Agriculture and Allied Science

Restructured and Revised Syllabi of Post-graduate Programmes

Volume - 1

- Genetics and Plant Breeding
- Seed Science and Technology
- Plant Genetic Resources
- Plant Physiology

- DR . BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH, DAPOLI, DIST. RATNAGIRI.
- VASANTRAO NAIK MARATHWADA KRISHI VIDYAPEETH PARBHANI,
- DR. PANJABRAO DESHMUKH KRISHI VIDYAPEETH, AKOLA
- MAHATMA PHULE KRISHI VIDYAPEETH, RAHURI, DIST.- AHMEDNAGAR (M.S.)

Compiled By

Dean & Director of Instruction
Co-Ordination Committee
of SAUs. 2022-23

Restructured and Revised Syllabus

M.Sc. & Ph. D.(Agriculture)

In

Genetics and Plant Breeding

Broad Subject Coordinator
Plant Science
Dr. J. E. Jahagirdar
Associate Dean,
College of Agriculture,
Osmanabad (VNMKV., Parbhani)

Discipline Coordinator
Genetics and Plant Breeding
Dr. H.V.Kalpande
Head,
Deptt.of Agril. Botany,
VNMKV Parbhani.

CONTENT

DISCIPLINE: GENETICS AND PLANT BREEDING

PREAMBLE

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

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

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

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

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

COMMITTEE ON PLANT SCIENCES

ICAR-BSMA Broad Subject	**ICAR-BSMA Approved Disciplines**	**Degree Programmes**		**Broad Subject Coordinator (Chairman of all Disciplines' SubCommittees)**	**Discipline Coordinator (Secretary of respective Discipline Sub-Committee)**
Plant Sciences	Genetics and Plant Breeding	M.Sc. (Agri.)	Ph.D.	Dr. J.E. Jahagirdar ADP, CoA, Osmanabad (VNMKV, Parbhani)	Dr. H.V. Kalpande Head, Dept. of Agril. Botany, VNMKV, Parbhani
	Seed Science and Technology	M.Sc. (Agri.)	Ph.D.		Dr. V.R. Shelar, SRO, STRU, MPKV, Rahuri
	Plant Physiology	M.Sc. (Agri.)	Ph.D.		Dr. R.S. Wagh Prof ,MPKV, Rahuri
	Plant Genetic Resources	M.Sc. (Agri.)	Ph.D.		Dr. R.B. Ghorade Head, Dept. Agril. Botany Dr.PDKV, Akola

Sub-Committee constituted for the finalization of common syllabi in Genetics and Plant Breeding discipline.

Sr.No	Name	Sub-Committee
1	Dr. H.V.Kalpande, Head, Agril. Botany,VNMKV, Parbhani	Discipline Coordinator
2	Dr. V.L.Amolic Head, Agril. Botany, MPKV, Rahuri	Discipline Co-Coordinator
3	Dr.R.B.Ghorade, Head, Agril. Botany,Dr.PDKV.Akola	Discipline Co-Coordinator
4	Dr.R.L.Kunkerkar, Head, Agril. Botany, Dr.BSKKV Dapoli	Discipline Co-Coordinator
5	Dr.Mrs.Priti. Sonkamble, Dr.PDKV.Akola	Member
6	Dr. R.D. Ratnparkhi ,Dr.PDKV.Akola	Member
7	Dr. D.V.Kusalkar, MPKV, Rahuri	Member
8	Dr. A.R.Aher, MPKV, Rahuri	Member
9	Dr.S.V.Sawardekar , Dr.BSKKV Dapoli	Member
10	Dr.U.B.Pethe, Dr.BSKKV Dapoli	Member
11	Dr.D.K.Zate, VNMKV, Parbhani	Member
12	Dr.M.P.Wankhade, VNMKV, Parbhani	Member

Implementation of New Curriculum

The universities offering PG programmes in Genetics And Plant Breeding need to be supported for establishing specialized laboratories equipped with state-of-the art equipment's for conducting practical classes especially, Molecular Breeding and Bioinformatics,, Mutagenesis and Mutation Breeding, Breeding for Quality and Special Traits and Breeding for Stress Resistance and Climate Change

One-time catch-up grant should be awarded to each SAU, offering PG programmes in Genetics and Plant Breeding for meeting expenditure for upgrading the course requirements.

Faculty training and retraining should be an integral component. For imparting total quality management, a minimum of two faculties in each department under SAU should be given on job training in reputed national and international institutes. To execute the new PG and Ph.D. programmes in Genetics and Plant Breeding discipline in effective manner, special funds from ICAR would be required for outsourcing of faculty from Indian/Foreign Universities for some initial years.

The already existing M.Sc. and Ph.D. Programmes in Genetics and Plant Breeding will be considered at par with the recommended M.Sc. & Ph.D. programme by Vth Deans Committee for admission and employment.

Expected Outcome

- Revamping of post graduate programme in whole of Genetics And Plant Breeding throughout the country.
- Imparting quality education.
- Development of technical manpower to cater the need of farmers governments, corporate sector and research organization in India and abroad.
- Exposure to the faculty in the latest technical knowhow.

Organization of Course Contents & Credit Requirements

Minimum Residential Requirement:

M.Sc.:- 4 Semesters
Ph.D.:- 6 Semesters

Name of the Departments / Divisions

- Genetics and Plant Breeding

Nomenclature of Degree Programme

(a) M.Sc. Programmes

- M.Sc. (Agriculture) Genetics and Plant Breeding

(b) Ph.D. Programmes

- Ph.D. (Agriculture) Genetics and Plant Breeding

Code Numbers

- All courses are divided into two series: 500-series courses pertain to Master"s level, and 600- series to Doctoral level.
- Credit Seminar for Master's level is designated by code no. 591, and the Two Seminars for Doctoral level are coded as 691 and 692, respectively.
- Master's research: 599 and Doctoral research: 699.
- Deficiency courses will be of 400 series.

Course Contents

The contents of each course have been organized into:

- Objective – to elucidate the basic purpose.
- Theory units – to facilitate uniform coverage of syllabus for paper setting.
- Suggested readings – to recommend some standard books as reference material. This does not obviously exclude such a reference material that may be recommended according to the advancement and local requirement.
- A list of International and National reputed Journals pertaining to the discipline is provided at the end which may be useful as study material for 500/600 series courses as well as research topics.
- Lecture schedule and practical schedule has also been given at the end of each course to facilitate the teacher to complete the course in an effective manner.

Eligibility for Admission Master's Degree Programme

B.Sc.(Agri.) / **B. Sc. (Hons.) Agriculture,** B. Sc. (Hort.) / B.Sc. (Hons.) Horticulture / B. Sc. (Forestry) / B.Sc. (Hons.) Forestry under 10+2+4 system with minimum of 5.50/10 or equivalent percentage of marks or equivalent degree with four years duration of agriculture related Universities and having the Common Entrance Test in Agriculture conducted by competent authority.

Doctoral Degree Programme

Master"s degree in concerned discipline with minimum of 6.50/10 or equivalent percentage of marks and based on CET score CET conducted by MAUEB or AIEEA – ICAR, Agricultural Universities

(AUs) which have expressed their willingness to utilize NTA scores for their PG admissions. If required the scores will be provided by NTA.

(i) Master Degree in the concerned Department/Discipline of Genetics and Plant Breeding and having appearing the Common Entrance Test of Genetics and Plant Breeding subject conducted by competent authority.

Sr. No	Name of Department	Specialization in Ph. D Agriculture	Eligibility criteria
1.	Genetics and Plant Breeding	Ph. D (Agriculture) Genetics and Plant Breeding	M.Sc. (Agri) Genetics and Plant Breeding

Credit Requirements

Course Details	Master's Degree	Doctoral Degree
Major Courses	20	15
Minor Courses	08	06
Supporting / Optional	06	05
Common PGS Courses	05	---
Seminar	01	02
Research	30	75
Total	**70**	**100**

M.Sc. Agriculture (Genetics and Plant Breeding)
Course Structure

LIST OF CORE COURSES/ DEPARTMENT WISE SPECIALIZATION/ COMPULSORY/SUPPORTING COURSES

CourseCode	Semester	Course Title	CreditHours
GPB 501*	I	Principles of Genetics	3 (2+1)
GPB 502*	I	Principles of Plant Breeding	3 (2+1)
GPB 503*	II	Fundamentals of Quantitative Genetics	3 (2+1)
GPB 504	III	Varietal Development and Maintenance Breeding	2 (1+1)
GPB 505	I	Principles of Cytogenetics	3 (2+1)
GPB 506*	II	Molecular Breeding and Bioinformatics	3 (2+1)
GPB 507	I	Breeding for Quality and Special Traits	3 (2+1)
GPB 508	II	Mutagenesis and Mutation Breeding	3 (2+1)
GPB 509	I	Hybrid Breeding	3 (2+1)
GPB 510	III	Seed Production and Certification	2 (1+1)
GPB 511	I	Crop Breeding-I (*Kharif* Crops)	3 (2+1)
GPB 512	II	Crop Breeding-II (*Rabi* Crops)	3 (2+1)
GPB 513	I	Breeding Vegetable Crops	3 (2+1)
GPB 514	II	Breeding Fruit Crops	3 (2+1)
GPB 515	I	Breeding Ornamental Crops	3 (2+1)
GPB 516	II	Breeding for Stress Resistance and Climate Change	3 (2+1)
GPB 517	III	Germplasm Characterization and Evaluation	2 (1+1)
GPB 518	III	Genetic enhancement for PGR Utilization	2 (1+1)
GPB 591	III	Master's Seminar	1 (1+0)
GPB 599	III &IV	Master's Research	30(0+30)

***Compulsory Courses**

Common Courses: (Non-Credit)

Course code	Semester	Course Title	Credits
PGS 501	I	Library and Information Services	0+1=1
PGS 502	I	Technical Writing and Communications Skills	0+1=1
PGS 504	I	Basic Concepts in Laboratory Techniques	0+1=1
PGS 503	II	Intellectual Property and its management in Agriculture	1+0=1
PGS 505	III	Agricultural Research, Research Ethics and Rural Development Programmes	1+0=1
PGS-506	III	Disaster Management	1+0=1

SUPPORTING/OPTIONAL COURSES

1. **Biochemistry**
2. **Computer science**
3. **Horticulture**
4. **Statistics**

Suggested Supporting Courses:

Course Code	Semester	Course Title	Credit Hrs.
BIOCHEM501		Basic Biochemistry	**3+1=4**
STAT 511		Experimental Designs	**2+1=3**
STAT-565		Statistical Genetics	**2+1=3**
Note: Apart from above courses student shall register courses from Any other discipline within faculty as per student advisory committee recommendation.			

Minor Disciplines:

1. Plant Physiology
2. Seed Technology
3. Molecular Biology and Biotechnology
4. Plant Pathology
5. Entomology
6. Horticulture
7. Agronomy
8. Forestry

Suggested Minor Courses:

Course Code	Semester	Course Title	Credit Hrs.
MBB-501		Principles of Biotechnology	3(0+3)
PP-501		Principles of plant physiology I- Plant Water Relations and Mineral Nutrition	3(2+1)
PP-503		Plant Development Biology :Physiological and Molecular Basis	3(2+1)

SST-503		Seed Production Principles and Techniques In Field Crops	2(1+1)
SST-507		Seed Legislation and Certification	3(2+1)
Note: Apart from above courses student shall register courses from Any other discipline within faculty as per student advisory committee recommendation.			

Compulsory Non Credit Deficiency Courses
(Those who are non-Agriculture Graduates)

Course Code	Semester	Course Title	Credit Hrs.
GPB121	II	Fundamentals of Genetics	3(2+1)
BOT121	II	Fundamentals of Crop Physiology	2(1+1)
GPB232	III	Fundamentals of Plant Breeding	2(1+1)
GPB243	IV	Principles of Seed Technology	3(1+2)
GPB355	V	Crop Improvement–I (*Kharif* Crops)	2(1+1)
BOT353	V	Intellectual Property Right	1(1+0)
GPB366	VI	Crop Improvement–II (*Rabi* crops)	2(1+1)

Students from Horticulture and Forestry stream will be required to complete Noncredit deficiency courses (6 to 10 credits) from the above courses related to the discipline in which admitted and as decided by the Student Advisory committee.

Ph.D. (Agriculture) GENETICS AND PLANT BREEDING
Course Structure
Semester wise core Courses offered based on credit requirement

1. **Ph. D. (Agriculture) Genetics and Plant Breeding**

Course Code	Semester	Course Title	Credit Hrs.
GPB 601*	I	Advances in Plant Breeding Systems	3(3+0)
GPB 602	I	Advances in Biometrical Genetics	3(2+1)
GPB 603	I	Molecular Cytogenetics for Crop Improvement	2(2+0)
GPB 604	II	Plant Genetics Resources, Conservation and Utilization	2(2+0)
GPB 605*	II	Genomics in Plant Breeding	3(3+0)
GPB 606	II	Population Genetics	2(2+0)
GPB 607	I	Crop Evolution	3(3+0)
GPB 608	II	Breeding Designer Crops	2(1+1)
GPB 609*	III	IPR and Regulatory Mechanism (e-course)	1(1+0)
GPB 691	III	Doctoral seminar	1+0
GPB 692	IV	Doctoral seminar	1+0
GPB 699	II-VI	Doctoral research	75

*Indicates Core Courses which are Compulsory for PhD Programme

Common Courses: (Non-Credit)

Course code	Semester	Course Title	Credits
PGS 501	I	Library and Information Services	0+1=1
PGS 502	I	Technical Writing and Communications Skills	0+1=1
PGS 504	I	Basic Concepts in Laboratory Techniques	0+1=1
PGS 503	II	Intellectual Property and its management in Agriculture	1+0=1
PGS 505	III	Agricultural Research, Research Ethics and Rural Development Programmes	1+0=1
PGS-506	III	Disaster Management	1+0=1

Note: Ph.D. students may be exempted from Non Credit Compulsory Courses (NCCC) if already studied during Master's degree.

Minor Disciplines:

1. Molecular Biology and Biotechnology
2. Plant Physiology
3. Seed Science and Technology

Suggested minor courses :

Course Code	Semester	Course Title	Credit Hrs.
MBB-604		Commercial plant tissue culture	2+0
PP-603		Molecular Approaches for Improving Physiological Mechanisms through Trait introgression	2+1
PP-606		Global Climate Change And Crop Response	2+0

SST-601		Hybrid seed production technology	2+1
SST-604		Genetic Purity and DUS Testing	2+1
SST-606		Advances in seed science	2+0
Note: Apart from above courses student shall register courses from Any other discipline within faculty as per student advisory committee recommendation.			

Disciplines for Supporting/ optional Courses:

1. Agriculture Statistics
2. Biochemistry
3. Entomology
4. Horticulture
5. Plant pathology
6. Horticulture
7. Agronomy

Suggested supporting and optional courses:

Course Code	**Semester**	**Course Title**	**Credit Hrs.**
ENTO-607		Plant Resistance to insects	1+1
PL.PATH-604		Molecular Basis of Host Pathogen Interaction	2+1
PL.PATH-606		Plant Biosecurity And Biosafety	2+0
STAT-614		Advanced Statistical Genetics	2+1
Note: Apart from above courses student shall register courses from Any other discipline within faculty as per student advisory committee recommendation.			

COURSE CONTENTS

GPB 501	PRINCIPLES OF GENETICS	2 + 1

Objective

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; Micro-RNAs (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;
Detection of transgenes in the exposed plant material;
Visit to transgenic glasshouse and learning the practical considerations.

LECTURE SCHEDULE
Theory

Lecture No.	Topic	Weightage
1.	**Introduction to Genetics** :Beginning of genetics, early concepts of inheritance	5
2.	Mendel's laws; Discussion on Mendel's paper,	8
3.	Chromosomal theory of inheritance; Multiple alleles,	
4.	Gene interactions,	10
5.	Sex determination, differentiation and sex-linkage, Sex-influenced and sex-limited traits;	
6.	**Linkage:** Linkage-detection, estimation Recombination and genetic mapping in eukaryotes	10
7.	Somatic cell genetics, Extra chromosomal inheritance.	
8. & 9	**Population** : Mendelian population, Random mating population, Frequencies of genes and genotypes, Causes of change: Hardy-Weinberg equilibrium	8
10.	Nature, structure and replication of the genetic material	8
11.	**Genetic Material:** Organization of DNA in chromosomes, ,	
12 & 13	Genetic code; Protein biosynthesis	
14 &15	Genetic fine structure analysis, Allelic complementation, Split genes, overlapping genes, Pseudogenes, Oncogenes, Gene families and clusters	8
16	Regulation of gene activity in prokaryotes and eukaryotes;	
17	Molecular mechanisms of mutation, repair and suppression;	
18	**Plasmid:** Bacterial plasmids, insertion (IS) and transposable (Tn) elements	8
19	Molecular chaperones and gene expression, RNA editing	
20 &21	Gene isolation, synthesis and cloning, genomic and cDNA libraries	8
22 & 23	PCR based cloning, positional cloning; Nucleic acid hybridization and immunochemical detection;	
24	DNA sequencing; DNA restriction and modification	8
25	Anti-sense RNA and ribozymes; Micro-RNAs (miRNAs	
26 & 27	Genomics and proteomics; metagenomics	5
28	**Transgenic:** Transgenic bacteria and bioethics	5
29	Gene silencing;	9
30	Genetics of mitochondria and chloroplasts	
31 &32	Concepts of Eugenics, Epigenetics, Genetic disorders	
	Total	**100**

Practical

Practical No.	Topic
1.	Estimation of probability and chi-square.
2 &3	Demonstration of genetic principles using laboratory organisms.
4	Study of Chromosome mapping using three-point test cross.
5	Study of tetrad analysis
6	Study of Induction and detection of mutations through genetic test
7 & 8	Study of genomic DNA extraction.
9	PCR amplification
10 & 11	Electrophoresis: basic principles and running of amplified DNA.
12	Study of extraction of proteins
13 &14	Study of extraction of isozymes
15	Study of Gene Transfer (Indirect method): Use of *Agrobacterium* mediated method
16	Study of Gene Transfer (direct method) Biolistic gun;
	Total

Suggested reading:

Daniel LH and Maryellen R. 2011. *Genetics: "Analysis of Genes and Genomes*
Gardner EJ and Snustad DP. 1991. *Principles of Genetics*. John Wiley and Sons. 8th ed.2006
Klug WS and Cummings MR. 2003. *Concepts of Genetics*. Peterson Edu. Pearson Education India; Tenth edition
Lewin B. 2008. *Genes XII*. Jones and Bartlett Publ. (International Edition) Paperback, 2018 Russell PJ. 1998. *Genetics*. The Benzamin/ Cummings Publ.Co.
Singh BD. 2009. *Genetics.* Kalyani Publishers (2nd Revised Edition)
Snustad DP and Simmons MJ. 2006. *Genetics*. 4th Ed. John Wiley and Sons. 6th Edition International Student Version edition
Stansfield WD.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 and Saharan RP. 2005. *Practical Manual on Basic and applied Genetics.* Dept. of Genetics *CCS HAU Hissar*

GPB 502	PRINCIPLES OF PLANT BREEDING	2 + 1

Objective

To impart theoretical knowledge and practical skills about plant breeding objectives, genetic consequences, breeding methods for crop improvement. Development of plant variety is the ultimate aim of any plant breeding programme. 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.

