	Applied Behaviour Change	3(2+1)	II
3.	EXT-503	Organisational Behavior and Development	3(2+1)	I
4.	EXT-504	Research Methodology in Extension	3(2+1)	II
5.	EXT-505	Capacity Development	3(2+1)	III
6.	EXT-506	ICTs for Agricultural Extension and Advisory Services	3(2+1)	III
7.	EXT-507	Evaluation and Impact Assessment	3(2+1)	IV
Total Credits			20	

B. Minor Courses

1.	AEC-507	Agricultural Finance and Project Management	3(2+1)	II
2.	AEC-502	Agricultural Production Economics	2(1+1)	I
3.	AHD-501	Management of sheep, Goat, pig and Poultry	3(2+1)	III
Total credits			08	

C. Supporting Course:

1.	STAT-502	Statistical Methods for applied social sciences	3(2+1)	I
2.	AHD-503	Livestock & Poultry housing management	3(2+1)	II
Total credits			6	

D. Common courses (Non-gradual)

Sl. No.	Course Code	Course Title	Credits	Semester
1.	PGS-501	Library and Information services	1(0+1)	I
2.	PGS-502	Technical writing and communication skills	1(0+1)	I
3.	PGS-503	Intellectual property and its management in agriculture	1(1+0)	II
4.	PGS-504	Basic concept in Laboratory techniques	1(0+1)	II
5.	PGS-505	Agricultural research, research ethics and rural development programme	1(1+0)	III
Total credits			05	

E. Master's seminar and thesis research:

1.	EXT-591	Master's seminar	1(0+1)	
2.	EXT-599	Thesis/research	30(0+30)	
Total credits			31(0+31)	
Grand total			70	

WHY THIS COURSE?**MAJOR COURSES**

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.

AIM OF THIS 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

LEARNING OUTCOMES

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

TEACHING METHODS/ACTIVITIES

- Lecture
- Assignment (Reading/Writing)S
- Book Review by students
- Student presentation
- Group Work

RESOURCES

- o Adolph B. 2011. **Rural Advisory Services World wide: A Synthesis of Actors and Issues.** GFRAS: Lindau, Switzerland. <https://www.g-fras.org/en/knowledge/gfras-publications.html?download=6:rural-advisory-services-worldwide&start=40>
- o Ashok G, Sharma P, Anisha S and Prerna T. 2018. **Agriculture Extension System in India Review of Current Status, Trends and the Way Forward.** Indian Council for Research on International Economic Relations (ICRIER). <http://icrier.org/pdf/Agriculture-Extension-System-in-India-2018.pdf>
- o Barber J, Mangnus E and Bitzer V. 2016. **Harnessing ICT for agricultural extension.** KIT Working Paper 2016:4. https://213ou636sh0ptphd141fgei1-wpengine.netdna-ssl.com/sed/wp-content/uploads/sites/2/2016/11/KIT_WP2016-4_Harnessing-ICT-for-agricultural-extension.pdf
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- o Bingen RJ and Simpson BM. 2015. **Farmer Organizations and Modernizing Extension and Advisory Services.** MEAS Discussion Paper. <http://meas.illinois.edu/wp-content/uploads/2015/04/Bingen-Simpson-2014-FarmerOrganizations-MEAS-Discussion-Paper.pdf>
- o Bitzer V, Wennink B and de Steenhuijsen PB. 2016. **The governance of agricultural extension systems.** KIT Working Paper 2016:1. http://213ou636sh0ptphd141fgei1-wpengine.netdna-cdn.com/sed/wp-content/uploads/sites/2/2016/03/WPS_1-2016-web.pdf

- Bitzer V, Wongtschowski M, Hani M and Blum M. 2016. **New directions for inclusive Pluralistic Service Systems.** In New Directions for Inclusive Pluralistic Service Systems Rome (Italy). FAO. <http://www.fao.org/3/a-i6104e.pdf>
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- Colverson KE. 2015. **Integrating Gender into Rural Advisory Services.** Note 4. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS: Lindau, Switzerland. <https://www.g-fras.org/en/good-practice-notes/integrating-gender-into-rural-advisory-services.html#SNote1>
- David S. 2018. **Migration and rural advisory services.** GFRAS Issues Paper 2. Global Forum for Rural Advisory Services. <https://www.g-fras.org/en/knowledge/gfras-publications/category/97-gfras-issues-papers.html?download=856:migration-and-rural-advisory-services>
- Davis K and Heemskerk W. 2012. **Coordination and Collective Action for Agricultural Innovation** Overview Module 1 Investment in Extension and Advisory Services as Part of Agricultural Innovation Systems. In Agricultural Innovation Systems: An Investment Sourcebook. Agricultural and Rural Development. World Bank. © World Bank. <http://siteresources.worldbank.org/INTARD/Resources/335807-1330620492317/9780821386842ch3.pdf>
- FAO. 2016. **New directions for inclusive Pluralistic Service Systems.** Report of FAO Expert Consultation. Food and Agriculture Organization of the United Nations and Royal Tropical Institute, Rome. <http://www.fao.org/3/ai6103e.pdf>
- FAO. 2017. **Climate-Smart Agriculture Sourcebook.** Available at: <http://www.fao.org/3/a-i3325e.pdf>
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- Francis J, Mytelka L, Van Huis A and Röling N (eds.). 2016. **Innovation Systems: Towards Effective Strategies in support of Smallholder Farmers.** Technical Centre for Agricultural and Rural Cooperation (CTA) and Wageningen University and Research (WUR)/Convergence of Sciences Strengthening Innovation Systems (CoS-SIS), Wageningen. https://publications.cta.int/media/publications/downloads/1829_PDF.pdf
- GFRAS. 2012. **Building Knowledge Systems in Agriculture Five Key Areas for Mobilising the Potential of Extension and Advisory Services.** Global Forum for Rural Advisory Services. [http://www.fao.org/uploads/media/1_gfras_positionpaper_final2_websmallpdf%20com%20\(1\).pdf](http://www.fao.org/uploads/media/1_gfras_positionpaper_final2_websmallpdf%20com%20(1).pdf)
- GFRAS. 2015. **Producer organisations in rural advisory services: Evidence and experiences.** Position Paper. Lindau: Global Forum for Rural Advisory Services. <http://www.g-fras.org/en/593-producer-organisations-in-rural-advisory-services-evidence-and-experiences.html>
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- GFRAS. 2016. **The New Extensionist Learning Kit.** <http://g-fras.org/en/knowledge/new-extensionist-learningkit-nelk.html#module-1-introduction-to-the-new-extensionist>
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- Manfre C, Rubin D and Nordehn C. 2017. **Assessing How Agricultural Technologies can Change Gender Dynamics and Food Security Outcomes.** A three part toolkit. Integrating Gender and Nutrition within Agricultural Extension Services (INGENAES).
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- Saravanan R, Suchiradipta B, Meera SN, Kathiresan C and Anandaraja N. 2015. **Web Portals for Agricultural Extension and Advisory Services.** Note 16. GFRAS Good Practice Notes for Extension and Advisory Services. GFRAS: Lindau, Switzerland. <https://www.g-fras.org/en/good-practice-notes/16-web-portals-for-agricultural-extension-and-advisory-services.html#SNote8>
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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>

EXT- 502

APPLIED BEHAVIOUR CHANGE

3(2+1)

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.

AIM OF THIS 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

LEARNING OUTCOMES

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

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.

PRACTICALS

1. Understanding perception – Attentional Blink and Repetition Blindness exercise
2. Understanding attention - Testing selective attention capacity and skills and processing speed ability through Stroop test
3. Hands-on experience in the techniques for assessing creative thinking – divergent and convergent thinking
4. Lab exercise in applying Maslow's need hierarchy to assess motivation
5. Learning - Classical conditioning and operant conditioning
6. Assessing learning styles through Barsch and Kolb inventories
7. Practical experience in building self-esteem
8. Assessment of emotional intelligence
9. Exercises in problem solving
10. Exercises in visual perception
11. Measuring self-concept using psychometric tools
12. Experiment on factors influencing information processing
13. Assessment of attitudes
14. Hands on experience in methods of persuasion
15. Field experience in assessing social judgement
16. Simulation exercise to understand decision-making under different situations
17. Exercise in rational decision-making.

TEACHING METHODS/ACTIVITIES

- Lecture cum discussion
- Class exercises
- Group Presentation

RESOURCES

- Eiser J, Richard. 2011. **Social Psychology: Attitudes, Cognition and Social Behaviour**. Cambridge: Cambridge University Press.(First Edition, 1986))
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- 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.
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EXT- 503

ORGANISATIONAL BEHAVIOR AND DEVELOPMENT

3(2+1)

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.

AIM OF THIS 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

LEARNING OUTCOMES

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

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.

PRACTICALS

1. Case Analysis of organization in terms of process – attitudes and values, motivation, leadership.
2. Simulation exercises on problem-solving – study of organizational climate in different organizations.
3. Study of organizational structure of development departments, study of departmentalization, span of control, delegation of authority, decision-making patterns.
4. Study of individual and group behaviour at work in an organization.
5. Conflicts and their management in an organization.
6. Comparative study of functional and nonfunctional organizations and drawing factors for organizational effectiveness.
7. Exercise on OD interventions (Interpersonal, Team, Structural, Comprehensive) with its procedure to conduct in an organization

TEACHING METHODS/ACTIVITIES

- Lecture cum discussion
- Cases
- Class exercises
- Group Presentation

RESOURCES

- Bhattacharyya DK. 2011. **Organizational Change and Development**, Oxford University Press.
- Hellriegel D, Slocum 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.
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- 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.

EXT- 504

RESEARCH METHODOLOGY IN EXTENSION

3(2+1)

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.

AIM OF THIS 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

LEARNING OUTCOMES

- 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

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, α , β , 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

PRACTICALS

1. Selecting a research problem and writing problem statement
2. Narrowing down research problem to purpose, research questions and objectives
3. Choosing, evaluating and reviewing research literature
4. Selection of variables through construct conceptualisation and defining variables
5. Choosing research design based on research problem
6. Choosing right sampling method and estimating sample size
7. Developing research methods and tools – questionnaires, interview schedule, check lists and focus group guides

8. Writing a research proposal
9. Field data collection using research methods and tools
10. Testing reliability and validity of research instruments
11. Hands on experience in using SPSS for coding, data exploration, editing, analysis and interpretation Formulation of secondary tables based on objectives of research
12. Writing report, writing of thesis and research articles
13. Presentation of reports

TEACHING METHODS/ACTIVITIES

- Lecture cum discussion
- Class exercises
- Assignment(Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Research Report

RESOURCES

- 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 andFuture 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/>

EXT- 505

CAPACITY DEVELOPMENT

3(2+1)

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.

AIM OF THIS 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 / tools
- 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

LEARNING OUTCOMES

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 & tools
- Formulate, implement and evaluate need based capacity development programmes

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.

PRACTICALS

1. Capacity development needs assessment exercise
2. Capacity development project formulation exercise
3. 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 & post training tests
4. Training methods – Practicing each method mentioned in contents as group exercise

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.

RESOURCES

- 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 andTechniques,** Department for International Development, United Kingdom
- DoPT.2014. **Civil Services Competency Dictionary: Strengthening Human Resource Managementof 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.**
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- GFRAS. 2012. **The New Extensionist: Roles, Strategies, and Capacities to Strengthen Extension andAdvisory Services,** Global Forum for Advisory Services
- GFRAS. 2015. **The New Extensionist: Core Competencies for Individuals,** GFRAS Brief3.
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- .ISNAR Briefing Paper 50.
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- IISD 2015. **Appreciative Inquiry and Community Development.** International Institute for SustainableDevelopment.
- LENCD 2011. **How to assess existing capacity and define capacity needs,** Learning Network onCapacity Development.
- Maguire. 2012. **Module 2: Agricultural Education and Training to Support Agricultural Innovation Systems.** Overview. Agricultural Innovation Systems: An Investment Source book. The World Bank.
- Mbabu AN and Hall A. 2012. **Capacity Building for Agricultural Research ForDevelopment-Lessons from Practice in Papua New Guinea.** United Nations University- Maastricht Economic and Social Research Institute on Innovation and Technology (UNU-MERIT). https://www.merit.unu.edu/archive/docs/hl/201302_Capacity%20Building%20for%20Agricultural%20Research%20Development_Final.pdf
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- Mishra DC. 1990. **New Directions in Extension Training.** Directorate of Extension, Ministry of Agriculture, Govt. of India, New Delhi.
- OECD/DAC. 2006. **The Challenge of Capacity Development: Working Towards GoodPractice,** Organisation for Economic Cooperation and Development.
- Pretty JN, Gujit I, Thompson J, and Scoones I. 1995. **A Trainer's Guide for ParticipatoryLearning and Action.** IIED Participatory Methodology Series.
- Rolf PL and Udai P. 1992. **Facilitating Development: Readings for Trainers, Consultantsand Policy-makers,** New Delhi: Sage Publications, pp. 359
- Rolf PL and Udai, P. 1990. **Training for Development,** (3rdedn) by (West Hartford, Kumarian Press, 1990, pp. 333.
- SIDA.2000. **Capacity Development.** SIDA Working Paper No. 4. Analysis of Needs forCapacity Development.
- SIDA. 2000. **Working Paper No. 4. Analysis of Needs for Capacity Development**
- Sulaiman RV and Mittal N. 2016. **Capacity Needs of Extension and Advisory Services(EAS) in South Asia.** Policy Brief No 1. Agricultural Extension in South Asia. <http://www.aesanetwork.org/policy-brief-no-1-capacity-needs-of-extension-and-advisory-services-eas-in-south-asia/>
- Swanson BE and Rajalahti R. (2010). **Strengthening Agricultural Extension and Advisory Services.A Guide for Facilitators.**
- TAP. 2013. **Capacity Development for Agricultural Innovation Systems - Key Conceptsand Definitions.** Tropical Agricultural Platform
- TAP. 2016. **Common Framework on Capacity Development for Agricultural InnovationSystems.** Guidance Note on Operationalization, Tropical Agricultural Platform

- UNDP. 1998. **Capacity Assessment and Development in a Systems and Strategic Management** Context. Technical Advisory Paper No. 3. Management Development and Governance Division Bureau for Development Policy, January 1998, United Nations Development Programme
- UNDP. 1998. **Capacity Assessment and Development in a Systems and Strategic Management** Context. Technical Advisory UNU-MERIT, Netherlands.
- UNDP. 2008. **Capacity Assessment Methodology. User's Guide. Capacity Development Group.** Bureau for Development Policy.
- UNDP. 2009. **Capacity Development: A UNDP Primer**, United Nations Development Programme
- WAC. 2013. **Assessing Capacity Needs and Strategy Development for Grassroots Rural Institutions: A Guide for Facilitators.** World Agroforestry Centre (WAC)
- **WEBSITES**
- **TAP-** Tropical Agriculture Platform for Capacity Development <https://www.tapipedia.org/>
- **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/>

EXT- 506

ICTs FOR AGRICULTURAL EXTENSION AND ADVISORY SERVICES

3(2+1)

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 constraints 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.

AIM OF THIS 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) & 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 services and advisory	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 & disruptive Technologies and advanced analytics for agricultural extension	1. Smart Technologies
		2. Human Computer Interactions

LEARNING OUTCOMES

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

BLOCK 1: INTRODUCTION TO INFORMATION AND COMMUNICATION TECHNOLOGIES (ICTS) & 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 & 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 CERA, 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 & 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.

PRACTICALS

1. Content and client engagement analysis
2. Designing extension content for ICTs
3. Creating and designing web portals, blogs, social media pages
4. Developing digital videos
5. Live streaming extension programmes and organising webinars
6. Working with Farmers call centres
7. Engaging with professional digital networks
8. Writing for digital media

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

RESOURCES

- o Andres D and Woodard J. 2013.**Social media handbook for agricultural development practitioners**.Publication by FHI360 of USAID. <http://ictforag.org/toolkits/social/SocialMedia4AgHandbook.pdf>
- o Barber J, Mangnus E and Bitzer V. 2016.**Harnessing ICT for agricultural extension**. KIT Working Paper 2016:4. https://213ou636shOptphd141fqi1-wpengine.netdna-ssl.com/sed/wp-content/uploads/sites/2/2016/11/KIT_WP2016-4_Harnessing-ICT-for-agricultural-extension.pdf
- o Bheenick K and Bionyi I. 2017.**Effective Tools for Knowledge Management and Learning in Agriculture**

- Fafchamps M and Minten B. 2012. **Impact of SMS based Agricultural Information on Indian Farmers.**The World Bank Economic Review, Published by the Oxford University Press on behalf of the International Bank for Reconstruction and Development.
- FAO 2011.**E-learning methodologies a guide for designing and developing e-learning courses.** Food and Agriculture Organization of the United Nations. <http://www.fao.org/docrep/015/i2516e/i2516e.pdf>
- George T, Bagazonzya H, BallantyneP, Belden C, Birner R, Del CR and Treinen S. 2017. **ICT in agriculture: connecting smallholders to knowledge, networks, and institutions.** Washington, DC: World Bank. <https://openknowledge.worldbank.org/handle/10986/1261316>
- Heike Baumüller. 2018. The little we know: An exploratory literature review on the utility of mobile phone enabled services for smallholder farmers. **Journal of International Development.** 30, 134–154.
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- Mayer RE. 2005. **The Cambridge handbook of multimedia learning.** New York:University of Cambridge.
- MEAS & Access Agriculture 2013.**A Guide to Producing Farmer-to-Farmer Training Videos.**https://www.agrilinks.org/sites/default/files/resource/files/MEAS%20Guide%20to%20Producing%20Farmer-to-Farmer%20Training%20Videos%202013_04.pdf
- Meera SN.2013. **Extension, ICTs and Knowledge Management: The 10 difficultquestions.** Blog 15.Agricultural Extension in South Asia.<http://www.aesanetwork.org/extension-icts-and-knowledge-management-the-10- difficult-questions/>
- Meera SN.2017.**Disruptive Technologies – Big Data and Internet of Things inStrengthening Extension & Advisory Services.**Blog 68.Agricultural Extension in SouthAsia.<http://www.aesanetwork.org/disruptive-technologies-big-data-and-internet-of-things-in- strengthening-extension-advisory-services/>
- Meera SN.2018. **A Treatise on Navigating Extension and Advisory Services throughDigital Disruption.** Blog 90.Agricultural Extension in South Asia.<http://www.aesanetwork.org/a-treatise-on-navigating-extension-and-advisory-services- through-digital-disruption/>
- Mittal N, Surabhi, Gandhi, Sanjay and Gaurav T. 2010.**Socio-Economic Impact of Mobile Phones on Indian Agriculture.**ICRIER Working Paper No. 246, Indian Council for Research on International Economic Relations (ICRIER), New Delhi.
- Preece J, Rogers Y, & Preece, J. 2007. **Interaction design: Beyond human-computerinteraction.** Chichester: Wiley.
- Saravanan R, Sulaiman RV, Davis K and Suchiradipta B. 2015.**Navigating ICTs forExtension and Advisory Services. Note 11.GFRAS Good Practice Notes for Extensionand Advisory Services.** GFRAS: Lindau, Switzerland. Available at https://agrilinks.org/sites/default/files/resource/files/gfras-ggp- note11_navigating_icts_for_ras_1.pdf
- Saravanan R and Suchiradipta B. 2015. **mExtension – Mobile Phones for AgriculturalAdvisory Services.** Note 17.GFRAS Good Practice Notes for Extension and AdvisoryServices. GFRAS: Lindau, Switzerland. www.g-fras.org/en/download.html?download=349:ggp-note-17-mextension-mobile-phones-for- agricultural-advisory-services
- Saravanan R and Suchiradipta B. 2016. **Social media policy guidelines for agriculturalextension and advisory services,** GFRAS interest group on ICT4RAS, GFRAS: Lindau,Switzerland. Available at www.g-fras.org/en/knowledge/gfras-publications.html?download=415:social-media-policy-guidelines-for-agricultural-extension- and-advisory-services
- SaravananR. 2010. (Ed.) **ICTs for Agricultural Extension: Global Experiments,Innovations and Experiences,** New India Publishing Agency (NIPA), New Delhi.http://www.saravananraj.net/wp-content/uploads/2014/12/32_India ICTs-for-Agricultural- Extension Saravanan.pdf
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- Saravanan R, Kathiresan C, and Indra DT. 2011. (Eds.) **Information and Communication Technology for Agriculture and Rural Development**, New India Publishing Agency (NIPA), New Delhi.
- Sophie T and Alice VDE.2018.**Gender and ICTs - Mainstreaming gender in the use of information and communication technologies (ICTs) for agriculture and rural development**, FAO.
<http://www.fao.org/publications/card/en/c/18670EN>
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- Vignare K. 2013. **Options and strategies for information and communication technologies within agricultural extension and advisory services**.MEAS Discussion paper.<http://meas.illinois.edu/wpcontent/uploads/2015/04/Vignare-K-2013-ICT-and-Extension-MEAS-Discussion-Paper.pdf>
- World Bank. 2017. **ICT in Agriculture (Updated Edition): Connecting Smallholders to Knowledge, Networks, and Institutions**. Washington, DC: World Bank.<https://openknowledge.worldbank.org/handle/10986/27526>
- **WEBSITES**
- **FAO** -Food and Agricultural Organisation (Research and Extension) <http://www.fao.org/research-and-extension/en/>
- **CTA**- The Technical Centre for Agricultural and Rural Cooperation: Digitalization <https://www.cta.int/en/channel/digitalisation-sid05951b8c7-e611-4f34-9ae6-8c0fc0c822bc>
- **GFRAS**- Global Forum for Rural Advisory Services <http://www.g-fras.org/en/>
- **AESA**-Agricultural Extension in South Asia <http://www.aesanetwork.org/>

EXT-507

EVALUATION AND IMPACT ASSESSMENT

3(2+1)

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.

AIM OF THIS 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
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

LEARNING OUTCOMES

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

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 (To), Pessimistic time (Po), Most likely time (TM), Expected time (TE), Float or Slack, Event Slack, Lead time, Lag time, Fast tracking, Crashing critical path, Activity Table, Dangers, 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?**

PRACTICALS

1. 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
2. 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.
3. Review any comprehensive programme evaluation report from published sources. Evaluate the report and write your observations following the 'Evaluating the Evaluation' approach.
4. 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.
5. Identify an on-going development programme and make-out 6 activities from the programme.

Draw a Gantt chart for 12 months programme activities.

6. Write a report on evaluation hierarchy levels and indicators as per Bennett's hierarchy of evaluation for any development programme or project.
7. Develop LFA four-by-four grid for any development programme or project with activities, outputs, purpose & goal and objectively verifiable indicators, means of verification & assumptions.
8. 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.
9. Refer any Environment Impact Assessment report and analyse steps in EIA. Write your observations.

TEACHING METHODS/ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Student presentation
- Group Work
- Guest Lectures

RESOURCES

- o Adrienne M, Gundel S, Apenteng E and Pound B. 2011. **Review of Literature on Evaluation Methods Relevant to Extension.** Lindau, Switzerland: Global Forum for Rural Advisory Services, Lindau, Switzerland

- Bagnol, B. 2014. **Conducting participatory monitoring and evaluation.** Pages 81-85 in FAO, Decision tools for family poultry development. FAO Animal Production and Health Guidelines, No. 16. Rome, Italy: FAO.
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- Hall A, Sulaiman VR, Clark N & Yoganand B. 2003. **From measuring impact to learning institutional lessons: An innovation systems perspective on improving the management of international agricultural research.** Agricultural Systems, 78(2):213–241.
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- Murray P. 2000. **Evaluating participatory extension programs: challenges and problems.** Australian Journal of Experimental Agriculture, Vol. 40 No. 4 pp. 519–526.
- Narayan D. 1993. **Participatory Evaluation: Tools for Managing Change in Water and Sanitation** (Technical Paper 207). Washington, D.C.: The World Bank.
- Neuchatel Group. 2000. **Guide for Monitoring, Evaluation and Joint Analyses of Pluralistic Extension Support.** Lindau, Switzerland: Neuchâtel Group.
- [www.g-fras.org/fileadmin/UserFiles/Documents/Frames-and-guidelines/M_E/ Guide-for-Monitoring-Evaluation-and-Joint-Analysis.pdf](http://www.g-fras.org/fileadmin/UserFiles/Documents/Frames-and-guidelines/M_E/Guide-for-Monitoring-Evaluation-and-Joint-Analysis.pdf)
- Njuki J, Mapila M, Kaaria S and Magombo T. 2008. **Using community indicators for evaluating research and development programmes: Experiences from Malawi.** *Development in Practice* 18(4):633–642.
- OECD. 1998. **Review of the DAC Principles for Evaluation of Development Assistance.**
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- <http://www.meas-extension.org/meas-offers/training/evaluatingextensionprograms>
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- Suvedi ,M and Morford S. 2003. **Conducting Program and Project Evaluations: A Primer for Natural Resource Program Managers in British Columbia**. Forrex-Forest Research Extension Partnership, Kamloops, B.C. Forrex Series 6.
- USAID .2011. **Evaluation policy**. Washington, D.C., USA: Bureau for Policy and Planning.
- Venkateswarlu, K and Raman, K.V. 1993. **Project Management Techniques for R&D in Agriculture**. Sterling Publishers Pvt.Ltd., New Delhi.
- Wholey JS, Harty HP and Newcomer KE. 1994. **Handbook of practical program evaluation**. San Francisco, USA: Jossey-Bass Publishers

WEBSITES

- **BETTER EVALUATION-** www.betterevaluation.org
- **TAP-Tropical Agriculture Platform: Monitoring and Evaluation** - www.tapipedia.org **GFRAS- Global Forum for Rural Advisory Services** <http://www.g-fras.org/en/> **AESA-Agricultural Extension in South Asia** <http://www.aesanetwork.org/>
- **USAID-** United States Agency for International Development: Evaluation
- <https://www.usaid.gov/evaluation> <https://education.illinois.edu/faculty/jennifer-greene>

MINOR COURSES

- 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.

Department of Agricultural Extension

Ph.D. in Agricultural Extension

A. Major Courses

Sl. No.	Course Code	Course Title	Credits	Semester
1.	EXT-601	Policy Engagement and Extension	3 (2+1)	I
2.	EXT-602	Methodologies for Social and Behavioural Sciences	3 (2+1)	I
3.	EXT-603	Technology Commercialization and Incubation	3 (2+1)	II
4.	EXT-604	Educational Technology and Instructional Design	3(2+1)	III
Total Credits			12	
B. Minor Courses				
1.	EXT-605	Risk Management and climate change adaptation	3(2+1)	II
2.	AEC-608	Natural Resource Management	3(2+1)	I
Total credits			06	
C. Supporting Course:				
1.	AEC-604	Advance Statistical Methods	3(2+1)	II
2.	AEC-605	Operations research	3(2+1)	I
Total credits			05	
1.	EXT-691	Doctoral Seminar-I	1(1+0)	
2.	EXT-692	Doctoral Seminar-II	1(1+0)	
3.	-	Thesis/Research	75	
Total credits			31(0+31)	
Grand total credits			100	

EXT-601

POLICY ENGAGEMENT AND EXTENSION

3(2+1)

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.

AIM OF THIS 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

LEARNING OUTCOMES

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

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.

PRACTICALS

1. Analysis of country/state level agricultural/extension policy to understand the policy intentions from strengthening EAS
2. Analysis of extension policy of other countries: policy intentions, processes adopted in development of the policy and mechanisms of policy implementation
3. 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
4. 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
5. Explore how different stakeholders influence policies (eg: policy advocacy of prominent NGOs, private sector and public sector) -What mechanisms and tools they use
6. 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.

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

RESOURCES

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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.

AIM OF THIS 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
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

LEARNING OUTCOMES

- 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

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

PRACTICALS

1. Practice in developing research instruments
2. Methods of assessing measurement properties of research instruments - dimensionality, reliability and validity
3. Hands-on exercise in minimising errors and biases
4. Hands-on experience in constructing tests, scale and indexes
5. Practice in summated scale development using confirmatory factor analysis
6. Hands on experience in assessing measurement invariance
7. Practicing and collecting data using participatory tools and techniques, analyzing and interpreting qualitative data
8. Hands-on experience in writing systematic review using meta-analysis
9. Field practice in conducting action research
10. Practical experience in writing research paper
11. Hands on exercises using software for qualitative data analysis
12. Practice in detecting and correcting plagiarism using software

TEACHING METHODS/ACTIVITIES

- Lecture
- Assignment(Reading/Writing)
- Student presentation
- Group Work
- Guest Lectures
- Research Report (Writing)

RESOURCES

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EXT-603

TECHNOLOGY COMMERCIALISATION AND INCUBATION

3(2+1)

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.

AIM OF THIS 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

LEARNING OUTCOMES

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

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 Grassroot and 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 policies; 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

PRACTICALS

1. Understanding the technology commercialisation process – Visit to Technology Commercialisation Unit of ICAR Institute/ Agricultural University
2. Understanding the IPR protection practices – Visit to Patent Attorney office
3. Hands-on experience in drafting IPR application – Patent/Copyright/ Trademark
4. Understanding protection of biological resources including plant varieties – Visit to PPVFRA Branch office/ ICAR Institute or Agricultural University involved in plant variety protection
5. Documenting Traditional and indigenous knowledge – Field experience in using various protocols of using traditional and indigenous knowledge
6. Protecting unique local goods through Geographical Indications – Hands on experiences in documenting and registering Geographical indications
7. Technology assessment/ validation of traditional and indigenous knowledge – QuIK and other methods
8. Hands on experience in technology valuation
9. Hands on experience in technology licensing process including drafting agreements
10. Understanding the Technology Business Incubation – Visit to Agri Business Incubator or Technology Business incubator
11. Hands on experience in planning and organising technology promotion events
12. Hands on experience in various techniques in business communication and Business etiquette

TEACHING METHODS/ACTIVITIES

- Lecture cum discussion
- Cases
- Class exercises

- Assignment (Reading/Writing)
- Student's Book/Publication Review
- Group Presentation

RESOURCES

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EXT-604

EDUCATIONAL TECHNOLOGY AND INSTRUCTIONAL DESIGN

3(2+1)

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 everything (IOE), augmented reality, artificial intelligence, etc. makes this course essential for extension professionals who are expected to act as harbingers of change.

AIM OF THIS 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

LEARNING OUTCOMES

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.

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.

PRACTICALS

1. 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
2. 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
3. Assessing learning styles through Barsch and Kolb inventories
4. Development and testing of survey instruments for evaluating learning outcomes/ competencies of students
5. Development and testing of survey instruments for performance appraisal / competency assessment of teachers.
6. 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
7. Designing and developing a theme based knowledge portals
8. Exercises on designing an online course using open source LMS like moodle or EdX
9. Select and evaluate or design for social media
10. Prepare a short research paper on recent theories and models of instructional design
11. 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
12. 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

13. Field visit to a virtual learning / augmented learning labs, e-learning labs, distance learning centres, etc.
14. Hands-on practice with video-editing software, web conferencing and video conferencing solutions

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

RESOURCES

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- [_Enhancing adult motivation-Bokos-Z1-.pdf](#)

WEBSITES

- **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/>

MINOR COURSES

- 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.

Title: 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 equip 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.

AIM OF THIS 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

LEARNING OUTCOMES

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

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 & SDMA; 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

Unit1: 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.

Unit2: 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.

PRACTICALS

1. Hands-on practice in using risk assessment/analysis tools
2. Case studies on risk / distress assessment in agriculture -Indian and global
3. Lessons / Experiences from NICRA Project in agriculture and allied sectors
4. Developing criteria, indicators and indices for assessment of risk, vulnerability and resilience
5. Hands on practice on use of vulnerability and risk assessment tools and techniques
6. Case studies on success stories of climate change adaptation and community based initiatives
7. Developing district and village level intervention plans for climate change adaptation
8. Field Visits to State Disaster Management Authority

9. Case studies on climate smart agriculture / villages from India and world
10. Case studies on impact assessment of crop insurance programs, disaster management programs
11. Capstone project on documenting ITKs and local practices related to reducing risk /climate resilience agriculture

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

RESOURCES

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WEBSITES

CSA-Centre for Sustainable Agriculture <http://csa-india.org/>

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/nicarevised/>

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>

Department of Agricultural Economics & Statistics

M.Sc. (Ag.) in Agricultural Economics & Statistics

Sl. No.	Course No.	Course Name	Credit Hrs.	Semester
Major Courses				
1.	AEC-501	Microeconomic theory and applications	3(3+0)	I
2.	AEC-502	Agricultural Production Economics	2(1+1)	II
3.	AEC-503	Agricultural marketing & price analysis	3(2+1)	II
4.	AEC-504	Macroeconomics & policy	2(2+0)	II
5.	AEC-505	Econometrics	3(2+1)	III
6.	AEC-507	Agricultural finance and project management	3(2+1)	I
7.	AEC-508	Linear programming	2(1+1)	II
8.	AEC-509	Research methodology for social sciences	2(1+1)	III
Total credits			20(12+8)	
Minor Courses				
1.	LPM-501	Cattle & Buffalo production management	3(2+1)	I
2.	AEC-517	Evolution of economic thoughts	1(1+0)	I
3.	AEC-510	Indian economy, history and contemporary issues	2(2+0)	III
4.	AEC-506	Agricultural development & policy analysis	2(2+0)	IV
Total credit Hrs.			08	
Supporting Courses				
1.	STAT-501	Mathematics for applied science/Agril. Economics	2(2+0)	II
	STAT-502	Statistical methods for applied/social sciences	3(2+1)	I
2.	STAT-511	Experimental Design (Plant science)	3(2+1)	I
Total credits			06	
Common Courses				
1.	PGS-501	Library And Information Services	1(0+1)	
2.	PGS-502	Technical Writing and Communications Skill	1(0+1)	
3.	PGS-503	Intellectual Property and Its Management in Agriculture	1(0+1)	
4.	PGS-504	Basic Concept in Laboratory Techniques	1(0+1)	
5.	PGS-505	Agriculture Research, Research Ethics and Rural Development Programmes	1(0+1)	
Total credit Hrs.			5(0+5)	
7.	AEC-591	Master's Seminar	1(1+0)	II
8	AEC-599	Master's Research	30	I-IV
Grand Total Credit Hrs.			70	

AEC-501

MICRO ECONOMIC THEORY AND APPLICATIONS

3(3+0)

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.

Objective 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).

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.

Block 1- Introduction to micro-economics

UNIT I 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 II: 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 III 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 IV 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.

Duopoly: Cournot model and reaction curves; Stackelberg's model, Bertrand model; Oligopoly

Unit V : 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 .

Suggested Readings:

- Modern Micro Economics by A. Koutsoyiannis, Published by MACMILLAN PRESS LTD
- Micro Economic Theory by Ferguson and Gould by Richard D Erwin INC USA
- Richard A. Bilas, Micro Economic Theory.
- Leftwich Richard H., The Price System and Resources Allocation
- Allen, C.L., A Frame Work of Price Theory.

AEC-502

AGRICULTURAL PRODUCTION ECONOMICS

2(1+1)

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.

Objectives 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.

Block 1- Introduction to Production Economics

UNIT I – 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 II – 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 III- 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 IV- 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.

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.

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.

Suggested Readings:

- *E. O. Heady, Economics of Agricultural Production and resources use.*
- *John P. Doll and Frank Orazem, Production Economics: Theory with application*
- *Heady E.O. & Dillon, J L. 1961. Agricultural Production functions. Kalyani Publishers, Ludhiana, India. 667 p.*
- *3. Baumol, W.G. 1973. Economic theory and operations analysis. Practice Hall of India Private Limited, New Dehli. 626 p.*
- *4. Gardner BL & Rausser GC. 2001. Handbook of Agricultural Economics Vol. I Agricultural Production. Elsevier.*

AEC-503

AGRICULTURAL MARKETING AND PRICE ANALYSIS

3(2+1)

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.

Objective 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.

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.

Theory

Block 1- Introduction to Agricultural Marketing

UNIT I – 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 coordination.

Block 2- Agricultural Markets

UNIT II – 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 III- 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 IV- 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 V- Dynamics of price

Price forecasting – time series analysis – time series models – spectral analysis. Price policy and economic development – non-price instruments.

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.

Suggested Readings:

- Acharya, S. S. & Agarawal, N.L.2004. *Agricultural Marketing in India*. Oxford and IBHPublishing company Pvt. Ltd. New Delhi.
- Acharya, S. S. & Agarawal, N. L. 1994. *Agricultural Prices-Analysis and Policy*. Oxfordand IBH Publishing company Pvt. Ltd. New Delhi.
- Richard H Kohls and Joseph N. Uhl: *Marketing of Agricultural products by CollierMacMillan International*

AEC-504

MACRO ECONOMICS AND POLICY

2(2+0)

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.

Objective 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.

Block 1- Conceptualising Macro Economics

UNIT I. 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 II. 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 III. 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 IV: 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 V: THEORIES OF AGGREGATE 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 VI: INFLATION AND UNEMPLOYMENT

Inflation: Nature, Effects and control; Types of inflation – demand pull, cost push- stagflation, core inflation, hyperinflation; Phillips curve.

Suggested Readings:

- Stonier & Hague, A Text Book of Economic Theory
- Samuelson, P. A. 1948. Foundation of Economic Analysis. Harvard University Press
- M. C. Vaish, Allid, New Delhi, 1983 Macro-Economics Theory
- Gardner Ackley, Macmillan, New York, 1961 Macro-Economics Theory:
- T. F. Dernburg & D. M. McDougali-Macro Economics
- G. Sirkin – Introduction to Macro-Economics Theory
- R.L. Heibroker-Understanding Macro-Economics
- J.K Mehta –Macro Economics
- Michael R. Edgemand – Macro-Economics: Theory & Policy
- David' W. Pearce –The dictionary of modern Economics

AEC-505

ECONOMETRICS

3(2+1)

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.

Objective 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.

Block 1- Introduction to Econometrics

UNIT I : Introduction

Relationship between economic theory, mathematical economics, models and econometrics, methodology of econometrics-regression analysis.

Block 2- Classical Regression

UNIT II: 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 III: 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 IV: Qualitative variables and simultaneous equation models

Use of dummy variables- Introduction to simultaneous equations- identification problem

Practical

Single equation two variable model specification and estimation – hypothesis testing transformations of functional forms and OLS application-estimation of multiple regression model - hypothesis testing – testing and correcting specification errors – testing and managing Multicollinearity –estimation of regressions with dummy variables.

Suggested Readings;

- Dorfman R. 1996. *Linear Programming and Economic Analysis*. McGraw Hill.
- Greene, W.H. 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, G.S. 2002. *Econometrics*. Mc Graw-Hill.
- Pinndyck, R.S. and Rubinfeld, D.L. 1990. *Econometric Models and EconometricForecasts*. Mc Graw Hill.

AEC-506

AGRICULTURAL DEVELOPMENT AND POLICY ANALYSIS

2(2+0)

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.

Objectives 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.

Block 1- Introduction

UNIT I 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 II 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 III 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 IV 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.

Suggested Readings:

- 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

AEC-507

AGRICULTURAL FINANCE AND PROJECT MANAGEMENT

3(2+1)

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.

Objective of 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.

Theory

Block 1- Introduction to Agricultural Finance

UNIT I- 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 II- 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 III- 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 IV_- 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 V- 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.

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.

Suggested Readings:

- *E. Die Sollem, H. and Heady, E. O. (Ed.). Capital and Credit Needs in Changing Agriculture, Bauman*
- *Hopkins, A. Barry, Peter Jo, and Baker, C.B., Financial Management in Agriculture,*
- *William G. Murray and Aaron G. Nelson, Iowa State University 1960 Agricultural Finance*
- *Agricultural Finance in India: Role of Commercial Banks, Charnjit Chanona, Marketing and Economics Research Bureau, New Delhi, 1969.*
- *Gittinger, J. P. 1972, Economic analysis of agricultural projects, John Hopkins Univ.Press, Baltimore.*
- *Little, I.M.D. and J.A. Mirrless 1974, Project appraisal and planning for developing countries, Oxford and IBH publishing Co. New Delhi..*
- *Harberger, Arnold C 1972, Project Evaluation, collected papers, Macmillan.*

AEC-508

LINEAR PROGRAMMING

2(1+1)

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.

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.

AEC-509

RESEARCH METHODOLOGY FOR SOCIAL SCIENCES

2(1+1)

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.

Objective 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 data and interpretation of results

Theory

Block 1- Concepts of research methodology

UNIT I- 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 II – Hypothesis: Framing and Testing

Hypothesis – meaning - characteristics - types of hypothesis – review of literature – setting of Course Objective and hypotheses - testing of hypothesis.

UNIT III- 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 IV – 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 V – Data Analysis

Data coding, tabulation, cleaning. –Multivariate analysis –factor analysis’ PCA’ cluster analysis. Universal procedures for preparation of bibliography – writing of research articles.

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.

Suggested Readings-

- *Research Methodology in Agricultural Economics, Baker, C. B.*
- *An Introduction to Logic and Scientific Method, Cohen, M.R. and Nagel, R.*
- *The Theory of Enquiry, Devey, J. Logic*
- *Social Science Research and Thesis Writing, Dhondhyal, S. P.*
- *Correlation Analysis, Ezekiel, M.*
- *Linear Programming Methods, Heady, E. O.*
- *An Introduction to Scientific Research, Willson, E. R.*
- *Research Methodology: A Survey, Anil Kumar Alts, New Delhi, 2008.*

AEC-510

INDIAN ECONOMY: HISTORY AND CONTEMPORARY ISSUES

2(2+0)

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.

Objective

To introduce the students to the economic history over a period of time. It also highlights the contemporary issues of Indian economy.

Block 1- History of Indian Economy

UNIT I: 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 II: 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 III: 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 IV: 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.

Suggested Readings-

Indian Economy By Dutt and Sundaram.

AEC-517

EVOLUTION OF ECONOMIC THOUGHTS

1(1+0)

Theory

UNIT I:

Approaches for the study of history of economic thought – Absolutist vs. Relativist approaches – Evolution of Economic Thought vs. Economic History. Ancient economic thought – medieval economic thought – mercantilism – physiocracy – Forerunners of Classical Political Economy.

UNIT II:

Development of classical thoughts (Adam Smith, Robert Malthus and David Ricardo) – Critics of classical thoughts – socialist critics – socialist and Marxian Economic Ideas – Austrian School of Thought – Origins of Formal Microeconomic Analysis- William Stanley Jevons, Cournot and Dupuit.

UNIT III:

The birth of neoclassical economic thought – Marshal and Walras- General Equilibrium Theory – Welfare Theory – Keynesian economics.

UNIT IV:

The Era of globalization – Experiences of developing world – Rigidity of the past vs. emerging realism – The changing path of international institutions to economic growth and development approaches.

UNIT V:

Economic Thought in India – Naoroji and Gokhale – Gandhian Economics – Economic thought of independent India – Nehru's economic philosophy – Experiences of the structural adjustment programmes of the post liberalization era.

Department of Agricultural Economics & Statistics

Ph.D. in Agricultural Economics & Statistics

SN	Course code	Course Title	Credits	Semester
A. Major Courses				
1.	AEC-601	Advanced Microeconomics analysis	2(1+1)	I
2.	AEC-602	Advanced Macroeconomic analysis	2(2+0)	II
3.	AEC-604	Advanced Production Economics	3(2+1)	II
4.	AEC-603	Advanced Econometrics	3(2+1)	III
5.	COMMON	Research and publication Ethics	2(2+0)	III
Total credit			12	
B. Minor Courses				
1.	AEC-608	Natural Resource Management	3(2+1)	I
2.	AEC-606	Advanced Agril. Marketing & Price Analysis	3(2+1)	II
Total credit			06	
C. Supporting Courses				
1.	AEC-605	Operations Research	3(2+1)	I
2.	STAT-615	Advanced Times Series Analysis	2(2+0)	I
3.	STAT-604	Advanced statistical methods	3(2+1)	II
Total			05	
D. Common course				
1.	AEC - 691	Doctoral Seminar-I	1(0+1)	
2.	AEC - 692	Doctoral Seminar-II	1(0+1)	
3.	AEC - 699	Doctoral Research	75(0+75)	
Grand Total Credit			100	

AEC 601 ADVANCED MICRO ECONOMIC ANALYSIS

2(1+1)

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.