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; S_1 and S_2 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 inbreeds, breeding approaches for improvement of inbreeds, predicting hybrid performance; seed production of hybrid and their parent varieties/ inbreeds. Self-incompatibility, malesterility 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

LECTURE SCHEDULE

Lecture No.	Topic	Weightage
1	**Plant Breeding**, Early Plant Breeding; Accomplishments through plant breeding; Objectives of plant breeding;	4
2	**Aims, Objective and scope of plant breeding ,** Characteristics improved by plant breeding	4
3	**Pattern of evolution in crop plants** – Patterns of Evolution in Crop Plants: Centre of Origin, Agro-biodiversity and its significance.	3
4	**Prebreeding**-Pre-breeding and plant introduction and role of plant genetic resources in plant breeding.	3
5	**Genetics Basis of Breeding** Genetic basis of breeding: self and cross pollinated crops including mating systems and response to selection	3
6	**Nature of variability** – Types and components of variation	3
7	**Heritability-**Types, genetic advance and genotype environment interaction;	3
8	**Combining ability** 1. Types – General combing ability, specific combining ability 2. Utilizations in crop improvement	4
9	Types of gene actions and implications in plant breeding	3
10	**Methods of plant breeding for self- pollinated crops**-Introduction: definition and types, procedure merits and demerits	3
11	**Incompatibility** – definition, 1.Types incompatibility 2. Commercial exploitation 3. Mechanism, of incompatibility 4. Utilization in crop improvement	4
12	**Male sterility** – 1.Types of Male sterility 2. Commercial exploitation 3.Methods of transfer of male sterility, methods of transfer of restorer genes, 4. Utilization of male sterility in crop improvement achievements, limitations.	4
13	**Breeding Methods**- Selection: 1 Pure line theory (Johanssons) 2 Pure line selection 3 Mass Selection. Types, Procedure, Merits and demerits and achievements	4
14	**Pedigree method**- definition, Pedigree record, maintenance of pedigree record, procedure of pedigree methods, Applications, merits, demerits & achievements.	4
15	**Back cross method**- definition, procedure, Applications, merits, demerits, achievements	4
16	**Single seed descent methods and multiline breeding methods** definition, procedure, Applications, merits, demerits, achievements	4
17	**Population breeding** -Self-pollinated crops, diallel selective mating approach Transgressive breeding.	3

18	**Breeding methods in cross pollinated crops** -definition, procedure, Applications, merits, demerits, achievements	4
19	**Population Breeding** : 1.Mass selection and ear to row method , S1 and S2 progeny testing, progeny selection	3
20	**Population improvement programme** – Recurrent selection, schemes for intra and inter population improvement	3
21	**Synthetic Variety** – definition ,steps involved in developments of Synthetic merits, demerits, achievements	3
22	**Composites Variety** – definition ,steps involved in developments of composites merits, demerits, achievements	3
23&24	**Breeding methods in asexually propagated crops,** Clonal selection, apomixis, Apomixis in crop plants and their commercial exploitation, clonal selection - definition ,steps involved in developments merits, demerits, achievements	3
25	**Hybrid breeding**: Genetical and physiological basis of heterosis and inbreeding, production of inbreeds, breeding approaches for improvement of inbreeds, predicting hybrid performance	4
26	**Plant ideotypes** – Concepts of Plant ideotypes, role in crop improvement, transgressive breeding	3
27	**Special breeding techniques** – 1. Mutation breeding : definition, types , procedure of mutation breeding , application in crop improvement , achievements limitations	4
28 & 29	**Special breeding techniques-** 1. Biotic and abiotic stresses	4
30 & 31	**Cultivar development** – testing, release and notification, Maintenance breeding	3
32	Plant Breeding , Plant Breeders rights, Regulation for plant variety protection and farmers rights	3
	Total	**100**

Practical :

Practical No.	Topic
1.	Plant Breeder’s Kit.
2	Selfing , Emasculation and crossing technique.
3	Botanical description and floral biology ; Floral morphology, Selfing emasculation and crossing techniques in Cotton.
4	Botanical description and floral biology ; Floral morphology, Selfing emasculation and crossing techniques in Sorghum, Pearl millet.
5	Botanical description and floral biology ; Floral morphology, Selfing emasculation and crossing techniques in Pigeonpea, Green gram and Soybean
6	Botanical description and floral biology ; Floral morphology, Selfing emasculation and crossing techniques in Sunflower,
7	Botanical description and floral biology ; Floral morphology, Selfing emasculation and crossing techniques in Maize
8	Botanical description and floral biology ; Floral Morphology, Selfing emasculation and crossing techniques in Chilli, Tomato and Brinjal
9	Botanical description and floral biology ; Floral morphology, Selfing

	emasculation and crossing techniques in Okra
10	Selection methods in segregating populations
11	Evaluation of breeding material
12	Analysis of variance (ANOVA)
13	Estimation of heritability and genetics advance
14	Maintenance of experimental records
15	Techniques in hybrids seed production
16	Use of male – sterility in field crops Prediction of performance of double cross hybrid.

Suggested reading.

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 House.

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 J P. 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 Publishers, New Delhi.

Singh S and Pawar IS. 2006. *Genetic Bases and Methods of Plant Breeding*. CBS

GPB 503 FUNDAMENTALS OF QUANTITATIVE GENETICS* 2 + 1

OBJECTIVE:

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 × T, NCDs, and TTC; Concept of combining ability and gene action, G × 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 D2 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 × T analysis and interpretation, QTL analysis;
Use of computer packages;
Diallel analysis;
G × E interaction and stability analysis.

LECTURE SCHEDULE

Lecture No.	Topic	Weightage
1	**Introduction Quantitative Genetics :** Introduction and historical background of quantitative genetics	2
2	**Mendelian traits *vs* polygenic traits. :** Nature of quantitative traits and its Inheritance. Genetical foundation of quantitative traits.	2
3 &4	**Multiple factor hypothesis.:** Analysis of continuous variation. Important features of multiple factor hypothesis	8
5 & 6	**Variations associated with polygenic traits.:** Phenotypic, genotypic & environmental. Non allelic interactions. Nature of gene action - additive, dominance, epistatic and linkage effects.	6
7 & 8	**Principles of Analysis of Variance (ANOVA):** Expected variance components, random and fixed models; MANOVA.	8
9 &10	**Biplot analysis:** Comparison of means and variances for significance.	8
11	**Designs for plant breeding experiments:** Principles and applications.	2
12 & 13	**Genetic diversity analysis Association analysis. Path analysis:** Metroglyph, cluster and D^2 analyses phenotypic and genotypic	8

	correlations Parent. Progeny regression analysis.	
14 &15	**Discriminant function Selection indices:** Principal component analysis selection of parents. Simultaneous selection models.	8
16	**Concepts of selection:** Heritability and genetic advance.	2
17	**Generation mean analysis action:** 3, 5, and 6 parameter models, scaling tests	2
18,19, 20 & 21	**Mating designs:** Diallel, Partial diallel, line x tester analysis, NCDs and TTC	12
22	**Combing ability:** Concepts of combining ability and gene action	2
23	**Analysis of genotype x environment interaction:** Adaptability and stability.	4
24 & 25	**Models for GxE analysis and stability parameters:** Methods & features of stability models.	8
26	**AMMI analysis:** Principles and interpretation.	2
27	**QTL mapping:** Strategies for QTL mapping - desired populations for QTL mapping.	4
28 & 29	**Statistical methods in QTL mapping:**QTL mapping in Genetic Analysis. Marker assisted selection (MAS).	4
30 & 31	**Approaches to apply MAS in Plant breeding:** Selection based on marker - simultaneous selection based on marker and phenotype - factors influencing MAS.	8
	Total	100

Practical :

Practical No	**Topic**
1 &2	**Variability** :Analysis and interpretation of variability parameters Partitioning of variance
3	**Metroglyph** :Analysis and interpretation of Index score and Metroglyph
4	**D^2 analysis** : Clustering and interpretation.
5	Correlation: Genotypic and phenotypic correlation analysis and interpretation
6	**Path analysis** : Path coefficient analysis and interpretation
7	**Heterosis** :Estimation of different types of heterosis, inbreeding depression
8 & 9	**Generation mean analysis** :-A,B and C scaling test, Analytical part and Interpretation – Estimation of different types of gene actions.
10	QTL analysis
11&12	Use of computer packages
13 & 14	Diallel analysis. Griffing's methods I and II – Diallel analysis. Hayman's graphical approach. Diallel analysis: interpretation of Results. NCD and their interpretations.
15 &16	Stability : G × E interaction and stability analysis

Suggested Reading

Bos I and 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 and Jinks JL.1985. Biometrical Genetics (3rd Ed.). Chapman and Hall, London.

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

Naryanan SS and Singh P. 2007. Biometrical Techniques in Plant Breeding. Kalyani Publishers, New Delhi.

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

Sharma JR. 2006. Statistical and Biometrical Techniques in Plant Breeding. New Age International Pvt. Ltd.

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

Singh RK and Chaudhary BD. 1987. Biometrical Methods in Quantitative Genetic analysis. Kalyani Publishers, New Delhi.

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

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

e-Suggested Reading

www.iasri.icar.gov.in

www.hau.ac.in/OPstat

GPB 504 VARIETAL DEVELOPMENT AND MAINTENANCE BREEDING 1+1

OBJECTIVE:

The purpose of this course is to make students well acquainted with the techniques and procedures of varietal development. They 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 and millets (wheat, barley, paddy, pearl millet, sorghum, maize and ragi, etc.); Pulses (green gram, black gram, cowpea, pigeon pea, chickpea, field pea, 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 regulationsin 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.

LECTURE SCHEDULE

Lecture No.	Topic	Weightage
1-2	**Variety Development and Maintenance :** Definition- variety, cultivar, extant variety, essentially derived variety, independently derived variety, reference variety, farmers' variety, hybrid, and population; Variety testing, release and notification systems in India and abroad.	20
3-4	**DUS testing :** DUS Descriptors for major crops; Genetic purity concept and maintenance breeding.	10
5	**Safeguards during seed production** : Factors responsible for genetic deterioration of varieties	08
6-7	**Maintenance of varieties :** Maintenance of varieties in self and cross-pollination crops, isolation distances in various crops	08
8	**Principles of seed production :** Methods of nucleus and breeder seed production.	08
9	**Generation system of seed multiplication:** Nucleus, breeders, foundation and certified seeds	08
10-13	**Quality seed production technology :** Quality seed production technology of self and cross-pollinated crop varieties viz. cereals & millets (wheat, barley, paddy, pearlmillet, 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).	20
14	**Seed certification procedures:**	08

	The steps involved in seed certification, Seed certification Agencies	
15-16	**Seed laws and plant variety protection regulations in India and International systems :** Seed law 1966, seed rules 1968, seed order 1983, Seed act 2003, PVP & FRA.	10
	Total	100

Practical:

Practical No.	Topic
1	Identification of suitable areas/locations for seed production.
2	Ear-to-row method.
3 &4	Main characteristics of released and notified varieties, hybrids and parental lines.
5	Study of Environmental Genetic Male Sterility: PGMS and TGMS.
6-7	Identification of important weeds/objectionable weeds.
8	Determination of isolation distance and planting ratios in different crops.
9-10	Seed production techniques of varieties in different crops.
11-13	Hybrid seed production technology of important crops e.g. Cotton, Sorghum, Bajra.
14-15	DUS testing and descriptors in major crops.
16	Variety release proposal formats in different crops.

Suggested Reading

Agarwal RL. 1997. Seed Technology. 2nd Ed. OXford & IBH.
Kelly AF. 1988. Seed Production of Agricultural Crops. Longman.
McDonald MB Jr and Copeland LO. 1997.
Seed Production: Principles and Practices. Chapman & Hall.
Poehlman JM and 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 505 PRINCIPLES OF CYTOGENETICS 2 + 1

OBJECTIVE :

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

Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

Practical

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

LECTURE SCHEDULE

Lecture No.	Topic	Weightage
1	**Introduction to Cytogenetics**: Important concepts of cytogenetics, important landmarks of cytogenetics	4
2	**Chromosome:** Structure of Chromosomes in prokaryotes and eukaryotes, chromonemata, chromosome matrix, chromomere, centromere, secondary constriction and teleomere. Special types of chromosomes.	7
3 & 4	**Chromosomal theory of inheritance** **Cell**: Cell structure, Cell cycle, cell division, mitosis and meiosis; differences, significance and deviation. Synapsis, structure and	7

	functions of synaptonemal complex and spindle apparatus, anaphase movement of chromosomes.	
5 & 6	**Crossing over**: mechanism of crossing over, mechanism and theories of crossing over, recombination models, cytological basis. Variation in chromosome structure. Evolutionary significance	7
7	**Karyotype:** Introduction to techniques of Karyotyping, Chromosome banding and painting, in situ hybridization and various application	4
8, 9 & 10	**Chromosomal aberrations:** Structural and numerical variations of chromosomes and implication. Symbols and terminologies for chromosome number euploidy, haploids, diploids and polyploids. Utilization of aneuploids in gene location.	8
11 & 12	**Variation in chromosome behaviour:**, somatic segregation and chimeras, endomitosis and somatic reduction. Evolutionary significance of chromosomal aberrations, balanced lethals and chromosome complexes.	7
13 & 14	Inter-varietal chromosome substitutions **Polyploidy**: concept of polyploidy, role of polyploidy in crop breeding. Evolutionary advantages of auto polyploids and allopolyploids.	7
15 & 16	**Aneuploids:** Role of aneuploids in basic and applied aspects of crop breeding, maintenance and utilization in gene mapping.	7
17	**Alien Addition and Alien substitution lines**, creation and utlization.	6
18	**Apomixis** Evolutionary and genetic problems in crop with apomixes.	4
19	Reversion of autopolyploids to diploids. Genome mapping in polyploids. Interspecific hybridization and allopolyploids.	5
20 & 21	Synthesis of new crops viz., wheat, triticale and brassica.	7
22, 23 & 24	**Distant Hybridization:** Hybrids between species with same chromosome number, alien translocations. Hybrids between species with different chromosome number. Gene transfer using amphidiploids in Bridge species.	8
25	Fertilization barriers in crop plants at pre and post fertilization levels In-vitro techniques to overcome the fertilization barriers in crops.	4
26, 27 & 28	Chromosome manipulations in wide hybridization; production and use of haploids, dihaploids and doubled haploids in genetics and plant breeding.	8
	Total	**100**

Practical

Practical No.	Topic
1	Study of cytological techniques, various chemicals to be used for fixation, dehydration, embedding, staining, cleaning
2	Study of various types of microscope.
3	Preparation of specimen for observation.

4	Study of Mitosis in agricultural crop
5	Study of Meiosis in agricultural crop
6	Study of Micrometery and study of pollen grain of agricultural crop
7	Study of pollen germination *in vivo and in vitro*
8	Study of staining and preparations of permanent slides
9	Study of Polyploidy.
10	Study of induction of haploids (Anther culture & Ovule culture)

Suggested Reading

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

GPB 506 MOLECULAR BREEDING AND BIOINFORMATICS* 2 + 1

OBJECTIVE:

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. 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 and sequencing by Edman degradation and 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 and 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 and PMC, OMIM and OMIA, ORF finder;
Comparative Genomic Resources: - Map Viewer (UCSC Browser and Ensembl);
Primer designing- Primer 3/ Primer BLAST.