Objective-

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.

Theory

Block 1- Consumer Theory

UNIT I 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 II : Market

Perfect competition – Monopoly, monopolistic competition and oligopoly. Oligopoly models collusive and non-collusive models of oligopoly - Cournot model, Chamberlin model, Stackleberg solution.

UNIT III 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 IV 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 V 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.

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.

Suggested Readings:

- Microeconomic Theory: A Mathematical Approach by James M. Henderson and Richrad E.Quandt , published by Tata McGRAW HILL Publishing Co Ltd
- Modern Micro Economics by A. Koutsoyiannis, Published by MACMILLAN PRESS LTD
- Micro Economic Theory by Ferguson and Gould by Richard D Erwin INC USA

AEC 602

ADVANCED MACRO ECONOMICS

2(2+0)

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 realeconomy.

Objectives-

To understand the functioning of national economy, its history and models. The policiesgoverning the modern economic system and concerned institutions.

Block 1- Introduction

UNIT I. OVERVIEW

Conceptual framework - Classical, Keynesian, Neo-Classical, and Neo-Keynesianmacroeconomics; Review of Keynes-Classical Synthesis; Aggregate Demand and Supply in the closed economywith

fixed and variable price level- determination of wage, prices, output and employment.

Block 2- Economic Models

UNIT II 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 III 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 IV 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 V Macroeconomic Policies

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.

Suggested Readings:

- R.L. Heibroker-Understanding Macro–Economics
- J.K Mehta –Macro Economics
- Michael R. Edgemand – Macro-Economics: Theory & Policy
- David’ W. Pearce –The dictionary of modern Economics
- Macro–Economic Theory: A Mathematical Treatment –R.G.D. Allen- London:Macmillan, 1968.
- Macro–Economics: An Introduction, G. F. Stanlake, Longman, London.
- Macro–Economics: Analysis and Policy, D.M. Mithai, Oxford and IBH, New Delhi, 1981.
- Critical Essays in Monetary Theory, Hicks, J. R.
- Theory of Money, Nawiyn, W. T.

AEC 603

ADVANCED ECONOMETRICS

3(2+1)

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 modelsthat will be used to test the hypothesis framed. Use different analysis depending upon the requirement and type of data.

Objective 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.

Theory

Block 1- Concepts

UNIT I- Review

Review of classical regression model – review of hypothesis testing – restrictions on parameters – single equation techniques.

Block 2- Least Squares and Dummy Variables

UNIT II – 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 III - 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 IV - Models and their extensions

Autoregressive distributed lag models – panel data fixed and random effects models and their extensions.

UNIT V - Simultaneous equation models

Simultaneous equation methods – identification – estimation by indirect least squares 2SLS, PIML, SURE, 3SLS.

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.

Suggested Readings.

1. Greene, W.H. 2002. *Econometric Analysis*. Pearson Education. Johnston, J. and Dinardo, J. 2000. *Econometric Methods*. Mc Graw-Hill. Koutseyianis, A. 1997. *Theory of Econometrics*. Barner & Noble

AEC 604

ADVANCED PRODUCTION ECONOMICS

3(2+1)

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.

Objectives 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.

Theory

Block 1- Production process

UNIT I – 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 II- 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 outputprices- Economic optimum with production function analysis - input use behaviour.

Block 3- Dynamics of production process

UNIT III – 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 IV- 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 V- Programming

Simulation and programming techniques in agricultural production-Multiple Objective Programming (MOP) – Goal programming, Weighted sum and Compromise programming – applications.

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.

Suggested Readings:

- Heady E.O. Economics of Agricultural Production and resources use. Practice Hall of India.
- Heady E.O. & Dillon, J L. 1961. Agricultural Production functions. Kalyani Publishers,Ludhiana, India. 667 p.
- Baumol, W.G. 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.

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 uncertainty 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.

Objectives-

To gain elementary knowledge of solving problems and decision making for managing farming and organisation in resource constraint in order to achieve the objective.

THEORY**Block 1- Concepts****Unit I- 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 II- 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 III - Modles

Markov Chains, Sequencing, Replacement models, Transportation and Assignment problems.

Block 3- Decision Making**Unit IV- 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 V- Game Theory

Game Theory – Two-person Zero sum game, Simulation, Network Analysis- PERT & CPM.

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.

Suggested Readings

- *Operations Research: An Introduction.* by Hamdy A. Taha
- *An Introduction to Operations Research* by Havinal Veerabhadrapa *Operations Research.* by PK Gupta and D.S Hira
- *OPERATIONS RESEARCH* by Rajaneesh Sharma
- *Operation Research* by J.K. Sharma *Greene, W.H. 2002. Econometric Analysis.* Pearson Education.
- *Johnston, J. and Dinardo, J. 2000. Econometric Methods.* Mc Graw-Hill. *Koutseyianis, A. 1997. Theory of*

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.

Objective:

To impart 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.

Theory

Block 1- Concepts

UNIT I- 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 II- 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 III- 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 IV – 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 V – 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.

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.

Suggested Readings:

- Rhodes, V. J. 1978. The Agricultural Marketing System. Grid Pub. Ohio.
- Acharya, S. S. & Agarawal, N.L.2004. Agricultural Marketing in India. Oxfordand IBH Publishing

- company Pvt. Ltd. New Delhi.
- Acharya, S. S. & Agarwal, N. L. 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

AEC -608

NATURAL RESOURCE MANAGEMENT

2(1+1)

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.

Objectives-

Concept building on natural resources. Gaining expertise in economic aspect of natural resources and maintain a balance between economic gains and environment conservation.

Theory

Block 1- Concepts

UNIT I - 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 II – 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 III – 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 IV – 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 V- 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.

Suggested Readings

- *Hackett SC. 2001. Environmental and Natural Resource Economics: Theory, Policy and the Sustainable Society. M.E. Sharpe, Armonk, NY.*
- *Hartwick JM & Olewiler ND. 1998. The Economics of Natural Resource Use. 2nd Ed. Addison-Wesley Educational Publ.*
- *Kerr JM, Marothia DK, Katar Singh, Ramasamy C & Bentley WR. 1997. Natural Resource Economics: Theory and Applications in India. Oxford & IBH.*
- *Pearce DW & 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.*

Department of Entomology

M.Sc. (Ag.) in Entomology

Sl. No.	Course No.	Course Name	Credit Hrs.	Semester
A. Major Course (20 credit)				
1.	ENT 501	Insect morphology	3 (2+1)	I
2.	ENT 502	Insect anatomy and physiology	3 (2+1)	I
3.	ENT 503	Insect taxonomy	3 (1+2)	I
4.	ENT 504	Insect ecology	3 (2+1)	I
5.	ENT 505	Biological control of insect pests and weeds	3 (2+1)	II
6.	ENT 506	Toxicology of insecticides	3 (2+1)	II
7.	ENT 508	Concepts of integrated pest management	2 (2+0)	III
Sub Total			20(13+7)	
B. Minor Course (8 credit)				
1.	PL PATH-504	Plant Nematology	3(2+1)	II
2.	PL PATH -515	Disease of field and Medicinal Crops	3(2+1)	III
3.	PL PATH -513	Biological control of plant disease	2(1+1)	IV
Sub Total			8 (5+3)	
C. Supporting course (6 credit) (*-Mandatory, ** -Mandatory, ** -Choose only 3 credit)				
1.	STAT-511*	Experimental Designs	3(2+1)	II
2.	ENT-507**	Host Plant Resistance	2(1+1)	I
3.	ENT-511**	Post Harvest Entomology	2(1+1)	III
4.	ENT-515**	Techniques in Plant Protection	1(0+1)	III
5.	ENT-520**	Plant quarantine, Biosafety and Biosecurity	2(2+0)	II
Sub Total			06	I
D. Common course				
1.	PGS-501	Library And Information Services	1(0+1)	I
2.	PGS-502	Technical Writing and Communications Skill	1(0+1)	I
3.	PGS-503	Intellectual Property and Its Management in Agriculture	1(0+1)	II
4.	PGS-504	Basic Concept in Laboratory Techniques	1(0+1)	II
5.	PGS-505	Agriculture Research, Research Ethics and Rural Development Programmes	1(0+1)	III
Total			5	
1.	ENT-591	Seminar	1(0+1)	IV
2.	ENT-599	Research	30(0+30)	IV
Sub Total			31(0+31)	
Grand Total			70	

ENT 501

INSECT MORPHOLOGY

3(2+1)

Objective

To acquaint the students with the external morphology of the insect's body and the functioning of various bodyparts.

Theory

UNIT I

External Morphology: Insect body wall structure, cuticular outgrowths, colouration and special integumentary structures in insects, body tagmata, sclerites and segmentation.

Head- Origin, structure and modification; mouthparts, antennae, their types and functioning; tentorium and necksclerites.

Thorax- Areas and sutures of tergum, sternum and pleuron, pterothorax; wings: structure and modifications, venation, wing coupling apparatus and mechanism of flight; legs: structure and modifications.

Abdomen- Segmentation and appendages; genitalia and their modifications; embryonic and post-embryonic development.

UNIT II

Insect sense organs (mechano-, photo- and chemo- receptors); organogenesis at pupal stage; insect defense; chaetotaxy; morphological traits in relation to forensic entomology.

UNIT III

Types of immature stages in insect orders, morphology of egg, nymph/larva and pupa, identification of different immature stages of crop pests and stored product insects. Comparative study of life history strategies in hemi- metabola and holometabola, immature stages as ecological and evolutionary adaptations, significance of immature stages for pest management.

Practical

Preparation of permanent mounts of different body parts and their appendages of taxonomic importance including male and female genitalia; dissection of genitalia. Types of immature stages in insects; their collection, rearing and preservation. Identification of immature insects to orders and families, in endopterygote orders viz., Diptera, Lepidoptera, Hymenoptera and Coleoptera using key.

Learning outcomes

- Students are expected to have a complete understanding of the comparative morphology of the external features of insects that can be utilized in taxonomy, ecology and applied entomology.

Suggested Reading:

- Chapman, RF. 1998. *The Insects: Structure and Function*. Cambridge Univ. Press, Cambridge.
- Duntson, PA. 2004. *The Insects: Structure, Function and Biodiversity*. Kalyani Publ., New Delhi.
- Evans, JW. 2004. *Outlines of Agricultural Entomology*. Asiatic Publ., New Delhi.
- Gillott, C. 1995. *Entomology*, 2nd Ed. Plenum Press, New York, London.
- Gullan, P.J. and Cranston, P.S. 2000. *The Insects, An Outline of Entomology*, 2nd Ed. Blackwell Science, U.K.
- Richards, OW and Davies, RG. 1977. *Imm's General Text Book of Entomology*. 10th Ed. Chapman and Hall, London.
- Snodgrass, RE. 1993. *Principles of Insect Morphology*. Cornell Univ. Press, Ithaca.
- Tembore, D.B. 2000. *Modern Entomology*, Himalaya Publishing House, Mumbai.
- Chu, HF. 1992. *How to Know Immature Insects*. William Brown Publication, Iowa.
- Peterson, A. 1962. *Larvae of Insects*. Ohio University Press, Ohio.
- Stehr, FW. 1998. *Immature Insects*. Vols. I, II. Kendall Hunt Publication, Iowa.

ENT 502

INSECT ANATOMY AND PHYSIOLOGY

3 (2+1)

Objective

To impart knowledge about the anatomy and physiology of insect body systems; nutritional physiology; and their applications in entomology.

Theory

UNIT I

Scope and importance of insect physiology; physiology of integument, moulting, chemistry

of cuticle,

biosynthesis of chitin; growth, hormonal control, metamorphosis and diapause; pheromone secretion, transmission, perception and reception.

UNIT II

Physiology and mechanism of digestion, circulation, respiration, excretion, reproduction, secretion (**exocrine** & endocrine glands) and nerve impulse transmission in insects.

UNIT III

Importance of insect nutrition- role of vitamins, proteins, amino acids, carbohydrates, lipids, minerals and other food constituents; extra and intra-cellular microorganisms and their role in physiology; artificial diets.

Practical

Latest analytical techniques for analysis of free amino acids of haemolymph; determination of chitin in insect cuticle; examination and count of insect haemocytes; preparation and evaluation of various diets; consumption, utilization and digestion of natural and artificial diets.

Learning outcomes

☐ Students are expected to have a thorough understanding of insect growth and development, physiology of exoskeleton, endoskeleton and different organ systems; action and role of hormones, pheromones, physiology of nutrition and its application.

Suggested Reading

- Chapman RF. 1998. *Insects: Structure and Function*. ELBS Ed., London.
- Duntson PA. 2004. *The Insects: Structure, Function and Biodiversity*. Kalyani Publ., New Delhi.
- Gullan, P.J. and Cranston, P.S. 2000. *The Insects: An Outline of Entomology*, 2nd Ed. Blackwell Science, U.K.
- Kerkut GA and Gilbert LI. 1985. *Comprehensive Insect Physiology, Biochemistry and Pharmacology*. Vols. I-XIII. Pergamon Press, New York.
- Patnaik BD. 2002. *Physiology of Insects*. Dominant Publishers, New Delhi.
- Richards OW and Davies RG. 1977. *Imm's General Text Book of Entomology*. 10th Ed. Vol. 1. *Structure, Physiology and Development*. Chapman and Hall, New York.
- Simpson, SJ. 2007. *Advances in Insect Physiology*, Vol. 33, Academic Press (Elsevier), London, UK.
- Wigglesworth VB. 1984. *Insect Physiology*. 8th Ed. Chapman and Hall, New York.

ENT 503

INSECT TAXONOMY

3(1+2)

Objective

To sensitize the students on the theory and practice of classifying organisms (with special reference to animals) and the rules governing the same. To introduce the students to the classification of insects up to the level of families with hands-on experience in identifying the families of insects with an emphasis on the practical aspects.

Theory

UNIT I

History of insect classification; principles of systematics and its importance. Identification, purpose, methods character matrix, taxonomic keys. Descriptions- subjects of descriptions, characters, nature of characters, analogy v/s homology, parallel v/s convergent evolution, intraspecific variation in characters, polythetic and polymorphic taxa, sexual dimorphism. Brief evolutionary history of insects- introduction to phylogeny of insects and Classification of Superclass Hexapoda – Classes – Ellipura (Collembola, Protura), Diplura and Insecta- and the Orders contained. International Code of Zoological Nomenclature, Phylocode, its brief explanation and uses. Process of speciation and interbreeding allopatric species. Molecular systematics, DNA barcoding, karyological and

biochemical approaches in taxonomy. Insect labeling protocols and procedures.

UNIT II

Distinguishing characters, general biology, habits and habitats of insect orders and economically important families contained in them. Collembola, Protura, Diplura. Class Insecta: Subclass Apterygota – Archaeognatha, Thysanura. Subclass: Pterygota, Division Palaeoptera – Odonata and Ephemeroptera. Division: Neoptera: Subdivision: Orthopteroid and Blattoid Orders (=Oligoneoptera: Plecoptera, Blattodea, Isoptera, Mantodea, Grylloblattodea, Dermaptera, Orthoptera, Phasmatodea, Mantophasmatodea, Embioptera, Zoraptera), Subdivision: Hemipteroid Orders (=Paraneoptera): Psocoptera, Phthiraptera, Thysanoptera and Hemiptera.

UNIT III

Distinguishing characters, general biology, habits and habitats of insect orders and economically important families contained in them (Continued). Division Neoptera – Subdivision Endopterygota, Section Neuropteroid- Coleopteroid Orders: Strepsiptera, Megaloptera, Raphidioptera, Neuroptera and Coleoptera, Section Panorpid Orders Mecoptera, Siphonaptera, Diptera, Trichoptera, Lepidoptera, and Section Hymenopteroid Orders: Hymenoptera.

Practical

Study of Orders of insects and their identification using taxonomic keys. Keying out families of insects of different major Orders: Odonata, Orthoptera, Blattodea, Mantodea, Isoptera, Hemiptera, Thysanoptera, Phthiraptera, Neuroptera, Coleoptera, Diptera, Lepidoptera and Hymenoptera. Field visits to collect insects of different orders.

Learning outcomes

- Students are expected to know the evolution of arthropods, especially insects and other hexapods, and their hierarchical classification.
- Acquire working skills for collecting, mounting, and preserving insects.
- Understand the basic concepts of taxonomic hierarchy, identification, taxonomic characters, variations, taxonomic keys and preparation of taxonomic papers.
- Identify insects of economic importance up to family levels, taking up the insect orders of agriculture and veterinary importance.

Suggested Reading

- CSIRO 1990. *The Insects of Australia: A Text Book for Students and Researchers*. 2nd Ed. Vols. I and II, CSIRO. Cornell Univ. Press, Ithaca.
- Freeman S and Herron JC. 1998. *Evolutionary Analysis*. Prentice Hall, New Delhi.
- Gullan, P.J. and Cranston, P.S. 2010. *The Insects: An outline of Entomology*. 4th Ed. Wiley-Blackwell Publications, West Sussex, UK.
- Mayr, E. 1971. *Principles of Systematic Zoology*. Tata McGraw Hill, New Delhi.
- Richards OW and Davies RG. 1977. *Imm's General Text Book of Entomology*. 10th Ed. Chapman and Hall, London.
- Ross HH. 1974. *Biological Systematics*. Addison Wesley Publ. Company.
- Triplehorn CA and Johnson NF. 1998. *Borror and DeLong's Introduction to the Study of Insects*. 7th Ed. Thomson/ Brooks/ Cole, USA/Australia.

ENT 504

INSECT ECOLOGY

3(2+1)

Objective

To teach the concepts of ecology, basic principles of distribution and abundance of organisms and their causes. Study life tables, constructing life tables, organization of communities, diversity indices. Train students in sampling methodology, calculation of diversity indices, relating insect population fluctuations to biotic and/or abiotic causes.

Theory

UNIT I

History and definition. Basic Concepts. Organisation of the Biological world. Plato's Natural Balance vs Ecological Dynamics as the modern view. Abundance and diversity of insects, Estimates and Causal factors. Study of abundance and distribution and relation between the two. Basic principles of abiotic factors and their generalised action on insects. Implications for abundance and distribution of organisms including insects- Law of the Minimum, Law of Tolerance, and biocoenosis, Systems approach to ecology.

UNIT II

Basic concepts of abundance- Model vs Real world. Population growth basic models – Exponential vs Logistic models. Discrete vs Continuous growth models. Concepts of Carrying capacity, Environmental Resistance and Optimal yield. Vital Statistics- Life Tables and their application to insect biology. Survivorship curves. Case studies of insect life tables. Population dynamics- Factors affecting abundance- Environmental factors, dispersal and migration, Seasonality in insects. Classification and mechanisms of achieving different seasonality- Diapause (Quiescence) - aestivation, hibernation.

UNIT III

Biotic factors- Food as a limiting factor for distribution and abundance, Nutritional Ecology. Food chain- web and ecological succession. Interspecific interactions- Basic factors governing the interspecific interactions- Classification of interspecific interactions - The argument of cost-benefit ratios. Competition- Lotka-Volterra model, Concept of niche ecological homologues, competitive exclusion. Evolution of mimicry, colouration, concept of predator satiation; evolution of life history strategies.

UNIT IV

Community ecology- Concept of guild, Organisation of communities- Hutchinson Ratio, May's d/w , Relation between the two and their association with Dyar's Law and Prizibram's law. Relative distribution of organisms, Concept of diversity- the Wallacian view. Assessment of diversity. Diversity- stability debate, relevance to pest management. Pest management as applied ecology. Climate change and insect pest/ natural enemy population; ecological engineering.

Practical

Types of distributions of organisms. Methods of sampling insects, estimation of densities of insects and understanding the distribution parameters- Measures of central tendencies, Poisson Distribution, Negative Binomial Distribution. Determination of optimal sample size. Learning to fit basic population growth models and testing the goodness of fit. Fitting Holling's Disc equation, Assessment of prey-predator densities from natural systems and understanding the correlation between the two. Assessing and describing niche of some insects of a single guild. Calculation of niche breadth, activity breadth and diagrammatic representation of niches of organisms. Calculation of diversity indices- Shannon's, Simpson's and Avalanche Index and understanding their associations and parameters that affect their values. Problem solving in ecology. Field visits to understand different ecosystems and to study insect occurrence in these systems.

Learning outcomes

- The students are expected to be well versed with the basic concepts of ecology, ecological succession, population ecology, community ecology, nutritional ecology and different insect-ecosystem interactions.
- Quantification of insect diversity and abundance, life table analyses, predator-prey and host-parasitoid relations, functional and numerical responses, niche breadth and overlap.

Suggested Reading

- Begon, M., Townsend, C.R. and Harper, J. L. 2006. *Ecology: From Individuals to Ecosystems*. 4th Ed. Blackwell Publishing, USA/ UK/ Australia.
- Chapman J. L. and Reiss MJ. 2006. *Ecology: Principles and Applications*. 2nd Ed. Cambridge Univ. Press, Cambridge.
- Fowler, J., Cohen, L. and Jarvis, P. 1998. *Practical Statistics for Field Biology*. 2nd Ed. John Wiley & Sons, Chichester, West Sussex PO19 8SQ, England.
- Gotelli N. J and Ellison AM. 2004. *A Primer of Ecological Statistics*. Sinauer Associates, Inc., Sunderland, MA.
- Gotelli N. J. 2001. *A Primer of Ecology*. 3rd Ed. Sinauer Associates, Inc., Sunderland, MA
- Gupta RK. 2004. *Advances in Insect Biodiversity*. Agrobios, Jodhpur.
- Krebs CJ. 1998. *Ecological Methodology*. 2nd Ed. Benjamin-Cummings Publ. Co., New York.
- Krebs CJ. 2001. *Ecology: The Experimental Analysis of Distribution and Abundance*. 5th Ed. Benjamin-Cummings Publ. Co., New York.
- Magurran AE. 1988. *Ecological Diversity and its Measurement*. Princeton Univ. Press, Princeton.
- Price PW. 1997. *Insect Ecology*. 3rd Ed. John Wiley, New York.
- Real LA and Brown JH. (Eds). 1991. *Foundations of Ecology: Classic Papers with Commentaries*. University of Chicago Press, Chicago.
- Schowalter, Timothy D. 2011. *Insect Ecology – An Ecosystem Approach*. 3rd Ed. Academic Press, London, UK/CA, USA.
- Southwood TRE and Henderson PA. 2000. *Ecological Methods*. 3rd Ed. Methuen and Co. Ltd., London.
- Speight MR, Hunta MD and Watt AD. 2006. *Ecology of Insects: Concepts and Application*. Elsevier Science Publ., The Netherlands.
- Townsend, Colin R., Begon, Michael and Harper, John L. 2008. *Essentials of Ecology*. 3rd Ed. Blackwell Publishing, USA/ UK/ Australia.
- Wilson EO and William H Bossert WH. 1971. *A Primer of Population Biology*. Harvard University, USA.
- Wratten SD and Fry GLA. 1980. *Field and Laboratory Exercises in Ecology*. Arnold, London.

ENT 506

TOXICOLOGY OF INSECTICIDES

3(2+1)

Objective

To orient the students with structure and mode of action of important insecticides belonging to different groups, development of resistance to insecticides by insects, environmental pollution caused by toxic insecticides and their toxicological aspects.

Theory

UNIT I

Definition and scope of insecticide toxicology; history of chemical control; pesticide use and pesticide industry in India.

UNIT II

Classification of insecticides and acaricides based on mode of entry, mode of action and chemical nature; categorization of insecticides on the basis of toxicity – criteria for bees, beneficial insects and other insects in general; structure and mode of action of organochlorines, organophosphates, carbamates, pyrethroids, tertiary amines, neonicotinoids, oxadiazines, phenyl pyrazoles, insect growth regulators, microbials, botanicals, new promising compounds/ new insecticide molecules; nanopesticides; drawbacks of insecticide abuse.

UNIT III

Principles of toxicology; evaluation of insecticide toxicity; joint action of insecticides- synergism, potentiation and antagonism; factors affecting toxicity of insecticides; insecticide compatibility,

selectivity and phytotoxicity. bioassay definition, objectives, criteria, factors, problems and solutions.

UNIT IV

Insecticide metabolism; insect-pest resistance to insecticides; mechanisms and types of resistance; insecticide resistance management and pest resurgence.

UNIT V

Insecticide residues, their significance and environmental implications; procedures of insecticide residue analysis. Insecticide Act, registration procedures, label claim, and quality control of insecticides; safe use of insecticides; diagnosis and treatment of insecticide poisoning.

Practical

Insecticide formulations and mixtures; laboratory and field evaluation of bio-efficacy of insecticides; bioassay techniques; probit analysis; evaluation of insecticide toxicity. Toxicity to beneficial insects. Pesticide appliances. Working out doses and concentrations of pesticides. Procedures of residue analysis.

Learning outcomes

- Students are expected understand the concept of toxicity, bio-efficacy, insecticide formulations, modes of action of insecticides, estimation of insecticide residues and have significant know-how about the functioning of various types of spray equipments.

Suggested Readings

- Chattopadhyay SB. 1985. *Principles and Procedures of Plant Protection*. Oxford and IBH, New Delhi.
- Gupta HCL. 1999. *Insecticides: Toxicology and Uses*. Agrotech Publ., Udaipur.
- Ishaaya I and Degheele (Eds.). 1998. *Insecticides with Novel Modes of Action*. Narosa Publ. House, New Delhi.
- Matsumura F. 1985. *Toxicology of Insecticides*. Plenum Press, New York.
- Perry AS, Yamamoto I, Ishaaya I and Perry R. 1998. *Insecticides in Agriculture and Environment*. Narosa Publ. House, New Delhi.
- Prakash A and Rao J. 1997. *Botanical Pesticides in Agriculture*. Lewis Publication, New York.
- Pedigo, L.P. and Marlin, E. R. 2009. *Entomology and Pest Management*, 6th Edition, Pearson Education Inc., Upper Saddle River, New Jersey 07458, U.S.A.
- Dovener, R.A. Mueninghoff, J.C. and Volgar, G.C. 2002. Pesticides formulation and delivery systems: meeting the challenges of the current crop protection industry. ASTM, USA
- Dodia, D.A. Petel, I.S. and Petal, G.M. 2008. *Botanical Pesticides for Pest Management*. Scientific Publisher (India), Jodhpur.
- Ishaaya, I. and Degheele, D. 1998. *Insecticides with Novel Modes of Action: Mechanism and Application*. Narosa Publishing House, New Delhi.
- Mathews G.A. 2002. *Pesticide Application Methods*. 4th Ed. Intercept. UK.
- Otto, D. and Weber, B. 1991. *Insecticides: Mechanism of Action and Resistance*. Intercept Ltd., U.K.
- Roy, N.K. 2006. *Chemistry of Pesticides*. Asia Printograph Shahdara Delhi.
- Krieger, R. I. 2001. *Handbook of Pesticide Toxicology*. Vol-II. Academic Press. Orlando Florida.

ENT 507

HOST PLANT RESISTANCE

2(1+1)

Theory

UNIT I

History and importance of resistance; principles, classification, components, types and mechanisms of resistance.

UNIT II

Insect-host plant relationships; theories and basis of host plant selection in phytophagous insects.

UNIT III

Chemical ecology, tritrophic relations, volatiles and secondary plant substances; basis of resistance. Induced resistance - acquired and induced systemic resistance.

UNIT IV

Factors affecting plant resistance including biotypes and measures to combat them. UNIT V

Screening techniques; breeding for insect resistance in crop plants; exploitation of wild plant species; genetransfer, successful examples of resistant crop varieties in India and world.

UNIT VI

Role of biotechnology in plant resistance to insects.

Practical

Screening techniques for measuring resistance; measurement of plant characters and working out their correlations with plant resistance; testing of resistance in important crops; bioassay of plant extracts of susceptible/resistant varieties; demonstration of antibiosis, tolerance and antixenosis.

Learning outcomes

Students are expected to acquire a thorough knowledge of the types and basis of mechanisms involved in host plant resistance, screening techniques to measure resistance and insect resistance breeding.

Suggested Readings

- Dhaliwal GS and Singh R. (Eds). 2004. *Host Plant Resistance to Insects -Concepts and Applications*. PanimaPubl., New Delhi.
- Maxwell FG and Jennings PR. (Eds). 1980. *Breeding Plants Resistant to Insects*. John Wiley and Sons, NewYork.
- Painter RH. 1951. *Insect Resistance in Crop Plants*. MacMillan, London.
- Panda N and Khush GS. 1995. *Plant Resistance to Insects*. CABI, London.
- Smith CM. 2005. *Plant Resistance to Arthropods – Molecular and Conventional Approaches*. Springer, Berlin.

ENT 508

CONCEPTS OF INTEGRATED PEST MANAGEMENT

2(2+0)

Objective

To familiarize the students with principles of insect pest management, including concept and philosophy of IPM. Train students in computation of ETL and implementing IPM programmes.

Theory

UNIT I

History, origin, definition and evolution of various terminologies. Importance of resistance, principles, classification, components, types and mechanisms of resistance. National and international level crop protection organizations; insecticide regulatory bodies; synthetic insecticide, bio-pesticide and pheromone registration procedures; label claim of pesticides – the pros and cons.

UNIT II

Concept and philosophy, ecological principles, economic threshold concept and economic consideration. Insect- host plant relationships; theories and basis of host plant selection in phytophagous insects.

UNIT III

Tools of pest management and their integration- legislative, quarantine regulations, cultural,

physical and mechanical methods; semiochemicals, biotechnological and bio-rational approaches in IPM. Pest survey and surveillance, forecasting, types of surveys including remote sensing methods, factors affecting surveys; political, social and legal implications of IPM; pest risk analysis; pesticide risk analysis; cost-benefit ratios and partial budgeting; case studies of successful IPM programmes. ITK-s in IPM, area-wide IPM and IPM for organic farming; components of ecological engineering with successful examples.

UNIT IV

Characterization of agro-ecosystems; sampling methods and factors affecting sampling; population estimation methods; crop loss assessment direct losses, indirect losses, potential losses, avoidable losses, unavoidable losses; global and Indian scenario of crop losses. Computation of EIL and ETL; crop modeling; designing and implementing IPM system. Screening techniques; breeding for insect resistance in crop plants; exploitation of wild plant species; gene transfer, successful examples of resistant crop varieties in India and world.

Learning outcomes

Students are expected to have significant knowledge of IPM concepts, estimation of losses due to insect pests, computation of ETL, EIL and should be able to take management decisions.

Suggested Readings

- Dhaliwal GS and Arora R. 2003. *Integrated Pest Management – Concepts and Approaches*. Kalyani Publ., New Delhi.
- Horowitz AR and Ishaaya I. 2004. *Insect Pest Management: Field and Protected Crops*. Springer, New Delhi.
- Ignacimuthu SS and Jayaraj S. 2007. *Biotechnology and Insect Pest Management*. Elite Publ., New Delhi.
- Pedigo RL. 2002. *Entomology and Pest Management*. 4th Ed. Prentice Hall, New Delhi.
- Norris RF, Caswell-Chen EP and Kogan M. 2002. *Concepts in Integrated Pest Management*. Prentice Hall, New Delhi.
- Subramanyam B and Hagstrum DW. 1995. *Integrated Management of Insects in Stored Products*. Marcel Dekker, New York.

ENT 509

PESTS OF FIELD CROPS

3(2+1)

Objective

To familiarize the students about nature of damage and seasonal incidence of pestiferous insects that cause loss to major field crops and their effective management by different methods.

Theory

Systematic position, identification, distribution, host-range, bionomics, nature and extent of damage, seasonal abundance and management of insect and mite pests and vectors. Insect pest scenario in relation to climate change.

UNIT I

Polyphagous pests: grasshoppers, locusts, termites, white grubs, hairy caterpillars, and non-insect pests (mites, birds, rodents, snails, slugs etc.). Insect pests of cereals and millets and their management.

UNIT II

Insect pests of pulses, tobacco, oilseeds and their management.

UNIT III

Insect pests of fibre crops, forage crops, sugarcane and their management.

Practical

Field visits, collection and identification of important pests and their natural enemies; detection and estimation of infestation and losses in different crops; study of life history of important insect pests.

Learning outcomes

Students are expected to acquire knowledge of insect pests of field crops, their nature of damage, life history traits and effective management.

Suggested Readings

- David, BV and Ramamurthy, VV. 2001. *Elements of Economic Entomology*. Popular Book Depot, Chennai.
- Dhaliwal GS, Singh R and Chhillar BS. 2006. *Essentials of Agricultural Entomology*. Kalyani Publ., New Delhi.
- Dunston AP. 2007. *The Insects: Beneficial and Harmful Aspects*. Kalyani Publ., New Delhi
- Evans JW. 2005. *Insect Pests and their Control*. Asiatic Publ., New Delhi.
- Nair MRGK. 1986. *Insect and Mites of Crops in India*. ICAR, New Delhi.
- Prakash I and Mathur RP. 1987. *Management of Rodent Pests*. ICAR, New Delhi.
- Saxena RC and Srivastava RC. 2007. *Entomology at a Glance*. Agrotech Publ. Academy, Udaipur.

ENT 511

POST HARVEST ENTOMOLOGY

2(1+1)

Objective

To focus on requirement and importance of grain and grain storage, to understand the role of stored grain pests and to acquaint with various stored grain pest management techniques for avoiding losses in storage.

Theory

UNIT I

Introduction, history of storage entomology, concepts of storage entomology and significance of insect pests. Post-harvest losses *in toto vis-à-vis* total production of food grains in India. Scientific and socio-economic factors responsible for grain losses. Concept of seed vault.

UNIT II

Important pests namely insects, mites, rodents, birds and microorganisms associated with stored grain and field conditions including agricultural products; traditional storage structures; association of stored grain insects with fungi and mites, their systematic position, identification, distribution, host range, biology, nature and extent of damage, role of field and cross infestations and natural enemies, type of losses in stored grains and their effect on quality including biochemical changes.

UNIT III

Ecology of insect pests of stored commodities/grains with special emphasis on role of moisture, temperature and humidity in safe storage of food grains and commodities. Stored grain deterioration process, physical and biochemical changes and consequences. Grain storage- types of storage structures i.e., traditional, improved and modern storage structures in current usage. Ideal seeds and commodities' storage conditions.

UNIT IV

Important rodent pests associated with stored grains and their non-chemical and chemical control including fumigation of rat burrows. Role of bird pests and their management. Control of infestation by insect pests, mites and microorganisms. Preventive measures- Hygiene/sanitation, disinfestations of stores/receptacles, legal methods. Curative measures- Non-chemical control measures- ecological, mechanical, physical, cultural, biological and engineering. Chemical control- prophylactic and curative- Characteristics of pesticides, their use and precautions in their handling with special emphasis on fumigants. Insecticide resistance in stored product pests and its management; recent advances (MAS, PPP, HS) in storage pest management; integrated approaches to stored grain pest management.

Practical

Collection, identification and familiarization with the stored grains/seed insect pests and nature of damage caused by them; detection of hidden insect infestation in stored food grains; estimation of uric acid content in infested produce; estimation of losses in stored food grains; determination of moisture content in stored food grains; familiarization of storage structures, demonstration of preventive and curative measures including fumigation techniques; treatment of packing materials and their effect on seed quality. Field visits to save grain campaign, central warehouse and FCI warehouses and institutions engaged in research or practice of grain storage like CFTRI, IGSMRI, Hapur etc. (only where logistically feasible).

Learning outcomes

- Students are expected to acquire knowledge of pestiferous insects, mites, rats and birds affecting stored produce, their nature of damage, life history traits and effective management.
- Detection of insect infestation and familiarization with different storage structures.
- Learning preventive and curative measures to manage infestation in storage houses.

Suggesting Readings

- Hall DW. 1970. *Handling and Storage of Food Grains in Tropical and Subtropical Areas*. FAO. Agricultural Development Paper No. 90 and FAO, Plant Production and Protection Series No. 19, FAO, Rome.
- Jayas DV, White NDG and Muir WE. 1995. *Stored Grain Ecosystem*. Marcel Dekker, New York.
- Khader V. 2004. *Textbook on Food Storage and Preservation*. Kalyani Publ., New Delhi.
- Khare BP. 1994. *Stored Grain Pests and Their Management*. Kalyani Publ., New Delhi.
- Subramanyam B and Hagstrum DW. 1995. *Interrelated Management of Insects in Stored Products*. Marcel Dekker, New York.

ENT 515

TECHNIQUES IN PLANT PROTECTION

1(0+1)

Objective

To acquaint the students with appropriate use of plant protection equipments and techniques related to microscopy, computation, pest forecasting, etc.

Theory

UNIT I

Pest control equipments, principles, operation, maintenance, selection, and application of pesticides; release of bio-control agents; seed dressing, soaking, root-dip treatment, dusting, spraying, and pesticide application through irrigation water; application of drones in plant protection.

UNIT II

Soil sterilization, solarization, deep ploughing, flooding, techniques to check the spread of pests through seed, bulbs, corms, cuttings and cut flowers.

UNIT III

Uses of light, transmission and scanning electron microscopy.

UNIT IV

Protein isolation from the pest and host plant and its quantification using spectrophotometer and molecular weight determination using SDS/PAGE.

UNIT V

Use of tissue culture techniques in plant protection. Computer application for predicting/ forecasting

pest attack and identification.

Learning outcomes

Students are expected to have a good knowledge of different plant protection equipments and techniques related to pest forecasting.

Suggested Readings

- Alford DV. 1999. *A Textbook of Agricultural Entomology*. Blackwell Science, London. Crampton JM and Eggleston P. 1992. *Insect Molecular Science*. Academic Press, London.

ENT 520

PLANT QUARANTINE, BIO-SAFETY AND BIO-SECURITY

2(2+0)

Objective

To acquaint the learners about the principles and the role of Plant Quarantine in containment of pests and diseases, plant quarantine regulations and set-up. Also, to facilitate students to have a good understanding of the aspects of biosafety and biosecurity.

Theory

UNIT I

Definition of pest, pesticides and transgenics as per Govt. notification; relative importance; quarantine – domestic and international. Quarantine restrictions in the movement of agricultural produce, seeds and planting material; case histories of exotic pests/diseases and their status.

UNIT II

Plant protection organization in India. Acts related to registration of pesticides and transgenics. Insecticide regulatory bodies, synthetic insecticides, bio-pesticides and pheromone registration procedures. History of quarantine legislations, PQ Order 2003. Environmental Acts, Industrial registration; APEDA, Import and Export of bio-control agents.

UNIT III

Identification of pest/disease free areas; contamination of food with toxigens, microorganisms and their elimination; Symptomatic diagnosis and other techniques to detect pest/pathogen infestations; VHT and other safer techniques of disinfection/salvaging of infected material.

UNIT IV

WTO regulations; non-tariff barriers; pest risk analysis, good laboratory practices for pesticide laboratories; pesticide industry; sanitary and phytosanitary measures. Global Positioning System (GPS) and Geographic Information System (GIS) for plant biosecurity, pest/disease and epidemic management, strategies for combating risks and costs associated with agroterrorism event, mitigation planning, integrated approach for biosecurity. Biosafety, policies and regulatory mechanism, Cartagena Protocol on Biosafety and its implications, issues related to release of genetically modified crops.

Learning outcomes

Students offering this course are expected to have a good knowledge of the rules and regulations of Plant Quarantine, WTO regulations, GAP, Sanitary and Phytosanitary measures.

Suggested Readings

- Rajeev K and Mukherjee RC. 1996. *Role of Plant Quarantine in IPM*. Aditya Books.
- Rhower GG. 1991. Regulatory Plant Pest Management. In: *Handbook of Pest Management in Agriculture*. 2nd Ed. Vol. II. (Ed. David Pimental), CRC Press.
- Shukla, A. and Veda, O.P. 2007. *Introduction to Plant Quarantine*. Samay Prakashan, New Delhi.

Department of Entomology

Ph.D. in Entomology

Sl. No.	Course No.	Course Name	Credit Hrs.	Semester
A.	Major Course (12 credit)			
1.	ENT-602	Insect physiology and nutrition	3 (2+1)	I
2.	ENT-603	Insect ecology and diversity	3 (2+1)	I
3.	ENT-605	Bio-inputs for pest management	3 (2+1)	II
4.	ENT-606	Insect toxicology and residues	3 (2+1)	II
Sub Total			12(8+4)	
B.	Minor Course (6 credit)			
1.	ENT 601	Insect phylogeny and systematics	3(1+2)	I
2.	PPA-604	Molecular basis of host pathogen interaction	3(2+1)	II
Sub Total			06(3+3)	
C.	Supporting Course			
1.	STAT-604	Advanced statistics methods	3(2+1)	I
	OR			
	STAT-612	Advanced design of experiments	3(2+1)	II
2.	PL PATH-606	Plant Biosecurity and Biosafety	2(2+0)	III
	OR			
	ENT-610	Integrated Pest Management	2(2+0)	III
Sub Total			05	
1.	ENT-691	Seminar I	1(0+1)	III
2.	ENT-692	Seminar II	1(0+1)	IV
3.	ENT-699	Research	75(0+75)	
Grand Total			100	

ENT 601

INSECT PHYLOGENY AND SYSTEMATICS

3(1+2)

Objective

To familiarize the students with different schools of classification, phylogenetics, classical and molecular methods, evolution of different groups of insects. Detailed study about the International Code of Zoological Nomenclature; ethics and procedure for taxonomic publications.

Theory

UNIT I

Detailed study of three schools of classification- numerical, evolutionary and cladistic. Methodologies employed. Development of phenograms, cladograms, molecular approaches for the classification of organisms. Methods in identification of homology. Species concepts, speciation processes and evidences. Zoogeography.

UNIT II

Study of different views on the evolution of insects- alternative phylogenies of insects: Kukalova Peck and Kristensen. Fossil insects and evolution of insect diversity over geological times.

UNIT III

Detailed study of International Code of Zoological Nomenclature, including appendices to ICZN; scientific ethics. Nomenclature and documentation protocols and procedures; report preparation on new species; deposition of holotypes, paratypes, and insect specimens as a whole in national and international repositories – requirements and procedures.

UNIT IV

Concept of Phylocode and alternative naming systems for animals. A detailed study of selected representatives of taxonomic publications – small publications of species descriptions, works on revision of taxa, monographs, check lists, faunal volumes, etc. Websites related to insect taxonomy and databases. Molecular taxonomy, barcoding species and the progress made in molecular systematics.

Practical

Collection, curation and study of one taxon of insects- literature search, compilation of a checklist, study of characters, development of character table, and construction of taxonomic keys for the selected group. Development of descriptions, photographing, writing diagrams, and preparation of specimens for “type like” preservation. Submission of the collections made of the group. Multivariate analysis techniques for clustering specimens into different taxa, and development of phenograms. Rooting and character polarization for developing cladograms and use of computer programmes to develop cladograms.

Learning outcomes

- Scholars are expected to understand the concepts of taxonomic hierarchy, study taxonomic characters, variations, intra-specific phenotypic plasticity; prepare taxonomic keys for specific groups and write taxonomic papers and reviews.
- Scholars should be able to identify insects of economic importance up to family/ generic levels and specialize in any one group of insects up to species level identification.

Suggested Readings

- CSIRO 1990. *The Insects of Australia: A Text Book for Students and Researchers*. 2nd Ed. Vols. I and II, CSIRO. Cornell Univ. Press, Ithaca.
- Dakeshott J and Whitten MA. 1994. *Molecular Approaches to Fundamental and Applied Entomology*. Springer-Verlag, Berlin.
- Freeman S and Herron JC. 1998. *Evolutionary Analysis*. Prentice Hall, New Delhi. Hennig W. 1960. *Phylogenetic Systematics*. Urbana Univ. Illinois Press, USA.
- Hoy MA. 2003. *Insect Molecular Genetics: An Introduction to Principles and Applications*. 2nd Ed. Academic Press, New York.
- Mayr E and Ashlock PD. 1991. *Principles of Systematic Zoology*. 2nd Ed. McGraw Hill, New York. Mayr E. 1969. *Principles of Systematic Zoology*. McGraw-Hill, New York.
- Quicke DLJ. 1993. *Principles and Techniques of Contemporary Taxonomy*. Blackie Academic and Professional, London.
- Ross HH. 1974. *Biological Systematics*. Addison Wesley Publ. Co., London.
- Wiley EO. 1981. *Phylogenetics: The Theory and Practices of Phylogenetic Systematics for Biologists*. Columbia Univ. Press, USA.

ENT 602

INSECT PHYSIOLOGY AND NUTRITION

3(2+1)

Objective

To impart knowledge to the students on detailed physiology of various secretory and excretory systems, moulting process, chitin synthesis, physiology of digestion, transmission of nerve impulses, nutrition of insects, pheromones etc.

Theory

UNIT I

Physiology and biochemistry of insect cuticle and moulting process. Biosynthesis of chitin, chitin-protein interactions in various cuticles, hardening of cuticle.

UNIT II

Digestive enzymes, digestive physiology in phytophagous, wood boring and wool feeding insects, efficiency of digestion and absorption, role of endosymbionts in insect nutrition, nutritional effects on growth and development; physiology of excretion and osmoregulation, water conservation mechanisms.

UNIT III

Detailed physiology of nervous system, transmission of nerve impulses, neurotransmitters and modulators. Production of receptor potentials in different types of sensilla, pheromones and other semiochemicals in insect life, toxins and defense mechanisms.

UNIT IV

Endocrine system and insect hormones, physiology of insect growth and development-metamorphosis, polymorphism and diapause. Insect behaviour in IPM- Concept of super-normal stimuli and behavioural manipulation as potential tool in pest management, use of semio-chemicals, auditory stimuli and visual signals in pest management.

Practical

Preparation of synthetic diets for different groups of insects; rearing of insects on synthetic, semi-synthetic and natural diets; determination of co-efficient of utilization; qualitative and quantitative profile of bio-molecules: practicing analytical techniques for analysis of free amino acids of haemolymph; zymogram analyses of amylase; determination of chitin in insect cuticle; examination and count of insect haemocytes.

Learning outcomes

- The scholars are expected to have thorough theoretical and practical knowledge of insect physiology that can be made use of in practical/ applied entomological aspects.
- Understand how physiological systems in insects are integrated to maintain homeostasis.

Suggested Readings

Ananthkrishnan TN. (Ed.). 1994. *Functional Dynamics of Phytophagous Insects*. Oxford and IBH, New Delhi.

- Bernays EA and Chapman RF. 1994. *Host-Plant Selection by Phytophagous Insects*. Chapman and Hall, London.
- Kerkut GA and Gilbert LI. 1985. *Insect Physiology, Biochemistry and Pharmacology*. Vols. I-XIII. Pergamon Press, Oxford, New York.
- Muraleedharan K. 1997. *Recent Advances in Insect Endocrinology*. Association for Advancement of Entomology, Trivandrum, Kerala.
- Rockstein, M. 1978. *Biochemistry of Insects*, Academic Press.
- Simpson, SJ. 2007. *Advances in Insect Physiology*, Vol. 33, Academic Press (Elsevier), London, UK.

ENT 603

INSECT ECOLOGY AND DIVERSITY

3(2+1)

Objective

To impart advanced practical knowledge of causal factors governing the distribution and abundance of insects and the evolution of ecological characteristics. Study insect-plant interactions; get acquainted with biodiversity and conservation.

Theory

UNIT I

Characterization of distribution of insects- Indices of Dispersion, Taylor's Power law. Island Biogeography. Population dynamics- Life tables, Leslie Matrix, Stable age distribution, Population projections. Predator-Prey Models- Lotka-Volterra and Nicholson-Bailey Model. Crop Modeling- an introduction.

UNIT II

Insect Plant Interactions. Fig-figwasp mutualism and a quantitative view of types of associations. Role of insects in the environment. Adaptations to terrestrial habitats. Evolution of insect diversity and role of phytophagy as an adaptive zone for increased diversity of insects. Evolution of resource harvesting organs, resilience of insect taxa and the sustenance of insect diversity- role of plants. Herbivory, pollination, predation, parasitism. Modes of insect-plant interaction, tri-trophic interactions. Evolution of herbivory, monophagy vs polyphagy. Role of plant secondary metabolites. Meaning of stress- plant stress and herbivory. Consequences of herbivory to plant fitness and response to stress. Constitutive and induced plant defenses. Host seeking behavior of parasitoids.

UNIT III

Biodiversity and Conservation- RET species, Ecological Indicators. Principles of Population genetics, Hardy Weinberg Law, Computation of Allelic and Phenotypic frequencies, Fitness under selection, Rates of Evolution under selection. Foraging Ecology- Optimal foraging theory, Marginal Value Theorem, and Patch departure rules, central place foraging, Mean-variance relationship and foraging by pollinators, Nutritional Ecology.

UNIT IV

Reproductive ecology- Sexual selection, Mating systems, Reproductive strategies – timing, egg number, reproductive effort, sibling rivalry and parent-offspring conflict. Agro-ecological vs Natural Ecosystems –Characterisation, Pest Control as applied ecology- case studies.

Practical

Methods of data collection under field conditions. Assessment of distribution parameters, Taylor's power law, Iwao's patchiness index, Index of Dispersion, etc. Calculation of sample sizes by different methods. Fitting Poisson and Negative Binomial distributions and working out the data transformation methods. Hardy-Weinberg Law, Computation of Allelic and Phenotypic Frequencies – Calculation of changes under selection, Demonstration of genetic drift. Assessment of Patch Departure rules. Assessment of Resource size by female insects using a suitable insect model, fruit flies/*Goniozus*/Female Bruchids etc.- A test of reproductive effort and fitness. Construction of Life tables and application of Leslie Matrix – population projections, Stable age distribution. Exercises in development of Algorithms for crop modeling.

Learning outcomes

- The scholar is expected to develop expertise in methods of data collection for insect population studies, data transformation for analyses, diversity estimates, assessing distribution parameters, study the impact of abiotic and biotic factors on the distribution and abundance of insects.
- Should gain significant knowledge on construction of life tables and their analyses, assessment of resource size by female insects, reproductive effort and fitness.

Suggested Readings :

- Barbosa P and Letourneau DK. (Eds.). 1988. *Novel Aspects of Insect-Plant Interactions*. Wiley, London.
- Elizabeth BA and Chapman RF. 1994. *Host-Plant Selection by Phytophagous Insects*. Chapman and Hall, New York.
- Freeman S and Herron JC. 1998. *Evolutionary Analysis*. Prentice Hall, New Delhi.
- Gotelli NJ and Ellison AM. 2004. *A Primer of Ecological Statistics*. Sinauer Associates, Sunderland, MA.

- Gotelli NJ. 2001. *A Primer of Ecology*. 3rd Ed., Sinauer Associates, Sunderland, MA, USA.
- Krebs C. 1998. *Ecological Methodology*. 2nd Ed. Benjamin-Cummings Publ. Co., New York.
- Krebs CJ. 2001 *Ecology: The Experimental Analysis of Distribution and Abundance*. 5th Ed. Benjamin-Cummings Publ. Co., New York.
- Magurran AE. 1988. *Ecological Diversity and its Measurement*. Princeton University Press, Princeton.
- Real LA and Brown JH. (Eds.). 1991. *Foundations of Ecology: Classic Papers with Commentaries*. University of Chicago Press, USA.
- Southwood TRE and Henderson PA. 2000. *Ecological Methods*. 3rd Ed. Wiley Blackwell, London.
- Strong DR, Lawton JH and Southwood R. 1984. *Insects on Plants: Community Patterns and Mechanism*. Harvard University Press, Harvard.
- Wratten SD and Fry GLA. 1980. *Field and Laboratory Exercises in Ecology*. Arnold Publ., London.

ENT 604

INSECT BEHAVIOUR

2(1+1)

Objective

To acquaint the students with a thorough understanding of how natural selection has led to various survival strategies manifested as behavior in insects.

Theory

UNIT I

Defining Behaviour- Concept of Umwelt, instinct, fixed action patterns, imprinting, complex behavior, induced behavior, learned behavior and motivation. History of Ethology- development of behaviorism and ethology, contribution of Darwin, Frisch, Tinbergen and Lorenz; Studying behavior- Proximate and Ultimate approaches, behavioural traits under natural selection, genetic control of behavior and behavioural polymorphism.

UNIT II

Orientation- Forms of primary and secondary orientation including taxes and kinesis; Communication- primary and secondary orientation, responses to environmental stimuli, role of visual, olfactory and auditory signals in inter- and intra-specific communication, use of signals in defense, mimicry, polyphenism; evolution of signals.

UNIT III

Reproductive behavior- mate finding, courtship, territoriality, parental care, parental investment, sexual selection and evolution of sex ratios; Social behavior- kin selection, parental manipulation and mutualism; Self organization and insect behavior.

UNIT IV

Foraging- Role of different signals in host searching (plant and insects) and host acceptance, ovipositional behavior, pollination behavior, co-evolution of plants and insect pollinators. Behaviour in IPM- Concept of super-normal stimuli and behavioural manipulation as potential tool in pest management, use of semio- chemicals, auditory stimuli and visual signals in pest management.

Practical

Quantitative methods in sampling behavior; training bees to artificial feeders; sensory adaptation and habituation in a fly or butterfly model, physical cues used in host selection in a phytophagous insect, chemical and odour cues in host selection in phytophagous insect (DBM or gram pod borer), colour discrimination in honey bee or butterfly model, learning and memory in bees, role of self-organization in resource tracking by honeybees. Evaluation of different types of traps against fruit flies with respect to signals; Use of honey bees/*Helicoverpa armigera* to understand behavioural polymorphism with respect to learning and response to pheromone mixtures, respectively.

Learning outcomes

- Scholars are expected to be well versed with the behavior and orientation of insects towards

exploitation as a tool in IPM.

Suggested Readings

- Ananthkrishnan TN. (Ed.). 1994. *Functional Dynamics of Phytophagous Insects*. Oxford and IBH, New Delhi.
- Awasthi VB. 2001. *Principles of Insect Behaviour*. Scientific Publ., Jodhpur.
- Bernays EA and Chapman RF. 1994. *Host-Plant Selection by Phytophagous Insects*. Chapman and Hall, London.
- Brown LB. 1999. *The Experimental Analysis of Insect Behaviour*. Springer, Berlin.
- Krebs JR and Davies NB. 1993. *An Introduction to Behavioural Ecology*. 3rd Ed. Chapman and Hall, London.
- Manning A and Dawkins MS. 1992. *An Introduction to Animal Behaviour*. Cambridge University Press, USA.
- Mathews RW and Mathews JR. 1978. *Insect Behaviour*. A Wiley-InterScience Publ. John Wiley and Sons, New York.

ENT 605

BIO-INPUTS FOR PEST MANAGEMENT

3(2+1)

Objective

To appraise the students with advanced techniques in handling of different bio-agents, modern methods of biological control and scope in cropping system-based pest management in agro-ecosystems.

Theory

UNIT I

Scope of classical biological control and augmentative bio-control; introduction and handling of natural enemies; nutrition of entomophagous insects and their hosts, dynamics of bio-agents *vis-à-vis* target pest populations.

UNIT II

Bio-inputs: mass production of bio-pesticides, mass culturing techniques of bio-agents, insectary facilities and equipments, basic standards of insectary, viable mass-production unit, designs, precautions, good insectary practices.

UNIT III

Colonization, techniques of release of natural enemies, recovery evaluation, conservation and augmentation of natural enemies, survivorship analysis and ecological manipulations, large-scale production of bio-control agents, bankable project preparation.

UNIT IV

Scope of genetically engineered microbes and parasitoids in biological control, genetics of ideal traits in bio-control agents for introgressing and for progeny selections, breeding techniques of bio-control agents.

Practical

Mass rearing and release of some commonly occurring indigenous natural enemies; assessment of role of natural enemies in reducing pest populations; testing side effects of pesticides on natural enemies; effect of semio-chemicals on natural enemies, breeding of various bio-control agents, performance of efficiency analyses on target pests; project document preparation for establishing a viable mass-production unit /insectary; observation of feeding behavior acts of predatory bugs/ beetles.

Learning outcomes

- Scholars are expected to learn the mass multiplication techniques of the more common and economically feasible natural enemies to be exploited under IPM programmes.

- They should be able to guide entrepreneurs for establishing a viable mass-production unit /insectary.

Suggested Readings

- Burges HD and Hussey NW. (Eds.). 1971. *Microbial Control of Insects and Mites*. Academic Press, London.
- Coppel HC and James WM. 1977. *Biological Insect Pest Suppression*. Springer Verlag, Berlin.
- De Bach P. 1964. *Biological Control of Insect Pests and Weeds*. Chapman and Hall, London.
- Dhaliwal, GS and Koul O. 2007. *Biopesticides and Pest Management*. Kalyani Publ., New Delhi.
- Gerson H and Smiley RL. 1990. *Acarine Biocontrol Agents – An Illustrated Key and Manual*. Chapman and Hall, New York.
- Huffakar CB and Messenger PS. 1976. *Theory and Practices of Biological Control*. Academic Press, London.

ENT 606

INSECTICIDE TOXICOLOGY AND RESIDUES

3(2+1)

Objective

To acquaint the students with the latest advancements in the field of insecticide toxicology, biochemical and physiological target sites of insecticides, and pesticide resistance mechanisms in insects.

Theory

UNIT I

Penetration and distribution of insecticides in insect systems; insecticide selectivity; factors affecting toxicity of insecticides. Modes of action of newer insecticide molecules; developments in bio-rational approaches; SPLAT; RNAi technology for pest management.

UNIT II

Biochemical and physiological target sites of insecticides in insects; developments in biorationals, biopesticides and newer molecules; their modes of action and structural – activity relationships; advances in metabolism of insecticides.

UNIT III

Joint action of insecticides; activation, synergism and potentiation. UNIT IV

Problems associated with pesticide use in agriculture: pesticide resistance; resistance mechanisms and resistant management strategies; pest resurgence and outbreaks; persistence and pollution; health hazards and other side effects.

UNIT V

Estimation of insecticidal residues- sampling, extraction, clean-up and estimation by various methods; maximum residue limits (MRLs) and their fixation; bound and conjugated residues, effect on soil fertility; insecticide laws and standards, and good agricultural practices.

Practical

Residue sampling, extraction, clean-up and estimation of insecticide residues by various methods; calculations and interpretation of data; biochemical and biological techniques for detection of insecticide resistance in insects; preparation of EC formulation using neem oil;

Learning outcomes

- Scholars are expected to be well versed with the latest technologies of bioassays, insecticide/pesticide residue analysis and solving problems associated with insect resistance to insecticides.

Suggested Readings

- Busvine JR. 1971. *A Critical Review on the Techniques for Testing Insecticides*. CABI, London.
- Dhaliwal GS and Koul O. 2007. *Biopesticides and Pest Management*. Kalyani Publ., New Delhi.
- Hayes WJ and Laws ER. 1991. *Handbook of Pesticide Toxicology*. Academic Press, New York.

- Ishaaya I and Degheele (Eds.). 1998. *Insecticides with Novel Modes of Action*. Narosa Publ. House, New Delhi.
- Matsumura F. 1985. *Toxicology of Insecticides*. Plenum Press, New York.
- O' Brien RD. 1974. *Insecticides Action and Metabolism*. Academic Press, New York.
- Perry AS, Yamamoto I, Ishaaya I and Perry R. 1998. *Insecticides in Agriculture and Environment*. Narosa Publ. House, New Delhi.
- Prakash A and Rao J. 1997. *Botanical Pesticides in Agriculture*. Lewis Publ., New York.

ENT 610

INTEGRATED PEST MANAGEMENT

2(2+0)

Objective

To acquaint the students with recent concepts of integrated pest management; surveillance and data base management; successful national and international case histories of integrated pest management, non- conventional tools in pest management.

Theory

UNIT I

Principles of sampling and surveillance, database management and computer programming; simulation techniques, system analysis and modeling.

UNIT II

Study of case histories of national and international programmes, their implementation, adoption and criticism; global trade and risk of invasive pests; updating knowledge on insect outbreaks and their management.

UNIT III

Genetic engineering and new technologies- their progress and limitations in IPM programmes, deployment of benevolent alien genes for pest management- case studies; scope and limitations of bio-intensive and ecological based IPM programmes; application of IPM to farmers' real time situation.

UNIT IV

Challenges, needs and future outlook; dynamism of IPM under changing cropping systems and climate; insect pest management under protected cultivation; strategies for pesticide resistance management.

Learning outcomes

- Having gained sufficient experience in advanced studies of IPM the scholars should be able to independently frame IPM schedules for major crops/ cropping ecosystems (cereal / pulse crop / oilseed crop based/ vegetable crop based agro-ecosystems).

Suggested Readings

- Dhaliwal GS and Arora R. 2003. *Integrated Pest Management – Concepts and Approaches*. Kalyani Publ., New Delhi.
- Dhaliwal GS, Singh R and Chhillar BS. 2006. *Essentials of Agricultural Entomology*. Kalyani Publ., New Delhi.
- Flint MC and Bosch RV. 1981. *Introduction to Integrated Pest Management*. Springer, Berlin. Koul O and Cuperus GW. 2007. *Ecologically Based Integrated Pest Management*. CABI, London.
- Koul O, Dhaliwal GS and Curperus GW. 2004. *Integrated Pest Management –Potential, Constraints and Challenges*. CABI, London.
- Maredia KM, Dakouo D and Mota-Sanchez D. 2003. *Integrated Pest Management in the Global Arena*. CABI, London.
- Metcalf RL and Luckman WH. 1982. *Introduction to Insect Pest Management*. John Wiley and Sons, New York.
- Norris RF, Caswell-Chen EP and Kogan M. 2002. *Concepts in Integrated Pest Management*. Prentice Hall, New Delhi.
- Pedigo RL. 1996. *Entomology and Pest Management*. Prentice Hall, New Delhi.
- Subramanyam B and Hagstrum DW. 1995. *Integrated Management of Insects in Stored Products*. Marcel Dekker, New York.

Department of Plant Physiology

M.Sc. (Ag.) in Plant Physiology

Sl. No.	Course No.	Course Name	Credit Hrs.
Semester-I			
1.	PP-501	Principles of plant physiology-I, Plant water relations and mineral nutrition	3(2+1)
2.	PP-502	Principles of plant physiology-II, metabolic processes and growth regulation	3(2+1)
3.	SST-501	Seed Development Biology	2(1+1)
4.	AGRON -503	Principle and practices of weed management	3(2+1)
5.	PGS-501	Library And Information Services	1(0+1)
6.	PGS-502	Technical Writing and Communications Skill	1(0+1)
Semester-II			
1.	PP-503	Plant developmental biology: Physiological and molecular basis	3(2+1)
2.	PP-507	Photosynthetic processes, crop growth and productivity and concepts of crop modelling	3(2+1)
3.	GPB-506	Principle of Plant Breeding	3(2+1)
4.	STAT-511	Experimental Design	3(2+1)
5.	PGS-503	Intellectual Property and Its Management in Agriculture	1(0+1)
6.	PGS-504	Basic Concept in Laboratory Techniques	1(0+1)
Semester-III			
1.	PP-505	Hormonal regulation of plant growth and development	3(2+1)
2.	PP-508	Physiology of field crop	2(2+0)
3.	PP-591	Master's Seminar	1(1+0)
4.	PGS-505	Agriculture Research, Research Ethics and Rural Development Programmes	1(0+1)
5.	AGRON-502	Principle and practices of soil fertility and nutrient management	3(2+1)
Semester-IV			
1	PP-510	Seed Physiology	3(2+1)
2.	PP-599	Master's Research	30
		Total	33
		Grand Total	70

Sl. No.	Course No.	Course Name	Credit Hrs.	Semester
Major Courses				
1.	PP-501	Principles of plant physiology-I, Plant water relations and mineral nutrition	3(2+1)	I
2.	PP-502	Principles of plant physiology-II, metabolic processes and growth regulation	3(2+1)	I
3.	PP-503	Plant developmental biology: Physiological and molecular basis	3(2+1)	II
4.	PP-507	Photosynthetic processes, crop growth and productivity and concepts of crop modelling	3(2+1)	II
5.	PP-505	Hormonal regulation of plant growth and development	3(2+1)	III
6.	PP-508	Physiology of field crop	2(2+0)	III
7.	PP-591	Master's Seminar	1(1+0)	III
8.	PP-510	Seed Physiology	3(2+1)	IV
Total			20	
Minor Courses				
1.	SST-501	Seed Development Biology	2(1+1)	I
2.	GPB-506	Principle of Plant Breeding	3(2+1)	II
3.	AGRON-502	Principle and practices of soil fertility and nutrient management	3(2+1)	III
Total			08	
Supporting Courses				
1.	STAT-511	Experimental Design	3(2+1)	II
2.	AGRON -504	Principle and practices of water management	3(2+1)	
Total			06	
Common Courses				
1.	PGS-501	Library And Information Services	1(0+1)	I
2.	PGS-502	Technical Writing and Communications Skill	1(0+1)	I
3.	PGS-503	Intellectual Property and Its Management in Agriculture	1(0+1)	II
4.	PGS-504	Basic Concept in Laboratory Techniques	1(0+1)	II
5.	PGS-505	Agriculture Research, Research Ethics and Rural Development Programmes	1(0+1)	III
Total			05	
PP-591		Master's Seminar	1(1+0)	
PP-599		Master's Research	30	
G. Total			70	

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, PP503)

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 removedundancyfromUGprogrammeandaddnewrecentconceptsanddevelopments.

II) Physiology courses that provide insights on plant responses to environmental and internal factors (PP 504, PP 505, PP506)

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 molecularmechanisms.

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, PP512)

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 (PP601,PP602,PP603)

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, PP605)*

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 (PP606)*

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, PP608)*

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) (PP609, PP610)*

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. Implementation of the revised syllabus needs a sanction of an approximate recurring budget of Rs. 20.0 lacs per annum in addition to one time equipment and maintenance grant of Rs. 2.00crores.

M.Sc. I Semester

PP 501 PRINCIPLES OF PLANT PHYSIOLOGY I - PLANT WATER 3(2+1)
RELATIONS AND MINERAL NUTRITION

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.

Aim of this 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

Learning Outcomes

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.

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; Method 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 the irrelevance

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
- 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
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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

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

PRACTICALS

1. Standard solutions and preparation of different forms of solutions
2. Studies on the basic properties of water
3. Demonstration of surface tension of water and other solvents
4. Measurement of plant water status: Relative water content and rate of water loss
5. Determination of water potential through tissue volume and Chardakov's test
6. Determination of water potential using pressure bomb, osmometer, psychrometer
7. Determination of soil moisture content and soil water potential
8. Use of soil moisture probes and soil moisture sensors
9. Measurement of transpiration rate in plants; use of porometry Measurement of CCATD and its relevance
10. Demonstration and use of anti-transpirants to reduce transpiration
11. Influence of potassium and ABA on stomatal opening and closing respectively
12. Deficiency and toxicity symptoms of nutrients
13. Effect of water stress on plant growth and development

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)

- Studentpresentation

- Practicals

RESOURCES BLOCK 1:

Unit 1:

- Jordi Martínez-Vilalta and Núria Garcia-Forner Water potential regulation, stomatal behaviour and hydraulic transport under drought: deconstructing the iso/anisohydric concept Plant, Cell and Environment (2017) 40,962–976
- A. S. Mangrich, E. M. C. Cardoso, M. E. Doumer, L. P. C. Romão, M. Vidal, A. Rigol, E. H. Novotny. Improving the Water Holding Capacity of Soils of Northeast Brazil by Biochar Augmentation. Chapter 16, pp339–354

Unit 2:

- McElrone, A. J., Choat, B., Gambetta, G. A. and Brodersen, C. R. (2013) Water Uptake and Transport in Vascular Plants. Nature Education Knowledge4(5):6
- Hodson, R.C. and J. Acuff. 2006. Water transport in plants: anatomy and physiology. Pages 163-183, in 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), 383pages.

Unit 3:

- Caspar C.C. Chater, Robert S. Caine, Andrew J. Fleming, Julie E. Gray Plant Physiology Jun 2017, 174 (2) 624-638; DOI:10.1104/pp.17.00183
- Petra Dietrich, Dale Sanders, Rainer Hedrich, The role of ion channels in light-dependent stomatal opening, Journal of Experimental Botany, Volume 52, Issue 363, 1 October 2001, Pages 1959–1967, <https://doi.org/10.1093/jexbot/52.363.1959>

Unit 4:

- Sreeman, S.M., 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.

Unit 5:

- SeyedYahyaSalehi-LisarHamidehBakhshayeshan-Agdam, (2016). Drought Stress in Plants: Causes, Consequences, and Tolerance. Drought Stress Tolerance in Plants, Vol 1 pp1-16

BLOCK 2:

Unit 1:

- Pandey, Renu. (2015). Mineral Nutrition of Plants. [10.1007/978-81-322-2286-6_20](https://doi.org/10.1007/978-81-322-2286-6_20).
- Barker A. V. and D. J. Pilbeam (2015). Handbook of Plant Nutrition, Second Edition. Books in Soils, Plants, and the Environment Series, the 2nd Edition, CRC Press.

Unit 2:

- Vatansever, R., Ozyigit, I. I., 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, M. M., and Sijam, K. (2012). Arbuscularmycorrhizal fungi and plant root exudates bio-communications in the rhizosphere. African Journal of Microbiology Research, 6(46),7295-7301.

Unit 3:

- Rajasekar, M., D. UdhayaNandhini 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/](https://doi.org/)

10.20546/ijcmas.2017.603.283

- Alshaal, Tarek and El-Ramady, Hassan. (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 PlantPhysiology
- Taiz L and Zeiger E. 2015. *Plant Physiology and development*.6thEd
- Salisbury FB and Ross C. 1992 (4th Ed.) PlantPhysiology
- Emanuel Epstein and Arnold J. Bloom.2004, Mineral nutrition of plants: principles and perspectives.2ndEd.
- Hopkins WG and Huner NPA. 2004. *Introduction to PlantPhysiology*
- Kramer, P. J., Water relations ofplants
- Kirkham, M. B., Principles of soil and plant waterrelations
- Hopkins WG, 2008, Introduction to PlantPhysiology

M.Sc.(Ag.) I Semester

PPY 502

PRINCIPLES OF PLANT PHYSIOLOGY-II: METABOLIC PROCESSES AND GROWTH REGULATION

3(2+1)

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.

AIM OF THIS 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

LEARNING OUTCOMES

By the end of this course, the student will be able to:

- figure out the fundamental metabolic processes inplant
- describe the physiological mechanisms and metabolic events associated with regulation of plant growth

BLOCK 1: METABOLIC PROCESSES AND GROWTH REGULATION

Unit 1: Carbon Metabolism – Photochemical Processes

- Chloroplast ultrastructure with special mention of lamellarsystem
- Excitation,electronandprotontransfersandtheirrelevanceinenergyconservation

- 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

- CO₂ diffusion mechanisms and diffusive conductances, concept of C_i 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 CO₂ concentrating mechanisms (CCM) and spatial and temporal differences in carboxylation
- Ecological aspects of C₄ and CAM photosynthesis
- Product synthesis, Starch and Sucrose biosynthesis

Unit 3: Carbon Metabolism: Respiration

- Mitochondrial organization and functions
- Aspects of Glycolysis, TCA cycle and mitochondria
- Relevance of growth and maintenance respiration
- Concepts of C/N 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-nitrogen 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 triacylglycerol, 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.

PRACTICALS

1. Radiant energy measurements
2. Separation and quantification of chlorophylls
3. Separation and quantification of carotenoids
4. O₂ evolution during photosynthesis
5. Anatomical identification of C₃ and C₄ plants
6. Measurement of gas exchange parameters, conductance, photosynthetic rate, photorespiration
7. Measurement of respiration rates
8. Estimation of reducing sugars, starch
9. Estimation of NO₃, free amino acids in the xylem exudates, quantification of soluble proteins
10. Bioassays for different growth hormones- Auxins, Gibberellins, Cytokinins, ABA and ethylene
Demonstration of photoperiodic response of plants in terms of flowering

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

RESOURCES

Block 1:

Unit 1:

- Kirchoff, H., (2019) Chloroplast ultrastructure in plants, New Phytologist <https://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.

Unit 2:

- 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. <http://dx.doi.org/10.1098/rstb.2016.0401>
- Raven, J. A., and Beardall, J. (2015). The ins and outs of CO₂. *Journal of experimental botany*, 67(1), 1-13.
- Rae, B. D., Long, B. M., Förster, B., Nguyen, N. D., Velanis, C. N., Atkinson, N. and McCormick, A. J. (2017). Progress and challenges of engineering a biophysical CO₂- concentrating mechanism into higher plants. *Journal of Experimental Botany*, 68(14), 3717-3737.

Unit 3:

- Hagemann, M., Weber, A. P., 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.

Unit 4:

- Liesche, J., and Patrick, J. (2017). An update on phloem transport: a simple bulk flow under complex regulation. *F1000Research*, 6.
- Jensen, K. H., Berg-Sørensen, K., Bruus, H., Holbrook, N. M., Liesche, J., Schulz, A., and Bohr, T. (2016). Sap flow and sugar transport in plants. *Reviews of modern physics*, 88(3), 035007.
- Julius, B. T., Leach, K. A., Tran, T. M., Mertz, R. A., and Braun, D. M. (2017). Sugar transporters in plants: new insights and discoveries. *Plant and Cell Physiology*, 58(9), 1442-1460.

Unit 5:

- Rao, D. L. N. (2014). Recent advances in biological nitrogen fixation in agricultural systems. In *Proclndian NatlSci Acad* (Vol. 80, No. 2, pp.359-378).
- Hoffman, B. M., Lukoyanov, D., Yang, Z. Y., Dean, D. R., and Seefeldt, L. C. (2014). Mechanism of nitrogen fixation by nitrogenase: the next stage. *Chemical reviews*, 114(8), 4041-
- Mus, F., Crook, M. B., Garcia, K., Costas, A. G., Geddes, B. A., Kouri, E. D. and Udvardi, M. K. (2016). Symbiotic nitrogen fixation and the challenges to its extension to nonlegumes. *Appl. Environ. Microbiol.*, 82(13), 3698-3710.

Unit 6:

- 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: Bioactivity of secondary metabolites of various plants: a review. *Int J Pharm Sci and Res* 2019; 10(2): 494-04. doi: 10.13040/IJPSR.0975-8232.10(2).494-04..

Unit 7:

- 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., and Asami, T. (2018). Chemical regulators of plant hormones and their applications in basic research and agriculture. *Bioscience, biotechnology, and biochemistry*, 82(8), 1265-1300.

Unit 8:

- Zwanenburg, B., Pospíšil, T., and Zeljković, S. Č. (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.

Unit 9:

- 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:

- Plant Physiology, Taiz, Lincoln, Zeiger, Eduardo Origanl American edition published by Sinauer Associates, Inc., 2006; 4th ed., 2007, XXVI, ISBN: 978-3-8274-1865-4; © Springer.
- Plant Physiology by Frank Boyer Salisbury and Cleon Ross.
- Introduction to Plant Physiology 3e (Wie) by William G. Hopkins.

M.Sc.(Ag.) II Semester

PP 503 PLANT DEVELOPMENTAL BIOLOGY: PHYSIOLOGICAL AND 3(2+1)
MOLECULAR BASIS

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 day 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 understanding of plant developmental biology has been put to 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.

AIM OF THIS 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

LEARNING OUTCOMES

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.

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 7: Tissue culture and micro-propagation

- Applications of tissue culture for plant production, callus induction, somatic embryogenesis, regeneration from different explants.
- Micro-propagation, tip and axillary node culture of commercially important crops, hardening and ex-vitro establishment, concept of somatic hybridization and protoplast culture.

Unit 8: Application of in-vitro techniques for crop improvement

- Development of somoclonal variants, 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

PRACTICALS

1. Studying shoot apical meristem, floral meristem development and pollen tube development
2. 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.
3. Studying effect of temperature on- a) thermomorphogenesis- measuring hypocotyl elongation under different temperature conditions and b) sex determination using cucurbits/sesame plants.
4. Measure physiological parameters of fruit ripening and study the expression of key genes regulating ripening.
5. Study the effect of ethylene, its inhibitor and scrubber on ripening (tomato).
6. Study different sterilization techniques, prepare media stocks and plant hormones.
7. Inoculate explant (seed and leaf tissue) of model plant for callus induction.
8. Subculture the callus and standardize regeneration protocol for shoot and root induction using callus and leaf explant.
9. Micro-propagation using meristem tip and axillary node culture.
10. Standardize anther/ pollen culture for haploid production in model/crop/horticultural plant.

11. Isolation of protoplast from Arabidopsis/tobacco and its culturing
12. Study about selectable marker, reporter gene, PCR, southern and northern blotting techniques.
13. Transformation of tobacco callus or leaf explant by *Agrobacterium tumefaciens* and *Agrobacterium rhizogenes* for production of transgenic
14. Molecular characterization of transgenic- PCR, southern blotting, gene expression.

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment(Reading/Writing)
- Student presentation
- Practicals

RESOURCES

Unit 1:

- Karl J. Niklas. Plant Evolution- An Introduction to the History of Life.
- B. Bahadur *et al.* (eds.), Plant Biology and Biotechnology: Volume I: Plant Diversity, Organization, Function and Improvement
- M. De Jong and O. Leyser. Developmental Plasticity in Plants. Cold Spring Harbor Symposia on Quantitative Biology.63-73.
- Dirk Inze and Lieven De Veylder (2006). Cell Cycle Regulation in Plant Development. Annu. Rev. Genet. 2006.40:77–105

Unit 2:

- J. Derek Bewley *et al.*, Seeds-Physiology of Development, Germination and Dormancy.
- Kent J. Bradford and Hiroyuki Nonogaki (2007). Seed Development, Dormancy and Germination. Blackwellpublishing.

Unit 3:

- Matthew MS Evans and M. Kathryn Barton (1997). Genetics Of Angiosperm Shoot Apical Meristem Development. Annu. Rev. Plant Physiol. Plant Mol. Biol. 48:673–701.
- Keni Jiang and Lewis J. Feldman (2005). Regulation of Root Apical Meristem Development. Annu. Rev. Cell Dev. Biol.21:485–509.
- Piazza *et al.*, (2005). Evolution of leaf developmental mechanisms. New Phytologist. 167:693–710.
- Fiona Tooke and Nick Battey (2003). Models of shoot apical meristem function. New Phytologist. 159:37–52.
- Zheng-Hua Ye (2002). Vascular Tissue Differentiation And Pattern Formation In Plants. Annu. Rev. Plant Biol.53:183–202.
- Maureen L. Condit (2014). Totipotency: What It Is and What It Is Not. Stem Cells And Development. 23(8). 796-

Unit 4

- Komeda, Y. 2004. Genetic regulation of time to flower in Arabidopsis thaliana. Annu. Rev. Plant Biol. 55:521-535.
- Zeevaart, J.A.D. 1976. Physiology of flower formation. Annu. Rev. Plant Physiol. 27: 321-348. Zeevaart, J.A.D. 2006. Florigen coming of age after 70 years. Plant Cell 18: 1783-1789.
- JohnR.Pannel.(2017).PlantSexDetermination.CurrentBiology27,R191–R197.
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- Veronica E. Franklin-Tong. Self-Incompatibility in Flowering Plants-Evolution, Diversity, and

Mechanisms, Springer

Unit 5:

- Howard Thomas (2013). Senescence, ageing and death of the whole plant. *New Phytologist*. 197:696–711.
- Eric Lam, Hiroo Fukuda and Jean Greenberg. Programmed cell death in higher plants. Reprinted from *Plant Molecular Biology*, Volume 44 (3), 2000
- Eng-Chong Pua and Michael R. Davey: *Plant Developmental Biology - Biotechnological Perspectives*.

Unit 6:

- Meng Chen (2004). Light Signal Transduction In Higher Plants *Annu. Rev. Genet.* 38:87–117.
- Christian Fankhauser and Joanne Chory (1997). Light Control Of Plant Development *Annu. Rev. Cell Dev. Biol.* 13:203–229.
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- Keara A. Franklin *et al.*, (2014). Interaction of light and temperature signaling. *Journal of Experimental Botany*. 65(11):2859–2871.

Unit 7:

- Bhojwani SS and Razdan MK. *Plant tissue culture: theory and practice*, a revised edition. Elsevier publication.
- Bhojwani SS, Sant Saran, Dantu and Prem Kumar. *Plant Tissue Culture: An Introductory Text*.
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Unit 8:

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- Jim M. Dunwell, (2010). *Haploids in flowering plants: origins and exploitation*.

General Source Information:

- Eng-Chong Pua and Michael R. Davey: *Plant Developmental Biology - Biotechnological Perspectives*.
- B. Bahadur *et al.* (eds.), *Plant Biology and Biotechnology: Volume I: Plant Diversity, Organization, Function and Improvement*.
- J. Derek Bewley *et al.*, *Seeds-Physiology of Development, Germination and Dormancy*.
- M. De Jong and O. Leyser. *Developmental Plasticity in Plants*. *Cold Spring Harbor Symposia on Quantitative Biology*. 63-73.
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- Viola Willemsen and Ben Scheres (2004). Mechanisms of pattern formation in plant embryogenesis. *Annu. Rev. Genet.* 38:587–614

- Momokolkeuchi, *et al.*, (2016). Review- Plant regeneration: cellular origins and molecular mechanisms. *Development*, 143:1442-1451.
- JohnR.Pannel.(2017).PlantSexDetermination.*CurrentBiology*27,R191–R197.
- Veronica E. Franklin-Tong. *Self-Incompatibility in Flowering Plants -Evolution, Diversity, and Mechanisms*.Springer.
- Peter van Dijk and Jos van Damme (2000). Apomixis technology and the paradox of sex. *Trends in Plant Sciences* 5(2):81-84.

M.Sc.(Ag.) II Semester

PP- 507

PHOTOSYNTHETIC PROCESSES, CROP GROWTH AND PRODUCTIVITY AND CONCEPTS OF CROP MODELLING

3(2+1)

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.

AIM OF THIS 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. BiochemicalProcesses
		4. Product Synthesis andTranslocation
		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

LEARNING OUTCOMES

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.

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

- Ultra structure 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

- CO₂ diffusion and resistances (g_s and g_m). Concept of C_i determining CO₂ diffusion.
- RuBisCO activation state, kinetics and catalytic properties
- Carboxylation processes in C₃, C₄ and CAM plants and their relevance
- CO₂ concentrating mechanisms and their importance in improving carbon assimilation
- Ecological significance of C₄ and CAM photosynthesis
- Photorespiration and Mitochondrial respiration and net carbon gain
- Carbon isotope discrimination and its importance as a surrogate of C_i

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 C₃ 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, Peanut Grow etc
- Machine learning approaches and IoT for making informed on-farm decisions

Unit 4: Examples of Robust Models Extensively Used

- Duncan's yield prediction model
- Passioura's model for growth maximising

PRACTICALS

1. Plant sampling for leaf area and biomass estimation; analysis of growth and yield parameters – LAD, NAR, CGR, LAI, LAR, SLA partitioning efficiency, HI.
2. Measurement of light interception, light extinction coefficient, energy utilization efficiency based energy intercepted, and realized.
3. Gas exchange: principles and uses to assess variations in CO₂ and water vapour transfer, determination of A/gs and intrinsic WUE
4. Quantification of chlorophyll content by various methods: colorimetric and SPAD meter. The concept of SLN
5. Chlorophyll fluorescence and quenching coefficients
6. Theoretical aspects of carbon isotope fractional and its use in determining WUE
7. Quantification of RuBisCO content by ELISA (if possible)
8. Determination of RuBisCO activity and activation state using radioactive CO₂
9. CO₂ and light response curves and computation of carboxylation efficiency, quantum efficiency, relative limitations of photosynthesis at single leaf level.
10. Adoption of crop models: Growth and yield prediction by Duncan's and Passioura's models

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

RESOURCES

Block 1:

Unit 1:

- Goyne, P. J., Milroy, S. P., Lilley, J. M., and Hare, J. M. (1993). Radiation interception, radiation use efficiency and growth of barley cultivars. *Australian Journal of Agricultural Research*, 44(6), 1351-1366.
- <https://www.sciencedirect.com/topics/chemistry/photosynthetic-pigment>.
- Frank, H. A., Young, A., Britton, G., and Cogdell, R. J. (Eds.). (2006). *The photochemistry of carotenoids* (Vol. 8). Springer Science and Business Media.

Unit 2:

- Ruban, A. V. (2016). Nonphotochemical chlorophyll fluorescence quenching: mechanism and effectiveness in protecting plants from photodamage. *Plant Physiology*, 170(4), 1903-1916.
- Maxwell, K., and Johnson, G. N. (2000). Chlorophyll fluorescence—a practical guide. *Journal of experimental botany*, 51(345), 659-668.
- https://www.researchgate.net/publication/38051229_The_photochemical_reaction_in_photosynthesis.

Unit 3:

- Wang, Y., Stessman, D. J., and Spalding, M. H. (2015). The CO₂ concentrating mechanism and photosynthetic carbon assimilation in limiting CO₂: how *Chlamydomonas* works against the gradient. *The Plant Journal*, 82(3), 429-448.
- Dietz, K. J., and Pfanschmidt, T. (2011). Novel regulators in photosynthetic redox control of plant metabolism and gene expression. *Plant Physiology*, 155(4), 1477-1485.
- Farquhar, G. D., Ehleringer, J. R., and Hubick, K. T. (1989). Carbon isotope discrimination and photosynthesis. *Annual review of plant biology*, 40(1), 503-537.

Unit 4:

- Paul, M. J., and Foyer, C. H. (2001). Sink regulation of photosynthesis. *Journal of experimental botany*, 52(360), 1383-1400.

- De Schepper, V., De Swaef, T., Bauweraerts, I., and Steppe, K. (2013). Phloem transport: a review of mechanisms and controls. *Journal of experimental botany*, 64(16),4839-4850.

Unit 5:

- Weraduwege, S.M., Chen, J., Anozie, F.C., Morales, A., Weise, S.E., and Sharkey, T. D. (2015). The relationship between leaf area growth and biomass accumulation in *Arabidopsis thaliana*. *Frontiers in plant science*, 6, 167.
- Hay, R. K. M. (1995). Harvest index: a review of its use in plant breeding and crop physiology. *Annals of applied biology*, 126(1),197-216.
- Irving, L. (2015). Carbon assimilation, biomass partitioning and productivity in grasses. *Agriculture*, 5(4),1116-1134.

Block 2:

Unit 1:

- de Freitas Lima, M., Eloy, N. B., de Siqueira, J. A. B., Inzé, D., Hemerly, A. S., and Ferreira, P. C. G. (2017). Molecular mechanisms of biomass increase in plants. *Biotechnology Research and Innovation*, 1(1), 14-25.
- Raines, C. A. (2011). Increasing photosynthetic carbon assimilation in C3 plants to improve crop yield: current and future strategies. *Plant physiology*, 155(1),36-42.
- vonCaemmerer, S., and Evans, J. R. (2010). Enhancing C3 photosynthesis. *Plant Physiology*, 154(2), 589-592.

Unit 2:

- <http://ijid.informaticspublishing.com/index.php/ijid/article/download/111838/78332>
- <https://www.mdpi.com/1424-8220/18/8/2674/pdf>

Unit 3:

- <http://ijid.informaticspublishing.com/index.php/ijid/article/download/111838/78332>
- <https://www.mdpi.com/1424-8220/18/8/2674/pdf>

Unit 4:

- Splinter, W. E. (1974). Modelling of plant growth for yield prediction. *Agricultural Meteorology*, 14(1-2),243-253.

General Source Information:

- Molecular mechanisms of Photosynthesis 2nd Edition 2014 by Robert E Blankenship
- Canopy Photosynthesis: From Basics to Applications. 2016 Editors: Hikosaka, Kouki, Niinemets, Ülo, Anten, Niels P.R.
- The Leaf: A Platform for Performing Photosynthesis. 2018. Editors:
- Adams III, William W., Terashima, Ichiro.
- Handbook of Photosynthesis 3rd Edition. 2016. Mohammad Pessarakli

M.Sc.(Ag.) III Semester

PP 508

PHYSIOLOGY OF FIELD CROPS

2(2+0)

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.