LECTURE SCHEDULE

Lecture No.	Topic	Weightage
1 & 2	Genotyping; Biochemical and Molecular markers; Morphological, biochemical and DNA-based markers (RFLP, RAPD, AFLP, SSR, SNPs, ESTs, etc.), Functional markers.	8
3	Mapping populations (F2s, back crosses, RILs, NILs and DH); Molecular mapping and tagging of agronomically important traits.	8
4	Statistical tools in marker analysis.	4
5	Allele mining.	4
6	Marker-assisted selection for qualitative and quantitative traits.	4
7	QTLs analysis in crop plants.	4
8	Marker-assisted backcross breeding for rapid introgression.	4

9 &10	Genomics- assisted breeding; Generation of EDVs; Gene pyramiding.	4
11	Introduction to Comparative Genomics	4
12	Large scale genome sequencing strategies.	
13	**Genome projects** : Human genome project; Arabidopsis genome project; Rice genome project.	4
14	Comparative genomics tools.	4
15	Introduction to proteomics.	4
16 &17	2D gel electrophoresis; chromatography and sequencing by Edman degradation and mass spectrometry; Endopeptidases.	4
18	Nanotechnology and its applications in crop improvement.	4
19 & 20	Recombinant DNA technology, transgenes, method of transformation. selectable markers and clean transformation techniques, vector-mediated gene transfer, physical methods of gene transfer.	4
21 & 22	Production of transgenic plants in various field crops: cotton, wheat, maize, rice, soybean, oilseeds, sugarcane, etc. and commercial releases.	4
23 &24	Biotechnology applications in male sterility/ hybrid breeding, molecular farming; Application of Tissue culture in molecular breeding.	4
25	MOs and related issues (risk and regulations);	4
26 & 27	GMO; International regulations, biosafety issues of GMOs; Regulatory procedures in major countries including India, ethical, legal and social issues.	4
28	Intellectual property rights.	4
29	Introduction to bioinformatics.	4
30	Bioinformatics tools.	4
31 & 32	Biological data bases (primary and secondary), implications in crop improvement.	4
	Total	**100**

Practical

Practical No.	**Topic**
1	Requirements for plant tissue culture laboratory;
2	Techniques in plant tissue culture;
3	Media components and media preparation
4	Aseptic manipulation of various explants, observations on the contaminants occurring in media, interpretations
5	Inoculation of explants, callus induction and plant regeneration;
6	Standardizing the protocols for regeneration;
7	Hardening of regenerated plants; Establishing a greenhouse and hardening procedures
8	Visit to commercial micropropagation unit
9	Transformation using Agrobacterium strains GUS assay in transformed cells/ tissues;
10	DNA isolation, DNA purity and quantification tests;

11	Gel electrophoresis of proteins and isozymes, PCR-based DNA markers, gel scoring and data analysis for tagging and phylogenetic relationship
12	Construction of genetic linkage maps using computer software
13	NCBI Genomic Resources, GBFF, Swiss Prot, Blast n/ Blast p,
14	Gene Prediction Tool, Expasy Resources, PUBMED and PMC, OMIM and OMIA, ORF finder;
15	Comparative Genomic Resources: - Map Viewer (UCSC Browser and Ensembl);
16	Primer designing- Primer 3/ Primer BLAST

Suggested Reading

Azuaje F and Dopazo J. 2005. Data Analysis and Visualization in Genomics and Proteomics. John Wiley and 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 V L and Nasim A. 1990. Genetic Engineering and Biotechnology: Concepts, Methods and Applications. Oxford & IBH.

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

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

Jollès P and 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 and Russel D. 2001. Molecular Cloning - a Laboratory Manual. 3rd Ed. Cold Spring Harbor Lab. Press.

Singh B D. 2005. Biotechnology, Expanding Horizons. Kalyani Publishers, New Delhi.

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

GPB 507 BREEDING FOR QUALITY AND SPECIAL TRAITS 2 + 1

OBJECTIVE:

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

THEORY

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

Practical

Grain quality evaluation in rice; Correlating ageing and quality improvement in rice;
Quality analysis in millets;
Estimation of anti-nutritional factors like tannins in different varieties/ hybrids: A comparison;
Quality parameters evaluation in wheat, pulses and oilseeds;
Evaluation of quality parameters in cotton, sugarcane and potato;
Value addition in crop plants;
Post-harvest processing of major field crops;
Quality improvement in crops through tissue culture techniques;
Evaluating the available populations like RIL, NIL, etc. for quality improvement using MAS procedures;
Successful example of application of MAS for quality trait in rice, mustard, maize, etc.

LECTURE SCHEDULE

Lecture No.	Topic	Weightage
1	Developmental biochemistry and genetics of carbohydrate	8
2	Developmental biochemistry and genetics of proteins, fats.	
3	Developmental biochemistry and genetics of vitamins, amino acids.	
4	Developmental biochemistry and genetics of anti-nutritional factors.	
5	Nutritional improvement- a human perspective	3
6	Breeding for grain quality parameters in rice and its analysis- golden rice and aromatic rice, breeding strategies, achievements and application in Indian context	4
7	Molecular basis of quality traits and their manipulation in rice,	3
8	Post-harvest manipulation for quality improvement	2
9	Breeding for baking qualities in wheat, characters to be considered	4
10	Breeding strategies- Molecular and cytogenetic manipulations for quality	6

	improvement in wheat	
11	Breeding for quality improvement in barley	8
12	Breeding for quality improvement in oat	
13	Breeding for quality improvement in sorghum	8
14	Breeding for quality improvement in pearl millet	
15	Quality protein maize- concept and breeding strategies	5
16	Breeding for quality improvement in forage crops	5
17	Genetic resource management for sustaining nutritive quality in crops	4
18	Breeding for quality in pulses	6
19	Breeding for quality in pulses	
20	Breeding for quality in groundnut, sesame, sunflower and minor oilseeds	6
21	Breeding for quality in groundnut, sesame, sunflower and minor oilseeds	
22	Molecular basis of fat formation and manipulation to achieve more PUFA in oil crops	2
23	Genetic manipulation for quality improvement in cotton	6
24	Genetic engineering protocols for quality improvement- achievements made	8
25	Genetic engineering protocols for quality improvement- achievements made	
26	Value addition in crops	4
27	Classification and importance quality characters	4
28	Nutritional genomics and second generation transgenics	4
	Total	**100**

Practicals

Practical No.	Topics
1	Grain quality evaluation in rice
2	Correlating and ageing and quality improvement in rice
3	Quality analysis in millets
4	Estimation of anti nutritional factors in different varieties/hybrids
5	Quality parameters evaluation in wheat
6	Quality parameters evaluation in pulses
7	Quality parameters evaluation in oilseeds
8	Quality parameters evaluation in cotton
9	Quality parameters evaluation in forage crops
10	Quality parameters evaluation in maize
11	Value addition in crop plants
12	Post harvest processing of major field crops
13	Quality improvements in crops through tissue culture techniques
14	Evaluating the available populations like RIL, NIL etc. for quality improvement using MAS procedures
15	Successful example of application of MAS for quality trait in rice, mustard, maize, etc

Suggested Reading

Chahal GS and SS Ghosal. 2002. Principles and procedures of plant breeding – Biotechnological and Conventional approaches, Narosa Publications.

Chopra VL. 1997. Plant Breeding. Oxford & IBH. 2018.
FAO 2001. Speciality Rices of the World - Breeding, Production and Marketing. Oxford & IBH,1 Nov 2001.
Ghosh P. 2004. Fibre Science and Technology. Tata McGraw Hill.
Gupta S K. 2007. Advances in Botanical Research Vol. 45 Academic Press USA.
Hay R K. 2006. Physiology of Crop Yield. 2nd Ed. Blackwell.
Nigam J. 1996. Genetic Improvement of Oilseed Crops. OXford & IBH.
Singh BD. 1997. Plant Breeding. Kalyani Publishers, New Delhi.
Singh RK, Singh UK and Khush GS. 2000. Aromatic Rices. OXford & IBH.

GPB 508	MUTAGENESIS AND MUTATION BREEDING	1 + 1

OBJECTIVE:

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

Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

Practical

Precautions on handling of mutagens; Dosimetry-Studies of different mutagenic agents: Physical mutagens and Chemical mutagens;
Learning on Radioactivity- Production source and isotopes at BRIT, Trombay, Learning about gamma chamber;
Radiation hazards: Monitoring – safety regulations and safe transportation of radioisotopes, visit to radio isotope laboratory; learning on safe disposal of radioisotopes;
Hazards due to chemical mutagens – Treating the plant propagules at different doses of physical and chemical mutagens;
Procedures in combined mutagenic treatments;
Raising the crop for observation; Mutagenic effectiveness and efficiency, calculating the same from earlier literature;
Study of M1 generation – Parameters;
Study of M2 generation – Parameters;
Mutation breeding in cereals and pulses-achievements made and an analysis;
Mutation breeding in oilseeds and cotton- achievements and opportunities;
Mutation breeding in forage crops and vegetatively propagated crops;
Procedure for detection of mutations for polygenic traits in M2 and M3 generations.

LECTURE SCHEDULE

Lecture No.	Topic	Weightage
1	Mutation and its history - Nature and classification of mutations: spontaneous and induced mutations, micro and macro mutations,	**6**
2	Pre and post adaptive mutations - Detection of mutations in lower and higher organisms – paramutations.	**4**
3	Mutagenic agents: Physical - Radiation types and sources: Ionising and non-ionizing radiations *viz*., X rays, γ rays, ,α and β particles, protons, neutrons and UV rays - Radiobiology	**6**
4	Mechanism of action of various radiations (photoelectric absorption, Compton scattering and pair production) and their biological effects – RBE and LET relationships.	**6**
5	Effect of mutations on DNA - Repair mechanisms operating at DNA, chromosome, cell and organism level to counteract the mutation effects -Dosimetry - Objects and methods of treatment.	**6**
6	Factors influencing mutation: dose rate, acute *vs* chronic irradiation, recurrent irradiation, enhancement of thermal neutron effects - Radiation sensitivity and modifying factors: External and internal sources- Oxygen, water content, temperature and nuclear volume.	**6**

7	Chemical mutagens- Classification - Base analogues, antibiotics, alkylating agents, acridine dyes and other mutagens: their properties and mode of action - Dose determination and factors influencing chemical mutagenesis. Treatment methods using physical and chemical mutagens - Combination treatments	**6**
8	Other causes of mutation - direct and indirect action, comparative evaluation of physical and chemical mutagens.	**4**
9	Observing mutagen effects in M1 generation: plant injury, lethality, sterility, chimeras *etc*.,	**8**
10	Observing mutagen effects in M2 generation -Estimation of mutagenic efficiency and effectiveness – spectrum of chlorophyll and viable mutations -– Mutations in traits with continuous variation.	**8**
11	Factors influencing the mutant spectrum: genotype, type of mutagen and dose, pleiotropy and linkage *etc*.	**8**
12	Individual plant based mutation analysis and working out effectiveness and efficiency in M3 generation - Comparative evaluation of physical and chemical mutagens for creation of variability in the same species – Case studies.	**8**
13	*In vitro* mutagenesis – callus and pollen irradiation; Handling of segregating generations and selection procedures; Validation of mutants.	**6**
14	Mutation breeding for various traits (disease resistance, insect resistance, quality improvement, etc) in different crops- Procedures for micromutations breeding/polygenic mutations.	**6**
15	Achievements of mutation breeding- varieties released across the world- Problems associated with mutation breeding.	**4**
16	Use of mutagens in genomics, allele mining, TILLING.	**8**
	Total	**100**

Practicals

Practical No.	Topic
1	Learning the precautions on handling of mutagens; Dosimetry.
2	Studies of different mutagenic agents: Physical mutagens.
3	Studies of different mutagenic agents: Chemical mutagens.
4	Learning on Radioactivity – Production of source and isotopes at BRIT, Trombay Learning about gamma chamber; Radiation hazards - Monitoring – safety regulations and safe transportation of radioisotopes.
5	Visit to radio isotope laboratory.
6	learning on safe disposal of radioisotopes - Hazards due to chemical mutagens.
7	Treating the plant propagules at different doses of physical and chemical mutagens - Learning combined mutagenic treatments; Raising the crop for observation.
8	Mutagenic effectiveness and efficiency; Calculating the same from earlier literature.
9	Study of M1 generation – Parameters to be observed.
10	Study of M2 generation – Parameters to be observed.
11	Mutation breeding in cereals and pulses – Achievements made and an analysis.
12	Mutation breeding in oilseeds and cotton – Achievements and opportunities.

13	Mutation breeding in forage crops and vegetatively propagated crops.
14	Procedure for detection of mutations for polygenic traits in M_2 and M_3 generations.

Suggested Reading

Alper T. 1979. Cellular Radiobiology. Cambridge Univ. Press, London.
Chadwick KH and Leenhouts HP. 1981. The Molecular Theory of Radiation Biology. Springer- Verlag.
Cotton R, Edkin E and Forrest S. 2000. Mutation Detection: A Practical Approach. OXford Univ. Press.
International Atomic Energy Agency. 1970. Manual on Mutation Breeding. International Atomic Energey Agency, Vienna, Italy.
Shu QY, Forster BP and Nakagawa N. 2012. Plant Mutation Breeding and Biotechnology. Gutecnberg Press Ltd. Rome Italy ISBN:978-925107-022-2 (FAO).
Singh BD. 2003. Genetics. Kalyani Publishers, New Delhi.
Strickberger MW. 2005. Genetics. 3rd Ed. Prentice Hall.
Web reading:
www.barc.gov.in

GPB 509	**HYBRID BREEDING**	**2 + 1**

Objective:

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

Theory

Unit -I

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

Unit II

Prediction of heterosis from various crosses, inbreeding depression, coefficient of inbreeding and its estimation, residual heterosis in F2 and segregating populations, importance of inbreeding in exploitation of heterosis – case studies.; Relationship between genetic distance and expression of heterosis, case studies; Divergence and genetic distance analyses, morphological and molecular genetic distance in predicting heterosis; Development of heterotic pools in germplasm/ genetic stocks and inbreeds, their improvement for increasing heterosis.

Unit III

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

Unit IV

Hybrid seed production system: 3-line, 2-line and 1-line system; Development of inbreeds and parental lines- A, B and R lines – functional male sterility; Commercial exploitation of heterosis, maintenance breeding of parental lines in hybrids; Fixation

of heterosis in self, cross and often cross pollinated crops, asexually/ clonally propagated crops, problems and prospects; Apomixis in fixing heterosis-concept of single line hybrid; Organellar heterosis and complementation.

Unit V

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

Practical

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

Lecture No.	Topic	Weightage
1	**History of heterosis** – Nomenclature, definitions of heterosis, Heterosis in natural population & inbred population.	**5**
2 &3	**Genetic consequences** - Selfing in self pollinated crops, cross pollinated crops & asexually propagated crops.	**5**
4 &5	Pre Mendelian & post Mendelian ideas .	**5**
6	**Heterosis concept ;** Genetic Basis : 1. Dominance Hypothesis 2. Over dominance Hypothesis 3. Epistasis	**5**
7	**Physiological basis of heterosis.** 1. Embryo development & heterosis 2. Early Seedling growth & heterosis. 3. Later growth & heterosis 4. Mitochondrial complementation.	**3**
8	**Biochemical & molecular basis of heterosis.**	**5**
9	**Estimation of heterosis** 1. Average heterosis 2. Heterobeltiosis 3. Standard heterosis Biometrical basis of heterosis	**4**
10	Evolutionary concepts of heterosis & Prediction of heterosis from	**2**

	various crosses.	
11	**Inbreeding depression,** Definition, Frequency of inbreeding, Genetic basis of inbreeding depression, Degrees of inbreeding depression.	**4**
12	**Effects of inbreeding :** 1. Genetic effect 2. Morphological effect.	**2**
13	**Estimation of inbreeding depression.** 1. High 2. Moderate 3. Low 4. No inbreeding depression Importance of inbreeding in exploitation of heterosis	**4**
14	Relationship between genetic distance & expression of divergence & Genetic distance analysis.	**3**
15	Morphological & molecular genetic distance in predicting heterosis.	**2**
16	Development of heterosis pools in germplasm/ genetic stocks & in breeds, Improvement of increase heterosis.	**2**
17 &18	**Male sterility :-** Definition, Feature of Male sterility, Types of male sterility 1. Genetic Male sterility 2. Cytoplasmic Male sterility 3. Cytoplasmic genetic Male sterility 4. Chemical induced Male sterility 5. Transgenic Male sterility	**5**
19	**Use of Male sterility** :- In heterosis breeding maintenance, transfer & restoration of different types of Male sterility	**5**
20 & 21	**Self incompatibility** :- Definition Types ; 1. Heteromorphic system 2. Homomorphic system a) Gametophytic b) Sporophytic use of self in compatibility in development of hybrids.	**5**
22	**Hybrid seed production system -** 3 line, 2 line & 1 line system.	**3**
23 &24	**Development of inbred lines :** 1. Conventional method / Selfing of heterozygous. 2. Non – Conventional method :- Use of monoploids.	**5**
25	**Evaluation of inbred lines :** 1. Top cross methods (Conventional method) General combining ability 2. Single cross method.	**4**
26	Maintenance of A, B & R lines Commercial exploitation of heterosis.	**4**
27	**Fixation of heterosis in self, cross & asexually propagated crops.** 1. Asexually reproduction. 2. Apomixis 3. Balanced lethal system. 4. Polyploidy.	**4**
28	**Development of male sterile line** - Transfer of male sterile line, problems & prospects	**4**
29	Organceller heterosis & Complementation.	**2**

30	Creation of male sterility through genetic engineering & its exploitation in heterosis.	**4**
31 & 32	Heterosis breeding in wheat, rice, maize, cotton, pearl millet, sorghum & oil seed crops. (rapeseed- mustard, sunflower, safflower and castor oilseed crops) and pigeonpea.	**5**
	Total	**100**

PRACTICAL :

Practical No.	Topic
1.	Calculation of selection indices and selection differential.
2.	Characterization of male sterile line in millets using morphological descriptors
3.	Identification of restorer lines & diversification of male sterile source.
4.	Creation of male sterile, its diversification & identification of restorer lines in forage crops.
5.	Development of male sterile in oilseeds pulses & cotton.
6.	Problems of Apomicts breeding.
7.	Estimation of heterotic parameters in self-pollinated crops
8.	Estimation of heterotic parameters in cross pollinated crops
9.	Estimation of heterotic parameters in asexually propagated crops
10.	Estimation of heterosis. :Estimation from the various models for heterosis parameters
11	Hybrid seed production in field crops—an account on the released hybrids, their potential, problems and ways of overcoming it
12.	Current status & future trends of hybrid of different crops. Hybrid breeding at National and International level, opportunities ahead.