AIM OF THIS 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

LEARNING OUTCOMES

After completion of this course, students will accrue comprehensive knowledge on various physiological processes of variety of field crops.

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 disorder

AIM OF THIS 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.

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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

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

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TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment(Reading/Writing)
- Student presentation

RESOURCES

Pulses:

- Grain Legumes: Editors: **De Ron**, Antonio M. (Ed.) 2015.Springer
- **Legumes under Environmental Stress: Yield, Improvement and Adaptations**. Edited by M.M Azooz and P. Ahmad, Hoboken, NJ: John Wiley and Sons, Ltd., 328 pages.ISBN:978-1-118-91708-4
- Pulse Crops: Biotechnological Strategies to Enhance Abiotic Stress Tolerance .S. GaneshanP. M. GaurR. N. ChibbarDr. Narendra Tuteja Dr. Sarvajeet Singh Gill Dr. RenuTuteja chapter17
- Climate Change and Management of Cool Season Grain Legume Crops . Edited by Shyam Singh Yadav, David L. McNeil, Robert Redden, Sharanagouda A. Patil Springer
- Nature's pulse power: legumes, food security and climate change. Michael J.
- Considine, Kadambot H.M. Siddique, and Christine H. Foyer J Exp Bot. 2017 Apr 1; 68(8): 1815–1818. Published online 2017 May 11. doi:[10.1093/jxb/erx099](https://doi.org/10.1093/jxb/erx099)

Sugarcane:

- Glassop D, Rae AL and Bonnett GD (2014) Sugarcane flowering genes and pathways in relation to vegetative regression. Sugar Tech. 16(3): 235-240. DOI 10.1007/s12355-013-0284-z
- McCormick AJ, Watt DA and Cramer MD (2009) Supply and demand: sink regulation of sugar accumulation in sugarcane. Journal of Experimental Botany. 60(2): 357-364. DOI10.1093/jxb/em310
- Moore PH and Botha FC (2014) Sugarcane: physiology, biochemistry, and functional biology. John Wiley and Sons ISBN978-1-118-77119-8
- Ram B, RajulaShanthy T, Viswanathan R, Hemaprabha G and Palaniswami C (2016) Handbook on sugarcane. ICAR-Sugarcane Breeding Institute. ISBN 978-93-85267- 03-1
- Shrivastava AK, Solomon S, Rai RK, Singh P, Chandra A, Jain R and Shukla SP (2015) Physiological interventions for enhancing sugarcane and sugar productivity. Sugar Tech. 17(3): 215-226. DOI10.1007/s12355-014-0321-6

Maize:

Rice:

- Evans, L.T., 1996. Crop Evolution, Adaptation and Yield. Cambridge University Press.

- Jeff L. Bennetzen, J.I AND Hake, S.C. (2009) Hand Book of Maize: Its Biology, Springer-Verlag NewYork
- Singh, C.B.andKhare, D. (2015). Genetic Improvement of Field Crops. Scientific Publishers,Jodhpur.
- Tollenaar M., Dwyer L.M. (1999) Physiology of Maize. In: Smith D.L., Hamel C. (eds) Crop Yield. Springer, Berlin,Heidelberg
- Yoshida, S., 1981. Fundamentals of Rice Crop Science. IRRI.
- Rehman, Abdul. (2016). Photosynthesis under heat stress. Handbook of Photosynthesis, Edition: Third Edition, Publisher: CRC Press Taylor and Francis Group, pp. 697-701.
- Negrão S, Courtois B, Ahmadi N, Abreu I, Saibo N, Oliveira MM (2011) Recent updates on salinity stress in rice from physiological to molecular responses. Crit Rev Plant Sci30:329-377
- Von Caemmerer, S., Quick, W.P. and Furbank, R.T., 2012. The development of C4 rice: current progress and future challenges. science, 336(6089), pp.1671-1672.
- S. Hubbart S. Peng P. Horton Y. Chen E. H. Murchie. Trends in leaf photosynthesis in historical rice varieties developed in the Philippines since 1966;Journal of Experimental Botany, 2007, Vol. 58 (12),3429–3438
- 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.
- Pandey V and Shukla A (2015) Acclimation and Tolerance Strategies of Rice under Drought Stress. Rice Science22(4):147-161.

Cereals and Millets:

- Kole, Chittaranjan. 2006. Cereals and millets
- Samuel A. Matz. 2006. Cerealscience

Wheat:

- Rinki, Mamrutha HM, Sareen Sindhu, Tiwari Vinod, Singh GP 2018. Dissecting the physiological and anatomical basis for high yield potential in HD 2967. Vegetos. 31: 121-124.
- Kumar R, Kaur A, Ankita P, Mamrutha HM, Singh GP 2019. CRISPR based genome editing in wheat: A comprehensive review and future prospects. Molecular biology reports10.1007/s11033-019-04761-3
- R.Tiwari and H.M. Mamrutha. 2014. Precision Phenotyping for Mapping of Traits for Abiotic Stress Tolerance in Crops. Biotechnology: Prospects and Applications. Editors. R.K. Salar, S.K. Gahlawat, P. Siwach and J.S. Duhan. Pp79-85. Publisher: Springer.
- Wheat Physiological Breeding II: A Field Guide to Wheat Phenotyping. (CIMMYT publication)
- Breeding for field crops book by David Allen Sleper and John Milton Poehlman
- Wheat Physiological Breeding volume I and II by Mathew Reynolds from (CIMMYT): Wheat Physiological Breeding: A Field Guide to Wheat Phenotyping.
- Mamrutha H.M. *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

M.Sc.(Ag.) III Semester

PP-505 HORMONAL REGULATION OF PLANT GROWTH AND DEVELOPMENT 3(2+1)

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.

AIM OF THIS 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

LEARNING OUTCOMES

After successful completion of this course, the students are expected to be able to:

1. acquire basic knowledge about plant hormones and plant growth regulators.
2. understand the physiological roles and mechanisms of actions of plant hormone.
3. obtain practical knowledge about application of plant growth regulators in agricultural and horticulture.

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
- 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 Brassinosteroids and 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 Tricentanol
- 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 Tricentanol 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 – casestudies

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 gynoeious 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.

PRACTICALS

1. Extraction of Auxins from plant tissue
2. Separation and detection of Auxins by GC / GC-MS / HPLC / Immunological technique
3. Bioassay of auxin- effect on rooting of cuttings
4. Extraction of abscisic acid (ABA) from plant tissue
5. Separation and detection of ABA by HPLC/Immunological technique
6. ABA bioassays- effect on stomatal movement
7. Preparation of samples for ethylene estimation in plant tissue
8. Estimation of ethylene in plant tissues using gas chromatography
9. Ethylene bioassays, estimation using physico-chemical techniques- effect on breaking dormancy in sunflower and groundnut
10. Extraction of Gibberellins from plant tissue- GC / GC-MS /HPLC
11. Separation and detection of GA by GC/GC-MS/HPLC/Immunological technique

12. GA bioassays- effect on germination of dormant seeds
13. Cytokinin- extraction from plant tissue
14. Separation and detection of cytokin in by GC / GC-MS /HPLC
15. Cytokinin bioassays- effect on apical dominance and senescence / staygr

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment(Reading/Writing)
- Student presentation
- Practicals

RESOURCES

- Davies, P.J. 2004, Plant Hormones: Biosynthesis, Signal Transduction and Action, 2nd Edition. Kluwer Academic Publishers, Dordrecht, TheNetherlands.
- 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.
- Tucker, G.A. and Roberts, J.A. 2000. Plant Hormone Protocols. Humana Press- Springer Science, New York,USA.
- Buchanan B B, Gruissem W and Jones R L Biochemistry and Molecular biology of Plants, 2ndEdition
- LincolnTaizandEduardoZeiger.PlantPhysiologyandDevelopment,6thEdition.
- Teaching Tools in Plant Biology, The American Society of PlantBiologists
- The ArabidopsisBook(<http://www.arabidopsisbook.org/>)

M.Sc.(Ag.)IV Semester

PPY-510

SEED PHYSIOLOGY

3(2+1)

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.

AIM OF THIS 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

LEARNING OUTCOMES

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.

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

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- 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 develop.

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

- 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

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- 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

PRACTICALS

1. Determination of seed reserves: carbohydrates, proteins and lipids
2. Study of different seed structures
3. Kinetics of seed imbibition; Seed germination test, enzymatic activities and respiration during germination and vigour testing methods.
4. Accelerated ageing test to know the seed vigour and storability
5. Measurement of seed moisture content
6. Determination of amylase activity in germinating seeds
7. Measurement of electrical conductivity in seed leachate
8. Measurement of seed viability using tetrazolium chloride
9. Determination of dehydrogenase activity
10. Seed germination study- Determination of Germination Index and seedling growth
11. Measurement of seed vigour index
12. Dormancy breaking treatments
13. Seed priming techniques
14. Effect of environmental stresses on seed germination and seedling growth

15. Effect of hormones on seed germination

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment(Reading/Writing)
- Student presentation
- Practicals

Resources:

- 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
- Vanangamudi K, Natarajan K and Vanangamudi M, *Seed Physiology*, Associated Publishing Company
- Bewley JD and Black M, 1994 *Seeds: Physiology of Development and Germination*, Springer
- N.W. Pammenter and Patricia Berjak (2000). Aspects of recalcitrant seed physiology. *R.Bras. Fisiol. Veg.*, 12:56-69.
- Prakash. M. 2011. *Seed physiology of crops*.(ed). Satish Serial Publishing house, New Delhi.
- Roberto Benech-Arnold, Rodolfo Sanchez. 2004. *Handbook of Seed Physiology: Applications to Agriculture*. CRC Press.
- Vijayakumar, A. 2001. Seed Dormancy an overview. In : *Recent techniques and Participatory Approachs in Quality seed production* (eds. K. Vanangamudiet *al.*), TNAU, Coimbatore. pp287-396.
- Padmavathi, S., M. Prakash, S. Ezhil Kumar, G. Sathianarayanan and A.Kamaraj. 2012. *A Text Book of Seed Science and Technology*. New India Publishing Agency, NewDelhi.
- Tina Steinbrecher Gerhard Leubner-Metzger (2017). The biomechanics of seed germination. *Journal of Experimental Botany*, 68(4):765–783.
- http://sbc.ucdavis.edu/Research_pages/Seed_physiology_and_technology/.
- Bench ALR and Sanchez RA. 2004. *Handbook of Seed Physiology*. Food Product Press.

Department of Plant Physiology

Ph.D. in Plant Physiology

Sl. No.	Course No.	Course Name	Credit Hrs.	Semester
Major Courses				
1.	PP-602	Signal perception and transduction and regulation of physiological processes	2(2+0)	I
2.	PP-603	Molecular approaches for improving physiological mechanisms through trait introgression	3(2+1)	I
3.	PP-606	Global climate change and crop response	2(2+0)	II
4.	PP-607	Physiological and molecular aspects of source sink capacity for enhancing yield	3(3+0)	II
5.	PP-608	Seed and fruit growth and their quality improvement	2(2+0)	III
Total			12	
Minor Courses (Choice based)				
1.	AGRON-607	Stress crop production	3(2+1)	III
4.	SST-601	Hybrid seed production technology	3(2+1)	I
Total			06	
Supporting Courses				
1.	SST-602	Organic Seed Production	2(2+0)	II
2.	STAT-612	Advanced Design & Experiment	3(2+1)	II
Total			05	
3.	PP-691	Doctoral Seminar-I	1(1+0)	III
4.	PP -692	Doctoral Seminar-II	1(1+0)	IV
5.	PP -699	Doctoral Research	75	IV
Total			05	
G. Total			100	

Ph.D. I Semeste

PP- 602	SIGNAL PERCEPTIONS AND TRANSDUCTION AND REGULATION OF PHYSIOLOGICAL PROCESSES	2(2+0)
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WHY THIS COURSE?

Biosignaling is emerging as an important field 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.

AIM OF THIS 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

LEARNING OUTCOMES

By the end of this course, the student will be able to:

1. comprehend various signaling 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

BLOCK 1: SIGNAL PERCEPTIONS AND TRANSDUCTION : REGULATION OF PHYSIOLOGICAL PROCESSE

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 components 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.

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation

RESOURCES

Block 1:

Unit 1:

- 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, pp.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), pp.2063-2079.
- Pollard, T.D., Earnshaw, W.C., Lippincott-Schwartz, J. and Johnson, G., 2016. *Cell Biology E-Book*. Elsevier Health Sciences.

Unit 2 :

- Braun, Y., Smirnova, A.V., Weingart, H., Schenk, A. and Ullrich, M.S., 2007. A temperature-sensing histidine kinase—function, genetics, and membrane topology. In *Methods in enzymology* (Vol. 423, pp. 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, pp. 139-167). Academic Press.
- Ortiz-Urquiza, A. and Keyhani, N.O., 2016. Molecular genetics of *Beauveria bassiana* infection of insects. In *Advances in genetics* (Vol. 94, pp.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.

Unit 3:

- Hedden, P. and Thomas, S.G. eds., 2008. *Annual Plant Reviews, Plant Hormone Signaling* (Vol. 24). John Wiley and Sons.
- Eckardt, N.A., 2015. The plant cell reviews dynamic aspects of plant hormone signaling and crosstalk.
- Chow, B. and McCourt, P., 2006. Plant hormone receptors: perception is everything. *Genes and development*, 20(15), pp.1998-2008.

Unit 4

- Leduc, N., Roman, H., Barbier, F., Péron, T., Huché-Théliér, L., Lothier, J., Demotes-Mainard, S. and Sakr, S., 2014. Light signaling in bud outgrowth and branching in plants. *Plants*, 3(2), pp.223-250.

- Kami, C., Lorrain, S., Hornitschek, P. and Fankhauser, C., 2010. Light-regulated plant growth and development. In *Current topics in developmental biology* (Vol. 91, pp. 29- 66). AcademicPress.
- Coureux, P.D. and Genick, U.K., 2007. Triggering and Monitoring Light-Sensing Reactions in Protein Crystals. In *Methods in enzymology* (Vol. 422, pp. 305-337). AcademicPress.
- Leduc, N., Roman, H., Barbier, F., Péron, T., Huché-Théliér, L., Lothier, J., Demotes- Mainard, S. and Sakr, S., 2014. Light signaling in bud outgrowth and branching in plants. *Plants*, 3(2),pp.223-250.
- Kami, C., Lorrain, S., Hornitschek, P. and Fankhauser, C., 2010. Light-regulated plant growth and development. In *Current topics in developmental biology* (Vol. 91, pp. 29- 66). AcademicPress.
- Coureux, P.D. and Genick, U.K., 2007. Triggering and Monitoring Light-Sensing Reactions in Protein Crystals. In *Methods in enzymology* (Vol. 422, pp. 305-337). AcademicPress.

Unit 5:

- Wang, C.S., Hsu, S.W. and Hsu, Y.F., 2013. New insights into desiccation-associated gene regulation by *Lilium longiflorum* ASR during pollen maturation and in transgenic Arabidopsis. In *International review of cell and molecular biology* (Vol. 301, pp. 37-94). AcademicPress.
- Ben-Ari, G. and Lavi, U., 2012. Marker-assisted selection in plant breeding. In *Plant Biotechnology and Agriculture* (pp. 163-184). AcademicPress.
- Peleg, Z.V.I., Walia, H. and Blumwald, E., 2012. Integrating genomics and genetics to accelerate development of drought and salinity tolerant crops. In *Plant Biotechnology and Agriculture* (pp. 271-286). AcademicPress.
- Zhu, J.K., 2016. Abiotic stress signaling and responses in plants. *Cell*, 167(2), pp.313- 324.
- Pandey, G.K., Pandey, A., Prasad, M. and Böhmer, M., 2016. abiotic stress signaling in plants: functional genomic intervention. *Frontiers in plant science*, 7,p.681.
- Inaba, T., Yazu, F., Ito-Inaba, Y., Kakizaki, T. and Nakayama, K., 2011. Retrograde signaling pathway from plastid to nucleus. In *International review of cell and molecular biology*(Vol. 290, pp. 167-204). AcademicPress.

Unit 6:

- Khan, M.I.R., Reddy, P.S., Ferrante, A. and Khan, N.A. eds., 2019. *Plant Signaling Molecules: Role and Regulation Under Stressful Environments*. Woodhead Publishing.
- Sparks, E., Wachsman, G. and Benfey, P.N., 2013. Spatiotemporal signalling in plant development. *Nature Reviews Genetics*, 14(9),p.631.
- Becraft, P.W., 2002. Receptor kinase signaling in plant development. *Annual review of cell and developmental biology*, 18(1),pp.163-192.
- Sparks, E., Wachsman, G. and Benfey, P.N., 2013. Spatiotemporal signalling in plant development. *Nature Reviews Genetics*, 14(9),p.631.

Unit 7:

- Rabellino, D., Boyd, J.E., McKinnon, M.C. and Lanius, R.A., 2019. The Innate Alarm System: A Translational Approach. In *Stress: Physiology, Biochemistry, and Pathology* (pp. 197-212). AcademicPress.
- Newton, A.C., Torrance, L., Holden, N., Toth, I.K., Cooke, D.E., Blok, V. and Gilroy, E.M., 2012. Climate change and defense against pathogens in plants. In *Advances in applied microbiology* (Vol. 81, pp. 89-132). AcademicPress.
- Reverchon, S., Muskhelishvili, G. and Nasser, W., 2016. Virulence program of a bacterial plant pathogen: the Dickeya model. In *Progress in molecular biology and translational science* (Vol. 142, pp. 51-92). AcademicPress.
- Rabellino, D., Boyd, J.E., McKinnon, M.C. and Lanius, R.A., 2019. The Innate Alarm System: A Translational Approach. In *Stress: Physiology, Biochemistry, and Pathology* (pp. 197-212). AcademicPress.
- Reverchon, S., Muskhelishvili, G. and Nasser, W., 2016. Virulence program of a bacterial plant pathogen: the Dickeya model. In *Progress in molecular biology and translational science* (Vol. 142, pp. 51-92). AcademicPress.
- Davies, P.J. ed., 2004. *Plant hormones: biosynthesis, signal transduction, action!*. Springer Science and BusinessMedia.

- Dzhavakhiya, V.G. and Shcherbakova, L.A., 2007. Creation of disease-resistant plants by gene engineering. In *Comprehensive and Molecular Phytopathology* (pp. 439-466).Elsevier.
- Dyakov, Y.T. and Ozeretskoykaya, O.L., 2007. Vertical pathosystem: avirulence genes and their products. In *Comprehensive and Molecular Phytopathology* (pp. 181- 215).Elsevier.
- Yamane, H., Konno, K., Sabelis, M., Takabayashi, J., Sassa, T. and Oikawa, H., 2010. Chemical defence and toxins of plants.
- Vinutha, T., Gupta, O.P., Prashat, G.R., Krishnan, V. and Sharma, P., 2014. Molecular mechanism of Begomovirus evolution and plant defense response. In *Plant Virus–Host Interaction* (pp. 345-357). Academic Press.

General Source Information

- Laszlo Bogre and Gerrit Beemster, 2008. Plant cell monographs. Plant Growth Signaling.
- Signals and Signal Transduction Pathways in Plants by Klaus Palme (Editor), 2012, Springer ISBN-13:9789401041072
- Memon, A.R. and Durakovic, C., 2014. Signal perception and transduction in plants. *Periodicals of Engineering and Natural Sciences (PEN)*,2(2).
- Signal Transduction Mechanism: EduRev: https://edurev.in/studytube/Lecture-15- Signal-transduction-mechanisms/d82aff0d-53d8-4d71-a16c-185c6bdb517b_p
- Signaling and Communication in Plants, ISBN-10: 3540892273Springer; 2009 edition (March 18,2009)
- Signal Transduction in Plants: Current Advances; 2012, by S K Sopory (Editor), Ralf Oelmuller (Editor), S C Maheswari (Editor), ISBN-13:9781461355182
- Plant Signalling Networks: Methods and Protocols, by Dr.Zhi-Yong Wang, Springer, 2016, ISBN-13:9781493961696
- Developmental and Cell Biology Series: Hormones, Signals and Target Cells in Plant Development Series Number 41, by Daphne J. Osborne, Michael T. McManus, Cambridge University Press, ISBN-13:9780521330763
- How Plants Communicate by Sarah Machajewski, 2018, Rosen Education Service, ISBN-13:9781538301852
- SignalTransductioninPlantsbyPAducci(Editor),2011,ISBN-13:9783034899383
- Reactive Oxygen Species: Signaling Between Hierarchical Levels in Plants, by Franz- Josef Schmitt (Editor), Suleyman I Allakhverdiev (Editor), 2017, Wiley- ScrivenerISBN-13:9781119184881
- Biocommunication: Sign-Mediated Interactions Between Cells and Organisms by Richard Gordon (Editor), Joseph Seckbach (Editor), 2017, World Scientific Publishing Europe Ltd ISBN-13:9781786340443
- Annual Plant Reviews: Intracellular Signaling in Plants by Peter Hedden, Richard Napier, Zhenbiao Yang (Editor) 2008, Wiley-Blackwell (an imprint of John Wiley and Sons Ltd) ISBN-13:9781405160025

Ph.D. I Semester

PP- 603 MOLECULAR APPROACHES FOR IMPROVING PHYSIOLOGICAL 3(2+1)
MECHANISMS THROUGH TRAITINTROGRESSION

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”.

AIM OF THIS 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 laborately. 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

LEARNING OUTCOMES

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

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—F₂, 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, QTLseqetc.,
- Composite interval mapping and other approaches for QTLdiscovery

Unit 3: Identification of QTLs by Association Mapping Approach

- Concepts of assembling a “Panel” of germplasm amenable for association mapping based on molecular and phenotypicdiversity.
- Concepts of linkage disequilibrium, LD decay and populationstructure
- Concepts QTL discovery in structuredpopulations
- Phenotyping of the association mappingpopulations
- 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 allelicvariants
- Identification of differentially expressed genes through transcriptome, metabolome and proteome analysis in contrastinggenotypes.
- Gene identification through forward (inducing mutations with radiation, chemicals, or insertional mutagenesis)and reverse genetic approaches (site-directed mutagenesis, gene knockout orknockdown)
- 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 cropimprovement
- Gene stacking strategies for traitimprovement
- *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 nucleasesetc
- CRISPR as tool to generate loss-of-function and gain-of-functiontransgenics

Unit 4: Characterization of Transformed Plants and Event Selection Strategies

- Molecular analysis bySouthern, qRT-PCR/Northern analysis, andimmunoassays
- Concepts of copy number and desirable number of independentevents
- Evaluation of transgenics based on empirical/physiological/biochemical processes under specific conditions – containment and confined fieldtrials
- Generation of T1 populations, eventcharacterization

- 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.

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

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment(Reading/Writing)
- Student presentation
- Practicals

RESOURCES

Block 1:

Unit 1:

- Physiological breeding I: interdisciplinary approaches to improve crop adaptation Edited by Reynolds, M.P. 2012. Chapters 2, 3, 5:153
- Reynolds M. and Langridge P., 2016, Physiological breeding. Current Opinion in Plant

Biology,31:162–17.1

- Sheshshayee M.S., Preethi N.V., Rohini S., Sowmya H.R., Smitharani A., Pooja B., Prathibha M.D. and Raju Soolanayakanahally, 2018, Introgression of Physiological Traits for a Comprehensive Improvement of Drought Adaptation in Crop Plants. *Front. Chem.*, 10.
- Mariano Cossani and Reynolds M., 2012, Physiological Traits for Improving Heat Tolerance in Wheat. *Plant Physiology*, Vol.160:1710–1718
- Thomas Payne, Matthew Reynolds and Bent Skovmand, Searching genetic resources for useful variation in physiological traits Chapter 5. *Physiological breeding I: interdisciplinary approaches to improve crop adaptation* edited by Reynolds, M.

Unit 2:

- David Bonnett, Optimizing marker-assisted selection (MAS) strategies for crop improvement. Chapter 14: 153 *Physiological breeding I: interdisciplinary approaches to improve crop adaptation* edited by Reynolds, M.P.
- Breeding Rice for Drought-Prone Environments Edited by K.S. Fischer, R. Lafitte, S. Fukai, G. Atlin, and B. Hardy. 2003, IRRI. Section 4. What molecular tools are available for selection for drought tolerance?
- B.C.Y. Collard, M.Z.Z. Jahufer, J.B. Brouwer and E.C.K. Pang, An introduction to markers, quantitative trait loci (QTL) mapping and marker-assisted selection for crop improvement: The basic concepts. *Euphytica* (2005) 142:169–196
- Alexander E Lipka, Catherine B Kandianis, Matthew E Hudson, Jianming Yu, Jenny Drnevich, Peter J Bradbury and Michael A Gore 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
- Yang Xu, Pengcheng Li, Zefeng Yang, Chenwu Xu. Genetic mapping of quantitative trait loci in crops. *The crop journal* 5 (2017) 175–184
- Khanh Le Nguyen, Alexandre Grondin, Brigitte Courtois, and Pascal Gantet. Next- Generation Sequencing Accelerates Crop Gene Discovery. *Trends in Plant Science*, March 2019, Vol. 24, No.3

Unit 3:

- Jesse A. Poland and Trevor W. Rife, Genotyping-by-Sequencing for Plant Breeding and Genetics. *THE PLANT GENOME*, 2012.5:3
- Bertrand C. Y. Collard and David J. Mackill. Marker-assisted selection: an approach for precision plant breeding in the twenty-first century. *Phil. Trans. R. Soc. B* (2008) 363,557–572
- Nicolas Heslot, Jean-Luc Jannink, and Mark E. Sorrells. Perspectives for Genomic Selection Applications and Research in Plants. *Crop Sci.* 55:1–12 (2015).
- Laura Pascual, Elise Albert, Christopher Sauvage, Janejira Duangjit, Jean-Paul Bouchet, Frédérique Bitton, Nelly Desplat, Dominique Brunel, Marie-Christine Le Paslier, Nicolas Ranc, Laure Bruguier, Betty Chauchard, Philippe Verschave, Mathilde Causse. Dissecting quantitative trait variation in the resequencing era: complementarity of bi-parental, multi-parental and association panels. *Plant Science* 242 (2016) 120–130
- Association Mapping in Plants. Editors: Oraguzie, N.C., Rikkerink, E.H.A., Gardiner, S.E., de Silva, H.N. (Eds.) 2007. Page-1-39; 103-132.
- Myles, S., Peiffer, J., Brown, P. J., Ersoz, E. S., Zhang, Z., Costich, D. E., and Buckler, E. S. (2009). Association mapping: critical considerations shift from genotyping to experimental design. *The Plant Cell*, 21(8), 2194-2202.

Unit 4:

- Bertrand C.Y Collard and David J Mackill. 2007. Marker-assisted selection: an approach for precision plant breeding in the twenty-first century. *Phil Trans. Ser B2007*
- Xu, Yunbi, and Jonathan H. Crouch. "Marker-assisted selection in plant breeding: from publications to practice." *Crop science* 48.2 (2008):391-407.
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- Visarada, K. B. R. S., Kanti Meena, C. Aruna, S. Srujana, N. Saikishore, and N. Seetharama. "Transgenic breeding: perspectives and prospects." *Crop Science* 49, no. 5 (2009):1555-1563.
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- Ramalingam, Abirami, HimabinduKudapa, Lekha T. Pazhamala, Wolfram Weckwerth, and Rajeev K. Varshney. "Proteomics and metabolomics: two emerging areas for legume improvement." *Frontiers in plant science* 6 (2015):1116.
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- Borghi, Lorenzo. "Inducible gene expression systems for plants." In *Plant Developmental Biology*, pp. 65-75. Humana Press, Totowa, NJ,2010.
- Kwon, Kwang-Chul, Hui-Ting Chan, Ileana R. León, Rosalind Williams-Carrier, Alice Barkan, and

Henry Daniell. "Codon optimization to enhance expression yields insights into chloroplast translation." *Plant physiology* 172, no.1 (2016):62-77.

Unit 2:

- Kamthan, Ayushi, Abira Chaudhuri, Mohan Kamthan, and Asis Datta. "Genetically modified (GM) crops: milestones and new advances in crop improvement." *Theoretical and applied genetics* 129, no. 9 (2016):1639-1655.
- Chen, Weiqiang, and David W. Ow. "Precise, flexible and affordable gene stacking for crop improvement." *Bioengineered* 8, no. 5 (2017):451-456.
- Joung, Young Hee, Pil-Son Choi, Suk-Yoon Kwon, and Chee Hark Harn. "Plant Transformation Methods and Applications." In *Current Technologies in Plant Molecular Breeding*, pp. 297-343. Springer, Dordrecht, 2015.

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Unit 3:

- Gaj, Thomas, Charles A. Gersbach, and Carlos F. Barbas III. "ZFN, TALEN, and CRISPR/Cas-based methods for genome engineering." *Trends in biotechnology* 31, no. 7 (2013):397-405.

Unit 4:

- Register III, James C. "Approaches to evaluating the transgenic status of transformed plants." *Trends in biotechnology* 15, no. 4 (1997):141-146.
- Prabhu, K. V. "Use of GMOs Under Containment, Confined and Limited Field Trials and Post-Release Monitoring of GMOs." *Biosafety of Genetically Modified Organisms: Basic concepts, methods and issues* (Chowdhury MKA, Hoque MI, Sonnino A, eds). Food and Agriculture

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- Chen, Wei, and PoHao Wang. "Molecular Analysis for Characterizing Transgenic Events." In *Transgenic Plants*, pp.397-410. Humana Press, New York, NY, 2019.
- Giller, K. E. *Genetically Engineered Crops: Experiences and Prospects*. National Academies of Sciences, Engineering, and Medicine, 2016.

Block 3:

Unit 1:

- Wu, Rui, Xiaoran Wang, Yan Lin, Yiqiao Ma, Gang Liu, Xiaoming Yu, Silin Zhong, and Bao Liu. "Inter-species grafting caused extensive and heritable alterations of DNA methylation in Solanaceae plants." *PLoS One* 8, no.4 (2013): e61995

Unit 2:

- *Doubled Haploid Production in Crop Plants*. Editors: W. T. B. Thomas B. P. Forster B. Gertsson. Page 337-349, 2003
- Forster, B. P., and Thomas, W. T. (2005). Doubled haploids in genetics and plant breeding. *Plant Breed Rev*, 25, 57-88.

Ph.D. II Semester

PP 606

GLOBAL CLIMATE CHANGE AND CROP RESPONSE

2(2+0)

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 equip 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.

AIM OF THIS 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

After completion this course, students will be able to obtain in depth and basis knowledge on crop responses to climate change.

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, carbonequity/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 (CO₂, Methane, NO₂ etc.), their Production Rates, Monitoring and their Influence on Climate Change

GHGs: An Overview, - role of CO₂, 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. used in monitoring

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, C₃ and C₄ 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, CO₂, 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 increasing atmospheric CO₂ 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

- a. Agricultural biotechnology to produce crop varieties with enhanced carbon uptake.
- b. Nutrient management: Management of nitrogenous fertilizers;
- c. Tillage/residue management: 1. Conservation tillage CO₂ mitigation technology; 2. Biochar: A potential technique for carbon sequestration.
- d. Methane mitigation using reduced tillage technology, change in methanogenic bacterial activity using electron acceptors.
- e. 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.

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation

RESOURCES

- 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
- Research papers, review articles, National and International Reports
- Uprety, D.C. and Reddy, V.R. (2016), Crop responses to Global warming, Springer publication, ISBN 978-981-10-2004-9, pp 1-125 (2016)
- Climate Change and Agriculture Worldwide (Editor : Emmanuel Torquebiau) Springer Netherlands, 2015
- Climate Smart Agriculture: Building Resilience to Climate Change. Edited by Leslie Lipper, Nancy McCarthy, David Zilberman, Solomon Asfaw, Giacomo Branca, Springer, FAO, 2018
- Handbook of Climate Change and Agroecosystems: The Agricultural Model Intercomparison and Improvement Project (AgMIP) in 2 parts Kindle Edition by Rosenzweig Cynthia and Hillel Daniel (Author), Cynthia Rosenzweig (Editor), 2015
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 - Uprety, D.C. (2014). *Greenhouse gases and Crops*. Publishing India Group, ISBN 978- 81-928337-0-5, pp250-308.
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 - Babu, J.Y., Nayak, D.R. and Adhya, T.K. (2006). Potassium application reduces Methane emission from

flooded field planted torice. Biol. Fertil, Soils (2006), 42:532-54.

Ph.D. II Semester

PP 607

PHYSIOLOGICAL AND MOLECULAR ASPECTS OF SOURCE-SINK CAPACITY FOR ENHANCING YIELD

3(3+0)

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 i.e., yield associated traits. Yield plateau can be broken only by enhancing yield potential by structured improvement in source capacity and sink size.

AIM OF THIS 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 i.e., 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

LEARNING OUTCOMES

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

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 CO₂ 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- CO₂ 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 CO₂ Fixation

- RuBisCO carbon fixation activity - Increase and optimize kinetics of RuBisCO with enhanced specificity to CO₂.
- Engineer RuBisCO to minimize feedback regulation by metabolite inhibitors.
- Increased activation state by improving stability and function of RuBisCO activase; optimize RuBp regeneration – modulate specific enzyme levels.
- New concepts on photorespiratory synthet

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

- Optimize 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/fruitlet 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 casestudies.

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, canopyphotosynthesis.
- 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 impulses.

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment(Reading/Writing)
- Studentpresentation

RESOURCES

Introduction –suggested reading

- Ray DK, Mueller ND, West PC, Foley JA (2013) Yield Trends Are Insufficient to Double Global Crop Production by 2050. PLoS ONE 8(6): e66428. doi:10.1371/journal.pone.0066428
- World Agricultural Supply and Demand Estimates (USDA),2019
- Mitchell C. Hunter, Richard G. Smith, Meagan E. Schipanski, Lesley W. Atwood, and David A. Mortensen. (2017) Agriculture in 2050: Recalibrating Targets for Sustainable Intensification. BioScience • April 2017 / Vol. 67 No.4
- PirjoPeltonen-Sainio, TapioSalo, Lauri Jauhiainen, HeikkiLehtonen, ElinaSieviläinen (2015). Static yields and quality issues: Is the agri-environment program the primary driver? Ambio 2015, 44:544–556 DOI10.1007/s13280-015-0637-9

Source establishment - suggested reading

- Zhu G, Li G, Wang D, Yuan S, Wang F (2016) Changes in the Lodging-Related Traits along with Rice Genetic Improvement in China. PLoS ONE 11(7): e0160104. doi:10.1371/journal.pone.0160104
- Burgess AJ, Retkute R, Herman T and Murchie EH (2017) Exploring Relationships between Canopy Architecture, Light Distribution, and Photosynthesis in Contrasting Rice Genotypes Using 3D Canopy Reconstruction. Front. Plant Sci. 8:734. doi: 10.3389/fpls.2017.00734
- Donald R. Orta, B. Sabeeha S. Merchantd,, Jean Alricf, Alice Barkan et al., (2015). Redesigning photosynthesis to sustainably meet global food and bioenergy demand. PNAS, 112,8529–8536
- TANG Yun-jia, Johannes Liesche, (2017). The molecular mechanism of shade avoidance in crops- How data from Arabidopsis can help to identify targets for increasing yield and biomass production. Journal of Integrative Agriculture 16(6): 1244–1255
- Giovanna Sessa , Monica Carabelli , Marco Possenti , Giorgio Morelli and Ida Ruberti (2018). Multiple Pathways in the Control of the Shade Avoidance Response. Plants 7, 102;doi:10.3390/plants7040102
- Wille W, Pipper CB, Rosenqvist E, Andersen SB, Weiner J. 2017. Reducing shade avoidance responses in a cereal crop. AoB PLANTS 9: plx039; doi: 10.1093/aobpla/plx039
- Ricardo J. Haroa, Jorge Baldessaria, María E. Otegui (2017). Genetic improvement of peanut in Argentina between 1948 and 2004:Light interception, biomass production and radiation use efficiency. Field Crops Research 204,222–228
- Dagang Jiang, Weiting Chen, Jingfang Dong, Jing Li, Fen Yang1, Zhichao Wu, Hai Zhou,Wensheng Wang and Chuxiong Zhuang. (2018). Overexpression of miR164b- resistant OsNAC2 improves plant architecture and grain yield in rice. Journal of Experimental Botany, Vol. 69, No. 7 pp.1533–1543.
- Galina Smolikova, Elena Dolgikh, Maria Vikhnina, Andrej Frolov and Sergei Medvedev (2017). Genetic and Hormonal Regulation of Chlorophyll Degradation during Maturation of Seeds with Green Embryos. Int. J. Mol. Sci. 2017, 18, 1993; doi:10.3390/ijms18091993
- Zhu X, Chen J, Qiu K and Kuai B (2017) Phytohormone and Light Regulation of Chlorophyll Degradation. Front. Plant Sci. 8:1911. doi:10.3389/fpls.2017.01911
- Tomoaki Sato, YousukeShimoda, Kaori Matsuda, Ayumi Tanaka, Hisashi Ito (2018). Mg-dechelation of

chlorophyll a by Stay-Green activates chlorophyll b degradation through expressing Non-Yellow Coloring in *Arabidopsis thaliana*. *Journal of Plant Physiology* 222 (2018)94–102

- Mandy Christophera,*, KarineChenub, RaeleenJenningsa, Susan Fletcher, David Butlera, Andrew Borrellc, Jack Christopher. (2018). QTL for stay-green traits in wheat in well-watered and water-limited environments. *Field Crops Research* 217 (2018)32–44
- Howard Thomas and Helen Ougham (2014). The stay-green trait. *Journal of Experimental Botany*, Vol. 65, No. 14, pp. 3889–3900,2014
- Makoto Kusaba • Ayumi Tanaka • Ryouichi Tanaka. Stay-green plants: what do they tell us about the molecular mechanism of leaf senescence. *Photosynth Res* DOI 10.1007/s11120-013-9862-x

Source function - suggested reading

- Qingfeng Song, Yu Wang, Mingnan Qu, Donald R. Ort, Xin-Guang Zhu. (2017). The impact of modifying photosystem antenna size on canopy photosynthetic efficiency— Development of a new canopy photosynthesis model scaling from metabolism to canopy level processes. *Plant cell and environ.*40:2946–2957.
- Yi Xiao, Xin-Guang Zhu (2017) Components of mesophyll resistance and their environmental responses: A theoretical modelling analysis. *Plant Cell Environ.* 40:2729–2742.
- Berkley J. Walker, Andy VanLoocke, Carl J. Bernacchi, and Donald R. Ort (2016). The Costs of Photorespiration to Food Production Now and in the Future. *Annu. Rev. Plant Biol.* 67:107–29
- Paul F. South, Amanda P. Cavanagh, Helen W. Liu, Donald R. Ort (2019). Synthetic glycolate metabolism pathways stimulate crop growth and productivity in the field. *Science*. DOI:10.1126/science.aat9077
- Benedict M. Long , Wei YihHee, Robert E. Sharwood, Benjamin D. Rae, Sarah Kaineset *al.*, Carboxysome encapsulation of the CO₂-fixing enzyme Rubisco in tobacco chloroplasts. *Nature communication* DOI:10.1038/s41467-018-06044-0
- Douglas J. Orr, André Alcântara², Maxim V. Kapralov, P. John Andralojc, ElizabeteCarmo-Silva, Martin A.J. Parry. Surveying Rubisco diversity and temperature response to improve crop photosynthetic efficiency
- Arren Bar-Even (2018). Daring metabolic designs for enhanced plant carbon fixation. *Plant science* 201871-83
- Christer Jansson¹, John Vogel², Samuel Hazen³, Thomas Brutnell⁴ and Todd Mockler (2018). Climate-smart crops with enhanced photosynthesis. *Journal of Experimental Botany*, Vol. 69, No. 16 pp. 3801–3809,2018.
- Brendon Conlan, Rosemary Birch, Celine Kelso, Sophie Holland¹, Amanda P. De Souza, Stephen P Long, Jennifer L. Beck, Spencer M. Whitney. BSD is a Rubisco specific assembly chaperone, forms intermediary hetero-oligomeric complexes and is non-limiting to growth in tobacco.(2018) *Plant physiol*(accepted)
- Benedict M. Long, Wei YihHee, Robert E. Sharwood, Benjamin D. Rae, Sarah Kaines, Yi-Leen Lim, Nghiem D. Nguyen, Baxter Massey, SoumiBala, Susanne von Caemmerer, Murray R. Badger and G. Dean Price (2018) Carboxysome encapsulation of the CO₂-fixing enzyme Rubisco in tobacco chloroplasts. *Nature Communications*, (2018)9:3570
- Douglas J. Orr, André Alcântara, Maxim V. Kapralov, P. John Andralojc, ElizabeteCarmo-Silva (2016). Surveying Rubisco diversity and temperature response to improve crop photosynthetic efficiency. *Plant physiology* DOI:10.1104/pp.16.00750
- Frank A. Skraly, Madana M.R. Ambavaram, Oliver Peoples, Kristi D. Snell (2018). Metabolic engineering to increase crop yield: From concept to execution. *Plant Science* 273 (2018)23–32.

Improving Sink source and its capacity -Suggested reading

- Paul, 2018, Are GM Crops for Yield and Resilience Possible? –Review, *Trends in Plant Science*, Jan; 23(1):10-16. doi:10.1016/j.tplants.2017.09.007
- Ansari *et al.*, 2019, Comparative Studies of Late Planted Capsicum (*Capsicum annum*) for Growth and Yield under Polyhouse and Open Field Condition as Influenced by Different Growth Regulators, *Indian Res. J. Ext. Edu.* Vol.1, No.1
- Khumsupanet *al.*, 2019, CRISPR/Cas in *Arabidopsis*: overcoming challenges to accelerate improvements in crop photosynthetic efficiencies, *Physiologia Plantarum*.
- Amthoret *al.*, 2019, Engineering Strategies to Boost Crop Productivity by Cutting 4 Respiratory Carbon

Loss – Review, Plant Cell Advance Publication, doi:10.1105/tpc.18.00743

- Abdelrahman *et al.*, 2018, Genome editing using CRISPR/Cas9–targeted mutagenesis: An opportunity for yield improvements of crop plants grown under environmental stresses Neglected pollinators, Plant Physiology and Biochemistry 131 (2018)31–36
- Xu *et al.*, 2018, Genome-Wide Association Analysis of Grain Yield-Associated Traits in a Pan-European Barley Cultivar Collection, Plant genome, 11(1). doi: 10.3835/plantgenome2017.08.0073.
- Sgarmaet *al.*, Genome-wide association of yield traits in a nested association mapping population of barley reveals new gene diversity for future breeding, Journal of Experimental Botany, Vol. 69, No. 16 pp. 3811–3822,2018.
- Hong *et al.*, Genome-wide identification and extensive analysis of rice-endosperm preferred genes using reference expression database, J.Plant Biol.(2017)60:249-258.
- Mir *et al.*, High-throughput phenotyping for crop improvement in the genomics era, Plant Science, Inpress
- Nadolska-Orezyket *al.*, Major genes determining yield-related traits in wheat and barley, TheorAppl Genet (2017)130:1081-1098.
- Savadi, Molecular regulation of seed development and strategies for engineering seed size in crop plants- Review, Plant Growth Regulation (2018)84:401–422
- Sonnewaldet *al.*, Next-generation strategies for understanding and influencing source–sink relations in crop plants, Current Opinion in Plant Biology 2018, 43:63–70
- Zhang *et al.*, OsSRT1 is involved in rice seed development through regulation of starch metabolism gene expression, Plant Science 248 (2016)28–36
- Schebenet *al.*, Progress in single-access information systems for wheat and rice crop improvement, Briefings in Bioinformatics, 2018,1–7
- Verma *et al.*, Rice research to break yield barriers, Cosmos, Vol. 11, No. 1 (2015) 1– 18
- Li *et al.*, Systems model-guided rice yield improvements based on genes controlling source, sink, and flow, 2018, Journal of Integrative Plant Biology, Volume 60, Issue 12, 1154–1180
- Temperature regulation of plant phenological development, Environmental and Experimental Botany, 2015, Volume 111, Pages 83-90.
- Paul *et al.*, The Role of Trehalose 6-Phosphate in Crop Yield and Resilience, Plant Physiology, May 2018, Vol. 177, pp.12–23.
- Narnoliyaet *al.*, Transcriptional Signatures Modulating SAM Morphometric and Plant Architectural Traits Enhance Yield and Productivity in Chickpea, The plant journal, accepted paper

Ph.D. III Semester

PP 608 SEED AND FRUIT GROWTH AND THEIR QUALITY IMPROVEMENT 2(2+0)

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.

AIM OF THIS 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

LEARNING OUTCOMES

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 postharvest deterioration of seeds and fruits and to minimize the losses

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 digestible 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 Digestible Fiber, lycopene, still beans
- 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.

TEACHING METHODS / ACTIVITIES

- Lecture
- Assignment (Reading/Writing)
- Student presentation

RESOURCES

Unit 1 & 2:

- 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
- Vanangamudi K, Natarajan K and Vanangamudi M, Seed Physiology, Associated Publishing Company
- N.W. Pammenter and Patricia Berjak (2000). Aspects of recalcitrant seed physiology. R. Bras. Fisiol. Veg.,

12:56-69.

- Prakash. M. 2011. Seed physiology of crops.(ed). Satish Serial Publishing house, New Delhi..

Unit 3:

- Lee, K.R., Chen, G.Q. and Kim, H.U., 2015. Current progress towards the metabolic engineering of plant seed oil for hydroxy fatty acids production. *Plant cell reports*, 34(4),pp.603-615.
- Zhu, Y., Xie, L., Chen, G.Q., Lee, M.Y., Loque, D. and Scheller, H.V., 2018. A transgene design for enhancing oil content in Arabidopsis and Camelina seeds. *Biotechnology for biofuels*, 11(1),p.46.
- Patil, G., Mian, R., Vuong, T., Pantalone, V., Song, Q., Chen, P., Shannon, G.J., Carter, T.C. and Nguyen, H.T., 2017. Molecular mapping and genomics of soybean seed protein: a review and perspective for the future. *Theoretical and Applied Genetics*, 130(10),pp.1975-1991
- Tien Lea, D., Duc Chua, H. and Quynh Lea, N., 2016. Improving nutritional quality of plant proteins through genetic engineering. *Currentgenomics*,17(3),pp.220-229.
- Ufaz, S. and Galili, G., 2008. Improving the content of essential amino acids in crop plants: goals and
- Mene-Saffrane, L. and Pellaud, S., 2017. Current strategies for vitamin E biofortification of crops. *Current opinion in biotechnology*, 44,pp.189-197.
- Jiang, L., Wang, W., Lian, T. and Zhang, C., 2017. Manipulation of metabolic pathways to develop vitamin-enriched crops for human health. *Frontiers in plant science*, 8,p.937.
- Abhishek Bohra, Uday Chand Jha, Rintu Jha, S. J. Satheesh Naik, Alok Kumar Maurya, and Prakash G. Patil, Chapter-1. Genomic Interventions for Biofortification of Food Crops, A. M. I. Qureshi *et al.* (eds.), *Quality Breeding in Field Crops*, https://doi.org/10.1007/978-3-030-04609-5_1
- Julia L Finkelstein, Jere D Haas and Saurabh Mehta, Iron-biofortified staple food crops for improving iron status: a review of the current evidence, *Current Opinion in Biotechnology* 2017,44:138–145
- Raul Antonio Sperotto, Felipe Klein Ricachenevsky, Vinicius de Abreu Waldow, Janette Palma Fett, Iron biofortification in rice: It's a long way to the top, *Plant Science* 190 (2012)24–39
- Biofortification of Cereal Grains with Zinc by Applying Zinc Fertilizers, *ForsideBioZoom*2009.
- Jeongyeo Lee, IllSupNou, HyeRan Kim, Current status in calcium biofortification of crops, *J Plant Biotechnol* (2012) 39:23–32, DOI:<http://dx.doi.org/10.5010/JPB.2012.39.1.023>
- Divya Sharma, Gautam Jamr,, Uma M. Singh, SalejSood and Anil Kuma, Calcium Biofortification: Three Pronged Molecular Approaches for Dissecting Complex Trait of Calcium Nutrition in Finger Millet (*Eleusine coracana*) for Devising Strategies of Enrichment of Food Crops,2017, doi:10.3389/fpls.2016.02028
- Gemedede, H.F. and Ratta, N., 2014. Antinutritional factors in plant foods: Potential health benefits and adverse effects. *International Journal of Nutrition and Food Sciences*, 3(4),pp.284-289.
- Vasconcelos, I.M. and Oliveira, J.T.A., 2004. Antinutritional properties of plant lectins. *Toxicon*, 44(4), pp.385-403.

Unit 4:

- Kumar, D. and Kalita, P., 2017. Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries. *Foods*, 6(1), p.8.
- Kawakatsu, T., Hirose, S., Yasuda, H. and Takaiwa, F., 2010. Reducing rice seed storage protein accumulation leads to changes in nutrient quality and storage organelle formation. *Plant Physiology*, 154(4), pp.1842-1854.
- Afzal, I., Rehman, H.U., Naveed, M. and Basra, S.M.A., 2016. Recent advances in seed enhancements. In *New Challenges in Seed Biology-Basic and Translational Research Driving Seed Technology*.IntechOpen.
- Probert, R., Adams, J., Coneybeer, J., Crawford, A. and Hay, F., 2007. Seed quality for conservation is critically affected by pre-storage factors. *Australian Journal of Botany*, 55(3), pp.326-335.

Unit 5:

- Glenda Gillaspay, Hilla Ben-David, and Wilhelm Gruissem, *Fruits: A Developmental Perspective*, *The Plant Cell*, Vol. 5,1439-1451
- Nitsch, J. P. (1953). *The Physiology of Fruit Growth*. *Annual Review of Plant Physiology*, 4(1),199–

236.doi:10.1146/annurev.pp.04.060153.0012

- Rahul Kumar, Ashima Khurana, Arun K. Sharma, Role of plant hormones and their interplay in development and ripening of fleshy fruits, *Journal of Experimental Botany*, Volume 65, Issue 16, August 2014, Pages 4561– 4575, <https://doi.org/10.1093/jxb/eru277>
- Robert, H.S. Molecular Communication for Coordinated Seed and Fruit Development: What Can We Learn from Auxin and Sugars? *Int. J. Mol. Sci.* 2019, 20, 936.

Unit 6:

- Golubkina, N., Zamana, S., Seredin, T., Poluboyarinov, P., Sokolov, S., Baranova, H., Krivenkov, L., Pietrantonio, L. and Caruso, G., 2019. Effect of Selenium Biofortification and Beneficial Microorganism Inoculation on Yield, Quality and Antioxidant Properties of Shallot Bulbs. *Plants*, 8(4), p.102.
- Lovat, C., Nassar, A.M., Kubow, S., Li, X.Q. and Donnelly, D.J., 2016. Metabolic biosynthesis of potato (*Solanum tuberosum* L.) antioxidants and implications for human health. *Critical reviews in food science and nutrition*, 56(14), pp.2278-2303.
- Mak, Y.W., Chuah, L.O., Ahmad, R. and Bhat, R., 2013. Antioxidant and antibacterial activities of hibiscus (*Hibiscus rosa-sinensis* L.) and Cassia (*Senna bicapsularis* L.) flower extracts. *Journal of King Saud University-Science*, 25(4), pp.275-282.
- Kasote, D.M., Katyare, S.S., Hegde, M.V. and Bae, H., 2015. Significance of antioxidant potential of plants and its relevance to therapeutic applications. *International journal of biological sciences*, 11(8), p.982

Unit 7:

- Yahia, E.M. and Carrillo-Lopez, A. eds., 2018. *Postharvest Physiology and Biochemistry of Fruits and Vegetables*. Woodhead Publishing.
- Valero, D. and Serrano, M., 2010. *Postharvest biology and technology for preserving fruit quality*. CRC Press.
- Wills, R. and Golding, J., 2016. *Postharvest: an introduction to the physiology and handling of fruit and vegetables*. UNSW Press.
- Siddiqui, M.W. ed., 2015. *Postharvest biology and technology of horticultural crops: principles and practices for quality maintenance*. CRC Press.
- Corpas, F. J., and Palma, J. M. (2018). Nitric oxide on/off in fruit ripening. *Plant Biology*, 20(5), 805–807. doi:10.1111/plb.12852

Department of Seed Science & Technology

M.Sc. (Ag.) Seed Science & Technology

Major Courses (20 Credits)

Sl. No.	Course Code	Course Title	Credits	Semester
1.	SST 501	Seed Developmental Biology	2(1+1)	I
2.	SST 502	Seed Dormancy and Germination	2(1+1)	II
3.	SST 503	Seed Production Principles and Techniques in Field Crops	3(2+1)	I
4.	SST 504	Seed Production Principles and Techniques in Vegetable Crops	3(2+1)	II
5.	SST 507	Seed Legislation and Certification	3(2+1)	II
6.	SST 508	Post Harvest Handling and Storage of Seeds	3(2+1)	III
7.	SST 509	Seed Quality Testing and Enhancement	2(1+1)	I
8.	SST 511	Seed Industry and Marketing Management	2(1+1)	III
Total			20(12+8)	

Minor Courses

Sl. No.	Course Code	Course Title	Credits	Semester
1.	GPB-504	Varietal Development and Maintenance Breeding	2(1+1)	IV
2.	PP-510	Seed Physiology	3(2+1)	IV
3.	PL PATH-515	Disease of field and medicinal crops	3(2+1)	III
Total			8(5+3)	

Supporting Courses

Sl. No.	Course Code	Course Title	Credits	Semester
1.	STAT-511	Experimental Design	3(2+1)	II
Any one of the following as per needs of the students' thesis				
2.	SOIL-502	Soil Fertility and Fertilizer use	3(2+1)	I
3.	AGRON-502	Principle and practices of soil fertility and nutrient management	3(2+1)	III
4.	ENT-505	Biological control of insect pests and weeds	3(2+1)	II
5.	GPB-502	Principles of Plant Breeding	3(2+1)	I
6.	PP-505	Hormonal Regulation of Plant Growth and Development	3(2+1)	III
Total			6(4+2)	

1.		Common courses	5(0+5)	
2.	SST-591	Seminar	1(0+1)	III
3.	SST -599	Research	30(0+30)	
Total			31 (0+31)	
Grand Total			70(21+49)/ 70(22+48)	

SST 501

Seed Developmental Biology

2(1+1)

Why this course?

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

Aim of the course

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

Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

Practical

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

Teaching methods

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

Learning outcome

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

Resources:

Adkins, S.W., Ashmore, S.E. and Navi, S.C. 2007. Seeds: Biology, Development and Ecology. CAB International, Oxfordshire, UK.

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

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

Copeland, L. O. and McDonald, M. B. 2001. Principles of Seed Science and Technology. 4th Ed. Kluwer Academic publishers, USA.

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

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

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

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

Maiti, R.K., Sarkar, N.C. and Singh, V.P. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur, Rajasthan.

Bewley, J.D., Bradford, K.J., Hilhorst, H.W.M. and Nanogaki, H. 2013. Seeds: Physiology of Development, Germination and Dormancy. Springer, New York.

Suggested e-books <https://www.springer.com/in/book/9783642810619>

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

<https://www.springer.com/gp/book/9780792346456>

<https://www.cabi.org/bookshop/book/9780851997230>

<https://www.worldcat.org/title/seed-development-and-ermination/oclc/44954614>

https://books.google.co.in/books/about/Seeds.html?id=-ZbZr1F_z74C&redir_esc

<https://books.google.co.in/books/about/Seeds.html?id=6S75BwAAQBAJ&printsec=front>

[cover&source=kp_read_button&redir_esc=y#v=onepage&q&f=false](https://books.google.co.in/books/about/Seeds.html?id=6S75BwAAQBAJ&printsec=frontcover&source=kp_read_button&redir_esc=y#v=onepage&q&f=false)

Suggested websites <https://agriinfo.in/botany/18/> <http://www.seedbiology.de/structure.asp>

<http://www.fao.org/3/ad232e/AD232E02.htm>

sbc.ucdavis.edu/Research_pages/Seed_physiology_and_technology/ <https://courses.lumenlearning.com/wm-biology2/chapter/development-seeds-fruit>

www.ari.res.in/index.php?option=com_content&view=article&id=449&Itemid=137

2(1+1)

Seed Dormancy and Germination

SST 502

Why this course?

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

Aim of the course

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

Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV – Physiological and biochemical changes

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

Unit V - Molecular and genetic mechanisms

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

Practical

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

Teaching methods

- Classroom lectures
- Power point presentations

- Student assignments
- Laboratory experiments
- Group exercises on biochemical estimations

Learning outcome

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

Resources:

- Heydecker, W. 1985. Seed Ecology. Pennsylvania State University Press, USA.
- Prakash, M. 2011. Seed Physiology of Crops. Satish Serial Publishing house. Azadpur. New Delhi.
- Maiti, R. K., Sarkar, N. C. and Singh, V. P. 2012. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur.
- Khan, A. A. 1977. The Physiology and Biochemistry of Seed Dormancy and Germination. North -Holland Publishing Company, USA.
- Bewley, J and Black, M. 1994. Physiology of Development and Germination. Springer, New York.
- Kozlowski. T. T. 2012. Seed Biology: Importance, Development and Germination. (Vol. I). Academic Press Inc., New York.
- Maiti, R.K., Sarkar, N.C. and Singh, V.P. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur, Rajasthan.
- Bewley, J.D., Bradford, K.J., Hilhorst, H.W.M. and Nanogaki, H. 2013. Seeds: Physiology of Development, Germination and Dormancy. Springer, New York.
- Roberts, E.H. 1972. Viability of seeds. Springerlink, New York, USA.
- David R. Murray. 1985. Seed Physiology. Volume 2: Germination and Reserve Mobilisation. Academic Press, London, UK.
- Mayer, A.M. and Mayber, A.P. 1963. Germination of Seeds. Pergamon Press, Oxford, New York.
- Benech-Arnold R. and Rodolfo, S., 2004. Handbook of Seed Physiology: Applications to agriculture. CRC Press., Florida, USA.
- Black, M. and Bewley, J.D. 2000. Seed Technology and its Biological Basis. CRC Press. Florida, USA.
- Bewley, J.D and Black, M. 1982. Physiology and Biochemistry of Seeds in Relation to Germination. Volume 2: Viability, Dormancy and Environmental Control. Springerlink, New York, USA
- Bradbeer, J.W. 1988. Seed Dormancy and Germination. Chapman and Hall, New York, USA.
- Baskin, C. and Baskin, J.M. (2014) Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination. Academic Press, Cambridge, UK.
- Suggested e-books <https://www.springer.com/in/book/9780792373223>
<https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1756-1051.2000.tb01610.x>
<https://www.elsevier.com/books/seeds/baskin/978-0-12-416677-6>
https://books.google.co.in/books/about/Physiology_and_Biochemistry_of_Seeds_in.html?id=91nsCAAQBAJ&printsec=frontcover&source=kp_read_button&redir_esc=y#v=onepage&q&f=false
https://books.google.co.in/books/about/The_Germination_of_Seeds.html?id=aV62AgAAQBAJ&printsec=frontcover&source=kp_read_button&redir_esc=y#v=onepage&q&f=false
https://books.google.co.in/books/about/Seed_Dormancy_and_Germination.html?id=18HeBwAAQBAJ&printsec=frontcover&source=kp_read_button&redir_esc=y#v=onepage&q&f=false
- Suggested websites <https://agriinfo.in/botany/18/> <https://sproutnet.com/seed-dormancy/>
<https://www.britannica.com/science/germination> <http://www.biologyreference.com/Re-Se/Seed-Germination-and-Dormancy.html> <https://www.intechopen.com/books/advances-in-seed-biology/seed-dormancy>

Why this course?

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

Aim of the course:

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

Theory**Unit I**

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

Practical

- Seed selection - quality of seed on field establishment
- Sowing and nursery management techniques
- Planting - age of seedling on crop establishment - rice and pearl millet
- Isolation distance and border rows in hybrid seed production field - space and barrier isolation; modifying isolation based on border rows in maize
- Planting design for hybrid seed production - rice, maize, pearl millet, cotton, red gram, sunflower
- Practicing breeding tools for hybrid seed production - detasseling - emasculation and dusting
- Study on methods of achieving synchronization - rice, bajra, sunflower
- Practicing supplementary pollination - rice and sunflower
- Study on foliar nutrition and influence on seed yield
- Practicing roguing operation - identification of off-types, pollen shedders, shedding tassels, partials, selfed bolls

- Pre and post harvest sanitation operations - cereals, millets and pulses
- Estimation of shattering and shattering loss; study on insitu germination and loss
- Visit to seed production fields
- Visit to seed industry
- Seed production planning and economics of seed production - varieties
- Seed production planning and economics of seed production - hybrids

Teaching methods

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

Learning outcome

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

Resources

- Singhal, N. C. 2003. Hybrid Seed Production in Field Crops. Kalyani Publications, New Delhi.
- Joshi, A. K. and Singh, B. D. 2004. Seed Science and Technology. Kalyani Publishers, NewDelhi.
- Kulkarni, G. N. 2011. Principles of Seed Technology. Kalyani Publishers, New Delhi. Singhal, N. C. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi. Sen, S.and Ghosh, N. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.
- Mondal, S.S., Saha, M. and Sengupta, K. 2009. Seed Production of Field Crops. New IndiaPublishing Agency, New Delhi.
- Hebblethwaite, P. D. 1980. Seed Production. Butterworth Heinemann Ltd., London, UK. Agrawal, R.L. 2019. Seed Technology. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.
- McDonald, M.B. and Copeland, L. 1998. Seed Production Principles and Practices. CBS Publishers, New Delhi.
- Maiti, R.K., Sarkar, N.C. and Singh, V.P. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur, Rajasthan.
- Suggested e-books <https://www.springer.com/in/book/9780792373223>
<https://www.springer.com/in/book/9780412075513>
<https://www.nipabooks.com/info/9788190723763/seed-production-of-field-crops> <https://www.amazon.in/Production-Field-Crops-Brajesh-Tiwari/dp/9380179405>
[https://www.cambridge.org/core/journals/journal-of-agricultural-science/article/seedproduction-of-agricultural-crops-by-kelly-a-f-227-pages-harlow-longman-1988-price-2500-hard-covers-isbn-0-582-40410-x/8BE3C99DFDC0F02D48E CB53418504D10](https://www.cambridge.org/core/journals/journal-of-agricultural-science/article/seedproduction-of-agricultural-crops-by-kelly-a-f-227-pages-harlow-longman-1988-price-2500-hard-covers-isbn-0-582-40410-x/8BE3C99DFDC0F02D48E%20CB53418504D10)
- Suggested websites <https://agriinfo.in/botany/18/http://www.fao.org/3/a-e8935e.pdf>
http://www.agriquest.info/seed_production.php
http://agritech.tnau.ac.in/seed_certification/seedtech_index.html
[http://coin.fao.org/coinstatic/cms/media/16/13666518481740/seed_enterprises_enhancement_and_development_project_in_sierra_leone_mission_1_report .pdf](http://coin.fao.org/coinstatic/cms/media/16/13666518481740/seed_enterprises_enhancement_and_development_project_in_sierra_leone_mission_1_report.pdf)

SST 504

Seed Production Principles and Techniques in Vegetable Crops

3(2+1)

Why this course?

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

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

Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

Practical

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

Teaching methods

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

Learning outcome

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

Resources

Kulkarni, G. N. 2011. Principles of Seed Technology. Kalyani Publishers, New Delhi. Singhal, N. C. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi. Sen, S. and Ghosh, N. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.

Vanangamudi, K., Natarajan, N., Srimathi, P., Natarajan, K., Saravanan, T., Bhaskaran, M., Bharathi, A., Natesan, P. and Malarkodi, K. 2006. Advances in Seed Science and Technology. Vol. 2. Quality Seed Production in Vegetables. Agro bios, Jodhpur.

Hebblethwaite, P. D. 1980. Seed Production. Butterworth Heinemann Ltd, London, UK. George, R.A.T. 1985. Vegetable Seed Production. Lohman Inc., New York.

Agarwal, R.L. 2012. Seed Technology. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.

McDonald, M.B. and Copeland, L. 1998. Seed Production Principles and Practices. CBS Publishers, New Delhi.

Maiti, R.K., Sarkar, N.C. and Singh, V.P. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios, Jodhpur, Rajasthan.

Chadha, K.L. 1995. Advances in Horticulture. Volume 1 to 13. Malhotra Publishing House, New Delhi.

Suggested e-books <https://www.springer.com/in/book/9780792373223> <http://203.64.245.61/fulltext-pdf/EB/1900-2000/eb0021.pdf> <http://www.worldseed.org/wp-content/uploads/2017/01/Seed-Production-Good-practice-10.01.17-final.pdf> [https://trove.nla.gov.au/work/6862691?q&sort=holdings+desc&=1541066209 257&versionId=45008917+251246346](https://trove.nla.gov.au/work/6862691?q&sort=holdings+desc&=1541066209%20257&versionId=45008917+251246346)

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

SST 507

Seed Legislation and Certification

3(2+1)

Why this course?

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

Aim of the course

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

Theory

Unit I

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

Unit II

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

Unit III

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

Europe, Canada, Australia and USA.

Unit IV

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

Unit V

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

Practical

- Preparation of sowing report - varieties - transplanted and direct sown crops and hybrids
- Verification of sowing report - seed certification procedures
- Field inspection - estimation of area and isolation distance, stages of inspection for varieties and hybrids - procedures
- Practicing field counting procedures - methods for row planting, broadcasted - varieties
- Practicing field counting procedures - direct sown and transplanted crops - varieties
- Study on field counting procedures - hybrids - planting design, planting ratio and block method and double count
- Identification of contaminants - genetic and physical contaminants, procedure to remove partials, pollen shedders and shedding tassels
- Assessing and calculation of field standards for important crops
- LFR, partial rejection and downgrading - reasons, procedures and preparation of reports
- Yield estimation - single and multiple harvest crops
- Post harvest inspection - groundnut, cotton, pulses
- Inspection and maintenance (licence and renewal) of records in processing unit - float test, preparation of processing report and seed lot number construction
- Visit to seed certification agency / department
- Visit to grow-out test field
- Visit to seed retail shop - procedures followed by Seed Inspector, verification of records and reporting
- Procedure to issue tag, specification, bagging, tagging, labelling and sealing

Teaching methods

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

Learning outcome

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

Resources

Tunwar, N. S and Singh, S. V. 2003. Indian Minimum Seed Certification Standards. Central Seed Certification Board, Ministry of Agriculture, GOI, New Delhi.

Anon, 2016. Manual of Seed Certification Procedures. Directorate of Seed Certification, Coimbatore, Tamil Nadu.

Ramamoorthy, K., Sivasubramaniam, K. and Kannan, M. 2006. Seed Legislation in India. Agrobios, Jodhpur, Rajasthan.

Mishra, D. K., Khare, D., Bhale, M. S. and Koutu, G. K. 2011. Handbook of Seed Certification. Agrobios, Jodhpur, Rajasthan.

Chakrabarathi, S. K. 2010. Seed Production and Quality control. Kalyani Publishers, New Delhi.

Renugadevi, J, Srimathi, P., Renganayaki, P. R. and Manonmani, V. 2012. A Handbook of Seed Testing. Agrobios, Jodhpur, Rajasthan.

Trivedi, P.C. 2011. Seed Technology and Quality Control. Pointer Publications, Jaipur, Rajasthan.

Neema, N.P. 1986. Principles of Seed Certification and Testing. Allied Publishers, New Delhi

Sharma, P. 2008. Seed Legislation. Gene-tech Book Publishers, New Delhi.

Agarwal, R.L. 2012. Seed Technology. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.

Suggested e-books <http://cms.tn.gov.in/sites/default/files/documents/seed-certification-0.pdf>
<http://odishaseedsportal.nic.in/SeedPortalData/Resource%20Material/INDIANMINIMUM-SEED-CERTIFICATION-STANDARDS.pdf> <https://www.india.gov.in/my-government/documents/e-books>
[https://books.google.co.in/books/about/Principles of Seed Certification and Tes.html?id=SQWHAAAACAAJ&redir_esc=y](https://books.google.co.in/books/about/Principles_of_Seed_Certification_and_Tes.html?id=SQWHAAAACAAJ&redir_esc=y)
https://dl.sciencesocieties.org/publications/books/tocs/cssaspecialpubl/theroleofseedc_e

Suggested websites

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

SST 508

Post Harvest Handling and Storage of Seeds

3(2+1)

Why this course?

Healthy seeds are the demanding enterprise of the recent era for the production of high yield in the next season. The seeds must be well processed and stored for the maintenance of high- yielding crop. During storage, major losses of seeds are caused by various biotic and abiotic factors.

There is a need apply proper post harvest handling and storage techniques, which ultimately improve the market value and quality of the seed.

Aim of this course

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

Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

Seed storage - purpose and importance - factors affecting storage, optimum condition for storage of different seeds; storage principles - Harrington's thumb rule - concepts and significance of moisture equilibrium - maintenance of safe seed moisture - physical, physiological, biochemical and molecular

changes during seed storage - storage behaviour of orthodox and recalcitrant seeds - prediction of viability - viability nomograph.

Unit V

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

Practical

- Seed extraction - wet and dry methods
- Seed processing sequence for different crops
- Design of processing plant - equipments - estimation of processing efficiency
- Seed drying methods - principle and methods
- Practicing seed grading - upgrading techniques
- Delinting methods - assessment of mechanical damage
- Visit to seed processing unit
- Seed packaging - effect of packaging materials on seed longevity
- Prediction of viability during storage - viability nomograph and accelerated ageing test
- Assessing physical changes during seed storage
- Assessing physiological changes during seed storage
- Assessing biochemical changes during seed storage
- Storage behaviour of recalcitrant seeds
- Pre-storage seed treatments - protectants - antioxidants - halogens
- Practicing seed blending methods
- Seed storage godown - sanitation, fumigation - visit to seed storage godown and cold storage unit

Teaching methods

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

Learning outcome

The students will understand the principles and mechanism involved in seed processing, storage techniques and management practices to arrest the seed deterioration.

Students will also acquire skill on seed handling and storage methods on commercial basis.

Resources

Gupta, D. 2009. Seeds: their conservation principles and practices. Sathish serial publishinghouse. New Delhi.

Singhal, N. C. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.

Sen, S. and Ghosh, N. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi. Kulkarni, G. N. 2011. Principles of Seed Technology. Kalyani Publishers, New Delhi.

Justice, O. L. and Bass, L. N. 1978. Principles and Practices of Seed Storage. Agriculture HandBook No. 506, Castle House Publication Ltd., Washington.

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

Barton, L.V. 1961. Seed Preservation and Longevity, (Vol. 1). Leonard Hill, London.

Maiti, R.K., Sarkar, N.C. and Singh, V.P. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios,

Jodhpur, Rajasthan.

Gregg, B.R, Law, A.G, Viridi, S.S and Balis, J.S. 1970. Seed Processing. Avion printers, NewDelhi.

Suggested e-books http://dfsc.dk/pdf/Handbook/chapter8_internet.pdf

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

<https://www.springer.com/in/book/9780792373223> <http://203.64.245.61/fulltext-pdf/EB/1900-2000/eb0021.pdf>

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

<https://trove.nla.gov.au/work/6862691?q&sort=holdings+desc&=1541066209257&versi>

[onId=45008917+251246346 http://www.worldseed.org/wp-content/uploads/2017/01/Seed-Production-Good-practice-10.01.17-final.pdf](http://www.worldseed.org/wp-content/uploads/2017/01/Seed-Production-Good-practice-10.01.17-final.pdf)

Suggested websites <http://www.fao.org/3/a-ah803e.pdf>

agritech.tnau.ac.in/seed_certification/seedtech_index.html

<http://ecoursesonline.iasri.res.in/mod/page/view.php?id=17806>

<http://www.bcseeds.org/wp-content/uploads/2015/01/Seed-Processing-2015update.pdf>

https://www.carolinafarmstewards.org/wpcontent/uploads/2012/05/SeedProcessingandStorageVer_1pt3.pdf

SST 509

Seed Quality Testing and Enhancement

2(1+1)

Why this course?

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

Aim of the course

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

Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

Seed quality enhancement techniques - history and development; classification - physical, physiological and protective seed treatments - special seed treatments; physical seed treatment -

liquid floatation, specific gravity separation, irradiation, electric and electromagnetic seed treatments - principles and methods - seed pelleting and coating principles, purpose and methods.

Unit V

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

Practical

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

Teaching methods

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

Learning outcome

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

Resources

Chakrabarthy, S.K. 2010. Seed Production and Quality Control. Kalyani Publishers. New Delhi. Renugadevi, J., Srimathi, P., Renganayaki, P. R., and Manonmani, V. 2012. A Hand book of Seed Testing. Agrobios. Jodhpur, Rajasthan.

Tridevi, P.C. 2011. Seed Technology and Quality Control. Pointer Publication. Jaipur, Rajasthan.

Agrawal, P.K. 1993. Hand book of Seed Testing. Ministry of Agriculture, GOI, New Delhi. Agrawal, R.L. 1997. Seed Technology. Oxford & IBH.

Agrawal, P.K. and Dadlani, M. 1992. Techniques in Seed Science and Technology. 2nd Ed. South Asian Publications.

ISTA. 1999. Seed Science and Technology, 27th supplement.

Chalam, G.V. Singh, A and Douglas, J.E. 1967. Seed Testing Manual. ICAR & United States Agency for International Development, New Delhi.

Vasudevan, S.N., Doddagowder, S.R., Rakesh C.M. and Patil, S.B. 2013. Seed Testing and Quality Control. Agrotech Publications, Udaipur, Rajasthan.

International Seed Testing Association. 2018. Handbook on Seedling Evaluation, 4th Edition, Published by ISTA, Zurichstr, Switzerland.

International Seed Testing Association. 2019. International Rules for Seed Testing 2019. Published by ISTA, Zurichstr, Switzerland.

Copeland, L. O. and McDonald, M. B. 2001. Principles of Seed Science and Technology. 4th Ed. Kluwer Academic publishers, USA.

Suggested e-books

http://odishaseedsportal.nic.in/SeedPortalData/Resource%20Material/INDIAN_MINIMUM_SEED_CERTIFICATION_STANDARDS.pdf.

www.kopykitab.com/Seed-Testing-and-Quality-Control-by-Vasudevan-SN <https://www.istor.org/stable/10.14321/j.ctt7zt51m>

https://link.springer.com/chapter/10.1007/978-1-4615-1619-4_13

https://www.researchgate.net/publication/269694458_QUALITY_SEED_PRODUCTION_ITS_TESTING_AND_CERTIFICATION_STANDARD

<https://www.seedtest.org/upload/cms/user/ISTAMethodValidationforSeedTestingV1.01.pdf> <https://www.intechopen.com/books/new-challenges-in-seed-biology-basic-andtranslational-research-driving-seed-technology/recent-advances-in-seed-enhancements>

<https://www.intechopen.com/books/new-challenges-in-seed-biology-basic-andtranslational-research-driving-seed-technology/recent-advances-in-seed-enhancements>

Suggested websites

http://agritech.tnau.ac.in/seed/Seed_seedtesting.html

<https://core.ac.uk/download/pdf/85210907.pdf>

<https://www.betterseed.org/resources/seed-testing-accreditation-schemes/>

http://sbc.ucdavis.edu/About_US/Seed_Biotechnologies/Seed_Enhancement/ <https://www.seedtest.org/en/international-rules-for-seed-testing-content-1-1083.html>

SST 511

Seed Industry and Marketing Management

2(1+1)

Why this course?

India has a vibrant seed market. Over the years, the seed industry has evolved side by side with Indian agriculture. Indian seed industry is the fifth largest seed market in the world. This course will provide insights in seed industry development and better management of seed industry and seed marketing.

Aim of the course

To empower the students to become seed entrepreneurs by imparting knowledge on seed industry management and marketing strategies.

Theory

Unit I

Introduction to seed industry - genesis, growth and structure of seed industry - mission and objectives - present status of Indian and global seed industry - role of seed industry in Indian agriculture; government initiatives - seed hubs, seed villages and community seed production system.

Unit II

Seed industry - organization set up and functions - public, private, MNC's, seed corporations; structure of small, medium and large seed industries, components of seed industry - public private partnership - custom seed production - risk management - human resource - infrastructure - processing unit - storage go down.

Unit III

Seed production and distribution systems in state and central government; seed supply chains systems - seed production and distribution - planning, organization and coordination, staffing, assembling of resources; cost of seed production - overhead charges.

Unit IV

Seed marketing - definition - importance - role of marketing; type of markets - domestic and global market - problems and perspectives; marketing policies - seed marketing schemes - marketing channels, responsibilities of dealers - marketing mix.

Unit V

Seed demand forecasting - purpose - methods and techniques; indenting and seed dispatch procedures and forms - seed store records - maintenance - missing link in seed supply chain; market intelligence - SWOT analysis; seed cost analysis; seed pricing - policy - components of seed pricing

factors - local market rate (LMR) - fixation of procurement and sale price of seed.

Practical

- Data collection on status of Indian and global seed industry
- Assessing the factors influencing farmers preference and assessment of seed demand and supply
- Planning for establishment of small, medium and large seed industry
- Planning for establishment of seed production and processing unit
- Economics of seed production - varieties and hybrids
- Seed pricings and cost analysis
- Exercise on fixing seed procurement and sale price
- Study of marketing channels - domestic and international
- Maintenance of carryover seeds - Assessing risk factors in seed industry and their management
- Survey and interaction with seed dealers and distributors
- Visit to state seed corporations
- Visit to MNCs and expert discussion
- Case studies and SWOT analysis
- Visit to modern seed processing unit and advanced seed storage complex
- Custom seed production, contract farming and procurement - procedures
- Planning and preparation of project proposal for setup of a seed industry Final practical examination

Teaching methods

- Classroom lectures
- Survey
- Student assignment and presentation
- Economic analysis
- Group discussion
- Swot analysis
- Seed industry visit and interaction sessions.

Learning outcome

On completion of this course students will gain knowledge and confidence to manage seed industry and able to address the problems in seed industry and seed marketing.

Resources

Surdev Singh and Asokan, S.R. 1991. Seed Industry in India: A Management Perspective Oxford & IBH Publishing Co Pvt. Ltd., New Delhi.

Dadheech, P.K. 1996. Seed Programming, Management System and Concepts. Lok Sahitna Kendra, Jodhpur.

Acharya, S.S. and Agarwal, N. L. 2004. Agricultural Marketing in India. 4th Ed. Oxford and IBH.

Broadway, A. C and Broadway, A. 2003. A Text Book of Agri-business Management. Singh, S. 2004. Rural Marketing - Focus on agricultural Inputs. Vikas Publishing House. Kalyani Singh, A. K. and Pandey, S. 2005. Rural Marketing. New Age Publications.

Kugbei, S. 2008. Seed Economics. Scientific Publishers, Jodhpur, Rajasthan. Sharma, P. 2008. Marketing of Seeds, Green-Tech Book Publishers, New Delhi.

Suggested e-books

<https://link.springer.com/chapter/10.1007/978-1-4615-1783-2-15> <http://www.fao.org/3/V4450E/V4450E00.htm>

<https://books.google.co.in/books?id=vPVIbos4WkYC>

<http://download.nos.org/srsec319new/319EL19.pdf> <https://isengewant.de/Marketing-of-Seeds-By-Premjit-Sharma.pdf>

[https://www.kopykitab.com/A-Handbook-of-Seed-Processing-and-Marketing-by-Gaur-SC XII.](https://www.kopykitab.com/A-Handbook-of-Seed-Processing-and-Marketing-by-Gaur-SC-XII)

Suggested websites

www.gov.mb.ca www.agricoop.nic.in www.agri.nic.in <https://sathguru.com/seed/>

<http://www.fao.org/3/V4450E/V4450E03.htm> <https://www.seednet.gov.in/smis/SMIS-User%20Manual.pdf> <https://www.icrisat.org/seed-systems-models-lessons-learned/> <https://www.bookdepository.com/Seed-Industry-India-Gurdev-Singh/>

Department of Seed Science & Technology

Ph.D. in Seed Science & Technology

Major Courses

Sl. No.	Course Code	Course Title	Credits	Semester
1.	SST 601	Hybrid Seed Production Technology	3(2+1)	I
2.	SST 602	Organic Seed Production	2(1+1)	II
3.	SST 604	Genetic Purity and DUS Testing	3(2+1)	I
4.	SST 606	Advances in Seed Science	2(2+0)	III
5.	SST 610	Seed Planning, Trade and Marketing	2(1+1)	III
		Sub Total	12(8+4)	

Minor Courses

Sl. No.	Course Code	Course Title	Credits	Semester
1.	GPB-601	Advances in Plant Breeding Systems	3(3+0)	I
2.	PP-607	Physiological and Molecular aspects of source-sink capacity for enhancing yield	3(3+0)	II
		Sub Total	06(6+0)	

Supporting Courses

Sl. No.	Course Code	Course Title	Credits	Semester
1.	STAT-612	Advanced Design for Experiment	3(2+1)	II
Anyone of the following as per needs of the students' thesis				
1.	SOIL-603	Physical Chemistry of Soil	2(2+0)	II
2.	AGRON-608	Research and Publication Ethics	2(2+0)	II
3.	ENT-610	Integrated Pest Management	2(2+0)	III
4.	BIOCHEM-603	Biochemistry of Biotic and Abiotic Stresses	3(3+0)	III
5.	PPY-606	Global Climate Change and Crop Science	2(2+0)	II
6.	GPB-606	Population Genetics	3(3+0)	II
7.	VSC-514	Biotechnological approaches in vegetable crops	3(2+1)	III
		Sub Total	6(4+2)/ 5(4+1)	
1.	SST-691	Seminar I	1(0+1)	II
2.	SST- 692	Seminar II	1(0+1)	IV
3.	SST- 699	Thesis/Research	75(0+75)	
		Sub Total	100	

SST 601

Hybrid Seed Production Technology

3(2+1)

Why this course?

Indian seed industry is dominated by hybrid seeds. Hybrid seed production requires scientific specialized skills and knowledge. Hence, it is necessary to impart knowledge to the students on hybrid seed production techniques and scientific principles involved in hybrid seed production of various crops.

Aim of the course

To provide students a comprehensive knowledge and practical exposure on hybrid seed production techniques in agricultural and horticultural crops.

Theory

Unit I

Introduction - history - scope - importance of hybrid development - national and international scenario of seed industry - popular public sector hybrids in various crops. Heterosis-definition - expression - types - utilization of heterosis in hybrid development, hybrid vigour and seed vigour.

Unit II

Types of hybrids - intra-specific, inter-specific hybrids, single, double, three way cross, top cross hybrids - apomixes; generation system of seed multiplication in different types of hybrids. Development and maintenance of inbred lines - male sterile - maintainer lines - fertility restoration - transgenic hybrids - principles and method of development.

Unit III

Breeding tools - genetic mechanism - male sterility - types : CMS, GMS, CGMS, TGMS, PGMS - barnase and barstar system - pistillateness - self incompatibility. Manual creation of male sterility - emasculation and pollination - gametocides - mode of action, mechanism. Synchronization of flowering - problems - methods to achieve synchrony - planting ratio and supplementary pollination methods.

Unit IV

Techniques of hybrid seed production in major agricultural crops - cereals (wheat, rice), millets (maize, sorghum, bajra), pulses (red gram), oilseeds (sunflower, castor, mustard), cotton and forage crops.

Unit V

Hybrid seed production techniques in horticultural crops - tomato, brinjal, chilli, bhendi, onion, bitter gourd, bottle gourd, ridge gourd, cucumber, melon, cabbage, cauliflower, potato, coconut and papaya.

Practical

- Characteristics features of parental lines and their hybrids
- Floral biology of rice, maize, pearl millet, sunflower, castor and cotton
- Study on floral biology of vegetable crops - solanaceous and other vegetables
- Study on floral biology of cucurbitaceous crops
- Production and maintenance of A, B and R lines
- Practicing planting design and border rows - rice, maize, pearl millet, sunflower and red gram; brinjal and chillies
- Practicing planting design and border rows in tomato, cotton and cucurbitaceous vegetables
- Manipulation for synchronization - rice, sunflower, pearl millet and sorghum
- Practicing supplementary pollination - rice and sunflower
- Practicing field inspection in hybrid seed production plot - crops planted in ratio - sunflower, pearl millet, sorghum etc.,
- Practicing field inspection in hybrid seed production field - red gram, castor, cotton, cucurbits and tomato.
- Practicing roguing and identification of off-types - pollen shedders - shedding tassel - selfed fruits.
- Visit to hybrid seed production fields
- Visit to potato seed production plots
- Determination of cost benefit of hybrid seed production
- Visit to seed Industry and assessing problems and perspectives in hybrid seed production

Teaching methods

- Classroom lectures
- Power point presentation
- Student assignment and presentation
- Demonstration
- Field visits

Learning outcome

By learning this course, students will acquire a comprehensive knowledge and practical skills on hybrid seed production techniques both in agricultural and horticultural crops.

Resources

- McDonald, M. F. and Copeland, L. O. 2012. Seed Production: Principles and Practices. Springer Science & Business Media, Boston, United States.
- Basra, A. 1999. Heterosis and Hybrid Seed Production in Agronomic Crops. CRC Press., Florida, United States.
- Singhal, N. C. 2003. Hybrid Seed Production. Kalyani Publishers., New Delhi, India.
- Vanangamudi, K., Prabhu, M., Kalaivani, S., Bhaskaran, M and Manonmani, V. 2010. Vegetable Hybrid seed Production and Management. Agrobios., Jodhpur, India.
- Krishnan, M. 2012. Plant breeding and Hybrid Seed Production. Domin and Publishers & Distributors., New Delhi, India.
- Maiti, R. K., Sarkar, N.C. and Singh, V.P. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios., Jodhpur, India.
- Singhal, N. C. 2003. Hybrid Seed Production in Field Crops. Kalyani Publications, New Delhi.
- Frankel, R and Galun, E. 1977. Pollination Mechanisms, Reproduction and Plant Breeding. Springer Verlag, New York.
- Chhabra, A. K. 2006. Practical Manual of Floral Biology of Crop Plants. Department of Plant Breeding, CCSHAU, Hisar.
- Agarwal, R. L. 2012. Seed Technology. 3rd Ed. Oxford & IBH Publishers, New Delhi.
- Dar, S. H. 2018. Methods of Hybrid Seed Production in Major Crops. Educreation Publishing, Chhattisgarh.
- Joshi, A. K. and Singh, B. D. 2004. Seed Science and Technology. Kalyani Publishers, New Delhi.
- Kulkarni, G. N. 2011. Principles of Seed Technology. Kalyani Publishers, New Delhi.
- Singhal, N. C. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.
- Sen, S. and Ghosh, N. 2010. Seed Science and Technology. Kalyani Publishers, New Delhi.
- Mondal, S.S., Saha, M. and Sengupta, K. 2009. Seed Production of Field Crops. New India Publishing Agency, New Delhi.
- Hebblethwaite, P. D. 1980. Seed Production. Butterworth Heinemann Ltd., London, UK.
- Suggested e-books <https://www.springer.com/in/book/9780792373223>
<https://www.springer.com/in/book/9780412075513> <https://www.nipabooks.com/info/9788190723763/seed-production-of-field-crops> <https://www.kopykitab.com/Vegetable-Hybrid-Seed-Production-And-Management>
https://www.researchgate.net/publication/229432295_Hybrid_Seed_Production_and_Flow ers
<http://www.worldcat.org/title/seed-production-principles-and-ractices/oclc>
<https://libgen.is/search.php?req=Raymond+A++T+George&column=author>
[https://libgen.is/search.php?req=Raymond%20A%20T%20Georg e&column\[\]=author](https://libgen.is/search.php?req=Raymond%20A%20T%20Georg e&column[]=author)
https://www.researchgate.net/profile/Gulzar_S_Sanghera/publication/236865752_Advances_in_Hybrid_Rice_Technology_through_Applications_of_Novel_Technologies/links/0deec519b46087d815000000.pdf
- Suggested websites www.agriquest.info www.agriinfo.in www.seedquest.com
<https://agriinfo.in/botany/18/> <http://www.fao.org/3/a-e8935e.pdf> http://www.agriquest.info/seed_production.php
http://agritech.tnau.ac.in/seed_certification/seedtech_index.html

SST 602

Organic Seed Production

2(1+1)

Why this course?