Suggested Reading :

Agarwal R L. 1998. Fundamental of Plant Breeding and hybrid Seed Production. Science Publisher London.

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

Ben H L. 1998. Statistical Genomics – Linkage, Mapping and QTL Analysis. CRC Press.

Chahal G S and Gossal S S. 2002. Principles and procedures of Plant Breeding, Biotechnology and conventional Approaches. Narosa Publishing House. New Delhi

De J G. 1988. Population Genetics and Evolution. Springer-Verlag. 30 January 2012

Hartl D L. 2000. A Primer of Population Genetics. 3rd Ed. Sinauer Assoc.

Mettler L E and Gregg T G. 1969. Population Genetics and Evolution. Prentice-Hall. 25 April 1988

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

Mukherjee B K. 1995.The Heterosis Phenomenon. Kalyani Publishers, New Delhi.

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

Richards A J. 1986. Plant Breeding Systems. George Allen & Unwin. 30 May 1997

Singh B D. 2006. Plant Breeding. Kalyani Publishers, New Delhi.

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

Virmani S S. 1994. Heterosis and Hybrid Rice Breeding. Monographs of ”Theoretical and Applied Genetics”, Springer-Verlag.

GPB 510 SEED PRODUCTION AND CERTIFICATION 1 + 1

Objective:

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

Theory

Unit I

Importance of seed as basic input in agriculture; Seed quality concept and importance; Generation system of seed multiplication -Varietal replacement rate, Seed multiplication ratios, Seed replacement rate, Seed renewal period and seed demand and supply; Various factors influencing seed production –Physical and Genetic purity in seed production; Factors responsible for varietal and genetic deterioration.

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

Unit VI

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

Practical

Planting design for variety- hybrid seed production techniques, planting ratio of male and female lines, synchronization of parental lines and methods to achieve synchrony;

Identification of rogues and pollen shedders, supplementary pollination, detasseling, hand emasculation and pollination;

Pollen collection and storage methods, pollen viability and stigma receptivity;

Pre-harvest sanitation, maturity symptoms, harvesting techniques;

Visits to seed production plots - visit to seed industries;

Planning for seed production: cost benefit ratio, seed multiplication ratio and seed replacement rate;
General procedure of seed certification, identification of weed and other crop seeds as per specific crops, field inspection at different stages of a crop and observations recorded on contaminants and reporting of results, inspection and sampling, harvesting/ threshing, processing and after processing for seed law enforcement;
Specifications for tags and labels to be used for certification purpose.

Lecture schedule

Lecture No.	Topic	Weightage
1	Seed as basic input in agriculture; seed development in cultivated plants;	5
2	Seed quality concept and importance of genetic purity in seed production	10
3	Generation system of seed multiplication; maintenance of Nucleus seed, production of Breeder, Foundation and Certified seed– criteria involved	10
4	Seed multiplication ratios, seed replacement rate, demand and supply	5
5	Various factors influencing seed production –Physical and Genetic purity in seed production; Factors responsible for varietal and genetic deterioration.	10
6	Nucleus seed production and its maintenance - Maintenance of parental lines of hybrids, Production of breeder, foundation and certified seed and their quality maintenance;	10
7	Principles of seed production in self- and cross-pollinated crops	5
8	Hybrid seed production - system and techniques involved in Seed village concept;.	5
9	Organic seed production and certification	5
10 &11	Principles of seed production in field crops; Floral structure, pollination mechanism and seed production techniques in self- and cross-pollinated cereals and millets.	10
12	Floral structure, pollination mechanism and methods and techniques of seed production in major pulses and oilseed crops; Varietal and hybrid seed production techniques in Pigeon pea, Mustard, Castor and Sunflower	5
13	Floral structure, pollination mechanism and methods and techniques of seed production in major commercial fibres. Hybrid-seed production techniques in major vegetatively propagated crops	5
14	Seed certification - history, concept, objectives; Central seed certification board Seed certification agency/ organization and staff requirement; Legal status - Phases of seed certification, formulation, revision and publication of seed certification standards;	5
15 & 16	Minimum Seed Certification Standards (MSCS) for different crops - General and specific crop standards, Field and seed standards; Planning and management of seed certification programs; Eligibility of a variety for certification, area assessment, cropping history of the seed field	10
	Total	100

PRACTICAL

Practical No.	Topic

1 & 2	Planting design for variety- hybrid seed production techniques, planting ratio of male and female lines,
3	Synchronization of parental lines and methods to achieve synchrony
4	Identification of rogues and pollen shedders, supplementary pollination, detasseling, hand emasculation and pollination
5	Pollen storage, hand emasculation and pollination in Cotton, detasseling in Corn,
6	Identification of rogues and pollen shedders; Pollen collection, storage, viability and stigma receptivity;
7	Pre-harvest sanitation, maturity symptoms, harvesting techniques
8	Visits to seed production plots and seed industries
9	Planning for seed production: cost benefit ratio, seed multiplication ratio and seed replacement rate
10 &11	Study of General procedure of seed certification, identification of weed and other crop seeds as per specific crops, field inspection at different stages of a crop and observations recorded on contaminants and reporting of results,
	Inspection and sampling, harvesting/ threshing, processing and after processing for seed law enforcement
12	To study the specifications for tags and labels to be used for certification purpose.

Suggested Reading

Agrawal PK and Dadlani M. 1987. Techniques in Seed Science and Technology, South Asian Publishers, Delhi.

Agrawal RL. 1997. Seed Technology, OXford & IBH Publishing.

Anon, 1965. Field Inspection Manual and Minimum Seed Certification Standards, NSC Publication, New Delhi.

Anon. 1999. Manual of Seed Certification procedures. Directorate of Seed Certification, Coimbatore, Tamil Nadu.

Joshi AK and Singh BD. 2004. Seed Science and Technology, Kalyani Publishers, New Delhi.

Kelly AF. 1988. Seed Production of Agricultural Crops. John Wiley, New York.

Mc Donald MB and Copeland LO. 1997. Seed Science and Technology, Scientific Publisher, Jodhpur.

Ramamoorthy K, Sivasubramaniam K and Kannan M. 2006. Seed Legislation in India. Agrobios (India), Jodhpur, Rajasthan.

Singhal NC. 2003. Hybrid Seed Production in Field Crops, Kalyani Publications, New Delhi

Tunwar NS and Singh SV. 1988. Indian Minimum Seed Certification Standards. Central Seed Certification Board, Ministry of Agriculture, New Delhi.

e-Resources

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

GPB 511 CROP BREEDING I (*KHARIF* CROPS) 2 + 1

OBJECTIVE :

To provide in sight 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, releasedvarieties, eXamples of MAS used for improvement- QPM and Bt maize – strategies and implications.

Sorghum: 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- biofortified varieties – 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.

LECTURE SCHEDULE

Lecture No.	Topic	Weightage
1-3	**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.	8
4 &5	**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	8
6 &7	**Sorghum:** 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- biofortified varieties – strategies and implications	8
8& 9	**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	8
10 &11	**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	8
12 & 13	**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 improvement10	6
14-16	**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	8

	for failure, ways of overcoming them.	
17 & 18	**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	6
19- 21	**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	8
22 & 23	**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	8
24 & 25	**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.	4
26 & 27	**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.	8
28 &29	**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.	6
30-32	**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.	6
	Total	100

PRACTICAL

Practical No.	Topic
1 & 2	Floral biology, emasculation, pollination techniques in rice, maize, pigeon pea, soybean, sesame, cotton;

3	Study of range of variation for yield and yield components
4	Study of segregating populations in cereal, pulses and oilseed crops
5	Learning on the crosses between different species; attempting crosses between black gram and green gram
6	Evaluating the germplasm of cotton for yield, quality and resistance parameters,
7	Learning the procedures on development of Bt cotton
8	Visit to Cotton Technology Laboratory and Spinning Mills
9	Learning on the Standard Evaluation System (SES) and descriptors; Use of software for database management and retrieval
10	Practical learning on the cultivation of fodder crop species on sewage water, analysing them for yield components and palatability
11 & 12	Laboratory analysis of forage crops for crude protein, digestibility percent and other quality attributes
13	Visit to animal feed producing factories
14	Learning the practice of value addition
15 & 16	Visiting the animal husbandry unit and learning the animal experiments related with palatability and digestibility of fodder

Suggested Reading

Agarwal RL. 1996. Identifying Characteristics of Crop Varieties. OXford & IBH.

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

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

Chopra VL and 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 Ba nos, Manila, Philippines.

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

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

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

Nanda J S. 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 and Singh HG. 1993. Crop Breeding and Genetics. Kalyani.

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

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

Singh HG, Mishra SN, Singh TB, Ram HH and Singh DP. (Eds.). 1994. Crop Breeding in

India.International Book Distributing Co.
Walden DB. 1978. Maize Breeding and Genetics. John Wiley & Sons

GPB 512	CROP BREEDING II (*RABI* CROPS)	2 + 1

OBJECTIVE:

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

LECTURE SCHEDULE

Lecture No.	Topic	Weightage
1-3	**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	12
4 & 5	**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.	8
6 &7	**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	8

	MAS used for improvement	
8 & 9	**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	10
10- 13	**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.	12
14-16	**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.	10
17 -19	**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	12
20-22	**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	8
23-25	**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	10
26- 30	**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.	10
	Total	100

PRACTICAL

Practical No.	Topic
1 & 2	Floral biology, emasculation, pollination techniques in wheat, oats, barley
3	Floral biology, emasculation, pollination techniques in Chick Pea And Rajma
4	Floral biology, emasculation, pollination techniques in rapeseed mustard, sunflower and safflower
5	Study of range of variation for yield and yield components
6	Study of segregating populations in cereal, pulses and oilseed crops;
7	Use of descriptors for cataloguing; Learning on the crosses between different species
8	Trait based screening for stress resistance
9	Learning on the Standard Evaluation System (SES) and descriptors
10	Use of software for database management and retrieval

Suggested Reading

Agarwal R L. 1996. Identifying Characteristics of Crop Varieties. OXford & IBH.

Bahl P N and Salimath PM. 1996. Genetics, Cytogenetics and Breeding of Crop Plants. Vol. I.Pulses and Oilseeds. OXford & IBH.

Gupta S K. 2012. Technological Innovations in Major World Oil crops. Vol. I. Springer, USA.

Gupta S K. 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 and 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 Breeding and Genetics. John Wiley & Sons.

GPB 513	BREEDING VEGETABLE CROPS	2 + 1

OBJECTIVE:-

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

THEORY

Unit I

Breeding for Leafy vegetables: Amaranth, chenopods and lettuce.

Unit II

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

Unit III

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

Unit IV

Breeding for Cole crops: Cabbage, cauliflower, broccoli and knolkhol.

Breeding for Root vegetables: Carrot, beetroot, radish, sweet potato and tapioca.

Unit V

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

Practical

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

LECTURE SCHEDULE

Lecture No.	Topic	
1-4	Breeding for Leafy vegetables: Amaranth, chenopods and lettuce	16
5-8	Breeding for Cucurbits: Gourds, melons, pumpkins and squashes.	16
9-13	Breeding for Solanaceae: Potato and tomato, eggplant, hot pepper, sweet pepper	16
14-18	Breeding for Cole crops: Cabbage, cauliflower, broccoli and knolkhol.	16
19-24	Breeding for Root vegetables: Carrot, beetroot, radish, sweet potato and tapioca.	16
25-32	Breeding for other vegetable crops: Peas, beans, onion, garlic and okra	20
	Total	100

PRACTICAL

Practical No.	Topic
1 & 2	Study of Selection of desirable plants from breeding population
3	Observations and analysis of various qualitative and quantitative traits in germplasm
4	Study of Hybridization and handling segregating generations
5	Studt of Induction of flowering, palanological studies,
6	Study of Selfing and crossing techniques in vegetable crops
7	Study of Hybrid seed production of vegetable crops in bulk
8	Screening techniques for insect-pests in vegetable crops
9	Screening techniques for disease resistance in vegetable crops
10	Screening techniques for environmental stress resistance in vegetable crops
11	Demonstration of sib-mating and mixed population
12 & 13	Molecular marker techniques to identify useful traits in the vegetable crops
14	Special breeding techniques in vegetable crops
15	Visit to breeding blocks,
16	MAS for incorporating traits governed by major and polygenes.

Suggested Reading

Allard RW. 1999. Principles of Plant Breeding. John Wiley & Sons.
Fageria MS, Arya PS and Choudhary AK. 2000. Vegetable Crops: Breeding and Seed Production.Vol. I. Kalyani Publishers, New Delhi.

Kalloo G. 1988. Vegetable Breeding. Vols. I-III. CRC Press.
Kalloo G. 1998. Vegetable Breeding. Vols. I-III (Combined Ed.). Panima Edu. Book Agency.
Peter KV and Pradeep KT. 2008. Genetics and Breeding of Vegetables. ICAR.
Rai N and Rai M. 2006. Heterosis Breeding in Vegetable Crops. New India Publication Agency.
Ram HH. 2005. Vegetable Breeding-Principles and Practices. Kalyani Publishers
Sharma JP. 2010. Principles of Vegetable Breeding. Kalyani Publishers, New Delhi.
Singh BD. 1983. Plant Breeding. Kalyani Publishers.

GPB 514 BREEDING FRUIT CROPS 2 + 1

OBJECTIVE:

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

THEORY

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Practical

Germplasm documentation;
Floral biology of mango, guava, citrus, grape, pomegranate, pollen viability in major fruit crops;
Pollen germination to study time of anthesis and stigma receptivity;
Hybridization technique in important fruit crops, hybrid seed collection and raising;
Colchicine treatment for induction of polyploidy;
Exposure to resistance breeding and screening techniques;
Mutation breeding practices raising and evaluation of segregating populations;
Use of mutagens to induce mutations and polyploidy;
Visit to Biotechnology Lab and study of in-vitro breeding techniques.

LECTURE SCHEDULE

Lecture No.	Topic	Weightage
1 & 2	**Fruit crop breeding**: History, importance of fruit breeding	5
3 & 4	**Centers of diversity**- distribution, domestication and adaptation of commercially important fruits.	5
5-8	**Issues in fruit crop breeding** – heterozygosity, polyploidy, polyembryony, parthenocarpy and seed lessness, incompatibility and sterility systems	10

9-10	Apomixis - merits and demerits, types, variability for economic traits,.	5
11-13	Role of genetic engineering and biotechnology in improvement of fruit crops	10
13-14	Crop improvement in Mango,	10
15-16	Crop improvement in Banana,	5
17-18	Crop improvement in Citrus,	5
19-20	Crop improvement in Grapes,	5
21-22	Crop improvement in Papaya,	5
23-24	Crop improvement in Sapota	5
25-26	Crop improvement in Pomegranate,	5
27-28	Crop improvement in Pineapple	5
29	Crop improvement in Guava,	5
30	Crop improvement in Apple	5
31-32	Crop improvement in other Rosaceous crops and region specific fruit crops	10
	Total	100

PRACTICAL

Practical No.	**Topic**
1	Study of Germplasm documentation;
2 & 4	Study of Floral biology of mango, guava, citrus, grape, pomegranate,
5	Study of pollen viability in major fruit crops
6-7	Pollen germination to study time of anthesis and stigma receptivity;
8-9	Hybridization technique in important fruit crops, hybrid seed collection and raising
10	Colchicine treatment for induction of polyploidy
11-12	Exposure to resistance breeding and screening techniques
13	Mutation breeding practices raising and evaluation of segregating populations
14	Use of mutagens to induce mutations and polyploidy
15	Visit to Biotechnology Lab
16	Study of in-vitro breeding techniques

Suggested Reading

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

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

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

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

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

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

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

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

Ray PK. 2002. Breeding of Tropical and Sub-tropical Fruits. Narosa Publishing House, New Delhi.
Simmonds NW. 1976. Evolution of Crop Plants, Orient Longman, London.

GPB 515 BREEDING ORNAMENTAL CROPS 2 + 1

Objective :-

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

Theory

Unit I

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

Unit II

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

Unit III

Development of promising cultivars of important ornamental and flower crops; Role of Heterosis and its exploitation, production of F1 hybrids and utilization of male sterility.