After ascertaining the food security, the present day agriculture is moving towards quality farm produces, hence organic agriculture is getting momentum. The growing demand for organically produced farm produces among the consumers warrants more area under organic agriculture. Hence, organic agriculture needs the seeds which are produced organically and there is great scope for organic seed production.

Aim of the course

To make students to understand the concept of organic farming, principles and practices of organic seed production, certification and marketing.

Theory

Unit I

Organic farming - definition, genesis, concepts and principles; importance of organic farming and organic seed; organic seed - strategies, problems and perspectives - organic seed vs conventional seed; organic seed production - factors influencing seed production - soil health - GMO elements of seed.

Unit II

Techniques of organic seed production - selection of land - pre requisite for seed production - conversion period - soil amendments - green manures; multi-varietal seed techniques - organic sources of manures - bulky, concentrated and liquid manures, biofertilizers and biocontrol agents - organic seed treatment.

Unit III

Organic weed management practices - manual and mechanical methods - mulching - thermal weed control; growth promoting substances - panchakavya, fish amino acid etc.; organic plant protection measures - herbal insecticides - IPM strategies; post harvest techniques - drying, processing and grading; organic seed treatment and storage.

Unit IV

Organic certification application - registration - verification of records; organic seed certification - tagging; role of organizations in production and marketing of organic seed - national and international organizations involved - public, private - NGOs - International Federation of Organic Agriculture Movement (IFOAM) - basic standards and EU regulations - organic seed marketing.

Unit V

Crop specific organic seed production and post harvest seed management techniques for major food crops, vegetables and fruit crops - economics of organic seed production and demand for organic seed.

Practical

- Studying the field and seed standards for organic seed production
- Collection and identification of organic manures and liquids
- Preparation of organic products for soil application
- Preparation of panchakavya, starter solutions and vermiwash
- Organic priming of seeds with panchakavya and vermiwash
- Preparation of leaf extracts and starter solutions and preparation of organic products for foliar application
- Studying the effect of organic nutrients and foliar sprays on seed quality
- Preparation of organic products for seed treatment and studying the effect on seed quality
- Assessing the storage behaviour of organically treated seeds
- Selection of suitable container and dry leaves or shrubs for enhanced storability
- Organic treatment for management of seed health
- Production and assessment of bio control agents for effective pest control
- Economics of organic seed production and assessing demand
- Visit to organic farm and seed production field
- Visit to Department of organic certification
- Visit to organic retail shops

Teaching methods

- Classroom lectures
- Group assignments and presentation
- Laboratory and field experiments
- Demonstration
- Field visits

Learning outcome:

After completion of this course, students will gain knowledge, skill and confidence to take up organic seed production for sustainable agriculture.

Resources

White, J. M. 1995. Organic Vegetable Production. UF/IFAS Coop. Ext. Serv., HS720., Florida, United States.

Panda, S. C. 2012. Soil Management and Organic farming, Agrobios., Jodhpur, India.

Gehlot, D. 2010. Organic Farming: Components and Management. Agrobios., Jodhpur, India. Panda, S. C. 2013. Principles and Practices of organic Farming. Agrobios., Jodhpur, India.

Gehlot, D. 2012. Organic Farming: Standards, Accreditation, certification and Inspection. Agrobios., Jodhpur, India.

Suresh, N and Deshmukh. 2010. Organic Farming: Principles, Prospects and Problems. Agrobios., Jodhpur, India.

Bryan Connolly, B., Langer, J. and Lawn, C.R. 2011. Organic Seed Production and Saving: The Wisdom of Plant Heritage. Chelsea Green Publishing, Vermont, USA.

Suggested e books

<https://ufdcimages.uflib.ufl.edu/IR/00/00/33/80/00001/HS22700.pdf> <https://www.ifoam.bio/en/organic-landmarks/principles-organic-agriculture> www.apeda.gov.in/apedaweb/organic/organic.../english_organic

[_sept05.pdf](http://www.apeda.gov.in/apedaweb/organic/organic.../english_organic_sept05.pdf) https://ncof.dacnet.nic.in/Training/Training...in/Cert_and_Inspectio_n_manual.pdf

<https://www.ebooks.com/en-us/96381019/organic-seed-production-and-saving/bryanconnolly-jocelyn-langer-c-r-lawn/>

Suggested website

www.tnocd.net <https://www.sare.org/> <https://www.ifoam.bio/> <http://www.ncof.dacnet.nic.in>

<http://edis.ifas.ufl.edu/CV118>

www.harrismoran.com/technology/default.htm <https://attra.ncat.org/attra-pub-summaries/?pub=70>

<http://www.harrismoran.com/technology/default.htm> https://www.academia.edu/4601825/Organic_seed_production

http://www.cals.ncsu.edu/sustainable/peet/IPM/diseases/org_cert.html <https://www.sare.org/Learning-Center/Topic-Rooms/Organic-Production/Organic-Seeds>

SST 604

Genetic Purity and DUS Testing

3(2+1)

Why this course?

Genetic purity of seeds is one of the most important basic quality characters as per Seeds Act 1966. Loss of genetic purity leads to varietal deterioration leads to elimination of variety from seed supply chain. After establishment of PPV & FRA, varietal purity is assessed by using established DUS characters and guidelines. Human resource on methods of genetic purity assessment and DUS characters is much essential to prevent variety deterioration as well as for protection of plant varieties.

Aim of the course

To impart knowledge on various methods of genetic purity assessment and DUS testing for protection of plant varieties.

Theory

Unit I

Genetic purity - importance - factors influencing genetic purity; genetic / cultivar purity test objectives - principles - methods; laboratory tests - green house and field plot methods, grow - out test, seed and seedling growth tests; chemical and biochemical methods; anthocyanin pigmentation, secondary compounds, phenol, peroxidase and fluorescence tests - chromatography techniques.

Unit II

Electrophoretic analysis of proteins and isozymes; DNA finger printing methods - RAPD, AFLP, SSR, SNP and other markers; computer based machine vision technique and image analysis for varietal identification.

Unit III

Genesis of plant variety protection (PVP); International Union for Protection of New Varieties of Plants (UPOV) and its functions - GATT agreement in relation to plant variety protection; Protection of Plant Varieties and Farmer's Rights (PPV& FR) Act 2001 - objectives, salient features, farmer's rights, breeder's rights, researcher's rights - PPV& FRA Rules 2003.

Unit IV

Criteria for protection of new varieties of plants; Distinctness, Uniformity and Stability (DUS) testing - principles and procedures, guidelines, sample size, test duration, testing option; varieties of common knowledge - extant variety - essentially derived variety - collection of reference samples - grouping of varieties - example varieties; types and categories of characters - recording observations on characteristics - colour characteristics.

Unit V

Assessment of DUS characters of major crops based on morphological, biochemical and molecular markers - rice, maize, wheat, barley, black gram, green gram, red gram, cowpea, rajma, sunflower, groundnut, castor, mustard, tomato, brinjal, onion, potato, chilli, bhendi, cucurbits, cole crops, sugarcane, cotton, flower, fruit and tree species; statistical procedure - computer software for DUS testing; guidelines for registration of germplasm - impact of plant variety protection on seed industry growth.

Practical

- Genetic purity assessment based on seed characters
- Genetic purity assessment based on seedling growth tests, anthocyanin pigmentation
- Genetic purity assessment based on secondary compounds, phenol, peroxidase and fluorescence tests
- Chromatography analysis of secondary compounds Electrophoretic analysis of seedprotein and isozymes
- DNA fingerprinting using PCR techniques.
- DUS testing based on morphological descriptors of plant - rice and millets
- DUS testing based on morphological descriptors of plant - pulses and oil seeds
- DUS testing based on morphological descriptors of plant - vegetable crops
- DUS testing based on morphological descriptors of plant - flower, fruit and tree species
- Recording observations and interpretation of data
- Tree method of classification of varieties / cultivars
- Chemical and biochemical test applicable for DUS testing.
- Practical exercise on recording DUS characteristics, statistical analysis and interpretation in major agricultural crops
- Practical exercise on recording DUS characteristics, statistical analysis and interpretation in major horticultural crops
- Visit to DUS test centers

Teaching methods

- Classroom lectures
- Power point presentations
- Field and laboratory experiments

- Demonstration
- Field visits

Learning outcome

After completion of this course, the students will gain knowledge on the methods of assessing genetic purity and able to distinguish varieties based on DUS characters.

Resources

Joshi, A. K. and Singh, B. D. 2004. Seed Science and Technology, Kalyani Publishers, New Delhi, India.
 Choudhary, D. R. 2009. Guidelines for Storage and Maintenance of Registered Plant Varieties in the National Gene Bank. Published by Protection of Plant Varieties and Farmer's Rights Authority. Ministry of Agriculture, GOI, New Delhi, India.
 ISTA. 2010. Handbook of Variety Testing. International Seed Testing Association, Switzerland.
 Maiti, R. K., Sarkar, N. C. and Singh, V. P. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios., Jodhpur, India.
 Anon, 2016. Manual of Seed Certification Procedures. Directorate of Seed Certification, Coimbatore, Tamil Nadu.
 Ramamoorthy, K., Sivasubramaniam, K. and Kannan, M. 2006. Seed Legislation in India. Agrobios, Jodhpur, Rajasthan.
 Mishra, D. K., Khare, D., Bhale, M. S. and Koutu, G. K. 2011. Handbook of Seed Certification. Agrobios, Jodhpur, Rajasthan.
 Chakrabarthi, S. K. 2010. Seed Production and Quality Control. Kalyani Publishers, New Delhi. Trivedi, P. C. 2011. Seed Technology and Quality Control. Publications, Jaipur, Rajasthan.

Suggested e-books

<https://books.google.co.in/books?isbn=16118603932>. <https://books.google.co.in/books?isbn=81894220303>.
<https://books.google.co.in/books?id=2FbwZwEACAAJ> <https://books.google.co.in/books?id=J5bQtgAACAAJ>
<https://books.google.co.in/books?isbn=0851997392> <https://www.upov.int/edocs/tgdocs/en/tg023.pdf>

Suggested websites

www.seedquest.com www.ucanr.edu
www.sasa.gov.uk www.ppvfra.org
https://www.upov.int/test_guidelines/en/ <http://plantauthority.gov.in/crop-guidelines.htm> https://www.upov.int/resource/en/dus_guidance.html
https://www.upov.int/edocs/tgdocs/en/tgp_6_section_2.pdf
https://www.upov.int/publications/en/tg_rom/introduction.html

SST 606

Advances in Seed Science

2(2+0)

Why this course?

Seed science is the study of seeds from its development to storage. The seed science is interdisciplinary and is closely connected with botany, physiology, biochemistry and genetics. Exposing students to advanced and recent developments in seed science and technology will enable them to take up interdisciplinary advance research.

Aim of the course

To impart knowledge on the recent developments in various frontier areas of seed science and their application in seed technology.

Theory

Unit I

Physiological and molecular aspects of seed development - gene expression during seed development - selective elimination of cells - theories and concepts; physiological and molecular regulation of germination and dormancy; desiccation and stress tolerance - gene expression - mechanism - structural changes in membranes of developing seeds; prediction of seed dormancy and seed longevity using mathematical models; climate change effects on pollination, seed formation, development and quality.

Unit II

Recent techniques in seed production of self incompatible, protogyny, protandry and

apomictic plant species - Gene Use Restriction Technology (GURT) - terminator and verminator technology - Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) Cas - gene editing; seed proteomics - principles, methods, applications in seed science- genetic analysis and QTL mapping of traits related to seed vigour, ageing and longevity - OMICS in related to seed science and technology; somatic embryogenesis - principles and methods of production of synthetic/ somatic seeds - merits and demerits.

Unit III

Modern techniques for identification of varieties and hybrids - principles and procedures; DNA fingerprinting and other molecular techniques and their utilization - GM seeds and their detection techniques; Use of machine vision and image analysis techniques for varietal identification. Application of artificial intelligence (AI) and machine learning (ML) and virtual reality (VR) in seed science.

Unit IV

Recent accomplishments in seed enhancement research - seed coating, pelleting and priming techniques - physiological, molecular and sub-cellular basis of seed priming - detection and identification of seed borne diseases and insect pests through advanced techniques - ELISA and PCR based techniques.

Unit V

International movement of seeds - OECD seed certification schemes - recent developments in seed laws and policies - ethical issues and IPR system related to seed trade and movement.

Teaching methods

- Classroom lectures
- Power point presentations
- Student assignment and presentations

Learning outcome

After completion of this course the students will be able to take up research on seed biotechnology.

Resources

Benech-Arnold, R. and Rodolfo, S., 2004. Handbook of Seed Physiology: Applications to Agriculture. CRC Press., Florida, United States.

Black, M. and Bewley, J. D. 2000. Seed Technology and its Biological Basis. CRC Press. Florida, United States.

Figey, D. 2005. Industrial Proteomics: Applications for Biotechnology and Pharmaceuticals (No. TP248. 65. P76 I535 2005). United States.

Lombardo, L. 2014. Genetic Use Restriction Technologies: a review. Plant biotechnology journal. 12(8): 995-1005.

Nicolas, G., Bradford, K. J., Come, D. and Pritchard, H. W., 2003. The Biology of Seeds: Recent Research Advances. Proceedings.

Patterson, S. D. and Aebersold, R. H. 2003. Proteomics: the first decade and beyond. Nature genetics. 33(3s): 311.

Maiti, R. K., Sarkar, N. C. and Singh, V. P. 2006. Principles of Post Harvest Seed Physiology and Technology. Agrobios., Jodhpur, India.

Redenbaugh, K. 1993. Synseeds: Application of Synthetic Seeds to Crop Improvement. CRC Press, London, UK.

Bewley, J. D. and Black, M. 1994. Seeds: Physiology of Development and Germination. Springer, New York, USA.

Kozłowski, T. T. 2012. Seed Biology: Importance, Development and Germination. (Vol. I). Academic Press Inc., New York.

Bewley, J. D., Bradford, K. J., Hilhorst, H. W. M. and Nanogaki, H. 2013. Seeds: Physiology of Development, Germination and Dormancy. Springer, New York.

Rakshit, A. and Singh, H. B. 2018. Advances in Seed Priming. Springer Nature Singapore Ltd., Singapore.

Baskin, C. and Baskin, J. M. (2014) Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination. Academic Press, Cambridge, UK.

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

Suggested e-books

<https://www.springer.com/gp/book/9783540574484>

<https://www.synthego.com/resources/crispr-101-ebook>
<https://link.springer.com/book/10.1007/978-981-13-0032-5>
<https://www.springer.com/gp/book/9780306447471#aboutBook>
https://link.springer.com/chapter/10.1007/978-1-4615-1619-4_13
<https://www.cambridge.org/core/journals/experimental-agriculture/article/biology-of-seeds-recent-research-advances-edited-by-g-nicolas-k-j-bradford-d-come-and-h-wpritchard-wallingford-uk-cabi-international-2003-pp-472-9500-isbn-0851996531/57DACB0A07CFD0246AAD11713540F1E6>
https://www.researchgate.net/publication/240592094_Black_M_Bewley_JD_eds_2000_Seed_technology_and_its_biological_basis_419_pp_Sheffield_Sheffield_Academic_Press_89_hardback <https://www.crcpress.com/Handbook-of-Seed-Physiology-Applications-to-Agriculture/Benech-Arnold-Sanchez/p/book/9781560229292>
<https://www.elsevier.com/books/seeds/baskin/978-0-12-416677-6>
<https://international.neb.com/tools-and-resources/feature-articles/crispr-cas9-and-targeted-genome-editing-a-new-era-in-molecular-biology> <https://www.omicsonline.org/scholarly/seed-science-and-technology-journals-articlesppts-list.php>
<https://libgen.is/book/index.php?md5=F63727B21E14953F0003168A2452B3FE>
https://www.researchgate.net/publication/228621809_Techniques_for_detecting_genetically_modified_crops_and_products <https://www.intechopen.com/books/new-challenges-in-seed-biology-basic-and-translational-research-driving-seed-technology/recent-advances-in-seed-enhancements>
https://books.google.co.in/books/about/Advances_in_Seed_Priming.html?id=iBtfDwAAQB
[AJ&printsec=frontcover&source=kp_read_button&redir_esc=y#v=onepage&q&f=false](https://books.google.co.in/books/about/Advances_in_Seed_Priming.html?id=iBtfDwAAQB&printsec=frontcover&source=kp_read_button&redir_esc=y#v=onepage&q&f=false)
Suggested websites
sbc.ucdavis.edu www.seedbiotech.com <http://www.gmotesting.com/Testing-Options>
<https://www.ncbi.nlm.nih.gov/pubmed/25185773> <https://www.oecd.org/agriculture/seeds/>
<https://www.addgene.org/crispr/guide/> <https://www.yourgenome.org/facts/what-is-crispr-cas9> <https://cban.ca/gmos/issues/terminator-technology/>
<https://www.nature.com/articles/s41598-017-08669-5>
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5495694/>
<https://www.ias.ac.in/article/fulltext/reso/006/05/0039-0047>
<https://www.cell.com/action/showPdf?pii=S1360-1385%2807%2900038-6>
<https://www.sciencedirect.com/science/article/pii/S2215017X16301400>
<https://www.broadinstitute.org/what-broad/areas-focus/project-spotlight/questions-and-answers-about-crispr>

SST 610

Seed Planning, Trade and Marketing

2(1+1)

Why this course?

Introduction of high yielding varieties and hybrids in various crops enhanced the International trade on seeds. To meet the international and domestic seed demand, well structured planning and marketing is essential. This course will expose the students to gain knowledge and skill on planning for a sound seed programme and procedures of trade and to address the trade related issues.

Aim of the course

To impart knowledge on planning seed production programmes, national and international movement of seeds and marketing strategies.

Theory

Unit I

Seed industry - genesis, history and growth - structure of seed industry in India - mission and objectives of seed Industry; status and role of seed industry in Indian agriculture.

Unit II

Seed production programmes - characters, types; planning and organizing seed programmes in public and private sectors - small, medium, large and more advanced seed programmes - local, national and international seed programmes; seed demand forecasting - purpose - methods and

techniques - factors determining seed demand - seed multiplication ratio, seed replacement rate and variety replacement rate; seed production planning for varieties and hybrids - compact area approach and seed village - contractual seed production - custom seed production - public private partnership - transgenic seeds - demand assessment.

Unit III

New seed policy - genesis - functions; WTO - Indian seed industry - patenting and sui generis system - The Seeds Bill, 2004 and 2011; role and contributions of MNC's in seed trade in India; International trade of seeds - government policies - International organizations involved in seed movement and trade - International Seed Federation (ISF), ISTA - OECD seed schemes - operational guidelines; import and export of seeds - Exim policies - guidelines and salient features; seed production and quality control systems in SAARC Nations and other developed countries; quarantine measures - procedures, guidelines and certificates in international seed movement and trade.

Unit IV

Seed production and distribution system in central and state governments, co-operative and private organisations - seed marketing - definition, concept, importance and type of markets - domestic and global market - problems and perspectives; marketing policies - seed marketing schemes, marketing channels - responsibilities of dealers - marketing mix; handling and management of sales return seed stocks.

Unit V

Seed pricing - local market rate - factors affecting prices and pricing policies - fixation of procurement and sale price of seeds - cost analysis - seed market intelligence - marketing promotional activities; seed supply chain management - missing link - risk and management.

Practical

- Data collection on status of Indian and global seed industry
- Planning seed programmes for varieties and hybrids
- Planning for establishment of small and medium seed enterprises
- Planning for establishment of large scale seed enterprises
- Planning for custom seed production and contractual seed production
- Assessment of seed demand - demand forecasting methods
- Assessment of seed multiplication ratio, seed replacement rate and variety replacement rates for different crops
- Study on the economics of seed production and marketing
- Exercise on fixing procurement and sale price of seeds
- Study of seed marketing channels - survey and interaction with seed dealers and distributors
- Visit to plant quarantine station and study of quarantine requirements and certificates for domestic and international seed trade.
- Visit to modern seed processing unit, advanced seed storage complex and interactions
- Visits to state seed corporations
- Visit to MNCs and expert discussion
- Case studies and SWOT analysis
- Planning for establishment of new seed ventures and project preparations

Teaching methods

- Classroom lectures,
- Students assignment and presentations
- Group discussions
- Field visits and industry visits

Learning outcome

Completion of this course will enable the students to gain knowledge and to start successful seed business.

Resources

- Feistrizer, P. and Fenwickkelly, A. 1978. Improved Seed Production, FAO, Rome, Italy. Agrawal, R.L. 1996. Seed Technology, Oxford, IBH Publishing Co., New Delhi, India.
- Dadheech, P.K. 1996. Seed Programming, Management System and Concepts, LokSahitna Kendra., Jodhpur, India.
- Gurudev Singh and Asokan, S.R. 1997. Management of Seed Production Activity. Oxford and IBHPublishing Co., New Delhi, India.
- Joshi, A. K and Singh, B. D. 2004. Seed Science and Technology, Kalyani Publishers., New Delhi, India.
- Krishnasamy, V., Ponnuswamy, A. S., Balamurugan, P., Srimathi, P., Natarajan, N. and Raveendran, T.S. 2004. Compendium on Seed Science and Technology, Directorate of Publications., Tamil Nadu Agricultural University, Coimbatore, India.
- Singh, G. and Asokan, S.R. 1992. Seed Replacement Rate: Some Methodological Issues. Indian Institute of Management., Ahmedabad, India.
- Dadheech, P.K. 1996. Seed Programming, Management System and Concepts. Lok Sahitna Kendra, Jodhpur.
- Acharya, S.S. and Agarwal, N. L. 2004. Agricultural Marketing in India. 4th Ed. Oxford and IBH. Broadway, A. C and Broadway, A. 2003. A Text Book of Agri-business Management.
- Singh, S. 2004. Rural Marketing - Focus on agricultural Inputs. Vikas Publishing House.
- Kalyani Singh, A. K. and Pandey, S. 2005. Rural Marketing. New Age Publications. Kugbei, S. 2008. Seed Economics. Scientific Publishers, Jodhpur

Suggested e-books

- http://www.pondiuni.edu.in/storage/dde/downloads/mbaii_mm.pdf <http://agricoop.nic.in/divisiontype/seeds>
- <https://www.audiencebloom.com/all-in-one-guide-to-planning-and-launching-content-marketing-strategy/>
- <https://link.springer.com/chapter/10.1007/978-1-4615-1783-2-15> <http://www.fao.org/3/V4450E/V4450E00.htm>
- <https://books.google.co.in/books?id=vPVIbos4WkYC> <http://download.nos.org/srsec319new/319EL19.pdf>
- <https://isengewant.de/Marketing-of-Seeds-By-Premjit-Sharma.pdf> <https://www.kopykitab.com/A-Handbook-of-Seed-Processing-and-Marketing-by-GaurSC>

Suggested websites

- www.gov.mb.ca www.agricoop.nic.in www.agri.nic.in <https://sathguru.com/seed/>
- <http://www.fao.org/3/V4450E/V4450E03.htm> <https://www.seednet.gov.in/smis/SMIS-User%20Manual.pdf>
- <https://www.icrisat.org/seed-systems-models-lessons-learned/> <https://www.bookdepository.com/Seed-Industry-India-Gurdev-Singh/>

Animal Husbandry & Dairying (Livestock Production & Management)

M.Sc. (Ag.) Livestock Production & Management

Major Courses (20 Credits)

Sl. No.	Course Code	Course Title	Credits	Semester
1.	AHD-501	Management of sheep, Goat, pig and Poultry	3(2+1)	III
2.	AHD-502	Breeding and Reproductive Management	3(2+1)	II
3.	AHD-503	Livestock and Poultry Housing Management	3(2+1)	II
4.	AHD-504	Livestock Health Management	3(2+1)	I
5.	AHD-505	Nutrient Requirement of Ruminants	3(2+1)	III
6.	AHD-506	Non Ruminant Nutrition	3(2+1)	II
7.	AHD-507	Market Milk	2(1+1)	I
8.		Sub Total	20(13+7)	

Minor Courses (08 Credits)

Sl.No.	Course Code	Course Title	Credits	Semester
1.	AEC-502	Agricultural Production Economics	2(1+1)	I
2.	AEC-507	Agricultural Finance and Project Management	3(2+1)	II
3.	EXT-505	Capacity Development	3(2+1)	III
4.		Sub Total	8 (6+2)	

Supporting Courses (06 Credits)

Sl.No.	Course Code	Course Title	Credits	Semester
1.	STAT-511	Experimental Designs	3(3+0)	II
2.	STAT-502	Statistical methods for applied/social sciences	3(2+1)	I
3.		Sub Total	6 (5+1)	

Common Courses (05 Credits)

Sl. No.	Course Code	Course Title	Credits	Department	Semester
1.	PGS-501	Library And Information Services	1(0+1)	Library	I
2.	PGS-502	Technical Writing and Communications Skill	1(0+1)	Ag. Extension	I
3.	PGS-503	Intellectual Property and Its Management in Agriculture	1(0+1)	GPB	II
4.	PGS-504	Basic Concept in Laboratory Techniques	1(0+1)	SCA	II
5.	PGS-505	Agriculture Research, Research Ethics and Rural Development Programmes	1(0+1)	Agronomy	III
		SubTotal	5 (0+5)		
	AHD-591	Seminar	1(0+1)	-----	IV
	AHD-599	Research	30(0+30)	-----	IV
		SubTotal	31 (0+31)		
		Grand Total	70		

Semester- I

AHD-507

MARKET MILK

2 (1+1)

Theory:

Unit I : (6 Lectures)

Dairy industry: Status of dairy industry in India, Operation Flood programme. Technology Mission on dairying. National milk grid. Marketing federation, their concepts, achievements, limitations and impact on the dairy industry in India. Milk production trends and Dairy development through successive National plans. Recent policy changes to Dairy Sector (MMPO, GATT) and their impact on dairy industry in the country.

Unit II : (4 Lectures)

Processing: Importance of various milks in milk processing. Impact of processing on major and minor constituents of milk. Methods of milk Procurements, payments, quality assessment, handling and transportation of milk to processing dairies.

Unit III : (4 Lectures)

Milk preservation : methods of chilling milk, centrifugal separation, clarification and bactofugation and factors affecting their efficiency. Automatic desludging separators and clarifiers. Homogenization process and its significance in Dairy processing, theories of Homogenization and factors affecting it.

Unit IV : (2 Lectures)

Thermal processing of milk : Principles and methods of thermization, pasteurization and sterilization.

Unit V : (2 Lectures)

Special milks : Principles of production, processing and marketing of toned, double toned, reconstituted and recombined, sterilized flavoured and filled milk.

PRACTICAL: (16 Classes)

Assembling and disassembling of cream separator and separation of milk. Study of parts of LT LT and HTST pasteurizers and preparation of reports. Preparation of special milks like toned milk, double toned milk, chocolate milk, sterilized milk, flavoured and filled milk. Visit to milk plants and Milk products factories and submission of the report.

RESOURCES:

1. *Aneja, R.P., Mathur, B.N., Chandan, R. C., and Banerjee, A.K. (2002). Technology of Indian dairy products. A Dairy India Publication.*
2. *Goyal, M.R., Kumar, A. and Gupta, A.K. (2018). Novel Dairy Processing Technologies: Techniques, Management, and Energy Conservation. CRC Press.*
3. *Puniya AK (2015) Fermented Milk and Dairy Products; CRC Press/ Taylor and Francis (ISBN 9781466577978).*
4. *Shrott, C., and O'Brien (2003). Handbook of Functional Dairy Products. CRC Press.*
5. *TetraPak Dairy Processing Handbook (2015). www.dairyprocessinghandbook.com.*

Websites

Indian Dairy Product Market – Indian Council of Food and Agriculture
https://icfa.org.in/assets/doc/reports/Indian_Dairy_Product_Market.pdf Mechanized production of Indian Dairy Products- AMEFT <https://download.ameft.com/MechanisedProduction.pdf>

Indian Dairy Industry – Aavin- <https://aavinmilk.com/dairyprofile.html> Present Status of Traditional Dairy Products – Technische – TIB

<https://www.tib.eu/en/search/id/.../Present-Status-of-Traditional-Dairy-Products/>

Theory:**UNIT I (6 Lectures)**

Health and production inter relationship. General approach to plan animal health program.

UNIT II (18 Lectures)

Emerging disease problems in India and their management. Major reproductive disorders their prevention and control maintenance of herd reproductive health, mastitis, H.S., F.M.D., B.Q., Bloat, Milk fever control.

UNIT III (10 Lectures)

Specific disease problems in calves and their management. Sign of disease outbreak and procedure for early diagnosis. Predisposing Factors of Diseases.

UNIT IV (2 Lectures)

Immune status of neonates. Zoonosis concept and classification. Epidemiology of bacterial and viral diseases.

Practical: (17 Classes)

General examination of animals for signs of health. Package of practical for control and prevention of calf disease, immunization against different diseases. Collection preservation and transportation of clinical material for diagnosis purpose. Collection, preservation and examination of blood and blood smear for protozoa parasites. Examination of urine and faecal material. Preparation and use of insecticide solution. Procedure for autopsy and carcass disposal maintenance of health record. Data base animal health surveillance.

RESOURCES:

1. Ghosh B. 2007. *Integrating Crops and Livestock*, 1st ed. Gene-Tech Books.
2. Little DC and Edwards P. 2003. *Integrated Livestock-fish Farming Systems*. FAO.
3. Mukherjee TK, Moi PS, Panandam JM & Yang YS. (Eds.) 1992. *Integrated Livestock Fish Production Systems*. FAO/IPT Workshop on Integrated Livestock-Fish Production Systems, University of Malaya, Kuala Lumpur.
4. Raman KV & Balaguru T. (Eds.). 1992. *Farming Systems Research in India: Strategies for Implementation*. NAARM, Hyderabad.
5. Rana SS. 2015. *Recent Advances in Integrated Farming Systems*. CSK HPKV, Palampur.
6. Rangasamy A and Annadurai K. 2002. *Farming System in the Tropics*. Kalyani Publishers.
7. Renard C. (Ed.). 1997. *Crop Residues in Sustainable Mixed Crop/Livestock Farming Systems*. CABI.
8. Speirs M & Opsen O. 1992. *Indigenous Integrated Farming System in the Sahel*. World Bank.

Semester- II**Theory:****UNIT I (8 Lectures)**

Functional morphology of male and female reproductive organs of farm animals. Management strategies for attaining early maturity. Heat detect methods associated problems and their management.

UNIT II (14 Lectures)

Artificial management. Artificial Breeding and its economic importance, post A.I. Management pregnancy development and diagnosis. Management of down calves post-mortem care, factors influencing reproductive efficiency in buffaloes and crossbreed cattle and measures for improvement.

UNIT III (8 Lectures)

Management of breeding bulls, methods of semen collection, factors affecting of the quality semen production, evaluation processing and preservation of semen. Merits and demerits of different extenders.

UNIT IV (6 Lectures)

Maintenance of records for artificial breeding. Basic principle of inheritance. Methods of selection and system of breeding in animals. Blood and its composition, properties and function.

Practical: (16 Classes)

Examination of reproductive organs at various stages of reproductive cycle. Heat detection in cattle buffaloes. Preparation of heat expectancy chart. Calculation of heat detection index of herd. Artificial insemination by recto vaginal and spectrum method. Pregnancy diagnosis by per rectum method. Calculation of breeding efficiency, heritability and repeatability of the herd preparation of bull semen collection. Evaluation of semen, preparation of extenders dilution and preservation of semen, maintenance and handling of liquid semen. Cell count, cell volume haemoglobin, Blood sugar and blood serum.

RESOURCES:

1. Brah GS. 2016. *Animal Breeding: Principles and Applications*. Kalyani Publishers.
2. Lynch M & Walsh B. 1998. *Genetics and Analysis of Quantitative Traits*. Oxford University Press.
3. Morde RA & Thompson R. 2014. *Linear Models for the Prediction of Animal Breeding Values*. CABI.
4. Oldenbroek K & van der Waaij L. 2014. *Text book of Animal Breeding and Genetics*. Wageningen University and Research Centre (Free Online).
5. Tomar SS. 2010. *Textbook of Animal Breeding*. Universal Publishers.
6. Zeggini E & Morris A. 2010. *Analysis of Complex Disease Association Studies*. Academic Press.

AHD-503

LIVESTOCK AND POULTRY HOUSING MANAGEMENT

3(2+1)

Theory:

UNIT I (10 Lectures)

Principles of construction of farm building selection of site. Types and designs for various livestock and poultry. Space requirements of different categories of livestock and poultry under different housing systems.

UNIT II (8 Lectures)

Requirements of various housing components viz. ventilation, humidity and temperature control. Types of floors, walls, gates, roofs, stalls, manager sting devices and food storage.

UNIT III (16 Lectures)

Housing for experimental animals' methods of drainage and sewage disposal treatment and classification. Various types of septic and sedimentation tanks digestion tanks, sewage filtration. Sludge and lagoon, recycling of waste and sludge farming and Biogas, common disinfectants, detergents and sanitizers used on farm premises, method of application and factors affecting their efficiency.

UNIT IV (2 Lectures)

Construction of auxiliary buildings like bull exerciser. Wallowing tank, and feed processing unit.

Practical: (17 Classes)

Drawing of environmental profiles in different agro-climatic regions, layout plans including cost kl for different size units and categories of animals. Design and construction of different types of shades. Cleaning disinfection of sanitation of dairy farm. Equipment, Layout plans for waster/sewage disposal and sewage plant management.

RESOURCES:

1. Arora SP. 1997. *Feeding of Dairy Cattle and Buffaloes*. Kalyani Publication.
2. Dutta G. 1994. *Care and Management of Dairy Cattle and Buffaloes*, 3rd ed. ICAR.
3. Flanders F and Gillespie J. 2015. *Modern Livestock & Poultry Production*, 9th ed. Delmar Cengage Learning Edition.
4. Gupta PR. 2017. *Dairy India-2017*, 7th ed. Dairy India Yearbook, Thomson Press Ltd.
5. ICAR. Livestock Production and Management - ICAR eCourse PDF eBook (online free).
6. Phillips CJC. 2011. *Principles of Cattle Production*. CABI Publishing.
7. Sastry NSR. 2016. *Livestock Production Under Diverse Constraints - Indian Experience in its Management*. ISAPM Publication.
8. Thomas CK, Sastry NSR & Ravikiran G. 2012. *Dairy Bovine Production*, 2nd ed. Kalyani Publishers.
9. Tyler HD & Ensminger ME. 2006. *Dairy Cattle Science*, Pearson Prentice Hall Publishing.
10. *Selected articles from journals*.

AHD-506

NON-RUMINANT NUTRITION

3(2+1)

Theory:

UNIT I (11 Lectures)

Comparative gastro-intestinal physiology of Pig, Poultry. Feed sources for non-ruminants and their equivalent. M.E. and N.E. concept.

UNIT II (13 Lectures)

Feeding standard for pig and poultry, protein evaluation true digestibility. Biological value, net dietary protein value.

UNIT III (12 Lectures)

Egg replacement value chemical score EAAI. Energy, protein essential amino acid, mineral & vitamin for poultry and pig.

Practical: (17 Classes)

Ration composition for starter grower and layer birds. Ration composition for starter grower and finisher pigs.

RESOURCES:

1. Adamo G & Costanza A (Eds.). *Rabbits Biology, Diet and Eating Habits and Disorders*. Nova Biomedical.
2. Cheeke PR. 1987. *Rabbit Feeding and Nutrition*. Academic Press, Inc.
3. Chiba LI (Ed.). 2012. *Sustainable Swine Nutrition*. Wiley-Blackwell.
4. de Blas C & Wiseman J. (Eds.). 2010. *Nutrition of the Rabbit*, 2nd ed. CAB International.
5. D'Mello JPF. 2003. *Amino Acids in Animal Nutrition*, 2nd ed. CAB International.
6. Frape D. 2010. *Equine Nutrition and Feeding*, 4th ed. Wiley-Blackwell.
7. Hynd PI. 2019. *Animal Nutrition: From Theory to Practice*. CAB International.
8. Leeson S & Summers JD. 2009. *Commercial Poultry Nutrition*, 3rd ed. Nottingham University Press.
9. Leeson S & Summers JD. 2019. *Scott's Nutrition of The Chicken*, 4th ed. CBS Publishers and Distributors.
10. NRC. 2007. *Nutrient Requirements of Horses*, 6th Rev. ed. National Research Council. National Academy Press.
11. NRC. 1994. *Nutrient Requirements of Poultry*, 9th Rev. ed. National Research Council. National Academy Press.
12. NRC. 2012. *Nutrient Requirements of Swine*, 11th Rev. ed. National Research Council. National Academy Press.
13. Varga M. 2013. *Textbook of Rabbit Medicine*, 2nd ed. Butterworth-Heinemann.

Semester- III

AHD-501

MANAGEMENT OF SHEEP, GOAT, PIG AND POULTRY

3(2+1)

Theory:

UNIT I (16 Lectures)

Livestock and poultry development program currently in operation in the country, important breed of Sheep, Goat, Pig and poultry. Their Characteristics classification and distribution.

UNIT II (14 Lectures)

Management of Sheep, Goat, Pig and poultry during growth, reproduction and production. Rearing breed sic and young tic heifers, their marking for identification, Grazing, Docking, Dehorning, Dubbing and Sterilization.

UNIT III (6 Lectures)

Selection and disposal of culled animals. Different records of management of related animals. Economics of Sheep, Goat, Pig and poultry farming.

Practical: (17 Classes)

Preparation of management calendar for Sheep, Goat, Pig and poultry, judging of poultry identification, debeaking, caponization. Maintenance of records at the farm, calculation of the cost of meat, egg, wool, hair and milk.

RESOURCES:

1. DAHD. 2015. *Poultry Farm Manual: A Reference Guide for Central & State Poultry Farms*. 2014-15. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture and Farmers Welfare, Government of India.
2. FAO. 2003. Live bird marketing. In: *Egg Marketing - A Guide for the Production and Sale of Eggs* <http://www.fao.org/3/Y4628E/y4628e09.htm#bm9>
3. Bhat PN & Khan BU. 2009. *Goat Production*. Studium Press (India) Pvt. Ltd.
4. Bhatt PN & Arora CL. 2009. *Sheep Production*. Studium Press (India) Pvt. Ltd.
5. Devendra C & McLeroy GB. 1982. *Goat and Sheep Production in Tropics*. Longman.
6. Devendra C & Burns M. 1983. *Goat Production in the Tropics*. CABI Publishing.
7. Gupta JL. 2006. *Sheep Production and Management*. BS Publ.
8. ICAR. 2014. *Handbook of Animal Husbandry*, 3rd ed. ICAR.
9. Jindal SK. 2013. *Goat Production and Health Management*. New India Publishing Agency.
10. Kaushik SK. 2017. *Sheep Production*. ICAR Publ.
11. Peacock CP. 1996. *Improving Goat Production in the Tropics: A Manual for Development Workers*, OXFam, UK.
12. Sastry NSR. 2016. *Livestock Production Under Diverse Constraints - Indian Experience in its Management*. ISAPM Publication.
13. Solaiman SG. 2010. *Goat Science and Production*. Wiley-Blackwell.

AHD-505

NUTRIENT REQUIREMENTS OF RUMINANTS

3(2+1)

Theory:

UNIT I (8 Lectures)

Energy system starch equivalent, Scandinavian feed units. Total digestible nutrients, digestible energy, net energy.

UNIT II (10 Lectures)

Protein system- crude protein, digestible crude protein, protein equivalent rumen degradable, non-degradable protein.

UNIT III (6 Lectures)

Methods of determining energy requirements, basal metabolism, digestion trial. Direct and indirect calorimetric.

UNIT IV (12 Lectures)

Energy and protein requirement for maintenance, growth, reproduction, milk production, work, meat and wool for production of different ruminant species. Mineral and vitamin requirement, water requirement.

Practical: (17 Classes)

Analysis of feed for crude protein, crude fat, fiber. Dry matter & mineral like Ca, P and Mg. Computation of least cost rations. Computation of ration for cattle, buffalo, goat, sheep for different production traits.

RESOURCES:-

1. Church DC. 1988. *The Ruminant Animal: Digestive Physiology and Nutrition*, 2nd ed. Prentice-Hall.
2. Dehority BA. 2003. *Rumen Microbiology*. Nottingham University Press.
3. D'Mello JPF. 2003. *Amino Acids in Animal Nutrition*, 2nd ed. CAB International.
4. Givens D, Axford R & Owen E. (Ed.). 2000. *Forage Evaluation in Ruminant Nutrition*. CAB International.
5. Hynd PI. 2019. *Animal Nutrition: From Theory to Practice*. CAB International.
6. McDowell RL. 2012. *Nutrition of Grazing Ruminants in Warm Climates*. Academic Press.
7. Moran J. 2005. *Tropical Dairy Farming: Feeding Management for Small Holder Dairy Farmers in the Humid Tropics*. Landlinks Press
8. Pond WG, Church DB, Pond KR & Schoknecht PA. 2004. *Basic Animal Nutrition and Feeding*, 5th ed. Wiley.
9. Shirley RL. 2012. *Nitrogen and Energy Nutrition of Ruminants*. Academic Press.
10. Van Soest PJ. 1994. *Nutritional Ecology of the Ruminant*. Cornell University Press.
11. NRC. 2001. *Nutrient Requirements of Dairy Cattle*, 7th rev. ed. National Research Council. National Academies Press.
12. NRC. 2016. *Nutrient Requirements of Beef Cattle*, 8th rev. ed. National Academies of Sciences, Engineering, and Medicine. National Academies Press.
13. NRC. 2007. *Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids*. National Research Council National Academy Press.

Animal Husbandry & Dairying (Livestock Production & Management)

Ph.D. in Livestock Production and Management

Major Courses (12 Credits)

Sl.No.	Course Code	Course Title	Credits	Semester
1.	AHD-601	Physiology of Growth	2(1+1)	I
2.	AHD-602	Advanced Poultry Production.	3(2+1)	II
3.	AHD-603	Physiology of Reproduction.	2(2+0)	II
4.	AHD-604	Layout and Planning of Dairy and poultry Farms	3(2+1)	III
5.	AHD-605	Fodder crops and Cropping Scheme	2(1+1)	I
		Sub Total	12 (8+4)	

Minor Courses (06 Credits)

Sl.No.	Course Code	Course Title	Credits	Semester
1.	AEC-604	Advanced Production Economics	3(2+1)	II
2.	EXT-602	Methodologies for Social and Behavioural Research	3(2+1)	I
3.		Sub Total	6 (4+2)	

Supportive Courses (05 Credits)

Sl.No.	Course Code	Course Title	Credits	Semester
1.	STAT-612	Advanced Experimental Design.	3 (2+1)	II
2.	AGRON-608	Research and Publication Ethics.	2 (2+0)	II
3.		Sub Total	05 (4+1)	
	AHD-691	Doctoral Seminar I	1(0+1)	II
	AHD-692	Doctoral Seminar II	1(0+1)	III
	AHD-699	Research	75(0+75)	-----
		SubTotal	77 (0+77)	
		Grand Total	100	

SEMESTR-I

AHD-601 **PHYSIOLOGY OF GROWTH** **2(1+1)**

THEORY:

UNIT I (5 Lectures)

Cell structure and cellular physiology, elementary physiology, factors affecting growth, measurement of growth, relationship between growth and production, sex and growth.

UNIT II (6 Lectures)

Osmoregulation—regulation under different environments, energy metabolism calorimetric, R. Q., Basal metabolic rate, factors affecting M.B.R. temperature regulation and fever, mechanics of nutrient storage and utilization.

UNIT III (4 Lectures)

Circulatory system-blood, lymph, cerebrospinal fluids, synovial fluids. Blood composition, Haemoglobin, blood coagulation and hemodynamic.

UNIT IV (3 Lectures)

Respiratory system- Mechanism of respiration in animals and birds, transport and exchange of gases.

PRACTICAL: (18 Classes)

Determination of haemoglobin, RBC, WBC, Estimation of sugar, Ca, P in blood and serum Estimation

of RQ and respiration rate under various conditions of stress.

RESOURCES:

1. Brah GS. 2016. *Animal Breeding: Principles and Applications*. Kalyani Publishers.
2. Lynch M & Walsh B. 1998. *Genetics and Analysis of Quantitative Traits*. Oxford University Press.
3. Morde RA & Thompson R. 2014. *Linear Models for the Prediction of Animal Breeding Values*. CABI.
4. Oldenbroek K & van der Waaij L. 2014. *Text book of Animal Breeding and Genetics*. Wageningen University and Research Centre (Free Online).
5. Tomar SS. 2010. *Textbook of Animal Breeding*. Universal Publishers.
6. Zeggini E & Morris A. 2010. *Analysis of Complex Disease Association Studies*. Academic Press.

AHD- 605

FODDER CROPS AND CROPPING SCHEME

2(1+1)

THEORY:

Unit I (4 Lectures)

Important fodder crops and perennial grasses, their cultivation and management.

Unit II (10 Lectures)

Conservation of fodder, cropping schemes to supply fodder all-round the year.

Unit III (4 Lectures)

Management of pastures lands.

PRACTICAL: (18 Classes)

Preparation of cropping scheme to supply fodder throughout the year. Preparations of field for different crops. Conservation of green fodder.

RESOURCES:

1. Dryden G. 2008. *Animal Nutrition Science*. CAB International.
2. Kundu SS, Mahanta SK, Singh S & Pathak PS. 2016. *Animal Feed Technology*. Satish Publishers
3. Perry TW, Cullison AE & Lowrey RS. 2003. *Feeds and Feeding*, 6th ed. Pearson.
4. Pond WG, Church DB, Pond KR & Schoknecht PA. 2004. *Basic Animal Nutrition and Feeding*, 5th ed. Wiley.
5. Schofield EK (Ed.). 2005. *Feed Manufacturing Technology V*. American Feed Industry Association, Arlington.

SEMESTR-II

AHD-602

ADVANCED POULTRY PRODUCTION

3(2+1)

THEORY:

UNIT I (7 Lectures)

Background, current status and modern trends in poultry breeding. Major gene effect and gene frequency problems. Performance testing, space requirements, Pan effects and repeat ability of performance.

UNIT II (12 Lectures)

Hatch corrections and maximum genetic gains. Pure line breeding, inbreeding and hybridization. Blood type and immune-genetics in chickens; selection, its use, advantages and genetics gains through selection, correlation response.

UNIT III (12 Lectures)

Principle of poultry nutrition, requirement of energy, protein, minerals, vitamins and antibiotics for growing and laying birds. Feeding ingredients and formulation of poultry ration.

UNIT IV (5 Lectures)

Feeding and watering practices use of artificial light, housing, care of houses, laying cages, litter, manure and other management problems.

PRACTICAL: (18 Classes)

Estimation of gene frequencies. Estimation of heritability and repeatability. Formulation of selection indexes and estimation of the genetic gain and correlated response. Estimation of relationship and inbreeding coefficient. Formulation of poultry ration. Calculation of the protein and energy requirement for chick. Grower, layers and broiler ration. Calculation of ventilation requirement, heat production and insulation needed. Practical way of arranging light. Poultry house design and construction.

RESOURCES:

1. Etches RJ. 1995. *Reproduction in Poultry*. CAB International.
2. Scanes CG. 2014. *Sturkie's Avian Physiology*. Elsevier

AHD-603

PHYSIOLOGY OF REPRODUCTION

2(2+0)

THEORY:

UNIT I (8 Lectures)

Description of male and female reproductive organs. Embryonic and lateral growth of reproductive organs, glands associated with reproduction, hormones and reproduction.

UNIT II (12 Lectures)

Mating behaviour, fertilization and parturition, artificial insemination, general organization of artificial insemination in India and abroad, Advantages and limitation of A.I.

UNIT III (12 Lectures)

A.I. equipment's and their sterilization, methods of collection of semen. Composition of semen, morphology of sperms and their abnormalities, semen containers, semen transport, evolution, dilution and preservation of semen.

UNIT IV (6 Lectures)

Methods of insemination, repeaters, infertility, various male formation and diseases of reproductive organs leading to sterility, use of frozen semen in animal improvements.

RESOURCES:

1. Choudhuri S. 2014. *Bioinformatics for Beginners*. Academic Press.
2. Daniel S & Daniel G. 2012. *Likelihood, Bayesian, and MCMC Methods in Quantitative Genetics*. Springer.
3. Kute N & Shinde G. 2016. *Principles of Biometrical Genetics*. Daya Publications.
4. Marther K. 1997. *Biometrical Genetics*. Springer.
5. Michael JK & Harpal SP. 1996. *The Genetical Analysis of Quantitative Traits*. Springer.
6. Pawar IS & Singh S. 2010. *Theory and Application of Biometrical Genetics*. CBS Publications.
7. Weller JI. 2016. *Genomic Selection in Animals*. John Wiley & Sons.

SEMESTR-III

AHD-604

LAYOUT AND PLANNING OF DAIRY AND POULTR FARMS

3(2+1)

THEORY:

Unit I (18 Lectures)

Economic evaluation of dairy and poultry enterprises of various sizes.

UNIT II (18 Lectures)

Submission of project report with respect to feasibility of establishment of dairy and poultry farms.

PRACTICAL: (18 Classes)

Preparation of evaluation reports. Preparation of feasibility reports regarding establishment of Dairy / Poultry farms.

RESOURCES:

1. Ensminger ME. 1992. *Poultry Science*. International Book Distr. Co.
2. Hued LM. 2003. *Modern Poultry Farming*. Greenworld.
3. Powell-Owen W. 2008. *Poultry Farming and Keeping*. Daya Books.
4. Prasad J. 2005. *Poultry Production and Management*. Kalyani Publication
5. Singh RA. 1996. *Poultry Production*. 3rd ed. Kalyani Publication

Department of Animal Husbandry & Dairying (Dairy Technology)

M.Sc. (Ag.), Animal Husbandry & Dairying (Dairy Technology)

Major Courses (20 Credits)

Sl.No.	Course Code	Course Title	Credits	Semester
1.	AHD-507	Market Milk	2(1+1)	I
2.	AHD-508	Dairy Technology-I	3 (2+1)	I
3.	AHD-509	Dairy Technology-II	3 (2+1)	II
4.	AHD-510	Dairy Chemistry	3 (2+1)	II
5.	AHD-511	Dairy Microbiology	3 (2+1)	III
6.	AHD-512	Quality Control of Milk and Milk Products	3 (2+1)	III
7.	AHD-513	Rheology, Packaging of Milk and Milk Products and Dairy Plant Management	3 (2+1)	III
		Sub Total	20 (13+7)	

Minor Courses (08 Credits)

Sl.No.	Course Code	Course Title	Credits	Semester
1.	AEC-502	Agricultural Production Economics	2 (1+1)	I
2.	AEC-507	Agricultural Finance And Project Management.	3 (2+1)	II
3.	EXT-505	Capacity Development	3 (2+1)	III
		Sub Total	08 (05+3)	

Supportive Courses (06 Credits)

Sl.No.	Course Code	Course Title	Credits	Semester
1.	STAT-511	Experimental Design.	3 (2+1)	II
2.	STAT-502	Statistical methods for applied/social sciences	3(2+1)	I
3.		Sub Total	06 (4+2)	

Common Courses (05 Credits)

Sl. No.	Course Code	Course Title	Credits	Department	Semester
1.	PGS-501	Library And Information Services	1(0+1)	Library	I
2.	PGS-502	Technical Writing and Communications Skill	1(0+1)	Ag. Extension	I
3.	PGS-503	Intellectual Property and Its Management in Agriculture	1(0+1)	GPB	II
4.	PGS-504	Basic Concept in Laboratory Techniques	1(0+1)	SCA	II
5.	PGS-505	Agriculture Research, Research Ethics and Rural Development Programmes	1(0+1)	Agronomy	III
		SubTotal	5(0+5)		
	AHD-591	Seminar	1(0+1)	-----	IV
	AHD-599	Research	30(0+30)	-----	IV
		SubTotal	31 (0+31)		
		Grand Total	70		

Semester wise Course Distribution to be offered in M.Sc. (Ag.)

Semester- I

AHD-507 MARKET MILK

2(1+1)

Theory:

Unit I : (6 Lectures)

Dairy industry: Status of dairy industry in India, Operation Flood programme. Technology Mission on dairying. National milk grid. Marketing federation, their concepts, achievements, limitations and impact on the dairy industry in India. Milk production trends and Dairy development through successive National plans. Recent policy changes to Dairy Sector (MMPO, GATT) and their impact on dairy industry in the country.

Unit II : (4 Lectures)

Processing: Importance of various milks in milk processing. Impact of processing on major and minor constituents of milk. Methods of milk Procurements, payments, quality assessment, handling and transportation of milk to processing dairies.

Unit III : (4 Lectures)

Milk preservation : methods of chilling milk, centrifugal separation, clarification and bactofugation and factors affecting their efficiency. Automatic desludging separators and clarifiers. Homogenization process and its significance in Dairy processing, theories of Homogenization and factors affecting it.

Unit VI : (2 Lectures)

Thermal processing of milk : Principles and methods of thermization, pasteurization and sterilization.

Unit V : (2 Lectures)

Special milks : Principles of production, processing and marketing of toned, double toned, reconstituted and recombined, sterilized flavoured and filled milk.

PRACTICAL: (16 Lectures)

Assembling and disassembling of cream separator and separation of milk. Study of parts of LT LT and HTST pasteurizers and preparation of reports. Preparation of special milks like toned milk, double toned milk, chocolate milk, sterilized milk, flavoured and filled milk. Visit to milk plants and Milk products factories and submission of the report.

RESOURCES:

1. Aneja, R.P., Mathur, B.N., Chandan, R. C., and Banerjee, A.K. (2002). *Technology of Indian dairy products. A Dairy India Publication.*
2. Goyal, M.R., Kumar, A. and Gupta, A.K. (2018). *Novel Dairy Processing Technologies: Techniques, Management, and Energy Conservation. CRC Press.*
3. Puniya AK (2015) *Fermented Milk and Dairy Products; CRC Press/ Taylor and Francis (ISBN 9781466577978).*
4. Shrott, C., and O'Brien (2003). *Handbook of Functional Dairy Products. CRC Press.*
5. TetraPak Dairy Processing Handbook (2015). www.dairyprocessinghandbook.com.

WEBSITES

Indian Dairy Product Market – Indian Council of Food and Agriculture
https://icfa.org.in/assets/doc/reports/Indian_Dairy_Product_Market.pdf Mechanized production of Indian Dairy Products- AMEFT <https://download.ameft.com/MechanisedProduction.pdf>

Indian Dairy Industry – Aavin- <https://aavinmilk.com/dairyprofile.html> Present Status of Traditional Dairy Products – Technische – TIB

<https://www.tib.eu/en/search/id/.../Present-Status-of-Traditional-Dairy-Products/>

Theory:**UNIT I (7 Lectures)**

Indigenous milk products: Significance and role of indigenous dairy products in Indian dairy industry and economy. Characteristics and composition of various indigenous products, their prospects and constraints. Status of organized and unorganized sectors in the manufacture of these products.

UNIT II (4 Lectures)

Methods of production, physical-chemical changes during manufacture, quality attributes shelf life, preservation, packaging and latest processing innovation of khoa, chhena and paneer.

UNIT III (8 Lectures)

Fat-rich Dairy products: Basic principles of processing and quality, aspect of different cream-table half and half, sterilized and high fat cream. Quality aspect and shelf –life .Manufacture and use of cream powders .Basic principles manufacturing process fat losses, constructional and operational features of butter making equipments. Overrun in butter quality, storage and packaging of table butter, shelf-life defects and remedies.

UNIT IV (6 Lectures)

Recent concept in processing, storage, utilization and economy in manufacture of fat rich products. Manufacture packaging storage and utilization of butter powder and butter oil. Low fat spreads, status of Ghee in India. Methods of Ghee making. Innovation in Ghee production, procedure, packaging, preservation, composition, changes during manufacture, shelf-life and defects in Ghee .

UNIT V (6 Lectures)

Frozen milk products: definition, classification composition of ice-cream and other frozen desserts, status, trends and projection for frozen milk products industry in India. Role of milk constituents, other ingredients, process steps, packaging and storage on ice-cream quality. Technological aspect of ice-cream manufacture.

UNIT VI (5 Lectures)

Recent advances in ice-cream industry and their impacts. Technology for preparation of dried ice-cream mix. Indigenous frozen desserts- Kulfi Malai ka Braf, filled and imitation ice-cream, their production and quality.

Practical: (17 Classes)

Preparation of Khoa, chhena and paneer and their judging for market quality. Cream separation, cleaning and sterilization of cream separators. Preparation of Ghee and its judging. Preparation of ice cream and kulfi and their judging. Preparation of production reports of various milk products.

RESOURCES:

1. Barbosa-CA, G.V., Fontana Jr, A. J., Schmidt, S.J., and Labuza, T.P. (Eds.). (2008). *Water Activity in Foods: Fundamentals and Applications* (Vol. 13). John Wiley and Sons.
2. Britz, T., and Robinson, R.K. (Eds.). (2008). *Advanced Dairy Science and Technology*. John Wiley and Sons.
3. Chandan, R.C., and Kilara, A. (2ndEdn.) (2015). Dairy-based Ingredients. In: *Dairy Processing and Quality Assurance*.Wiley-Blackwell.
4. Chandan, R.C., Kilara, A., and Shah, N.P. (Eds.). (2015). *Dairy Processing and quality Assurance*. 2ndedn, Wiley-Blackwell, pp. 1-696.
5. Dekker, M. Benefits and potential risks of the lacto-peroxide system of raw milk preservation. www.fao.org/docrep/fao/009/a0729e/a0729e00.htm
6. Figura, L., and Teixeira, A.A. (2007). *Food physics: Physical properties-measurement and applications*. Springer Science and Business Media.
7. Goyal, M.R., Kumar, A., and Gupta, A.K. (Eds.). (2018). *Novel Dairy Processing Technologies: Techniques, Management, and Energy Conservation*. CRC Press.
8. Heldman, D.R. (2011). *Food preservation process design*. Academic Press.

Semester- II

AHD-509

DAIRY TECHNOLOGY-II

3(2+1)

Theory:

UNIT I (8 Lectures)

Cheese and fermented milk products: Technology of cheese, status and scope of cheese in dairy industry. Definition, classification and standards of cheese. Milk in relation to modern cheese making process. Treatment of cheese manufacture and their consequences. Manufacture of cheddar, Gouda, Mozzarella, Swiss, cottage and Roquefort cheese.

UNIT II (11 Lectures)

Role of starter culture in cheese quality. Status of calf and microbial rennet for cheese manufacture, yield optimization. Physical chemical changes during cheese ripening. Manufacture of process cheese, and cheese spreads: Mechanization of cheese making process. Modern concepts in accelerating cheese ripening. Packaging, storage and defects of cheese. Manufacturing, storage and packaging of Dahi, Yoghurt, Shrikhand, Lassi, Misti Dahi, Kefir acidophilus and bifido milk.

UNIT III (8 Lectures)

Concentrated and Dried milk products: Newer concept in milk quality in relation to processing and manufacture of Concentrated and Dried milk products. Principles and methods of manufacture, packaging and storage defects in SCM, EM and UHT sterilized concentrated milk.

UNIT IV (4 Lectures)

RSCM, REM and dried milks-WMP, SMP and instant milk powder. Special problems in handling buffalo milk for manufacture of concentrated and dried milk and infant milk foods.

UNIT V (5 Lectures)

Utilization of milk-by products: Status availability and utilization of dairy by-products. Associated economic and pollution problems. Manufacture of casein whey protein concentrate and whey beverages. Use of buffer milk.

Practical: (17 Classes)

Manufacture of cheddar and cottage cheese and their judging for market quality. Manufacture of Dahi, Yoghurt, Shrikhand, Lassi, Misti Dahi, and judging for their market quality. General study of evaporators. Manufacture of various types of casein. Preparation of whey drinks.

RESOURCES:

1. Aneja, R.P., Mathur, B.N., Chandan, R. C., and Banerjee, A.K. (2002). *Technology of Indian dairy products*. A Dairy India Publication.
2. Goyal, M.R., Kumar, A. and Gupta, A.K. (2018). *Novel Dairy Processing Technologies: Techniques, Management, and Energy Conservation*. CRC Press.
3. Puniya AK (2015) *Fermented Milk and Dairy Products*; CRC Press/ Taylor and Francis (ISBN 9781466577978)
4. Shrott, C., and O'Brien (2003). *Handbook of Functional Dairy Products*. CRC Press
5. TetraPak Dairy Processing Handbook (2015). www.dairyprocessinghandbook.com.
6. Johnson, M.E., Kapoor, R., McMahon, D. J., McCoy, D. R., and Narasimmon, R.G. (2009). Reduction of sodium and fat levels in natural and processed cheeses: Scientific and technological aspects. *Comprehensive Reviews in Food Science and Food Safety*, 8(3), 252-268.
7. Lucey, J.A., and Singh, H. (1997). Formation and physical properties of acid milk gels: a review. *Food Research International*, 30(7), 529-542.
8. Mc Sweeney, P.L.H. (2004). Biochemistry of cheese ripening. *International Journal of Dairy Technology*, 57(2-3), 127-144.
9. Mc Sweeney, P.L.H., Fox, P.F., Cotter, P.D., and Everett, D.W. (Eds.) (2017). *Cheese: Chemistry, physics and microbiology*, 4th Edn, Vol. 1, Academic Press.
10. Jana A.H., and Tagalpallewar, G.P. (2017) Functional properties of Mozzarella cheese for its end use application – A Review. *Journal of Food Science and Technology*, 54(12), 3766-3778.

Theory:**UNIT I (8 Lectures)**

Chemistry of milk constituents. Milk Lipids: Chemistry of milk constituents, Milk lipids: Various milk lipids and their composition, factors affecting, composition of butter fat quality, butter fat in terms of its physico-chemical constituents; deterioration of butter fat, oxidation and development of free fatty acids, fishiness and ketonic; rancidity, phospholipids and their composition.

UNIT II (4 Lectures)

Lactose: general physical and chemical properties of lactose, hydrolysis of lactose, fermentation of lactose.

UNIT III (6 Lectures)

Milk protein: Composition and general properties and classification of milk proteins, amino acid, composition of casein lactalbumin and lactoglobulin and their general properties.

UNIT IV (6 Lectures)

Inorganic constituents of milk; composition of ash of milk, major, minor and trace elements. Factors associated with variation in salt composition. Salt balance and its importance in processing of milk.

UNIT V (8 Lectures)

Milk vitamins and Enzymes. Fat and water soluble vitamins in milk their level in milk and milk products and their biological significance. Milk enzymes and their importance in relation to various milk constituents.

UNIT VI (4 Lectures)

Chemistry of milk products. Composition and physical and chemical changes during manufacture and storage of important milk products, cream, dahi, butter, renovated butter and Ghee.

Practical: (17 Classes)

Specific gravity of milk by lactometer. Determination of freezing point depression. Determination of fat by gravimetric and volumetric methods in milk and milk products. Estimation of lactose by iodimetric and Fehling's solution methods in milk and milk products. Determination of chloride, total solids, total ash, calcium, phosphorus magnesium in milk and milk products. Detection of common adulteration in Milk and Ghee.

REOURCES:

1. Mathur M., Datta Roy D and Dinakar P. 1999. *Text Book of Dairy Chemistry*. ICAR.
2. Robert G Jensen 1991. *Handbook of Milk Composition*. Academic Press.
3. Wong NP, Jenness R, Keeney M and Elmer HM. 1988 *Fundamental of Dairy Chemistry*. 3rd Ed. Van Nostrand Reinhold Co.
4. Fox PF, Uniacke-Lowe T, McSweeney PLH and O'Mahony JA 2015. *Dairy Chemistry and Biochemistry*. Springer International Publishing-Switzerland.
5. McSweeney PLH, O'Mahony and James A. 2013. *Advanced Dairy Chemistry Volume 1A: Proteins: Applied Aspects*. Springer-Verlag, New York.
6. McSweeney PLH, O'Mahony and James A. 2016. *Advanced Dairy Chemistry Volume 1B: Proteins: Applied Aspects*. Springer-Verlag, New York.
7. Boland, M., and Singh, H. (Eds.). (2019). *Milk proteins: from expression to food*. Academic Press.

Semester- III

AHD-511

DAIRY MICROBIOLOGY

3(2+1)

Theory:

UNIT I (7 Lectures)

General Microbiology: Introduction and scope of bacteriology, principles of classification and taxonomy of micro-organisms. Bacterial cell and its gross cell structure, principles of bacterial nutrition.

UNIT II (7 Lectures)

Nutritional groups of bacteria. Principles of intermediary metabolism, Growth phases factors affecting growth of bacteria. Microbiology of fluid milk; micro flora present in raw milk. Clean milk production.

UNIT III (7 Lectures)

Mastitis milk; pathogen in raw and their control. Bacteriological aspects of boiling, pasteurization, sterilization UHT and Bactofugation of milk; Heat resistant organisms in milk and their role in spoilage:

UNIT IV (7 Lectures)

Microbiology of milk products: Microbiology of butter, ice-cream, concentrated milks and evaporated milk), milk powder and cheese. Fermented milks and Indian dairy products (like khoa, Burfi, peda, chhana, paneer etc.)

UNIT V (8 Lectures)

Microbiology of starter culture: Bacteriology of starter culture, single and multiple strain culture, trend in the use of starters, propagation, production and preservation of lactic cultures by various methods including freeze drying, judging and activity rating of cultures.

Practical: (17 Classes)

General familiarities with dairy bacteriology laboratory equipments. Cleaning and sterilization of laboratory glass ware. Microscopic, its construction, function of different parts, use and care. Preparation of straining solutions and other reagents needed in microbiological work. **Staining methods:** Simple, Gram's spore and acid fast staining. Preparation of common selected media and dilution banks. Sampling of milk for bacteriological examination. Enumeration of no. of bacteria in milk and milk products as cream, butter, khoa, chhana, and ice-cream by S.P.C and D.M.C and judging bacteriological quality by dye-reduction test, presumptive coli form test enumeration coli form, yeasts yeasts and moulds. Enumeration of psychrophilic, thermophilic, thermoduric, lipolytic, proteolytic and enteric pathogenic bacteria in milk and milk products isolation and identification of lactic acid bacteria from milk and dahi and maintenance of pure culture.

RESOURCES:

1. Prajapati, J. B. and Behare, P. V. (2018). Textbook of Dairy Microbiology: Published by Directorate of Knowledge Management in Agriculture, ICAR, ISBN: 978-81-7164-182-6.
2. Ray B. 2003. Fundamental Food Microbiology. CRC Press.
3. Ramesh C. Ray, Montet Didier. 2014. Microorganisms and Fermentation of Traditional Foods. CRC Press, U.S.A.
4. Neusely da Silva, Marta HirotoTaniwaki, Valéria Christina Junqueira, NelianeSilveira, Maristela da Silva do Nascimento, Renato AbeilarRomeiro Gomes. 2012. Microbiological Examination Methods of Food and Water: A Laboratory Manual. CRC Press, USA.
5. PhotisPapademas. 2014. Dairy Microbiology: A Practical Approach. CRC Press.
6. Osman Erkmén, T. FarukBozoglu (2016) Food Microbiology: Principles into Practice, 2 Volume Set. Wiley Publishing.
7. Barbaros Ozer, GülsünAkdemir-Evrendilek (2014) Dairy Microbiology and Biochemistry: Recent Developments. CRC Press.
8. Robert W. Hutkins (2019). Microbiology and Technology of Fermented Foods, 2nd Ed, Wiley Blackwell, New Jersey, USA

AHD-512

QUALITY CONTROL OF MILK & MILK PRODUCTS

3(2+1)

Theory:

UNIT I (12 Lectures)

Legal standard for market milk and other designated milk. Procedure of sampling, Examination and testing for chemical and bacteriological qualities.

UNIT II (10 Lectures)

LP System and its use in preservation of milk quality control of ghee and its grading under Agmark, PFA and BIS. Legal aspects of various indigenous milk products.

UNIT III (8 Lectures)

Milk preservatives and their detection. Adulterants of milk and milk products and their detection.

UNIT IV (6 Lectures)

Rapid platform tests and tests for detection and control of bovine mastitis.

Practical: (17 Classes)

Analysis of milk for chemical and bacteriological quality at various stages of production, processing and handling. Assessment of the contamination of handling equipments. Detection of adulteration of milk and milk products with various adulterants including Urea. Detection of preservatives in milk and milk products.

AHD: 513

**RHEOLOGY, PACKAGING OF MILK & MILK PRODUCTS AND DAIRY
PLANT MANAGEMENT**

3(2+1)

Theory:

UNIT I (8 Lectures)

Rheology of Dairy Food: Introduction to rheology in foods, physical consideration in the study of food; its importance and practical application in selected dairy products. Type of texture in food rheological determination in different food stuffs hydrochlorides, and influence of food additives (stabilizer+ emulsifiers) on rheology of different food products.

UNIT II (6 Lectures)

Status of current packaging: Critical review of the existing knowledge and identification of gaps and problems in current packaging of dairy products. Adhesive, graphics and labeling used in food packaging.

UNIT III (7 Lectures)

Protective packaging of food: packaging of food products sensitive to oxygen, light, moisture and insect resistant packaging, retention of volatile flavors in food through packaging and special problems in canned foods. Packaging of dairy products like Fluid milk, cream, butter, cheese, Indian milk products, dried and frozen dairy products.

UNIT IV (5 Lectures)

Dairy plant management: Brief outlines of organizing, developing and financing a dairy scheme, factors determining as which product to manufacture. Method of pricing and payments. Programming raw material supplies, spare parts, utilities of lab and plant operations. Security of storage, plants and equipment, inventory control.

UNIT V (10 Lectures)

Maintenance of financial records, cost according personal management, contracts and sales agreement tenders. Credit and cash sales and collection. Requirements, specifications, arrangement operations and maintenance of equipments, floor space requirements, equipment layout and floor plans. General requirements of steam, refrigeration and water. Products losses and their control in Dairy plants Waste conservation and methods and cost of treatment. Laws affecting dairy industry insurance of plants and personal and various tax structure applied to dairy industry.

Practical: (17 Classes)

Study of instruments commonly used in dairy rheology. Assessment of microbiological quality of various dairy products. Collection of different types of packaging used in the packaging of various milk products. Preparation of Dairy schemes. Calculations on economy of machines used in dairy plant. Assembling and disassembling of Dairy plant equipments. Visit to dairy plants and factories and submission of visit reports.

RESOURCES:

1. Ahmed, J., Ptaszek, P., and Basu, S. (Eds.). (2016). *Advances in Food Rheology and its Applications*. Amsterdam: Woodhead Publishing.
2. Barnes, H. A., Hutton, J. F., and Walters, K. (1989). *An introduction to rheology*.
3. Elsevier Pub.
4. Bourne, M. (2002). *Food texture and viscosity: Concept and Measurement*. London: Elsevier Pub.
5. Irgens, F. (2014). *Rheology and Non-Newtonian Fluids*. New York: Springer International Publishing.
6. Malkin, A.Y., and Isayev, A.I. (2017). *Rheology: Concepts, methods, and applications*. Toronto: ChemTec Publishing.
7. Mezger, T.G. (2006). *The Rheology Handbook: For Users of Rotational and Oscillatory Rheometers*. Hannover: Vincentz Network GmbH and Co KG.
8. Mohsenin, N.N. (1970). Physical properties of plant and animal materials. Vol. 1. Structure, physical characteristics and mechanical properties. New York: Gordon and Breach Science Publishers.
9. Norton, I.T., Spyropoulos, F., and Cox, P. (Eds.). (2010). *Practical Food Rheology: An Interpretive Approach*. John Wiley and Sons.
10. Rao, M.A. (2013). *Rheology of fluid, semisolid and solid foods: Principles and applications*. New York: Springer Science and Business Media.
11. Sherman, P. (1979). *Food texture and rheology*. London: Academic press.

RESOURCES:

1. Ahmed, J., Ptaszek, P., and Basu, S. (Eds.). (2016). *Advances in Food Rheology and its Applications*. Amsterdam: Woodhead Publishing.
2. Barnes, H. A., Hutton, J. F., and Walters, K. (1989). *An introduction to rheology*. Elsevier Pub.
3. Bourne, M. (2002). *Food texture and viscosity: Concept and Measurement*. London: Elsevier Pub.
4. Irgens, F. (2014). *Rheology and Non-Newtonian Fluids*. New York: Springer International Publishing.
5. Malkin, A.Y., and Isayev, A.I. (2017). *Rheology: Concepts, methods, and applications*. Toronto: ChemTec Publishing.
6. Mezger, T.G. (2006). *The Rheology Handbook: For Users of Rotational and Oscillatory Rheometers*. Hannover: Vincentz Network GmbH and Co KG.
7. Mohsenin, N.N. (1970). Physical properties of plant and animal materials. Vol. 1. Structure, physical characteristics and mechanical properties. New York: Gordon and Breach Science Publishers.
8. Norton, I.T., Spyropoulos, F., and Cox, P. (Eds.). (2010). *Practical Food Rheology: An*

AHD-607**CONCENTRATED AND DRIED MILK PRODUCTS****3(2+1)****THEORY:****UNIT I (10 Lectures)**

Organization of milk condensory and dried milk factory. Selection of milk for condensing and drying.

UNIT II (8 Lectures)

Manufacturing, packing, storage and marketing of sweetened condensed milk.

UNIT III (10 Lectures)

Manufacturing, packing, storage and marketing of dried milk, baby milk formula, dried ice cream mix and lactose.

UNIT IV (8 Lectures)

Freeze drying of milk. Preparation of Khoa, Rabri etc.

PRACTICAL: (18 Lectures)

Layout of buildings and arrangement of equipment's for setting up of milk for condensory and dried milk factory. Estimation of requirements for setting up milk condensory and dried milk factory, handling various quantities of milk. Freeze drying of Milk. Preparation of Khoa and Rabri. Marketing report related to sale of concentrated and dried milk.

RESOURCES:

1. Aneja, R. P., Mathur, B. N., Chandan, R. C. and Banerjee, A. K. 2002. *Technology of Indian Milk Products*. Dairy India Publications, New Delhi. ISBN-13: 978-8190160308.
2. Askin, R. G. and Standridge, C. R. 1993. *Modeling and Analysis of Manufacturing System*. John Wiley and Sons. ISBN-13: 978-0471514183.
3. Gupta, V. 2018. *Dairy India*. 7th Edition. Dairy India Year Book. ISBN-13: 978-8190160339.
4. Haik, Y., Sivaloganathan, S. and Shahin, M. T. 2009. *Engineering Design Process*. 3rd Edition, Cengage Learning. ISBN-13: 978-8131510599.
5. Kessler, H. G. 1981. *Food Engineering and Dairy Technology*. Verlag A. Kessler.
6. Kutz, M. 2019. *Handbook of Farm, Dairy and Food Machinery Engineering*. 3rd Edition, Academic Press Inc. ISBN-13: 978-0128148037.
7. Sukumar De. 2001. *Outlines of Dairy Technology*, 1st Edition, Oxford University Press. ISBN-13: 978-0195611946.

SEMESTR-II

AHD-608

UTILIZATION AND DISPOSAL OF DAIRY WASTES

2(1+1)

THEORY:

UNIT I (6 Lectures)

Utilization of buttermilk and other dairy by-products.

UNIT II (8 Lectures)

Use of whey in industrial fermentation. Synthesis of vitamins and yeast production.

UNIT III V (4 Lectures)

A general treatment and methods of disposal of dairy effluents.

PRACTICAL: (18 Lectures)

Preparation of buttermilk concentrate. Preparation of whey drinks, e.g., Krishi Cola etc. Fermentation of whey for lactic acid. Treatment of dairy affluent before disposal.

RESOURCES:

1. Cichocki, A., Ansari, H. A., Rusinkiewicz, M. and Woelk, D. 2012. Workflow and Process Automation: Concepts and Technology (Vol. 432). Springer Science and Business Media. ISBN-13: 978-1461375999.
2. Groover, M. P. 2016. Automation, Production Systems and Computer-integrated Manufacturing. 4th Edition, Prentice Hall Press. ISBN-13: 978-9332572492.
3. Hollender, M. 2012. Collaborative Process Automation Systems. ISA.
4. Kant, K. 2010. Computer-based Industrial Control. 2nd Edition, PHI Learning Pvt. Ltd. ISBN-13: 978-8120339880.

AHD-609

DAIRY UTENSIL AND MACHINERY

2(2+0)

THEORY:

UNIT I (16 Lectures)

Metals and materials used in the dairy utensils and machinery.

UNIT II (20 Lectures)

Constructional details of different utensils and machinery used for handling and processing of milk and milk products.

RESOURCES:

1. Ahmed J. and Shafi-ur-Rahman, M. 2012. Handbook of Food Process Design. Wiley-Blackwell Publishing Ltd. ISBN-13: 978-1444330113.
2. Chen X. D. and Mujumdar A. S. 2008. Drying Technologies in Food Processing, Blackwell Publishing Ltd. ISBN-13: 978-8126549788.
3. Das, H. 2008. Food Processing Operation and Analysis. Asian Books. ISBN-13: 978-8186299784.
4. Geankoplis C. J., Hersel, A.A. and Lepek D.H. 2018. Transport Processes and Separation Process Principles, 5th Edition, Pearson. ISBN-13: 978-0134181028.
5. Saravacos, G. D. and Kostaropoulos, A. E. 2016. Handbook of Food Processing Equipment, 2nd Edition, Springer International. ISBN-13: 978-3319250182.
6. Valentas, K.J., Rotstein, E. and Paul Singh R. 1997. Handbook of Food Engineering Practice. CRC Press. ISBN-13: 978-0849386947.
7. Zeki Berk. 2018. Food Process Engineering and Technology, 3rd Edition, Academic Press. ISBN: 9780128120187.
8. Chaudhary, C., Rai, D. and Kumar, D. (Eds.). (2018). *Advances in Food Processing Techniques*. Kalyani Publishers

SEMESTR-III

AHD-610

MILK AND MILK PRODUCT BORNE DISEASES

2(2+0)

THEORY:

UNIT I (6 Lectures)

Pathogens in milk and dairy products.

UNIT II (12 Lectures)

Diseases transmitted from milk to man and from animal to man through dairy products.

UNIT III (18 Lectures)

Milk and public health. Dairy food borne infections and intoxications. Isolation and identification in milk products.

RESOURCES:

1. Prajapati, J. B. and Behare, P. V. (2018). Textbook of Dairy Microbiology: Published by Directorate of Knowledge Management in Agriculture, ICAR, ISBN: 978-81-7164-182-6.
2. Ray B. 2003. Fundamental Food Microbiology. CRC Press.
3. Ramesh C. Ray, Montet Didier. 2014. Microorganisms and Fermentation of Traditional Foods. CRC Press, U.S.A.
4. Neusely da Silva, Marta Hiroto, Taniwaki, Valéria Christina Junqueira, Neliane Silveira, Maristela da Silva do Nascimento, Renato Abeilar Romeiro Gomes. 2012. Microbiological Examination Methods of Food and Water: A Laboratory Manual. CRC Press, USA.
5. Photis Papademas. 2014. Dairy Microbiology: A Practical Approach. CRC Press.
6. Osman Erkmen, T. Faruk Bozoglu (2016) Food Microbiology: Principles into Practice, 2 Volume Set. Wiley Publishing
7. Barbaros Ozer, Gülsün Akdemir-Evrendilek (2014) Dairy Microbiology and Biochemistry: Recent Developments. CRC Press.

Department of Soil Conservation and Water Management

M.Sc. (Ag.) Soil Conservation and Water Management

Course code	Course title	Credit hours	Semester
(A)	Major courses	20	
SCW-501	Soils and soil conservation	3(2+1)	I
SCW-502	Soil and water conservation engineering	3(2+1)	I
SCW-503	Silviculture and Conservation Forestry	3(2+1)	II
SCW-504	Conservation irrigation and drainage	2(1+1)	II
SCW-505	Water Management and conservation farming	2(1+1)	II
SCW-506	Watershed and waste land management	2(1+1)	III
SCW-507	Chemistry of problem soils and their management	3(2+1)	III
SCW-508	Agrostology and agroforestry	2(1+1)	IV
(B)	Minor courses	08	
SOIL-501	Soil physics	3(2+1)	I
SOIL-508	Soil, water and air pollution	3(2+1)	III
AGRON-505	Conservation agriculture	2(1+1)	II
(C)	Supporting courses	06	
STAT-511	Experimental design	3(2+1)	II
AGRON-504	Principles and practice of water management	3(2+1)	II
(D)	Common courses	05	
PGS-501	Library and Information Services	1(0+1)	I
PGS-502	Technical Writing and Communications Skill	1(0+1)	I
PGS-503	Intellectual Property and Its Management in Agriculture	1(0+1)	II
PGS-504	Basic Concept in Laboratory Techniques	1(0+1)	II
PGS-505	Agriculture Research, Research Ethics and Rural Development Programmes	1(0+1)	III
SCW-550	Masters seminar	1(1+0)	II
SCW-560	Masters research	30	I-IV
	Total	70	

SCW-501

SOILS AND SOIL CONSERVATION

3(+1)

Theory:

- Unit I:** Modern concept of soil rock and minerals;
Unit II: Weathering of rocks and weathering indices;
Unit III: Factors of soil formation; Soil forming processes; evolution of soil body in nature;
Unit IV: Soil profile and concept of soil Pedon;
Unit V: Soil classification, U.S. Soil Taxonomy- its advantages and limitations.
Unit VI: Soils of India and Uttar Pradesh-their distribution and important physical and chemical characteristics.
Unit VII: Soil Survey- Objectives, types of soil survey, land use capability classification.
Unit VIII: Soil properties in relation to soil erodibility.
Practical: Study of soil profile; Preparation of land use capability map. Determination of particle size distribution, organic carbon, pH, electrical conductivity, available N,P and K in soil. Wet aggregate analysis of soils; erodibility indices-dispersion ratio and erosion ratio.

Suggested Readings

- Brady, NC Nature and properties of soil. S.Chand & Co. Pvt Ltd
- D. K. Das 2014Introduction of Soil Science Kalyani publishers
- Etela Styanarayan Soil Science Treatise
- Fundamentals of Soil Science by Indian Society of Soil Science
- Sharma, N.L. and Kumar, Vipin Soil Physics, Soil water conservation & Survey Rama Publishing House Meerut
- Soil Series criteria and norms, NBSS&LUP, Buletin-36.
- Micro-morphology of soils of India, NBSS&LUP, Buletin-34.
- M.M. Rai Principles of Soil Science
- Indian Society of Soil Science. 2002. *Fundamentals of Soil Science*. ISSS, New Delhi
- Buol EW, Hole ED, MacCracken RJ & Southard RJ. 1997. *Soil Genesis and Classification*. 4th Ed. Panima Publ.
- Dixon JB & 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 & Mattox RB. 1960. *Elements of Crystallography and Mineralogy*. Oxford & IBH.
- Wilding LP & Smeck NE. 1983. *Pedogenesis and Soil Taxonomy: II. The Soil Orders*. Elsevier.
- Wilding NE & Holl GF. (Eds.). 1983. *Pedogenesis and Soil Taxonomy*. I. *Concept an*.

SCW-502

SOILS AND WATER CONSERVATION ENGINEERING

3(+1)

Theory:

- Unit I:** Hydrologic processes- Precipitation, infiltration, evaporation, evapo-transpiration, runoff etc.
Unit II: Stream gauging-site selection, measurement of stream stage, measurement of stream discharge, rating curves. Hydrograph-segments components, factors affecting shape of hydrograph, unit hydrograph.
Unit III: Soil erosion, estimation of soil erosion, affects of erosion on natural resources public work and other economic aspects.
Unit IV: Sedimentation- sources, factors affecting sedimentation, sediment sampling measurements and control measures.
Unit V: Planning, design and construction of bunds and terraces.
Unit VI: Vegetative waterways and diversion ditches.
Unit VII: Gully control-vegetative measures, temporary check dams, permanent structures and their design, ponds and reservoirs- design and construction.
Unit VIII: Land clearing, land leveling; estimation of earthwork in land leveling; land development equipments.

Practical: Surveying and leveling. Estimation of precipitation, runoff and soil loss. Design and layout of contour bunds, terraces, waterways and diversion ditches. Visit to soil conservation centers and projects.

Suggested Readings

- Suresh R. Soil and Water Conservation Engineering
- Punamia V.C. (1989). Surveying volume-5th, Laxmi Publication.

SCW-503 SILVICULTURE AND CONSERVATION FORESTRY 3(2+1)

Theory:

Unit I: Forestry needs of the country; Extent of forests in India and Uttar Pradesh;

Unit II: Forest policy; Role of forest in national economy; Forest influences- productive, protective and bio-aesthetic.

Unit III: Locality factors;

Unit IV: Plant succession;

Unit I: Broad forest types of India and Uttar Pradesh;

Unit V: Natural and artificial regeneration of forest, silvicultural systems;

Unit VI: Tending operations; Participatory forest management, Joint forest management.

Unit VII: Soil conservation practices to support afforestation of problem-sites-ravines and gullied land, waterlogged areas, saline and alkali soils, steep hill slopes, landslides and slips and stream bank control;

Unit VIII: Shelter belt and wind breaks; Sand dune fixation; Choice of species for different problem site.

Practical: Nursery techniques; Soil working techniques; land scape planning; Identification of important tree species; Measurement of height and diameter to assess the plant growth; Silvicultural characteristics of tree species- *Acacia nilotica*, *Acacia catechu*, *Albizia sp.*, *Adina cordifolia*, *Azadirachta indica*, *Cassia sp.*, *Dalbergia sissoo*, *Eucalyptus sp.*, *Dandrocalamus strictus*, *Holptelia integrifolia*, *Popular sp.*, *Tectona grandis*, *Leucaena leucocephala*, *Prosopis juliflora*, *Pongamiapinnata*. Visit of Institutes related to Forestry and Soil Conservation.

Suggested Readings

- Dwivedi A.P. Agroforestry Principles and Practices
- Antony Joseph Raj and S.B. Lal Agroforestry Principles and Practices
- Social Forestry for Rural Development
- Khanna L.S. Theory and Practice of Indian Silvicultural Systems
- Kumar K Van Sanrakshan
- Partivan, KT and Dobariyal, M.J. Introduction to Forestry and agroforestry
- Desertification and its control, IARI, ICAR, New Delhi.

SCW-504: CONSERVATION IRRIGATION AND DRAINAGE 2(1+1)

Theory:

Unit I: Irrigation: Water resources and irrigation development of India.

Unit II: Water conveyance and control-design of pen channels, lining of watercourses and field channels,

Unit III: Measurement of irrigation water-velocity-area method, water meters, weirs, Parshall flume, orifices etc.

Unit IV: Water application methods and their design, comparative efficiency and economics of different methods of irrigation.

Unit V: Tube wells, hydraulics of wells, construction of tube wells, well development, common well troubles

Unit VI: Pumps-construction, operation maintenance, common troubles and remedies of centrifugal pumps,

- Unit VII:** Vertical turbine pumps submersible pumps, propeller and mixed flow pumps, jet pumps, air lift pumps hydraulic ram.
- Unit VIII:** Drainage; Causes of water logging, benefits of drainage, drainage co-efficient,, surface drainage methods design of drainage ditch sub-surface drainage methods, design of pipe drains. Drainage in relation to salinity control.
- Practical:** Measurement of irrigation water, study of tube wells and pumps, design and layout of irrigation and drainage systems.