Unit IV

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

Practical

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

Lecture No.	Topic	Weightage
1	History of improvement of ornamental plants;	6
2-4	Centre of origin of ornamental crop; Objectives and techniques in ornamental plant breeding.	10
5-6	Introduction, selection, hybridization, mutation and biotechnological techniques for improvement of ornamental and flower crops, viz., Rose and Jasmine	6
7-8	Introduction, selection, hybridization, mutation and biotechnological techniques for improvement of ornamental and flower crops in Chrysanthemum,	6
9-10	Introduction, selection, hybridization, mutation and biotechnological techniques for improvement of ornamental and flower crops in Tuberose and	6

	Gerbera	
11-12	Introduction, selection, hybridization, mutation and biotechnological techniques for improvement of ornamental and flower crops in Gladiolus and Dahlia	6
13-14	Introduction, selection, hybridization, mutation and biotechnological techniques for improvement of ornamental and flower crops in Lilium and Gaillardia	6
15-16	Introduction, selection, hybridization, mutation and biotechnological techniques for improvement of ornamental and flower crops in Petunia and Bouganvillea,	6
17-18	Introduction, selection, hybridization, mutation and biotechnological techniques for improvement of ornamental and flower crops in Marigold and Pansy.	6
19-20	Introduction, selection, hybridization, mutation and biotechnological techniques for improvement of ornamental and flower crops in Geranium and Antirrhinum	6
21-22	Introduction, selection, hybridization, mutation and biotechnological techniques for improvement of ornamental and flower crops in China aster and Orchids	6
23-24	Introduction, selection, hybridization, mutation and biotechnological techniques for improvement of ornamental and flower crops in Carnation and Hibiscus	6
25-26	Development of promising cultivars of important ornamental and flower crops;	6
27-28	Role of Heterosis and its exploitation, production of F1 hybrids and utilization of male sterility.	6
29-31	Production of open pollinated seeds, harvesting, processing and storage of seeds	6
32	Seed certification	6
	Total	100

Practical

Practical No.	Topic
1-4	Study of floral biology and pollination in important species and cultivars of ornamental crops;
5-6	Techniques of inducing polyploidy and mutation;
6-7	Production of pure and hybrid seed;
8-10	Methods of breeding suited to seed propagated plants;
11	Polyploidy and mutations to evolve new varieties;
12-15	Breeding methods for biotic and abiotic stresses;
16	Visit to research institutes involved in ornamental crop breeding

Suggested Reading

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

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

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

Bose T K and Yadav LP. 2003. Commercial Flowers. Naya Prokash Publishers, Kolkata.
Chadha K L and Bhattacharjee S K. Advances in Horticulture Vol. 12, Malhotra Publishing House, New Delhi.
Mc Donald M B and Kwong F Y. 2005. Flower Seeds Biology and Technology, CABI Publishing, Oxfordshire, U K.
Watts L.1980. Flower and Vegetable Plant Breeding. Grower Books.

GPB 516	Breeding for Stress Resistance and Climate Change	2 + 1

Objective :

Climate change is a big challenge to sustain higher crop productivity and nutritional quality. Concept of breeding for stress tolerance and development of hybrids/ varieties for climate change is of prime importance in plant breeding. Therefore this course is essential for budding plant breeders. To apprise about various abiotic and biotic stresses influencing crop yield, mechanisms and genetics of resistance and methods to breed stress tolerant varieties.

Theory

Unit I

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

Unit II

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

Unit III

Types and genetic mechanisms of resistance to biotic stresses –Horizontal and vertical resistance in crop plants; Quantitative resistance/ adult plant resistance and slow rusting resistance; Classical and molecular breeding methods - Measuring plant resistance using plant fitness; Behavioural, physiological and insect gain studies; Phenotypic screening methods for major pests and diseases; Recording of observations; Correlating the observations using marker data – Gene pyramiding methods and their implications.
Classification of abiotic stresses - Stress inducing factors, moisture stress/ drought and water logging and submergence; Acidity, salinity/ alkalinity/ sodicity; High/ low temperature, wind, etc.; Stress due to soil factors and mineral toxicity; Physiological and Phenological responses; Emphasis of abiotic stresses in developing breeding methodologies.

Unit IV

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

Unit V

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

Practical

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

LECTURE SCHEDULE

Lecture No.	Topic	Weightage
1	Concept and impact of climatic change	3
2	Importance of plant breeding with special reference to biotic and abiotic stress resistance	4
3	Classification of biotic stresses – major pests and diseases of economically important crops.	4
4-5	Concepts of resistance to insect and pathogen resistance; Analysis and inheritance of resistance variation.	5
6-7	Host defence responses to pathogen invasions- Biochemical and molecular mechanisms; Acquired and induced immunity and systemic acquired resistance (SAR).	5
8-9	Host-pathogen interaction, gene-for-gene hypothesis, molecular evidence for its operation and exceptions.	5
9-10	Concept of signal transduction and other host-defence mechanisms against viruses and bacteria.	5
11-13	Types and genetic mechanisms of resistance to biotic stresses –Horizontal and vertical resistance in crop plants; Quantitative resistance/ adult plant resistance and slow rusting resistance.	5
14-16	Classical and molecular breeding methods - Measuring plant resistance using plant fitness; Behavioural, physiological and insect gain studies;	10
17-19	Phenotypic screening methods for major pests and diseases; Recording of observations; Correlating the observations using marker data – Gene pyramiding methods and their implications.	10
20-23	Classification of abiotic stresses - Stress inducing factors, moisture stress/ drought and water logging and submergence; Acidity, salinity/ alkalinity/	10

	sodicity; High/ low temperature, wind, etc.; Stress due to soil factors and mineral toxicity; Physiological and Phenological responses; Emphasis of abiotic stresses in developing breeding methodologies	
24-27	Genetics of abiotic stress resistance; Genes and genomics in breeding cultivars suitable to low water regimes and water logging and submergence, high and low/ freezing temperatures; Utilizing MAS procedures for identifying resistant types in important crops like rice, sorghum, wheat, cotton, etc.;	10
28-29	Breeding for resistance to stresses caused by toxicity, deficiency and pollutants/ contaminants in soil, water and environment	8
30	Use of crop wild relatives as a source of resistance to biotic and abiotic factors in major field crops;	8
31-32	Transgenics in management of biotic and abiotic stresses, use of toxins, protease inhibitors, lectins, chitinases and Bt for diseases and insect pest management	8
	Total	100

PRACTICAL:

Practical No.	Topic
1 & 2	Understanding the climatological parameters and predisposal of biotic and abiotic stress factors- ways of combating them for diseases caused by fungi and bacteria.
3	Symptoms and data recording; use of MAS procedures;
4-6	Phenotypic screening techniques for sucking pests and chewing pests – Traits to be observed at plant and insect level;
7-8	Phenotypic screening techniques for nematodes and borers; Ways of combating them;
9	Evaluating the available populations like RIL, NIL, etc. for pest resistance;
10-11	Use of standard MAS procedures. Breeding strategies - Weeds – ecological, environmental impacts on the crops;
12-13	Breeding for herbicide resistance;
14	Screening crops for drought and flood resistance; factors to be considered and breeding strategies;
15	Screening varieties of major crops for acidity and alkalinity- their effects and breeding strategies;
16	Screening forage crops for resistance to sewage water and tannery effluents; Quality parameters evaluation

Suggested Reading:

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

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

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

Li P H and Sakai A. 1987. Plant Cold Hardiness. Liss, New York Springer

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

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

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

Russel G E. 1978. Plant Breeding for Pest and Disease Resistance. Butterworths.
Sakai A and Larcher W. 1987. Frost Survival in Plants. Springer-Verlag.
Turener N C and Kramer P J. 1980. Adaptation of Plants to Water and High Temperature Stress. John Wiley & Sons.
van der Plank J E. 1982. Host-Pathogen Interactions in Plant Disease. Academic Press.

GPB 517 Germplasm Characterization and Evaluation 1 + 1

Objective :

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

Theory

Unit I

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

Unit II

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

Unit III

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

Practical

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

LECTURE SCHEDULE :

Lecture No.	Topic	Weightage
1	Understanding genetic diversity in crop plants;	4
2	Crop descriptors, descriptor states	8
3	Germplasm characterization/ evaluation procedures; evaluation of germplasm for specific traits;	10

4 & 5	Measuring diversity using agro-morphological data, statistical procedures to measure population genetic variation	8
6	Markers and their use in PGR	8
7	Evaluation of biotic and abiotic stresses,	10
8 *9	Principles and methods for formulating core and mini core collections and their validation,	10
10	Web based tools for management of data	8
11 & 12	Principles and practices of germplasm regeneration and maintenance, breeding systems and mode of reproduction; maintaining sufficiently large populations for effective conservation of farmer landraces,	10
13	Evaluation and maintenance of wild relatives of crop plants. Genetic enhancement, Use of CWRs genetic resources for crop improvement	8
14	High throughput phenotyping systems- imaging and image processing concepts for automated germplasm characterization (phenotyping) –	8
15 & 16	Evaluation for nutritional traits, resistance traits -Biochemical and molecular markers for characterization	8
	Total	100

PRACTICAL

Practical No.	Topic
1 & 2	Study of Field layout and experimental designs;
3 & 4	Recording field data on germplasm evaluation in different agri-horticultural crops,
5	post-harvest handling;
6	Evaluating quality traits,
7 &8	Biochemical and phyto-chemical evaluation of crop germplasm,
9 & 12	Data processing; Documentation, analysis of diversity and cataloguing, data analysis, viability equations, sampling strategies, data documentation, cataloguing, biochemical analyses of samples

Suggested Reading :

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

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

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

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

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

Rana R S, Sapra R L, Agrawal RC and Gambhir R 1991. Plant Genetic Resources, Documentation and Information Management. NBPGR, New Delhi.

Stoskopf N C 1993. Plant Breeding: Theory and Practice, Westview Press.

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

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

GPB 518	Genetic enhancement for PGR Utilization	1 + 1

Objective :-

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

Theory

Unit I

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

Unit II

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

Unit III

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

Practical

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

LECTURE SCHEDULE

Lecture No.	Topic	Weightage
1	Concepts of gene pools; Introduction, potential of pre-breeding	8
2 & 3	Role of crop wild relatives, semi exotics, creating and managing variation, basic concepts to set up a successful pre-breeding programme.	8
4 -5	Understanding crop adaptation, handling and maintenance of CWRs, synchronization of flowering, overcoming impediments to flowering through photoperiodic adjustments, role of other barriers to flowering	8
6-7	Role of amphidiploids, semi exotics and other unadapted germplasm, identifying desirable traits in natural populations	10
8-9	Screening for biotic and abiotic stress resistance traits; screening of nutritionally important traits, genetic analysis to understand the inheritance of novel traits.	10
10-11	Parental selection for prebreeding, search for superior genotypes, breeding methods for trait transfer; moving the genes - unadapted to adapted, wide hybridization	10
12	Incongruity and its management, modern tools for incongruity management	8
13	Cytogenetical approaches for gene transfer such as alien addition and substitution,	10
14	Segregating populations and their management in wide crosses, purging the undesirable traits	10
15	Testing and improving the adaptability of wide cross derivatives, cytological studies, florescence microscopy, embryo rescue methods,	10
16	Pollen physiology and storage, pollen Storage methods to facilitate wide hybridization, pre- and post- zygotic barriers	8
	Total	100

PRACTICAL

Practical No.	Topic
1	Characterization of CWRs by visiting the fields;
2	Screening methods for special traits-biotic resistance;
3	Screening methods for special traits- abiotic resistance;
4	Screening for nutritional traits;
5	Crossability studies in CWRs of cereals.
6	Crossability studies in CWRs of legumes
7	Crossability studies in CWRs of oilseeds
8	Crossability studies in CWRs of vegetables
9	Assessment of pre and post-zygotic barriers in wide hybridization crosses;
10	Pollen storage studies;
11-14	Special requirements for growing CWRs, inducing flowering by manipulating day length, temperature, chemical spraying, etc.

Suggested Reading:

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

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

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

Duvick DN. 1990. Genetic enhancement and plant breeding. p. 90–96. *In: J.*

Janick and J.E. Simon (eds.), Advances in new crops. Timber Press, Portland.

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

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

Lynch M. and Walsh B. 1998. Genetics and analysis of quantitative traits. Sinauer Associates Inc., MA, USA.

Murphy D. 2007. Plant breeding and biotechnology: Societal context and the future of agriculture.

Cambridge University Press, Cambridge, UK. Ram JS. 2010. Plant Cytogenetics. CRC Press.

Ramanatha Rao V, Brown AHD, Jackson M. 2001. Managing Plant Genetic Diversity. CABI publication.

Sharma S, Upadhyaya HD, Varshney RK, et al. 2013. Pre-breeding for diversification of primary gene pool and genetic enhancement of grain legumes. Front. Plant Sci. 4: 309.

Yunbi Xu. 2010. Molecular plant breeding, CABI publishers

e-Resources

https://www.integratedbreedPlaning.net/pre-breeding-effective-use-plant-genetic-resources

http://www.croptrust.org/

http://www.bioversityinternational.org/training/training_materials/pre_breeding.htm

http://www.grdc.com.au/director/research/prebreeding.

Course Contents

GPB-601	Advances in Plant Breeding Systems*	3 (3+0)

OBJECTIVE:-

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**.**

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 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 sub-mergence tolerance; Biotic stress tolerance; Nutrient use efficiency, nitrogen fixation and assimilation, greenhouse gases and carbon sequestration; Breeding for bio-fortification.

Lecture No.	Topics	Weightage
1	**Advances in reproductive biology of crops**; Genes governing the whorls formation and various models proposed;	2
2	**Pollen pistil interaction**: biochemical and molecular basis, environmental factors governing anthesis and bottlenecks for gene transfer.	2
3	**Plant Breeding methodologies**: Classic versus modern;	2
4	**Over view of Pre and Post Mendelian breeding methods** in self and cross pollinated crops;	4
5	**Molecular and transgenic breeding approaches;** doubled haploid breeding,	4
6	Shuttle breeding,	2
7	Forward and reverse breeding,	2
8	Speed breeding,	2
9	Participatory plant breeding,	4
10	Breeding for organic situations	4
11	Principles and procedures in the formation of a complex population	4
12	Genetic basis of population improvement in crop plants;	2
13-14	**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	4
15	**Selection in clonally propagated crops** – Assumptions and realities.	4
16	Choice of molecular markers for plant breeding efficiency, fingerprinting and genetic diversity assessment	2
17	Application of MAS for selection of qualitative and quantitative traits	4
18	Gene pyramiding, accelerated backcrossing,	4
19	Marker-based utilization of exotic germplasm, introgression libraries.	2
20	**Genetic resources**: primary, secondary, tertiary and alien trans gene pool	4
21-22	**Male sterility and self-incompatibility** Molecular and biochemical basis of self-incompatibility and male sterility, nucleocytoplasmic interactions with special reference to male sterility – genetic, biochemical and molecular bases.	4
23-25	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;	4
26	Conversion of agronomically ideal genotypes into male sterile:	4

	Concepts and breeding strategies;	
27	Case studies - Generating new cyto-nuclear interaction system for diversification of male sterile	4
28-30	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 heterosis breeding;	4
31	Apomixis and its use in heterosis breeding	2
32	Incongruity: Factors influencing incongruity Methods to overcome incongruity mechanisms	2
33-36	Breeding for climate change -Improving root systems, abiotic stress tolerance, water use efficiency, flooding and sub-mergence tolerance;	4
37-38	Breeding for Biotic stress tolerance;	4
39	Breeding for Nutrient use efficiency,	4
40-41	Breeding for nitrogen fixation and assimilation, greenhouse gases and carbon sequestration;	4
42	Breeding for bio-fortification	2
	Total	100

Suggested Reading

Agarwal R L. 1996. Fundamentals of Plant Breeding and Hybrid Seed Production. Oxford & IBH.

Allard R W. 1966. Principles of Plant Breeding. John Wiley & Sons.

Briggs F N and Knowles P F. 1967. Introduction to Plant Breeding. Reinhold.

Fehr W R. 1987. Principles of Cultivar Development: Theory and Technique. Vol I. Macmillan. Hayes H K, Immer F R and Smith D C. 1955. Methods of Plant Breeding. McGraw-Hill.

Kang M S and Priyadarshan P M (Edit.). 2007. Breeding Major Food Staples. Blackwell Publishing.

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

Mandal A K, Ganguli P K and Banerji S P. 1995. Advances in Plant Breeding. Vol. I, II. CBS.

Richards A J. 1986. Plant Breeding Systems. George Allen & Unwin.

Sharma J R. 1994. Principles and Practice of Plant Breeding. Tata McGraw-Hill.

Simmonds N W. 1979. Principles of Crop Improvement. Longman.

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

Singh P. 1996. Essentials of Plant Breeding. Kalyani Publishers, New Delhi. Welsh JR. 1981. Fundamentals of Plant Genetic and Breeding. John Wiley.

GPB-602 Advances in Biometrical Genetics 3 (2+1)

Objective:-

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

Theory

Unit I

Continuous variation-evolutionary studies; Genetic principles of continuous variation, Qualitative and quantitative techniques-differences, population types, approaches; various types of metrics, F2, F□ and mixed; Selection of parents Simultaneous selection models; Use of Multiple regression analysis in selection of genotypes.

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

Practical :-

Generation mean analysis: ABC scaling test and Joint scaling test- Analysis and interpretation;
Estimation of variance of different filial generations and interpretations;
Diallel analysis: Numerical, graphical and combining ability analysis; Triallel analysis;
NC Designs: Triple test cross analysis;
Stability analysis: Eberhart and Russel model;
AMMI model - Principal Component Analysis model - Additive and multiplicative model - Shifted multiplicative model - Analysis and selection of genotypes - Methods and steps to select the best model - Selection systems - Biplots and mapping genotypes;

Construction of linkage maps and QTL mapping - Strategies for QTL mapping; statistical methods in QTL mapping;
Phenotype and Marker linkage studies;
Use of advanced software in biometrical analysis.

LECTURE SCHEDULE

Lecture No.	Topics	Weightage
1	Continuous variation-evolutionary studies; Genetic principles of continuous variation, Qualitative and quantitative techniques-differences,	8
2	Population types, approaches; various types of metrics, F2, F□ and mixed;	8
3	Selection of parents Simultaneous selection models; Use of Multiple regression analysis in selection of genotypes.	4
4	Components of mean- Additive effect, breeding value, coefficient of gene dispersion, dominance;	4
5	Simple scaling test, expectation of mean of character in various types of families in coupling and dispersed phase;	4
6-7	Epistasis- Specification, weighted and un-weighted joint scaling test; Effect of linkage to generation mean, specification of mean to G × E interaction	4
8	Component of variances-advantages, variances of different generations, balance sheet of variance;	4
9	Estimation of parameters-weighted and unweighted, least square analysis;	4
10	Random mating population; experimental population-BIPs, NCD-I, II, III,	4
11	Triple test cross for random mating population and inbreds;	4
12	Estimates of linkage and non-allelic interactions;	4
13	Combining ability analysis, Hayman’s Approach.	4
14	G × E Interaction, stability and adaptability;	4
15	Models in stability- pattern analysis, Additive main effect and Multiplicative interaction (AMMI) analysis and other related models	4
16-17	Additive and multiplicative model-Shifted multiplicative model, analysis and selection of genotype	4
18-19	Methods and steps to select the best model, Merits and limitation of different stability analysis methods.	4
20-21	Biplots and mapping genotypes	4
19	Construction of saturated linkage maps	4
20	Concept of framework map development	4
21-23	QTL mapping- strategies for QTL mapping-desired populations, statistical methods	4
24-27	Marker Assisted Selection (MAS) Approaches to apply MAS I plant breeding Selection based on markers-simultaneous selection based on marker and phenotype Factor influencing MAS	4

28-29	Heritability of the trait, proportion of genetic variance, linkage disequilibrium between markers and traits and selection methods	4
30-32	Use of advanced software packages for biometrical analysis, interpretation of analysed data.	4
	Total weightage	**100**

PRACTICAL

Practical No.	Topic
1	Generation mean analysis: ABC scaling test and Joint scaling test- Analysis and interpretation;
2	Estimation of variance of different filial generations and interpretations
3	Diallel analysis: Numerical, graphical and combining ability analysis
4	Triallel analysis;
5	NC Designs:
6	Triple test cross analysis;
7	Stability analysis: Eberhart and Russel model; Selection of stable genotypes using stability analysis
	Models in stability analysis
8	Additive main effect and Multiplicative interaction (AMMI)
9	Principal Component Analysis model
10	Additive and multiplicative model
11	Shifted multiplicative model Analysis and selection of genotypes
	Methods and steps to select the best model
12	Selection systems
13	Biplots and mapping genotypes
14	Construction of linkage maps and QTL mapping
	Strategies for QTL mapping
15	Statistical methods in QTL mapping
	Phenotype and Marker linkage studies
16	Use of advanced software in biometrical analysis.

Suggested Reading :

Bos I and Caligari P. 1995. Selection Methods in Plant Breeding. Chapman & Hall.
Dabholkar AR.1993. Elements of Biometrical Genetics. Concept Publishing Co. New Delhi.
Falconer DS and Mackay J. 1996. Introduction to Quantitative Genetics (4 Ed.). ELBS/ Longman,London.
Mather K and Jinks JL. 1985. Biometrical Genetics (3rd Ed.). Chapman and Hall, London.
Nandarajan N and Gunasekaran M. 2008. Quantitative Genetics and Biometrical Techniques in Plant Breeding. Kalyani Publishers, New Delhi.
Roy D. 2000. Plant Breeding, Analysis and Exploitation of Variation. Narosa Publishing House, New Delhi.
Singh P and Narayanan SS. 1993. Biometrical Techniques in Plant Breeding. Kalyani Publishers, New Delhi.
Singh RK and Choudhary BD. 1987. Biometrical Methods in Quantitative Genetics. Kalyani

Publishers, New Delhi.
Weir DS. 1990. Genetic Data Analysis. Methods for Discrete Population Genetic Data. Sinauer Associates.
Wricke G and Weber WE. 1986. Quantitative Genetics and Selection in Plant Breeding. Walter de Gruyter.

GPB-603 Molecular Cytogenetics for Crop Improvement 2 (2+0)

Objective:-

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

Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

Unit VI

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

LECTURE SCHEDULE

Lecture No.	Topics	
1	Organization and structure of genome-prokaryotic- bacterial, viral genome & eukaryotic genome, genome size	8

2	Organization of organellar genome- mitochondria and chloroplast structure, inheritance and expression of organellar DNA	4
3	Nuclear DNA organization- variation in DNA content, C value paradox	4
4	Nuclear and cytoplasmic genome interactions and signal transduction	4
5	Transcriptional & translational changes	4
6	Sequence complexity- introns, exons, repetitive sequences & its role	4
7-8	Karyotyping - symmetric & asymmetric, idiogram, bimodal karyotype, euchromatin & heterochromatin, chromosome banding & chromosome painting	4
9	Tracking introgressions using FISH, GISH	4
10	Localization and mapping of genes/genomic segments	4
11-12	Pre breeding and application of cytogenetical methods for crop improvement - location and mapping of genes on chromosomes, deficiency method	4
13	Interchange- genetic consequences, identification of chromosomes involved and gene location	4
14	Balanced lethal systems, their maintenance and utility	4
15	Multiple interchanges - its use in production of inbreds, transfer of genes- linked marker methods	4
16	Duplication - production and use	4
17	Inversions - location of genes, B/A chromosome translocation and gene location	4
18	Trisomics - types, production, breeding behavior and location of genes,	4
19	Use of balanced tertiary trisomics in hybrid seed production	4
20	Monosomics - method of production, breeding behavior and location of genes	4
21-22	Intervarietal substitutions - allelic and non-allelic interactions, telocentric method of mapping	4
23	Cytogenomics: Concept, tools and techniques for crop improvement;	4
24-25	Chromosome sorting: Isolation of specific chromosome for development of molecular maps and gene location	4
26-27	Role of polyploids in crop evolution and breeding -autopolyploids	4
27-28	Role of polyploids in crop evolution and breeding- allopolyploids	4
29-32	Distant hybridization - barriers of interspecific and intergeneric hybridization, behaviour of interspecific and intergeneric crosses	4
	Total	**100**

Suggested Reading :

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

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

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

Gupta P K. 2006. Cytogenetics. Rastogi Publisher

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

Mantel S H and Smith H. 1983. Plant Biotechnology. Cambridge University Press.

Sen S K and Giles K L. (Eds.). 1983. Plant Cell Culture in Crop Improvement. Plenum Press. 13 July 2013

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

GPB-604 Plant Genetic Resources, Conservation and Utilization 2 (2+0)

Objective:-

This course is needed to make the student aware about the importance of Plant Genetic Resources its Conservation and Utilization in crop improvement and to impart knowledge on the methods of germplasm conservation and its utilization.

Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

LECTURE SCHEDULE

Lecture No.	Topics	Weightage
1	Concept of natural reserves and natural gene banks	4
2	In situ conservation of wild species in nature reserves: in situ conservation components,	8
3	Factors influencing conservation value, national plan for in situ conservation.	6
4	In situ conservation of agro-biodiversity on-farm; scientific basis of in situ conservation on-farm, building on-farm conservation initiatives,	8

5-6	Implementation of on-farm conservation, management of in situ conserved genetic diversity on-farm, enhancing benefits for farmers from local crop diversity.	6
7-10	Ex situ conservation: components, plant genetic resources conservation in gene banks, national gene banks, gene repositories,	8
11	Preservation of genetic materials under natural conditions.	4
12-13	Perma-frost conservation, Guidelines for seed multiplication and exchange to network of active/ working collections, Orthodox, recalcitrant seeds- differences in handling	8
14	Clonal repositories, genetic stability under long term storage condition.	4
15	In-vitro storage, maintenance of in-vitro culture under different conditions,	4
16-19	In-vitro bank maintenance for temperate and tropical fruit crop species, spices, tubers, bulbous crops, medicinal and endangered plant species,.	8
20-22	Conservation of embryos and ovules, cell/ suspension cultures, protoplast and callus cultures, pollen culture, micropropagation techniques, problems, prospects of in-vitro gene bank	8
23-24	Cryopreservation- procedure for handling seeds of orthodox and recalcitrants-cryoprotectants,	4
25-26	Dessication, rapid freezing, slow freezing, vitrification techniques, encapsulation/dehydration techniques	4
27-28	National facilities, achievements, application of cryopreservation in agriculture, horticulture and forestry crops.	4
29	Problems and prospects; challenges aheads.	4
30-31	Concept and procedure for PGR management, germplasm characterization, evaluation and utilization;	4
32	Concept of core and mini core; collections and registration of plant germplasm.	4
	Total	**100**

Suggested Reading :

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

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

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

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

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

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

GPB-605	Genomics in Plant Breeding*	3 (3+0)

Objective:-

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.

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).

LECTURE SCHEDULE

Lecture No.	Topics	Weightage
1-3	Introduction to the plant genomes: Nuclear genome, Concept of genome size and complexity :C-value paradox, repetitive and unique DNA	6
4-5	Chloroplast and mitochondrial genomes; Concept of genome size and complexity: C-value paradox, repetitive and unique DNA	4
6-9	Genome sequencing: Principles and techniques of conventional approaches and next generation sequencing including sequencing-by-synthesis/ ligation and single molecule real time (SMRT) technologies;	6
10-11	Applications of sequence information: structural, functional and comparative	4

	genomics;	
12-13	Plant genome projects: Strategies for genome sequencing including shot gun and clone-by-clone method.	4
14-15	Molecular maps: Use of molecular markers/ SNPs for development of genetic and physical maps;	4
16-18	Linkage and LD-based gene mapping approaches including gene/ QTL mapping, genome wide association studies (GWAS) and association analysis;	4
19-22	Integration of genetic and physical map for map-based cloning of economically important genes.;	4
23	Concept of allele mining	4
24	Diversity array technology: concepts and applications	4
25-26	Functional genomics: concept of reverse and forward genetics;	4
27-28	Use of activation tagging, transposon tagging, insertional mutagenesis,	4
29-30	TILLING and ecoTILLING for crop improvement;	4
31-32	Genome-wide and gene-specific transcriptomics approaches: serial analysis of gene expression, massively parallel signature sequencing,.	4
33-34	Next generation sequencing, microarray, northern hybridization,	4
35-36	RT-PCR, qRT-PCR and molecular beacon	4
37	Concept of database development, management and bioinformatics.	4
38	Applications of bioinformatics tools/ software in genomics for crop improvement..	4
39	Basic concepts of high-throughput proteomics, metabolomics and phenomics	4
40-41	Recent transgene free genome editing tools such as CRISPR-Cas9 system, TALENS and ZFNs for crop improvement.	4
42-43	Cisgenesis and Intragenesis tools as twin sisters for Crop Improvement;	4
44-45	Genomics-based plant breeding: Genome-Wide Genetic Diversity Studies,	4
46	Identification of molecular markers linked to single Genes and QTL,	4
47-48	Marker Assisted Selection (Marker Assisted Backcross Selection, Association mapping, Breeding by Design, Genome selection).	4
	Total	**100**

Suggested Reading

Alonso J M, Stepanova A N. 2015. Plant Functional Genomics: Methods and Protocols. Springer.

Chopra V L, Sharma R P, Bhat S R and Prasanna B M. 2007. Search for New Genes. Academic Foundation, New Delhi.

Hackett P B, Fuchs J A and Messing J W. 1988. An Introduction to Recombinant DNA Technology— Basic Experiments in Gene and Manipulation. 2nd Ed. Benjamin Publication Co.

Primose S B and Twyman R M. 2006. Principles of Gene Manipulation and Genomics. 7th Ed.Wiley-Blackwell Publishing.

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

Singh BD. 2005. Biotechnology: Expanding Horizons. Kalyani Publishers, New Delhi.
Somers DJ, Langridge P, Gustafson JP. 2009. Plant Genomics: Methods and Protocols. Springer.

e-Resources

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)

Objective:-

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 Hardy-Weinberg law, Test of Hardy-Weinberg equilibrium; Mating frequencies: Non-dominance, Codominance, Snyder's ratio, importance and its effect over random mating 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 cross pollinated 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, heterozygous advantage-Survival of recessive and deleterious alleles in populations.

LECTURE SCHEDULE

Lecture No.	Topics	Weightage
1	Population: Properties of population.	4
2	Mendelian population.	4

3-5	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 mutat.	8
6-7	Hardy-Weinberg equilibrium, Hardy-Weinberg law,	6
8	Proof and applications of the Hardy-Weinberg law, Test of Hardy-Weinberg equilibrium;	4
9-10	Mating frequencies: Non-dominance, Codominance, Snyder's ratio, importance and its effect over random mating in succeeding generations	6
11	Multiple alleles, More than one locus,	4
12-13	Sex linked genes; Use of gene and genotypic frequencies evaluation in field population level; Interpretations - Changes of gene frequency, Migration, Mutation,.	8
14-15	Recurrent and non-recurrent Selection; Balance between selection and mutation; Selection favoring heterozygotes; Overdominance for fitness	8
16 & 17	Mating systems, Random mating population,	8
18-19	Nonrandom mating: selfing –inbreeding coefficient, panmictic index, sibmating, Assortative mating and disassortative mating ; .	8
20-22	Pedigree populations and close inbreeding, Estimation of linkage disequilibrium, Correlation between relatives and estimation of F;	8
23-25	Effect of inbreeding and sibbing in cross pollinated crops; Gene substitution and average effects; Breeding value- Genetic drift; Genetic slippage, Co-adapted gene complexes;	8
26-28	Homoeostasis- Adaptive organization of gene pools;	8
29-32	Polymorphism- Balanced and Non-balanced polymorphism, heterozygous advantage- Survival of recessive and deleterious alleles in populations	8
	Total	**100**

Suggested Reading :

Chawla V and Yadava R K. 2006. Principles of Population Genetics – A Practical Manual. Dept. of Genetics, CCS HAU Hisar.

Falconer DS and Mackay J. 1996. Introduction to Quantitative Genetics. Longman. Jain JP, Jain J and Parbhakaran V T. 1992. Genetics of Populations. South Asia Books.

Li C C. 1955. Population Genetics. The Univ. of Chicago Press.

Mather K and Jinks JL. 1982. Biometrical Genetics. Chapman & Hall.

Sorrens D and Doniel G. 2007. Methods in Quantitative Genetics. Series: Statistics for Biology and Health. Likelihood.

Tomar SS. 1992. Text Book of Population Genetics. Universal Publication.

GPB-607 Crop Evolution 3 (3+0)

Objective :

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, Medicinal Plants.

LECTURE SCHEDULE

Lecture No.	Topic	Weightage
1-2	Origin and evolution of species, Centres of diversity/origin, diffused centres	4
3-4	Time and place of domestication Patterns of evolution and domestication-examples and case studies	4
5-6	Domestication and uniformity, Characteristics of early domestication and changes	6
7-8	Concept of gene pools and crop evolution Selection and Genetic drift-consequences	4
9-10	Speciation and domestication -The process of speciation Reproductive isolation barriers	6
11-12	Genetic differentiation during speciation. Hybridization-speciation and extinction	4
13-14	Exploitation of natural variation- Early attempts to increase variation	4
15-18	Distant hybridization and introgression Interspecific, inter-generic hybridization Scope and limitations Techniques to overcome the limitations	8
19-20	Gene transfer into cultivated species, tools and techniques	4
21-22	Validation of transferred genes and their expression	4
23	Controlled intogression	4
24-25	Process in crop evolution and stabilization of polyploids,	4

	cytogenetics and genetic stabilization	
26	Genome organization-transgenesis in crop evolution	6
27-28	Multifactorial genome-intragenomic interaction-Genome introgression	4
29-30	Methods to study crop evolution-Contemporary methods based on morphological features	6
31-32	Cytogenetic analysis-Allozyme variations and crop evolution	6
33-35	DNA markers, genome analysis and comparative genomics	6
36-39	Evolutionary significance of polyploidy, Evolution of crop plants through ploidy manipulations	6
40-41	Polyploids: methods, use of autopolyploids: haploidy-method of production and use.	4
42-46	Allopolyploids-synthesis of new crops-case studies- cereals, pulses, oilseeds, vegetables, fibre crops, plantation crops, forage crops, tuber crops and medicinal plants	6
	Total	**100**

Suggested Reading :

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

GPB-608 Breeding Designer Crops 2 (1+1)

Objective :

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

Theory

Unit I

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

Unit II

Physiological efficiency as a concept, parametric and whole plant physiology in integrated mode; Physiological mechanism of improvement in nutrient use efficiency, water use efficiency, osmotic adjustment, photosynthetic efficiency, stay green trait and its significance in crop improvement; Breeding for special traits, viz., oil, protein, vitamins, amino acids, etc.; Ecospecific ideotypes, Ideotypes for high and low moisture conditions, low and high input conditions, conversion mechanism of C3 to C4 plants; Determination of genetics of above mentioned traits.