Suggested Readings

- Samra J.S., Sarda V.N. and Sikka A.K. (1996). Water harvesting and recycling –Indian experiences. IISWC, ICAR.
- Tyagi P.C., Joshi V.P., Mohan S.C., Singh P.N. Rainfed and irrigated agriculture for sustainable productivity, IISWC, ICAR.
- Michael, AM, Irrigation-Theory and practice Vikash Publishing House Pvt Ltd.
- Praharaj C.S., Singh U., Verma P., Kumar N., Hazara K.K., Nath C.P., Dev M.M. and Singh S.S. (2017). Training manual on scaling water productivity and resource conservation in upland rice crop ensuring per drop more crop. IIPR, ICAR Publication.

SCW-505 WATER MANAGEMENT AND CONSERVATION FARMING 2(1+1)

Theory:

Water management:

- Unit I:** Water requirement, factors affecting water requirement of crops, water use and water use efficiency; Irrigation scheduling-techniques, irrigation requirement of different crops and quality of water for irrigation;
- Unit II:** Evaporation and Evapo-transpiration, techniques of reducing ET losses and factors affecting ET.
- Unit III:** Conservation farming: Advances in dryland Agriculture-Rainfed farming and dry land farming, characteristics of dry land farming practices, water harvesting techniques.
- Unit IV:** Soil and water conservation techniques in dry land areas-vegetative cover, conservation tillage, mulching, cover crops, alley cropping, vegetative barriers.
- Unit V:** *In-situ* water conservation and runoff harvesting techniques-tillage, graded border strips, inter plot and inter row water harvesting.
- Unit VI:** Soil and water conservation techniques in difficult sites-ravenous areas, stream bank control, torrent control, land slips and land slides and desert areas.
- Practical:** Determination of moisture deficit, available soil moisture, water holding capacity of soil. Determination of moisture extraction pattern. Water requirement of different crops, moisture use and water use efficiency. Measurement of ET in field conditions.

Suggested Readings

- Reddy S.R. & Reddy Principles of Agronomy
- Suraj Bhan, R.L. Karale Conservation Farming

SCW-506: WATERSHED AND WASTELAD MANAGEMENT 2(1+1)

Theory:

- Unit I:** Watershed management:Concept, need, principles and components of watershed management; Integrated watershed management; Factors affecting watershed management;
- Unit II:** Runoff and soil loss management in a watershed;
- Unit III:** Socio-economic concept of watershed-people participation in watershed management.
- Unit IV:** Application of Remote Sensing, GIS and Isotope Technology in survey and problem identification for planning and management watershed. Policy approaches and

- management plan. Problems of watershed management.
- Unit V:** Wasteland management: Definition, concept and types of degraded and wasteland. Distribution and extent of watershed in India and Uttar Pradesh; Factors responsible for land degradation;
- Unit VI:** Characteristics of different types of degraded and wasteland; Problems of degraded land in Uttar Pradesh.
- Unit VII:** Appropriate techniques for management of different types of degraded and wasteland.
- Practical:** Preparation of master plan for watershed. Participatory Rural Appraisal (PRA) techniques in watershed. Watershed monitoring and evaluation. Estimation of runoff and soil loss in a Watershed area. A case study of watershed. Visit to model watersheds.

Suggested Readings

- Batt, P.N. (1979). Watershed management, IISWC, ICAR.
- Dhruva Narayan V.V. and Sastry G. Watershed Management
- Prasad R. (1988). Technology of wasteland development, associated publishing company.
- Patel AN and Singh . Principals pf Remote Sencing Scientific publisher India Jodhpur Samra J.S. and Mishra A.S. Participatory Rural Appraisal for Watershed Management
- Jat M.L., Bhakar, and S.R., Sharma, S.K. Dryland Technology
- Jat, M.L., Gill O.P. and B.S. Deora Rain Water Management

SCW-507: CHEMISTRY OF PROBLEM SOIL AND THEIR MANAGEMENT 3(2+1)

Theory:

- Unit I:** Acid soils- their origin, distribution, classification reclamation and management practices;
- Unit II:** Salt affected soils- their origin, distribution, classification reclamation and management practices
- Unit III:** Waterlogged Soils- their classification, changes in soil pH, electrical conductivity, redox potential and transformation of important plant nutrients during water logging, management of waterlogged soils for crop-production.
- Unit IV:** Fertility problems of eroded soils and their management;
- Unit V:** Quality of irrigation water and use of brackish water for crop production.
- Practical:** Determination of gypsum requirement of Sodic soils- preparation of saturation extract of soil and its analysis for cations and anions. Analysis of irrigation waters for their quality appraisal. Determination of hydraulic conductivity, bulk density, particle density and porosity of soils

Suggested Readings

- Brady, NC Nature and properties of soil. S.Chand & Co. Pvt Ltd
- D. K. Das 2014 Introduction of Soil Science Kalyani publishers
- Etela Styanarayan Soil Science Treatise
- Fundamentals of Soil Science by Indian Society of Soil Science
- Sharma, N.L. and Kumar, Vipin Soil Physics, Soil water conservation & Survey Rama Publishing House Meerut
- Soil Series criteria and norms, NBSS&LUP, Buletin-36.
- Micro-morphology of soils of India, NBSS&LUP, Buletin-34.
- M.M. Rai Principles of Soil Science
- Biswas TD & Narayanasamy G. (Eds.) 1996. *Soil Management in Relation to Land Degradation and Environment*. Bull. Indian Society of Soil Science No. 17.
- Doran JW & Jones AJ. 1996. *Methods of Assessing Soil Quality*. Soil Science Society of

- America, Spl Publ. No. 49, Madison, USA.
- Gurm Singh, Venkataramanan C, Sastry G & Joshi BP. 1990. *Manual of Soil and Water Conservation Practices*. Oxford & IBH.
 - Hudson N. 1995. *Soil Conservation*. Iowa State Univ. Press.
 - Indian Society of Soil Science 2002. *Fundamentals of Soil Science*. ISSS, New Delhi.
 - Oswal MC. 1994. *Soil Physics*. Oxford & IBH.

SCW-508

AGROFORESTRY AND AGROSTOLOGY

3(2+1)

Theory:

- Unit I :** Agroforestry, concept, need, scope, advantage and limitation of Agroforestry;
- Unit II:** Classification of Agroforestry systems Prevailing Agroforestry systems in India and Uttar Pradesh; Edaphic and climatic requirement of multipurpose tree species;
- Unit III:** Tree crop interaction, nutrient cycling, allelopathy and mycorrhiza inoculation; Non-wood forest product obtained from various agroforestry systems; shifting cultivation, Taungya cultivation,
- Unit IV:** Social and farm forestry.
- Unit V:** Agroforestry research and education in India. Agrostology-definition scope and types of grass covers, Ecological characteristics of important grass species;
- Unit VI:** Grass land and grazing land of Uttar Pradesh and India;
- Unit VII:** Establishment method of grasses; types of grazing; grasses, and legumes for special problem sites,
- Unit VIII:** Agronomy of important cultivated grasses.
- Practical:** Nursery and soil working techniques; Numerical problems on nursery size, quantity of seed and monitorial requirement in different soil working plantation; Indemnification of common NFTs, MPTs for agro-forestry; Layout and design of model Agroforestry systems. Study of morphological characteristics, Propagation techniques; cover capacity of selected grasses, identification of grasses.

Suggested Readings

- Dwivedi A.P. Agroforestry Principles and Practices
- Antony Joseph Raj and S.B. Lal Agroforestry Principles and Practices
- Social Forestry for Rural Development
- Khanna L.S. Theory and Practice of Indian Silvicultural Systems
- Kumar K Van Sanrakshan
- Partivan, KT and Dobariyal, M.J. Introduction to Forestry and agroforestry
- Desertification and its control, IARI, ICAR, New Delhi.

Department of Soil Conservation and Water Management

Ph.D. (Ag.) in Soil Conservation and Water Management

Course code	Course title	Credit hours	Semester
(A)	Major courses	12	
SCW-601	Advances in soil conservation engineering	3(2+1)	I
SCW-602	Advances in soil conservation forestry	3(2+1)	I
SCW-603	Advances in conservation farming	3(2+1)	II
SCW-604	Recent advances in soil conservation and water management	3(2+1)	III
(B)	Minor courses	06	
SOIL-601	Recent trend in soil physics	2(2+0)	I
SOIL-603	Physical chemistry of soil	2(2+0)	II
AGRON-605	Integrated farming system for sustainable agriculture	2(2+0)	III
(C)	Supporting courses	05	
STAT-604	Advanced statistical methods	3(2+1)	II
PPY-606	Global climate change and crop response	2(2+0)	II
SCW-691	Doctoral seminar	1(1+0)	II
SCW-692	Doctoral seminar	1(1+0)	III
SCW-699	Doctoral research	75	I-VI

SCW-601	ADVANCES IN SOIL CONSERVATION ENGINEERING	3(2+1)
Theory:		
Unit I:	Frequency analysis of rainfall intensity duration and frequency relationship.	
Unit II:	Estimation and measurement of stream flow rating curves. Flood routing, inflow-outflow relationship sedimentation of water storage structures.	
Unit III:	Ground water recharge, methods of ground water recharge hydraulic properties of aquifer, estimation of ground water recharge.	
Unit VI:	Rain water harvesting, Mechanical measurement of erosion control In arable and non-arable lands.	
Unit V:	Watershed management needs, objective management measures, selection of priority and planning	
Practical:	Computation and drawing of unit hydrograph Field measurement of runoff and sediment. Runoff and soil loss analysis by GIS technology. Computation of ground water recharge. Design of farm ponds, earth embankments and retaining wall.	

Suggested Readings

- Suresh R. Soil and Water Conservation Engineering
- Punamia V.C. (1989). Surveying volume-5th, Laxmi Publication.

SCW-602	ADVANCES IN SOIL CONSERVATION FORESTRY	2(2+0)
Theory:		
Unit I:	Forest resources in different regions of the world.	
Unit II:	Forest management sustained yield rotation, normal forest growing stock and its increment, yield regulations, working plan.	
Unit III:	Measurement of standing and felled trees, determination of volume, age and growth of trees and crop, enumeration surveys, volume table construction.	
Unit VI:	Scope and background of wood based industries in India.	
Unit V:	Planning for development of wood based industries.	
Unit VI:	Product and services available from forest timber, processed timber, pulp and paper.	
Unit VII:	Non-wood forests products: gum, resins, essential oil, tannin material etc. obtained from different tree species.	
Practical:	Measurement of trees and crops, enumeration surveys, suitability of timber for various purposes to forest based industries, identification of forest products.	

Suggested Readings

- Dwivedi A.P. Agroforestry Principles and Practices
- Antony Joseph Raj and S.B. Lal Agroforestry Principles and Practices
- Social Forestry for Rural Development
- Khanna L.S. Theory and Practice of Indian Silvicultural Systems
- Kumar K Van Sanrakshan
- Partivan, KT and Dobariyal, M.J. Introduction to Forestry and agroforestry
- Desertification and its control, IARI, ICAR, New Delhi.

SCW-603	ADVANCES IN CONSERVATION FARMING	3(2+1)
Theory:		
Unit I:	Changing concept of plant nutrient through crops, run-off and erosion leaching and volatilization etc. and their control.	
Unit II:	Soil hazards viz., soil sickness, toxicity, salinity, water logging, paddy, kankar, pan formation, drought etc. their causes, effects on plant growth and control through soil and crops management,	
Unit III:	Concept of minimum tillage and use of various mulches, their scope and methods.	
Unit IV:	Plant response to soil water, water requirement of crops, water use	

- efficiency, consumptive use of water.
- Unit VI:** Root distribution of crops and moisture extraction. Moisture stress in root zone and plant growth curve and yield relations.
- Unit VII:** Weather based conservation technology for potential area and conservation management in watershed area.
- Practical:** Determination of moisture, water requirement of crop, moisture stress, runoff prediction of soil loss parameters related to farming.

Suggested Readings

- Reddy S.R. & Reddy Principles of Agronomy
- Suraj Bhan, R.L. Karale Conservation Farming

SCW-604 RECENT ADVANCES IN SOIL CONSERVATION & WATER MANAGEMENT 3(2+1)

Theory:

- Unit I** Recent soil conservation and water management researches of various land resource regions and areas of India.
- Unit II:** Crop planning in relation to water supply. Farmer's response to water use management. Project planning - unit of planning, schedule of operation, economic aspect, monitoring and evaluation of scheme.
- Unit III:** Approaches to fertility management of eco-friendly crop production.
- Unit VI:** Remote sensing in crop water management and watershed development.
- Unit V:** Sustainable technologies identified for successful rainfed/dryland agriculture and alternate land use system.
- Unit VI:** Key resources and constraints and critical elements in rainfed/ dryland agriculture. Participatory approaches in watershed development.
- Practical:** Computation of crop water requirement. Map reading, selection, delineation and characterization of watershed. Watershed planning and monitoring using remote sensing and GIS. PRA technologies in watershed management.

Suggested Readings

- Khosla P.K. and Kohli R.K. Soil and Water Conservation Research in India
- Batt, P.N. (1979). Watershed management, IISWC, ICAR.
- Dhruva Narayan V.V. and Sastry G. Watershed Management
- Prasad R. (1988). Technology of wasteland development, associated publishing company.
- Patel AN and Singh . Principals pf Remote Sensing Scientific publisher India Jodhpur Samra J.S. and Mishra A.S. Participatory Rural Appraisal for Watershed Management
- Jat M.L., Bhakar, and S.R., Sharma, S.K. Dryland Technology
- Jat, M.L., Gill O.P. and B.S. Deora Rain Water Management

MBA-Agri Business Management

Report of the Sub-Committee on Agri Business Management constituted by the ICAR Broad
Subject Matter Area (BSMA) Committee for Social Sciences

Academic Regulations for the discipline of Agri Business Management

S. No.	Item	Recommendations																		
1	Mandatory	PG Regulations and syllabi should be uniform in all State Agricultural Universities (SAUs) including ICAR Deemed Universities and Central Agricultural Universities																		
2	Credit Load	Credit load should be uniform across all Programmes The proposed credit load is as follows. MBA (ABM) – 70																		
		<table border="1" style="width: 100%;"> <tr> <td>Major courses</td> <td>20</td> </tr> <tr> <td>Minor Courses</td> <td>08</td> </tr> <tr> <td>Supporting Courses</td> <td>06</td> </tr> <tr> <td>Common Courses</td> <td>05</td> </tr> <tr> <td>Seminar</td> <td>01</td> </tr> <tr> <td>Thesis/ Research</td> <td>30</td> </tr> <tr> <td>a. Summer Internship</td> <td>10 (6 credits for preparatory courses - 4 for internship)</td> </tr> <tr> <td>b. Research</td> <td>20 (10 credits for preparatory Courses + 10 Project work)</td> </tr> <tr> <td>Total Credits</td> <td>70</td> </tr> </table>	Major courses	20	Minor Courses	08	Supporting Courses	06	Common Courses	05	Seminar	01	Thesis/ Research	30	a. Summer Internship	10 (6 credits for preparatory courses - 4 for internship)	b. Research	20 (10 credits for preparatory Courses + 10 Project work)	Total Credits	70
Major courses	20																			
Minor Courses	08																			
Supporting Courses	06																			
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Seminar	01																			
Thesis/ Research	30																			
a. Summer Internship	10 (6 credits for preparatory courses - 4 for internship)																			
b. Research	20 (10 credits for preparatory Courses + 10 Project work)																			
Total Credits	70																			
4	Attendance	The minimum attendance required is 75% to be counted separately for theory and practical's.																		
5	Credit seminar	Credit seminar may be made compulsory																		
6	Submission of Synopsis	In the third semester for MBA, a colloquium is compulsory before submission of synopsis of final research project																		
7	Evaluation of project Report	MBA: one examiner. For Masters if the external examiner suggests major modifications to be made before acceptance/does not recommend the thesis for acceptance, the report shall be referred to another external examiner. If the second examiner recommends the report for its acceptance, recommendation shall be accepted, if the opinion of second examiner is also negative, the report shall not be considered for the award of the degree.																		
8	Course numbers	All series should be prefixed continuous from ABM 501.																		
9	Steps to prevent Plagiarism	The plagiarism certificate from the university may be made Mandatory to submit the report																		

SUMMARY OF THE COURSE STRUCTURE

I. Major Course: 20

Course Code	Course Title	Credit
ABM501	Principles of Management and Organizational behaviour	3 (3+0)
ABM502	Management Accounting and Control	3 (2+1)
ABM503	Applied Agribusiness Economics	2(2+0)
ABM- 504	Human Resource Management for Agricultural Organisations	2 (2+0)
ABM- 505	Production and Operations Management	2 (2+0)
ABM- 506	Agricultural and Food Marketing Management- I	2 (2+0)
ABM- 507	Agricultural and Food Marketing Management- II	2 (2+0)
ABM- 508	Agri supply chain management	2 (2+0)
ABM- 509	International trade in Agricultural Products	2 (2+0)
Total		20

II. Minor Courses: 08

Course Code	Course Title	Credits
ABM- 513	Management of Agro chemical industry	3(3+0)
ABM-514	Seed production Technology Management	3(3+0)
ABM-531	Advertising and Brand Management	1(1+0)
ABM- 535	Agri commodity Markets and Futures Trading	1(1+0)
Total		08

III. Supporting Courses: 06 Credits

Course Code	Course Title	Credit
ABM- 536	Strategic Management for Agri business Enterprises	2(2+0)
ABM- 537	Operations Management	2 (2+0)
ABM- 538	Financial Management in Agribusiness	2 (2+0)

IV. Master's Seminar: 01

Course Code	Course Title	Credit
ABM 591	Master's Seminar	01

V. Research (Summer Internship + Research Project): 30 (10+20)

A. Summer Internship/ Industrial Attachment

Course Code	Course Title	Credit
ABM 595	A. Summer Internship/ Industrial Attachment	04
Basic Courses mandatory for Summer Internship:06		
ABM 539	Communication for Management and Agri Business	3 (2+1)
ABM 540	Research Methodology for Agri Business Mgmt	3 (2+1)
Total		10

B. Research Project:20

Course Code	Course Title	Credit
ABM 599	B. Project work	10
Basic courses mandatory for Project:10		
ABM- 541	Computer Applications for Agri business	3 (2+1)
ABM542	Project management and agribusiness entrepreneurship	3

		(2+1)
ABM 543	Agribusiness environment & policy	2 (2+0)
ABM 544	Agri business laws and ethics	2 (2+0)

VI. Common Courses: 05 Credits

PGS 502*	Technical Writing and Communications Skills	1(0 +1)
PGS 503*	Intellectual Property and its management in Agriculture	1(1+0)
PGS 504	Basic Concepts in Laboratory Techniques	1(1+0)
PGS 505*	Agricultural Research, Research Ethics and Rural Development Programmes	1(1+0)
PGS 506 (e-Course)	Disaster Management	1(1+0)

*e-Course: Online/offline

MBA-AGRI-BUSINESS MANAGEMENT

Course Structure adopted by Department

FIRST SEMESTER, MBA (AGRI-BUSINESS)

CODE	Course Title	Credits
ABM 501	Principles of Management and Organizational Behaviour	3 (3+0)
ABM 502	Managerial Accounting and Control	3 (2+1)
ABM 503	Applied Agribusiness Economics	2 (2+0)
ABM 506	Agricultural and Food Marketing Management-I	2 (2+0)
ABM- 541	Computer Applications for Agri business	3(2 +1)
ABM542	Project Management and Agribusiness Entrepreneurship	3 (2+1)
ABM 543	Agribusiness Environment & Policy	2 (2+0)
PGS 503* (e-Course)	Intellectual Property and its Management in Agriculture	1 (1+0)
PGS 505*	Agricultural Research, Research ethics and Rural development program.	1 (1+0)
PGS 502*	Technical Writing and Communications skills	1 (0+1)
Sub total		21

II SEMESTER, MBA (AGRI-BUSINESS)

ABM 504	Human Resource Management for Agricultural Organizations	2(2+0)
ABM 505	Production and Operations Management	2(2+0)
ABM 507	Agricultural and Food Marketing Management- II	2 (2+0)
ABM- 513	Management of Agro Chemical Industry	3(3+0)
ABM-514	Seed Production Technology Management	3(3+0)
ABM- 538	Financial Management in Agribusiness	2 (2+0)
ABM- 508	Agri Supply Chain Management	2 (2+0)
ABM-531	Advertising and Brand Management	1(1+0)
ABM 539	Communication for Management and Agri business	3 (2+1)
Sub total		20

III SEMESTER, MBA (AGRI-BUSINESS)

ABM- 509	International trade in Agricultural Products	2 (2+0)
ABM- 535	Agri commodity Markets and Futures Trading	1(1+0)
PGS 504	Basic Concepts in Laboratory Techniques	1(1+0)
PGS-506(e-C)	Disaster Management	1(1+0)
ABM- 537	Operations management	2 (2+0)
ABM- 536	Strategic Management for Agri business Enterprises	2(2+0)
ABM 540	Research Methodology for Agri Business Mgmt	3 (2+1)

ABM 595	Summer Internship/ Industrial Attachment	04
ABM 591	Master's Seminar	01
Sub Total		17

MBA (Agri-Business) IV Semester

ABM 599	Project work	10
ABM 544	Agri business Laws and Ethics	2 (2+0)
Sub total		Total 12
Grand Total: 21+22+17+12=70		

*e- Course

DETAIL COURSES PROGRAMME: MBA (AGRI BUSINESS)

MAJOR COURSES (20 Credit)

Title: PRINCIPLES OF MANAGEMENT AND ORGANIZATIONAL BEHAVIOUR

Course Code: ABM- 501

Credit: 3+0

AIM OF THIS 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, Organizing, Directing and Controlling
2	Insights about Organizational Behaviour	1. Foundations of Individual behaviour
		2. Group Dynamics
3	Organizational Dynamics	1. Understanding and managing organizational culture
		2. Concept of Organizational Development

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 of Individual 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 organizational culture, power and political behavior in organizations, conflict Management, negotiation, managing organizational change, concept of organizational development

SUGGESTED READINGS:

- Stephen P. Robbins, Mary Coulter & Neharika Vohra. 2010. *Management*. Pearson Edu.
- Heinz Wehrich, Mark V. Cannice & Harold Koontz. 2015, *Management, A Global, Innovative and Entrepreneurial Perspective*, 14th Edition, McGraw Hill Education Pvt Ltd.
- James G. Beierlein, Kenneth C. Schneeberger, Donald D. Osburn. 2014. *Principles of Agribusiness Management*. Fifth edition. Waveland Press

- Neck, C. P., Houghton, J.D. and Murray E.L., 2017, *Organizational behavior*, SagePublication India Private Limited.
- Greenberg, J., 2013, *Behavior in Organisations*, PHI Learning Private Limited, NewDelhi.
- John A. Wagner III, J. A. and Hollenbeck, J. R., 2015, *Organizational Behaviour*,Routledge Taylor & Francis Group, New York.
- Harold Koontz & Keing Weighhrich.2010. *Essentials of Management*. Tata McGraw Hill

Title: MANAGERIAL ACCOUNTING AND CONTROL

Course Code: ABM- 502 504

Credit: 3 (2+1)

AIM OF THIS 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.

N o	Blocks	Units
1	Financial Accounting	1. Introduction to financial accounting
		2. Accounting standards
		3. Double Entry system
		4. Use of accounting software's
2	Managerial Accounting	1. Meaning of Managerial accounting
		2. Analysis of financial statements
		3. Cash flow and fund flow analysis
3	Cost Accounting	1. Introduction to cost accounting
		2. Standard costing
		3. Variance Analysis
		4. Budget and budgetary control

BLOCK 1: FINANCIAL ACCOUNTING

UNIT I: Financial Accounting- Meaning, Need, Accounting principles: Accounting Concepts and 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 Tools of Management Accounting, Analysis of Financial Statements- Ratio, time series, common size and Du point 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 of Cost, 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 Profit planning, 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

SUGGESTED READINGS

- S P Jain and K L Narang ,2014. *Financial Accounting*. 12th Edition. Kalyani publisher
- Sharma and Gupta, 2018. *Management Accounting* 13th Edition, Kalyani Publisher
- Maheshwari SN & Maheshwari SK. 2018. *Financial Accounting*. 6th Ed. Vikas Publ. House.

Title: APPLIED AGRIBUSINESS ECONOMICS

Course Code: ABM- 503

Credit: 2+0

AIM OF THIS 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

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 production and 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 of joint 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

SUGGESTED READINGS

- 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

Title: HUMAN RESOURCE MANAGEMENT FOR AGRICULTURAL ORGANISATION

Course Code: ABM- 504

Credit: 2 (2+0)

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 analytics

BLOCK 1: INTRODUCTION TO HUMAN RESOURCE MANAGEMENT

UNIT I: Strategic Human Resource Management, Human Resource Planning-Nature and Significance, 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 in Management, 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.

SUGGESTED READINGS

- Gary Dessler & Biju Varkkey 2016, *Human Resource Management*, XIV Edition, Pearson India
- VSP Rao. 2010, *Human Resource Management, Text and Cases*, 3rd Edition, ExcelBooks
- Ashwathapa K. 2016. *Human Resource Management, Text and Cases*. Tata McGraw Hill
- Michael J. Kavanagh, Mohan Thite & Richard D. Johnson. 2016, *Human Resource Information Systems*, Sage Publications
- Subba Rao P. 2004. *Essentials of Human Resource Management and Industrial Relations*. Himalaya Publ. House.

Title: PRODUCTION AND OPERATIONS MANAGEMENT

Course Code: ABM- 505

Credit: 2 (2+0)

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. Re engineering and Value engineering

BLOCK 1: INTRODUCTION TO PRODUCTION AND OPERATIONS MANAGEMENT

UNIT I: Nature Concept and Scope of Production and Operations Management; Factors Affecting 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 Core Competencies, 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 and Control, 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 Material Requirement, 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 interfacedesigns. Cloud operations management

BLOCK 3: QUALITY MANAGEMENT

UNIT V: Quality Assurance, Accepting Sampling, Statistical Process Control, Total Quality Management, 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.

SUGGESTED READINGS

- William J. Stevenson. 2014, *Operations Management*, 12th Edition, McGraw-Hill
- Panneerselvam K. 2012. *Production and Operations Management* 3rd Edition, PrenticeHall India Learning Private Limited
- S. N Chary, 2017, *Production and Operations Management*, McGraw HillEducation; 5 edition

Title: AGRICULTURAL AND FOOD MARKETING MANAGEMENT- I**Course Code: ABM- 506****Credit: 2 (2+0)**

AIM OF THE COURSE: To develop the understanding the concept of marketing system with specific inputs ofproduct, pricing, availability and promotional details

The course is organized as follows:

No	Blocks	Units
1	Overview of MarketingManagement	1. Marketing concept
		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,

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 line deletions, 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

SUGGESTED READINGS

- Kotler P. Keller K, Koshy A.& Jha M. 2013. *Marketing Management–Analysis, Planning, Implementation and Control*. Pearson Education.
- Ramaswamy V S 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
- Richard Gay, Alan Cjarlesworth, Rita Esen 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

Title: AGRICULTURAL AND FOOD MARKETING MANAGEMENT- II

Course Code: ABM- 507

Credit: 2 (2+0)

AIM OF THE COURSE: To develop learning about the basic concept of marketing with major emphasis on agri and foodmarketing 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

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 Liberalization: Economic structural adjustment programmes, Macro-economic stabilization, The role of the state in liberalized markets, Strategies for reforming agricultural marketing, Obstacles to be overcome in commercialization and Privatization 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 business units, 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 behavior, 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

SUGGESTED READINGS:

- Acharya, S. S. and Agarwal, N. L., 2011, Agricultural Marketing in India. 4th Ed.Oxford and IBH.
- Kohls, R. L.and Uhj, J. N., 2005, Marketing of Agricultural Products. 9th Ed. PrenticeHall.
- Mohan J, Agri-Marketing Strategies in India, NIPA
- Sharma Premjit. 2010. Agri-Marketing Management, Daya Publishing House

Title: AGRI SUPPLY CHAIN MANAGEMENT

Course Code: ABM- 508

Credit: 2 (2+0)

AIM OF THE COURSE: To introduce the students to the concepts, processes and framework of agricultural supply chainmanagement.

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

BLOCK 1: OVERVIEW OF SUPPLY CHAIN MANAGEMENT

UNIT I: Supply Chain: Changing Business Environment; SCM: Present Need; Conceptual Model 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 and Forecasting; 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 of Purchases 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 and Scheduling; 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: Bullwhipeffect (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.

SUGGESTED READINGS

- Acharya, S. S., and Agarwal, N. L., 2011, *Agricultural marketing in India*. Oxford andIBH.
- Altekar, R. V., 2006, *Supply Chain Management: Concepts and Cases*.PHI
- Chopra, S., Meindl, P. and Kalra, D. V., 2016, *Supply chain management: Strategy,Planning, and Operation*, Pearson Education India
- Mohanty R.P.2010. *Indian Case studies in Supply Chain Management & other LearningResources*. OXFORD
- N. Chandrasekaran.2010. *Supply Chain Management: Process, system &Practice*. OXFORD
- Singh Sukhpal. *Organic Produce Supply Chains in India-organisation and governance*.Allied Publ.

Title: INTERNATIONAL TRADE IN AGRICULTURAL PRODUCTS

Course Code: ABM- 509

Credit: 2 (2+0)

AIM OF THE COURSE: To impart knowledge to the students about international trade in agriculture and variousprovisions 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 supportsystems
2	Regulations and policy measures for International trade	1. India's foreign trade policy framework
		2. market entry methods
		3. Export procedures & documentations

BLOCK 1: INTRODUCTION TO INTERNATIONAL TRADE

- UNIT I:** International trade—basic concepts, WTO and its implications for Indian economy in general 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 comparative advantage, 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 and trade control; 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.

SUGGESTED READINGS:

- Study materials by the Center for WTO Studies, ITPO, New Delhi, The Future of Indian Agriculture
- International Trade and Food Security, Edited by F Brouwer, LEI - Wageningen UR, The Netherlands, P K Joshi, IFPRI, India. 2016.

MINOR COURSES (8 Credit)

Title: MANAGEMENT OF AGRO CHEMICAL INDUSTRY

Course Code: ABM- 513

Credit: 3+0

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.

AIM OF THIS 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

BLOCK 1: AGRO CHEMICALS

- UNIT 1:** Introduction: Agro-chemicals: Definition and classification; Basic knowledge of agro-chemicals; role and status 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) Chemical Structure 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 of pesticides 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.

SUGGESTED READINGS

- Dhaliwal GS, Singh R & Chhillar BS. 2014. *Essentials of Agricultural Entomology*. Kalyani Publishers
- Hayes WT & Laws ET. 1991. *Hand Book of Pesticides*. Academic Press.
- Matsumura F. 1985. *Toxicology of Insecticides*. 2nd Ed. Plenum Publ.
- Rajeev K & Mukherjee RC. 1996. *Role of Plant Quarantine in IPM*. Aditya Books.

Title: SEED PRODUCTION TECHNOLOGY MANAGEMENT

Course Code: ABM-514

Credit: 3+0

AIM OF THIS 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	1. Development and Management of Seed Programmes
		2. Maintenance of genetic purity
		3. Management of seed processing plant
		4. Seed Marketing

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 SeedCorporations, National Seed Project and State Farms and their role.

BLOCK 1: 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, RSCA and seed testing laboratories.

SUGGESTED READINGS

- Agrawal RL. 2017. *Seed Technology*. Oxford & IBH.
- Desai BB, KatechaPM & Salunkhe DK. 2009. *Seed Handbook: Biology, Production, Processing and Storage*. Marcel Dekker.
- Kelly A. 1988. *Seed Production of Agricultural Crops*. Longman.
- McDonald MB Jr. & Copeland LO. 2012. *Seed Production: Principles and Practices*. Chapman & Hall.

Title : ADVERTISING AND BRAND MANAGEMENT

Course Code: ABM-531

Credit:1+0

WHY THIS COURSE?

To impart basic understanding among the candidates about the advertising along with detailed aspects of brand management practices and techniques.

AIM OF THIS 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

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.

SUGGESTED READINGS

- Keller, Kevin Lane; *Strategic Brand Management*; Pearson education, New Delhi Verma, Harsha: *Brand Management*; Excel Books; New Delhi
- Kapferer, Jean Noel; *Strategic Brand Management*; Kogan Page; New Delhi
- Kumar, S. Ramesh; *Marketing and Branding–The Indian Scenario*; Pearson Education ; New Delhi Kapoor, Jagdeep ; *24 Brand Mantras*, Sage Publications; New Delhi
- Sengupta Subroto; *Brand Positioning: Strategies for competitive advantage*; Tata Mc GrawHill; New Delhi Clifton, Rita & Simmons., John; *Brands and Branding*; The Economist; Delhi

Title: AGRI COMMODITY MARKETS AND FUTURES TRADING

Course Code: ABM- 535

Credit: 1+0

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 futures trading	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

BLOCK 1: OVERVIEW OF COMMODITY MARKET IN INDIA

UNIT I: Introduction to commodity derivatives and price risk management in agricultural markets; 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 and forward 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 and collateralized commodity financing

UNIT V: Regulation of futures and trading practices in leading national and regional exchanges in India.

SUGGESTED READINGS:

- Hull, John C. 2017. *Fundamentals of futures and options markets*, Boston, Pearson publication.
- Ram, P. V. and Bala, S. D., 2016, *Strategic Financial Management*. Snow White Publ.

SUPPORTING COURSES

Title: STRATEGIC MANAGEMENT FOR AGRI BUSINESS ENTERPRISES

Course Code: ABM- 536

Credit: 2(2+0)

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

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 and structuring 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 of Strategic 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 and small businesses, Cases in strategic management

SUGGESTED READINGS:

- Thomas L. Wheelen & J. David Hunger. 2012, *Strategic Management & Business Policy, towards Global Sustainability*, Pearson India Edn. Thirteenth Edition
- Fred R. David & Forest R. David, 2016, *Strategic Management, Concept and Cases*, Pearson India Edn, Fifteenth Edition
- Thompson Jr., A. A., Peteraf, M. and Gamble, J. E., 2015, *Crafting and Executing Strategy*. McGraw Hill, Irwin.
- Stead, J. G. and Stead, E. W., 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

Title: OPERATIONS MANAGEMENT

Course Code: ABM- 537

Credit: 2 (2+0)

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 waitingline models	1. Types of inventory and inventory costs
3	Decision making under risk and uncertainty	1. Decision problem
		2. Decision trees

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

SUGGESTED READINGS

- 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.

Title: FINANCIAL MANAGEMENT IN AGRIBUSINESS

Course Code: ABM- 538

Credit: 2 (2+0)

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 & 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

BLOCK 1: FINANCIAL MANAGEMENT IN INDIA

UNIT I: Meaning, importance, nature and scope of financing in India, agribusiness financing in India; 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 and importance 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.

SUGGESTED READINGS

- Nelson AG & Murrey WG. 1988. *Agricultural Finance*. Kalyani Publ.
- Gordon and Natarajan. 2016. *Financial Markets and Services*. Himalaya Publishing House; Tenth Edition
- H R Machiraju. 2010. *Indian Financial System*. Vikas Publishing House
- IM Pandey. 2015. *Essentials of Financial Management*, Vikas Publishing House
- Khan & Jain. 2014. *Financial Management*. McGraw Higher Education
- Srivastav & Misra . 2010. *Financial Management*, Oxford University Press; Second edition
- G Sudarsana Reddy. 2010. *Financial Management*, Himalaya Publishing House.

BASIC COURSES MANDATORY FOR SUMMER INTERNSHIP

Title: COMMUNICATION FOR MANAGEMENT AND BUSINESS

Course Code: ABM- 539

Credit: 3 (2+1)

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

BLOCK 1: INTRODUCTION TO BUSINESS COMMUNICATION

UNIT I: Communication process, barriers to communication, methods of communication, effective communication, assertive communication, types of organizational 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 and creatively, introduction to case method of learning, case reading, approaches and analysis.

SUGGESTED READINGS:

- Peter W. Cardon. 2015, *Business Communication, Developing leaders for a networked world* Mc Graw Hill Education
- P. D Chaturvedi & Mukesh Chaturvedi. 2017, *Business Communication, Skills, Concepts, Cases and Applications*, Pearson India Education
- Courtland L. Bovee, John V. Thill & Abha Chatterjee 2013, *Business Communication*
- *Today*, Pearson Education, Tenth Edition.

Title: RESEARCH METHODOLOGY FOR AGRI BUSINESS MANAGEMENT

Course Code: ABM- 540

Credit: 3 (2+1)

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 metrics
		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

BLOCK 1: OVERVIEW OF RESEARCH

UNIT I: Meaning, Course Objective, types, and process of research; research methodology in management- 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 linear regression 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, CART models, 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, linear and 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.

SUGGESTED READINGS

- Cooper DR & Schindler PS. 2006. *Marketing Research Concepts and Cases*. TMH
- Ranjit Kumar. 2014. *Research Methodology*, Sage publications, 4th Edition
- Glenn J.C. 2010. *Hand book of Research Methods*. OXFORD.
- Kothari CR. 2018. *Research Methodology- Methods and Techniques*. New Age International Publishers; Fourth edition

BASIC COURSES MANDATORY FOR PROJECT

Title: COMPUTER APPLICATIONS FOR AGRI BUSINESS

Course Code: ABM- 541

Credit: 3 (2+1)

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 software's
		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

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 to computer 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 Intelligence (AI), Neural Networks, Fuzzy logical control systems

UNIT V: e-business/ e commerce: e business models, e commerce processes, electronic payment systems, 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.

SUGGESTED READINGS:

- Kenneth C. Laudon & Jane P. Laudon. 2016, *Management Information Systems- Managing the digital Firm*, 14th Edition, Pearson India
- Volonino, Woods, O/P. Wali Turban. 2015, *Information Technology for Management, Advancing Sustainable, Profitable Business Growth*, Wiley
- Jaiswal M. Mittal M.2005. *Management Information System*, OXFORD

Title: PROJECT MANAGEMENT AND AGRIBUSINESS ENTREPRENEURSHIP

Course Code: ABM- 542

Credit: 3 (2+1)

AIM OF THE 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 Entrepreneurship	1. Sources of Financing for entrepreneurs
		2. Preparation of Detail Project Report
		3. Structure and Government Policy Support

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 ENTREPRENEURSHIP

UNIT V: Sources of Financing, Structure and Government Policy Support: Estimating Financial Requirements, 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 Organizations like SIDO, DIC, KVIC, NSIC, SIDBI, NABARD and their role, Sick Industries and their Up gradation policy measures

SUGGESTED READINGS

- Arora, R. and Sood, S.K., *Fundamentals of Entrepreneurship and Small Business Management*. Kalyani Publishers, Ludhiana.
- Desai, Vasant, 2016, *Business Planning and Entrepreneurial Management*, Himalaya Publishing House, Mumbai.
- Ramachandaran, K., *Managing a New Business Successfully*. Global Business Press, New Delhi.
- Shukla, M.B., *Entrepreneurship and Small Business Management*. KitabMahal. New Delhi.
- Dandekar, V. M. and Sharma, V. K., 2016, *Agri-Business and Entrepreneurship Development*. Manglam Publications, New Delhi.
- T W Zimmerer, N M Scarborough. *Essentials of Entrepreneurship and small Business Management*, 5th Edition, PHI Learning Pvt Ltd
- Panigrahi S.R. & Singh B. 2017. *Agro Entrepreneurship*. Scientific Publishers(India)

Title: AGRIBUSINESS ENVIRONMENT AND POLICY

Course Code: ABM- 543

Credit: 2 (2+0)

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

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 AGRIBUSINESS

UNIT II: Economic reforms: liberalization, privatization and globalization specifically affecting Agri 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 AGRIBUSINESS

UNIT III: Emerging trends in farm supplies, farm production, agricultural finance, agro-processing, 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; Environmental issues and including carbon markets and Clean Development Management etc.

UNIT V: Other major issues: Intellectual property rights, importance of cooperative or collective actions in present scenario with examples of mergers and acquisitions, Farmers Producer Organizations etc

SUGGESTED READINGS

- FL Barnard, JT Akridge, FL Dooley, JC Foltz & EA Yeager. 2012, Agribusiness Management, Routledge, 4th Edition
- Aswathappa K. Essentials of Business Environment. Himalaya Publ.
- Francis Cherunilam 2003. Business Environment. Himalaya Publ.
- Kodekodi G.K. Viswanathan B. Agril. Development, Rural Institution & Economic Policy, OXFORD.

Title: AGRIBUSINESS LAWS AND ETHICS**Course Code: ABM- 544****Credit: 2 (2+0)**

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	Indian Contract Act
		Companies Act
2	Regulatory environment for agri business	Essential Commodities Act,
		Consumer Protection Act
3	Business ethics	Ethics in agri business functional areas
		Governance mechanism

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 AGRICULTURE BUSINESS

UNIT IV: Essential Commodities Act, Consumer Protection Act, RTI Act, MRTP Act- major provisions 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 social responsibilities, 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

SUGGESTED READINGS

- S B Mathur. 2010. *Business Law*. Tata McGraw Hill Edn. Pvt Ltd.
- Gulshan SS & 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, P.C. and Tulsian, B., 2015, *Business Law*. TMH, New Delhi.
- Singh Avtar, (2017), *Contract & Specific Relief*, Eastern Book Company; Twelfth edition
- Akhileshwar Pathak. 2015. *Legal Aspects of Business*. McGraw Hill Education. 6th Edition

COMMON COURSES

PGS 502 : TECHNICAL WRITING AND COMMUNICATIONS SKILLS

Credits 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

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

PGS 503: INTELLECTUAL PROPERTY AND ITS MANAGEMENT IN AGRICULTURE Credits 1+0
(e-Course/offline)

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

- *rbisch FH & Maredia K.1998. Intellectual Property Rights in Agricultural Biotechnology. CABI.*
- *Ganguli P. 2001. Intellectual Property Rights: Unleashing Knowledge Economy. McGraw-Hill.*
- *Intellectual Property Rights: Key to New Wealth Generation. 2001. NRDC & Aesthetic Technologies.*
- Ministry of Agriculture, Government of India. 2004. *State of Indian Farmer. Vol. V. Technology Generation and IPR Issues.* Academic Foundation.
- Rothschild M & Scott N. (Ed.). 2003. *Intellectual Property Rights in Animal Breeding and Genetics.* CABI.
- 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; National Biological Diversity Act, 2003.*

PGS 504 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 vaccumets; 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

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

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

PGS 505: AGRICULTURAL RESEARCH, RESEARCH ETHICS AND RURAL DEVELOPMENT PROGRAMMES (e-Course/offline) Credits 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 (IRD) 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

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

Objectives: To introduce learners to the key concepts and practices of natural disaster management; to equip them to conduct thorough assessment of hazards, and risks vulnerability; and capacity building.

Theory

UNIT I: Natural Disasters- Meaning and nature of natural disasters, their types and effects. Floods, Drought, Cyclone, Earthquakes, Landslides, Avalanches, Volcanic eruptions, Heat and cold Waves, Climatic Change: Global warming, Sea Level rise, Ozone Depletion

UNIT II: Man Made Disasters- Nuclear disasters, chemical disasters, biological disasters, building fire, coal fire, forest fire. Oil fire, air pollution, water pollution, deforestation, Industrial wastewater pollution, road accidents, rail accidents, air accidents, sea accidents.

UNIT III: Disaster Management- Efforts to mitigate natural disasters at national and global levels. International Strategy for Disaster reduction. Concept of disaster management, national disaster management framework; financial arrangements; role of NGOs, Community-based organizations, and media. Central, State, District and local Administration; Armed forces in Disaster response; Disaster response: Police and other organizations.

Suggested Readings

- Gupta HK. 2003. *Disaster Management*. Indian National Science Academy. Orient Blackswan.
- Hodgkinson PE & Stewart M. 1991. *Coping with Catastrophe: A Handbook of Disaster Management*. Routledge. Sharma VK. 2001. *Disaster Management*. National Centre for Disaster Management, India