Unit III

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

Unit IV

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

Unit V

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

Practical

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

LECTURE SCHEDULE

Lecture No.	Topic	Weightage
1	Breeding of crop ideotypes; Genetic manipulations through recombination breeding,	8
2	Genomics and transgenics for physiological efficiency, nutritional enhancement, special compounds-proteins, vaccines, gums, starch and fats.	8
3	Physiological efficiency as a concept, parametric and whole plant physiology in integrated mode;	6
4	Physiological mechanism of improvement in nutrient use efficiency, water use efficiency, osmotic adjustment, photosynthetic efficiency, stay green trait and its significance in crop improvement; traits	8
5-7	Breeding for special traits, viz., oil, protein, vitamins, amino acids, etc.;	8
8	Ecospecific ideotypes, Ideotypes for high and low moisture conditions, low and high input conditions, Conversion mechanism of C3 to C4 plants; Determination of genetics of above mentioned	6
9	Improvement in yield potential under sub-optimal conditions by manipulating source and sink, canopy architecture, plant-water relationships,	8
10	Effect of suboptimal conditions on cardinal plant growth and development processes,	8
11	Enhancing input use efficiency through genetic manipulations	8
12	Concept of biopharming and development of varieties producing targeted compounds	6
13	Development of varieties of nutraceuticals and industrial products;	8
14	Success stories in vaccines, modified sugars, gums and starch through biopharming	6
15	Biosafety management,	6
16	Segregation and isolation requirements in designer crop production and post-harvest management	6

Practical

Practical No.	Topic
1	Demonstration of plant responses to stresses through recent techniques
2	Water use efficiency studies in economically important plants
3	Transpiration efficiency studies in economically important plants
4	Screening techniques under stress conditions such as electrolyte leakage
5	Screening techniques under stress conditions such as TTC
6	Screening techniques under stress conditions such as chlorophyll fluorescence.
7	Screening techniques under stress conditions such as canopy temperature depression
8	Screening techniques under stress conditions such as stomatal conductance
9	Screening techniques under stress conditions such as chlorophyll estimation
10	Screening techniques under heat stress conditions
11	Screening techniques under drought stress conditions
12	Screening techniques under salt stress conditions

Suggested Reading

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

GPB-609 IPR and Regulatory Mechanism (e-course)* 1 (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.

LECTURE SCHEDULE

Lecture No.	Topic	Weightage
1	Historical perspectives and need for the introduction of Intellectual Property Right regime;	8
2	TRIPs and various provisions in TRIPS Agreement;	6
3	Intellectual Property and Intellectual Property Rights (IPR), benefits of securing IPRs;	8
4	Indian Legislations for the protection of various types of Intellectual Properties;	6
5	Fundamentals of patents,.	6
6	Copyrights,	6
7	Geographical indications,	6
8	Designs and layout,	6
9	Trade secrets and traditional knowledge, Trademarks,	6
10	Protection of plant varieties and farmers' rights and biodiversity protection;	8
11	Protectable subject matters, protection in biotechnology, protection of other biological materials, ownership and period of protection	8
12	National Biodiversity protection initiatives;	6
13	Convention on Biological Diversity	6
14	; International Treaty on Plant Genetic Resources for Food and Agriculture;	6
15-16	Licensing of technologies, Material transfer agreements, Research collaboration Agreement, License Agreement	8
	Total	

Suggested Reading :

Erbisch FH and 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.

LIST OF JOURNALS

S.No.	JrnID	ISSN	Name of Journal	NAAS Score
1	A060	0065-2660	Advances in Genetics	7.94
2	A218	0066-4197	Annual Review of Genetics	20.00
3	C146	1566-0621	Conservation Genetics	8.54
4	C147	1877-7252	Conservation Genetics Resources	6.97
5	C193	0959-437X	Current Opinion in Genetics and Development	11.58
6	C182	0172-8083	Current Genetics	9.89
7	C209	1424-8581	Cytogenetic and Genome Research (Cytogenetics and Cell Genetics)	7.64
8	C212	0095-4527	Cytology and Genetics	6.58
9	C217	1212-1975	Czech Journal of Genetics and Plant Breeding	6.87
10	E034	2149-1275	Ekin Journal of Crop Breeding and Genetics	4.88
11	F086	1664-8021	Frontiers in Genetics	10.60
12	G001	2160-1836	G3 - Genes Genomes Genetics	9.15
13	G016	0016-6731	Genetics	10.56
14	G017	0016-6723	Genetics Research	7.59
15	G018	0999-193X	Genetics Selection Evolution	10.30
16	G019	1415-4757	Genetics and Molecular Biology	7.77
17	G021	0534-0012	Genetika-Belgrade	6.76
18	G022	0831-2796	Genome (Canadian Journal of Genetics and Cytology)	8.17
19	G023	1474-760X	Genome Biology	19.58
20	G024	1759-6653	Genome Biology and Evolution	9.42
21	G025	1088-9051	Genome Research	15.04
22	G026	0888-7543	Genomics	11.74
23	I068	0019-5200	Indian Journal of Genetics and Plant Breeding	6.51
24	I112	2277-1913	Indian Research Journal of Genetics and Biotechnology	3.49
25	I258	0975-2862	International Journal of Genetics	4.07
26	I258a	2314-436X	International Journal of Genomics	8.33
27	J065	1234-1983	Journal of Applied Genetics	9.24
28	J263	0022-1333	Journal of Genetics	7.17
29	J264	1673-8527	Journal of Genetics and Genomics (Acta Genetica Sinica)	10.28
30	M081	1617-4615	Molecular Genetics and Genomics (Molecular and General Genetics)	9.29
31	M082	1096-7192	Molecular Genetics and Metabolism	10.80
32	N028	1061-4036	Nature Genetics	20.00
33	T057	0040-5752	Theoretical and Applied Genetics	11.70
34	T099	0168-9525	Trends in Genetics	17.64
35	A060	0065-2660	Advances in Genetics	7.94
36	E040	0975-928X	Electronic Journal of Plant Breeding	5.14
37	P098	0179-9541	Plant Breeding (Zeitschrift fur pflanzenzuchtung)	7.83
38	F084	2393-8234	Frontiers in Crop Improvement	4.67
39	M076	1380-3743	Molecular Breeding	8.59
40	B165	1344-7610	Breeding Science	8.09
41	C163	1984-7033	Crop Breeding and Applied Biotechnology	7.28

Restructured and Revised Syllabus

M.Sc. & Ph. D. (Agriculture)

In

Seed Science and Technology

Broad Subject coordinator
Plant Science Seed Science and Technology
Dr. J. E. Jahagirdar
Associate Dean,
College of Agriculture,
Osmanabad (VNMKV., Parbhani)

Discipline coordinator
Dr. V. R. Shelar
Seed Research Officer,
Seed Technology Research Unit,
MPKV, Rahuri.

CONTENTS

DISCIPLINE: SEED SCIENCE AND TECHNOLOGY

PREAMBLE

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

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

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

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

Organic seed system when viewed as an alternative to the dominant seed system helps to address the bigger problems in agriculture. Expanding organic seed systems can also increase economic opportunities for farmers who successfully produce organic seed in their farm.

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

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

COMMITTEE ON PLANT SCIENCES

ICAR-BSMA Broad Subject	ICAR-BSMA Approved Disciplines	Degree Programmes		Broad Subject Coordinator (Chairman of all Disciplines' Sub Committees)	Discipline Coordinator (Secretary of respective Discipline Sub-Committee)
Plant Sciences	Genetics and Plant Breeding	M.Sc. (Agri.)	Ph.D.	Dr. J.E. Jahagirdar ADP, CoA, Osmanabad (VNMKV, Parbhani)	Dr. H.V. Kalpande Head, Dept. of Agril. Botany, VNMKV, Parbhani
	Seed Science and Technology	M.Sc. (Agri.)	Ph.D.		Dr. V.R. Shelar, SRO, STRU, MPKV, Rahuri
	Plant Physiology	M.Sc. (Agri.)	Ph.D.		Dr. R.S. Wagh Prof ,MPKV, Rahuri
	Plant Genetic Resources	M.Sc. (Agri.)	Ph.D.		Dr. R.B. Ghorade Head, Dept. Agril. Botany Dr.PDKV, Akola

Committee on Seed Science and Technology

ICAR-BSMA Broad Subject	ICAR-BSMA Approved Disciplines	Degree Programmes		Broad Subject Coordinator (Chairman of all Disciplines' Sub Committees	Discipline Coordinator (Secretary of respective Discipline Sub-Committee)
Seed Science and Technology		M.Sc. Seed Science and Technology	Ph.D.	Dr. Jahagirdar	

Implementation of New Curriculum

The universities offering PG programmes in Seed Science and Technology need to be supported for establishing specialized laboratories equipped with state-of-the art equipments for conducting practical classes especially, Seed Biology, Seed Production, Seed Treatment & Storage.

One time catch up grant should be awarded to each SAU, offering PG programmes in Seed Science and Technology for meeting expenditure for upgrading the course requirements.

Faculty training and retraining should be an integral component. For imparting total quality management, a minimum of two faculty in each department under an SAU should be given on job training in reputed national and international institutes. To execute the new PG and Ph.D. programmes in different discipline of Seed Science and Technology in effective manner, special funds from ICAR would be required for outsourcing of faculty from Indian/Foreign Universities for some initial years.

The already existing M.Sc. and Ph.D. Programmes in Seed Science and Technology. will be considered at par with the recommended M.Sc. & Ph.D. programme by Vth Deans Committee for admission and employment.

Expected Outcome

- Revamping of post graduate programme in whole of Seed Science and Technology throughout the country.
- Imparting quality education.
- Development of technical manpower to cater the need of governments, corporate sector and research organization in India and abroad. Exposure to the faculty in the latest technical knowhow

Organization of Course Contents & Credit Requirements

Minimum Residential Requirement:

M.Sc.: 4 Semesters
Ph.D.: 6 Semesters

Name of the Departments / Divisions

Seed Science and Technology

Nomenclature of Degree Programme

(a) M.Sc. Programmes

i) M.Sc. (Seed Science and Technology)

(b) Ph.D. Programmes

i) Ph.D. (Seed Science and Technology)

Code Numbers

- All courses are divided into two series: 500-series courses pertain to Master's level, and 600- series to Doctoral level.
- Credit Seminar for Master's level is designated by code no. 591, and the Two Seminars for Doctoral level are coded as 691 and 692, respectively
- Deficiency courses will be of 400 series.
- Master's research: 599 and Doctoral research: 699

Course Contents

The contents of each course have been organized into:

- Objective – to elucidate the basic purpose.
- Theory units – to facilitate uniform coverage of syllabus for paper setting.
- Suggested Readings – to recommend some standard books as reference material. This does not obviously exclude such a reference material that may be recommended according to the advancement and local requirement.
- A list of international and national reputed journals pertaining to the discipline is provided at the end which may be useful as study material for 500/600 series courses as well as research topics.
- Lecture schedule and practical schedule has also been given at the end of each course to facilitate the teacher to complete the course in an effective manner.

Eligibility for Admission

- **Master's Degree Programme**

  (i) **B.Sc. Agriculture (4 year programme)**

  B.Sc. (Agri.) / B. Sc. (Hons.) Agriculture/ B. Sc. (Hort.)/ B.Sc. (Hons.) Horticulture/ B. Sc. (Forestry)/ B.Sc. (Hons.) Forestry or equivalent degree with four years duration of agriculture related Universities and having the Common Entrance Test conducted by competent authority.

- **Doctoral Degree Programme**

  (i) Master Degree in the Seed Science and Technology and having appearing the Common Entrance Test of Seed Science and Technology subject conducted by competent authority.

Sr. No	**Name of Department**	**Specialization in Ph. D** Seed Science and Technology	**Eligibility criteria**
1.	Seed Science and Technology	Ph. D. (Seed Science and Technology)	M.Sc. (Seed Science and Technology)

Credit Requirements

Course Details	**Master's Degree**	**Doctoral Degree**
Major Courses	20	15
Minor Courses	08	06
Supporting / Optional	06	05
Common PGS Courses	05	-
Seminar	01	02
Research	30	75
Total	**70**	**100**

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

Course No.	Course Title	Credits
SST 501*	Seed Developmental Biology	2 (1+1)
SST 502	Seed Dormancy and Germination	2 (1+1)
SST 503*	Seed Production Principles and Techniques in Field Crops	3 (2+1)
SST 504*	Seed Production Principles and Techniques in Vegetable Crops	3 (2+1)
SST 505	Seed Production Techniques in Fruits, Flowers, Spices, Plantation and Medicinal Crops	3 (2+1)
SST 506	Seed Production Techniques in Forage, Pasture and Green Manure Crops	2 (1+1)
SST 507*	Seed Legislation and Certification	3 (2+1)
SST 508*	Post Harvest Handling and Storage of Seeds	3 (2+1)
SST 509*	Seed Quality Testing and Enhancement	2 (1+1)
SST 510	Seed Technology of Tree Species	2 (1+1)
SST 511	Seed Industry and Marketing Management	2 (1+1)
SST 512	Seed Health Testing and Management	2 (1+1)
Major Courses (Min. 20 Credits from above courses including * marked courses)		20(12+8)

Minor Courses (Min. 8 Credits from below given disciplines)

GPB	Genetics and Plant Breeding	
STAT	Statistics	
BIOCHEM	Biochemistry	
PL PATH	Plant Pathology	
PL PHY	Plant Physiology	
ENT	Entomology	

Supporting Courses (Min. 6 Credits from below mentioned disciplines)

BIOCHEM	Biochemistry	
PL PATH	Plant Pathology	
ENT	Entomology	
Note: Apart from above supporting courses students shall registered courses in listed in restructured and revised syllabi of Post graduate Programme Vol. -2 (Page no. xii-xiii under 2.2) as per the Student Advisory Committee Recommendations		

Compulsory Non Credit courses (Min. 5 Credits from below courses)

PGS -501	Library and Information Services	1 (0+1)
PGS -502	Technical Writing & Communication Skills	1 (0+1)
PGS-503	Intellectual Property and its Management in Agriculture	1 (1+0)
PGS 504	Basic Concepts in Laboratory Techniques	1 (0+1)

PGS 505	Agricultural Research, Research Ethics and Rural Development Programmes	1 (1+0)
PGS 506	Disaster Management	1 (1+0)
Note: Some of the above courses which are in the form of e- courses/ MOCS shall be registered by the students apart from Similar course on these aspect, if available on line on SWAYAM or any other platform as per the Student Advisory Committee Recommendations		

SST -591	Seminar	1 (0+1)
SST-599	Research/ Thesis	30
	Total Credits	**70**
	Required Minimum 70 Credits	

***Compulsory Major Courses**

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

I. Course Title : Seed Developmental Biology*
II. Course Code III. C: SST 501II.
Hours : 2 (1+1)

IV. 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.

V. Aim of the course

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

VI. 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.

VII. 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.

VIII. Teaching methods

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

IX. 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.

X. Suggested Reading

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

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

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

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

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

Copeland, LO and McDonald MB. 2001. *Principles of Seed Science and Technology*. 4th Ed. Kluwer Academic publishers, USA. Frankel R and Galun E. 1977. *Pollination Mechanisms Reproduction and Plant Breeding*. Springer Verlag, New York.

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

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

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

XI. 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-germination/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=frontcover&source=kpread_button&redir_esc=y#v=onepage&q&f=false

XII. 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.iari.res.in/index.php?option=com_content&view=article&id=449&Itemid=137

Lecture Schedule
Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Floral biology — types of pollination, mechanisms; sporogenesis — micro and mega sporogenesis; gametogenesis — development of male and female gametes and their structures; pollination and fertilization	02
2.	Mode of pollination, double fertilization, factors affecting pollination, fertilization; self-incompatibility and male sterility.	01
3.	Embryogenesis — development of monocot and dicot embryos — embryo plane formation — development of endosperm, cotyledons and seed coat	02
4.	Hard seed; apomixis — identification, classification, significance and its utilization; poly-embryony — types and significance	01
5.	Haplontic and diplontic sterility system, causes of embryo abortion, embryo rescue technique; somatic embryogenesis.	01
6.	Seed development — source of assimilates — mechanism of translocation	01
7.	Chemical composition — synthesis and deposition of storage reserves	01

8.	Starch, protein, fat and secondary metabolites — hormonal regulation	01
9.	Maturation drying — orthodox and recalcitrant seeds	01
10.	Desiccation tolerance — mechanism — structural changes during desiccation	01
11.	Role of LEA protein	01
12.	Seed maturity indices	01
13.	Physiological and harvestable maturity;	01
14.	Biotic and abiotic factors influencing seed development, Development of hard seeds	01
	Total	**16**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	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	4
2.	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	4
3.	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	2
4.	Study on physiological and harvestable maturity and maturity indices in different crops	2
5.	Study on acquisition of seed dormancy and germination at different stages of maturity	2
6.	Preparation of seed album and identification of seeds	2
	Total	**16**

I. Course Title : Seed Dormancy and Germination

II. Course Code : SST 502

III.Credit Hours : 2 (1+1)

IV. 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.

V. 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.

VI. Theory

Unit I

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

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 seed bank — 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.

VII. 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 — a 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.

VIII. Teaching methods

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

IX. 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.

X. Suggested Reading

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

XI. 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=91nsCAAAQBAJ&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

XII. 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

Lecture Schedule
Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Seed dormancy — definition, concept and theories — significance — evolution; classification and mechanism of dormancy — ecological significance.	02
2.	Induction of dormancy during development — hormonal, physiological, molecular and genetic control of dormancy — maternal and paternal contribution	01
3.	Environmental factors influencing dormancy induction and release — seasonal influence — winter and summer annuals	01
4.	Secondary dormancy induction mechanism; artificial induction of dormancy and release; soil seed bank	01
5.	Natural release of dormancy and its mechanism; dormancy breaking — principles and methods.	01
6.	Seed germination — types and phases of germination; imbibition — pattern and water kinetics	01
7.	Events of germination — physical, physiological, biochemical changes	01
8.	Aerobic and anaerobic respiration quiescent.	01
9.	Enzyme activation — mechanism — factors affecting enzyme activation	01
10.	Breakdown of stored materials — starch, protein and fat	01
11.	Energy generation — mobilization of storage reserves — changes in phenolic compounds.	01
12.	Molecular and genetic control of seed germination — auto tropism; factors affecting germination — media — temperature — light —	02

	gases	
13.	*In-situ* and viviparous germination — causes and mechanism	01
14.	Pattern of seed germination — tri-phasic curve.	01
	Total	**16**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Seed dormancy — identification of dormancy; Estimation of ABA and GA in dormant and non-dormant seeds; Study on artificial induction of dormancy	4
2.	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	4
3.	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	2
4.	Estimation of hydrolytic enzyme — a amylase in different species; Estimation of hydrolytic enzyme — protease; Estimation of hydrolytic enzyme — lipase	4
5.	Estimation of dehydrogenase enzyme and respiratory quotient in seeds; Estimation of food reserve composition during seed germination	2
	Total	**16**

I. Course Title : Seed Production Principles and Techniques in Field Crops*
II. Course Code: SST 503
III. Credit Hours : 3 (2+1)

IV. 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.

V. Aim of the course

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

VI. Theory

Unit I

Importance of seed — seed quality concept — factors influencing seed production; generation 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, fox tail 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.

VII. 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.

VIII. Teaching methods

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

IX. Learning outcome

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

X. Suggested Reading

Agrawal RL. 2019. *Seed Technology*. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi. Hebblethwaite PD. 1980. *Seed Production*. Butterworth Heinemann Ltd., London, UK.

Joshi AK and Singh BD. 2004. *Seed Science and Technology*. Kalyani Publishers, New Delhi. Kulkarni GN. 2011. *Principles of Seed Technology*. Kalyani Publishers, New Delhi.

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

McDonald MB and Copeland L. 1998. *Seed Production Principles and Practices*. CBS Publishers,

New Delhi.

Mondal SS, Saha M and Sengupta K. 2009. *Seed Production of Field Crops*. New India Publishing Agency, New Delhi.

Singhal NC. 2003. *Hybrid Seed Production in Field Crops*. Kalyani Publications, New Delhi.

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

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

XI. 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/seed-production-of-agricultural-crops-by-kelly-a-f-227-pages-harlow-longman-1988-price-2500-hard-covers-isbn-0-582-40410-x/8BE3C99DFDC0F02D48ECB53418504D10

XII. 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_enhacement_and_development_project_in_sierra_leone_mission_1_report_.pdf

Lecture Schedule
Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Importance of seed — seed quality concept — factors influencing seed production	03
2.	Generation system of seed multiplication — classes of seed	02
3.	Stages of seed multiplication in varieties and hybrids	02
4.	Seed multiplication ratio (SMR) — seed replacement rate (SRR) — seed renewal period (SRP) — varietal replacement rate (VRR).	02
5.	Genetic and agronomic principles of variety and hybrid seed production	02
6.	Methods and techniques of seed production in varieties and hybrids of important cereals and millets — wheat, oat, rice, maize, sorghum and pearl millet	03
7.	Varietal seed production in small millets — finger millet, fox tail millet, little millet, kodo millet, proso millet and barnyard millet.	02
8.	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.	03
9.	Methods and techniques of seed production in major oil seed crops — groundnut, sesame — varietal and hybrid seed production in sunflower, castor and mustard	02
10.	Varietal seed production in minor oilseed crops (safflower, linseed, niger)	02
11.	Varietal and hybrid seed production in cotton — varietal seed	02

	production in jute.	
12.	Seed production planning for varieties of major crops	02
13.	Seed production planning for hybrids of major crops	03
14.	Seed hubs, seed village concept and community seed bank.	02
	Total	**32**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Seed selection — quality of seed on field establishment; Sowing and nursery management techniques; Planting — age of seedling on crop establishment — rice and pearl millet	2
2.	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	3
3.	Practicing breeding tools for hybrid seed production — detasseling — emasculation and dusting; Study on methods of achieving synchronization — rice, bajra, sunflower	2
4.	Practicing supplementary pollination — rice and sunflower; Study on foliar nutrition and influence on seed yield	2
5.	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	3
6.	Visit to seed production fields; Visit to seed industry	2
7.	Seed production planning and economics of seed production of varieties and hybrids.	2
	Total	**16**

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

II. Course Code : SST 504

III. Credit Hours: 3 (2+1)

IV. 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.

V. 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 Tropical / 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 and other important crops of the region.

Unit V

Vegetative and clonal multiplication — methods, merits and demerits; clonal multiplication — Potato, Sweet Potato, Colocasia, Tapioca and Yam.

VII. 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 Solanceous, 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.

VIII. 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

IX. Learning outcome

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

X. Suggested Reading

Agarwal RL. 2012. *Seed Technology*. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.

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

George RAT. 1985. *Vegetable Seed Production.* Lonhman Inc., New York.

Hebblethwaite PD. 1980. *Seed Production.* Butterworth Heinemann Ltd, London, UK.

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

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

McDonald MB and Copeland L. 1998. *Seed Production: Principles and Practices.* CBS Publishers, New Delhi.

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

Singhal NC. 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.

XI. 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

XII.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

Lecture Schedule
Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Importance and present status of vegetable seed industry	02
2.	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.	04
3.	Varietal and hybrid seed production techniques in important cucurbitaceous vegetables — gourds and melons	03
4.	Varietal and hybrid seed production techniques in important cole crops — Cauliflower, Cabbage, Knol-Khol	02
5.	Varietal and hybrid seed production techniques in important root vegetables — Carrot, Beetroot, Turnip, Radish and other Tropical / temperate/ hilly vegetable crops.	03
6.	Varietal seed production techniques in major Leguminous vegetables — peas and beans	03
7.	seed production techniques in leafy vegetables — Amaranthus, Palak, Spinach, And Lettuce.	03
8.	Seed production techniques in tuber crops — Potato, Sweet Potato, Colocasia, Tapioca and Yam	03
9.	Seed-plot technique in potato — true potato seed (TPS) production techniques	02
10.	Seed production techniques in bulb crops — Onion, Garlic.	02
11.	Vegetative and clonal multiplication — methods, merits and demerits	02
12.	Clonal multiplication — Potato, Sweet Potato, Colocasia, Tapioca and Yam.	03
	Total	**32**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Identification of vegetable seeds; Study on sowing and nursery management; Study on transplanting and age of seedling on crop establishment; Studying floral biology of Solanceous, Malvaceous and Cucurbitaceous vegetable crops	3
2.	Studying floral biology of other vegetable crops; Practicing planting design for hybrid seed production	2
3.	Modification of sex ratio in cucurbits, Practicing emasculation and pollination methods	2
4	Practicing roguing operations — identification of off-types — selfed fruits; Harvesting methods — single and multiple harvesting method	2
5.	Practicing seed extraction methods — wet methods — tomato, brinjal, other cucurbitaceous fruits; Seed extraction — dry methods — Chillies, Bhendi, Cucurbitaceous;	3
6.	Visit to seed production fields; Visit to private seed industry	2
7.	Seed production planning and economics of seed production of varieties and hybrids.	2
	Total	**16**

I. Course Title : **Seed Production Techniques in Fruits, Flowers, Spices, Plantation and Medicinal Crops**

II. Course Code : **SST 505**
III. Credit Hours : **3 (2+1)**

IV. Why this course?

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

V. Aim of the course

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

VI. Theory

Unit I

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

Unit II

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

Unit III

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

Unit IV

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

Unit V

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

VII. Practical

- Study on the floral biology and pollination mechanism;
- Identification of seeds of fruits, flowers, spices, plantation and medicinal crops;
- Selection of mother plants and trees — phenotypic characters and genotypic characters;

- Study on different types of clonal and vegetative propagules;
- Seed and clonal standards of vegetatively propagating crops;
- Germination improvement treatments for seeds and vegetative propagules;
- Study on selection of planting materials and sowing methods;
- Nursery management practices for elite seedling production;
- Seed extraction methods — wet method and dry method;
- Post harvest seed handling — seed grading, upgrading techniques
- Study of seed storage techniques;
- Practicing seed germination enhancement techniques in fruits, spices and plantation crops;
- Practicing seed germination enhancement techniques in flowers and medicinal crops;
- Planning for seed production — economics of seed production in flower crops;
- Visit to mother tree orchard;
- Visit to plantation and orchard.

VIII. Teaching methods

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

IX. **Learning outcome**

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

X. Suggested Reading

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

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

Singh SP. 2001. *Seed Production of Commercial Vegetables.* Agrotech, New Delhi. Vanangamudi K and Natarajan K. 2008. *Advances in Seed Science and Technology. QualitySeed Production in Spices, Plantation, Medicinal and Aromatic crops* (Vol. 5). Agrobios.Jodhpur.

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

XI. **Suggested e-books**

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

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

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

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

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

XII. **Suggested websites**

www.cimap.res.in/english/index.php
www.dmapr.org.in/amprs.kau.in/basic-page/publications
http://ecoursesonline.iasri.res.in/course/view.php?id=153
http://ecoursesonline.iasri.res.in/course/view.php?id=612
http://www.celkau.in/Crops/Plantation%20Crops/Rubber/production.aspx
http://sbc.ucdavis.edu/Courses/Seed_Production/

Lecture Schedule
Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Scope for seed production in fruits, flowers, spices, plantation and medicinal crops	02
2.	Factors influencing seed production and quality; propagation methods — seed and clonal propagation; seed and seedling standards; propagation and seed production techniques in major tropical, sub-tropical and temperate fruit crops	04
3.	Seed orchards — seed collection, extraction processing and storage techniques	02
4.	Seed production techniques in commercially important flower crops — nursery management,	02
5.	Clonal propagation, planting, seed crop management, post-harvest seed handling and storage techniques	03
6.	Seed production techniques in commercially important seed spices and other spices	04
7.	Nursery management, sowing, seed crop management and post-harvest seed handling and storage techniques in important seed spices	04
8.	Seed production in commercially important plantation crops — mother tree selection — criteria — nursery management	03
9.	Elite seedling production, planting, plantation management, post-harvest handling and storage techniques.	03
10.	Methods of quality seed production in commercially important medicinal plants	02
11.	Nursery management, sowing, seed crop management, post-harvest handling and storage methods in commercially important medicinal plants	03
	Total	**32**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Study on the floral biology and pollination mechanism; Identification of seeds of fruits, flowers, spices, plantation and medicinal crops; Selection of mother plants and trees — phenotypic characters and	3

	genotypic characters	
2.	Study on different types of clonal and vegetative propagules; Seed and clonal standards of vegetatively propagating crops	2
3.	Germination improvement treatments for seeds and vegetative propagules; Study on selection of planting materials and sowing methods;	2
4	Nursery management practices for elite seedling production; Seed extraction methods — wet method and dry method	2
5.	Post harvest seed handling — seed grading, upgrading techniques Study of seed storage techniques; Practicing seed germination enhancement techniques in fruits, spices and plantation crops	3
6.	Practicing seed germination enhancement techniques in flowers and medicinal crops; Planning for seed production — economics of seed production in flower crops	2
7.	Visit to mother tree orchard; Visit to plantation and orchard.	2
	Total	**16**

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

II. Course Code : SST 506

III. Credit Hours : 2 (1+1)

IV. Why this course?

Agriculture and animal husbandry in India is interwoven and livestock is the source of income when crop failed. To feed the livestock population, cultivation and seed production of fodder and forage crops are much important. Likewise green manure crops maintain soil health, which created heavy demand for quality seed. Hence, study of seed production techniques in these crops will help to produce quality seeds to meet the growing needs.

V. Aim of the course

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

VI. Theory

Unit I

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

Unit II

Quality seed production techniques in major fodder crops — Lucerne, hedge Lucerne, Leucaena, fodder sorghum, fodder maize and oats.

Unit III

Seed and planting material production techniques of major forage grasses — Bajra -Napier grass, Guinea grass, Deenanath grass and *Cenchrus* sp.; forage legumes *Stylosanthus*, Cowpea and Berseem.

Unit IV

Seed production techniques in major green manure crops — *Glyricidia*, *Sesbania* sp., Sunnhemp, Daincha, Jute and *Tephrosia* sp.

Unit V

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

VII. Practical

- Seed collection and identification of seeds;
- Estimation of seed setting and shattering loss;
- Maturity indices — determination of physiological and harvestable maturity;
- Seed extraction and threshing methods;
- Separation of ill filled seeds — practicing different methods;

- Study of seed and clonal materials — standards;
- Quality of planting material and vegetative propagules on crop establishment;
- Seed quality analysis in forage and fodder crops — tiller wise quality analysis;
- Seed quality analysis in determinate and indeterminate crops;
- Study on effect of ratooning on seed quality;
- Practicing seed quality enhancement techniques;
- Practicing different seed extraction and dormancy breaking treatments;
- Preparation of vegetative propagules and planting;
- Planning for seed production in fodder and green manure crops;
- Economics of seed production in fodder, forage crops and green manure crops;
- Visit to forage and fodder seed production farms.

VIII. Teaching Methods

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

IX. Learning outcome

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

X. Suggested Reading

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

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

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

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

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

XI. Suggested e-books

https://www.cabi.org/bookshop/book/9780851992143

https://cgspace.cgiar.org/handle/10568/49375

http://www.fao.org/docrep/009/a0503e/a0503e00.htm

http://www.igfri.res.in/pdf/old_bulletins/tropical_pasture.pdf

https://cgspace.cgiar.org/bitstream/handle/10568/4479/Seed.pdf?sequence=
&isAllowed=y

XII. Suggested websites

www.igfri.res.in/

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

Lecture Schedule
Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Scope and importance of seed production in forage, pasture and green manure crops	01
2.	Factors influencing seed production — seasonal influence; problems and constraints in seed production — seed set, shattering and seed dormancy; vegetative and clonal propagules and apomictic seed.	02
3.	Quality seed production techniques in major fodder crops — lucerne, hedge lucerne, Leucaena, fodder sorghum, fodder maize and oats.	03
4.	Seed and planting material production techniques of major forage grasses — Bajra -Napier grass, Guinea grass, Deenanath grass and *Cenchrus* sp.; forage legumes *Stylosanthus*, Cowpea and Berseem.	03
5.	Seed production techniques in major green manure crops — *Glyricidia, Sesbania* sp., Sunnhemp, Daincha, jute and *Tephrosia* sp.	03
6.	Post-harvest seed handling — processing, threshing, grading and upgrading	02
7.	Dormancy breaking and germination improvement — quality standards for seed and vegetative propagules.	02
	Total	**16**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Seed collection and identification of seeds; Estimation of seed setting and shattering loss	2
2.	Maturity indices — determination of physiological and harvestable maturity	2
3.	Seed extraction and threshing methods; Separation of ill filled seeds — practicing different methods	2
4	Study of seed and clonal materials — standards; Quality of planting material and vegetative propagules on crop establishment	2
5.	Seed quality analysis in forage and fodder crops — tiller wise quality analysis; Seed quality analysis in determinate and indeterminate crops; Study on effect of ratooning on seed quality; Practicing seed quality enhancement techniques	3

6.	Practicing different seed extraction and dormancy breaking treatments; Preparation of vegetative propagules and planting	2
7.	Planning for seed production in fodder and green manure crops; Economics of seed production in fodder, forage crops and green manure crops	2
8.	Visit to forage and fodder seed production farms	1
	Total	**16**

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

IV. 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.

V. Aim of the course

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

VI. 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.

VII. 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.

VIII. Teaching methods

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

IX. 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.

X. Suggested Reading

Agarwal RL. 2012. *Seed Technology*. Oxford & IBH Publishing Company Pvt. Ltd., New Delhi.

Anon. 2016. *Manual of Seed Certification Procedures*. Directorate of Seed Certification, Coimbatore, Tamil Nadu.

Chakrabarthi SK. 2010. *Seed Production and Quality Control*. Kalyani Publishers, New Delhi.

Mishra DK, Khare D, Bhale MS and Koutu GK. 2011. *Handbook of Seed Certification*. Agrobios, Jodhpur, Rajasthan.

Neema NP. 1986. *Principles of Seed Certification and Testing*. Allied Publishers, New Delhi

Ramamoorthy K, Sivasubramaniam K and Kannan M. 2006. *Seed Legislation in India.* Agrobios, Jodhpur, Rajasthan.

Renugadevi J, Srimathi P, Renganayaki PR and Manonmani V. 2012. *A Handbook of Seed Testing.* Agrobios, Jodhpur, Rajasthan.

Sharma P. 2008. *Seed Legislation.* Gene-tech Book Publishers, New Delhi. Trivedi PC. 2011. *Seed Technology and Quality Control.* Pointer Publications, Jaipur, Rajasthan.

Tunwar NS and Singh SV. 2003. *Indian Minimum Seed Certification Standards.* Central Seed Certification Board, Ministry of Agriculture, GOI, New Delhi.

XI. Suggested e-books

http://cms.tn.gov.in/sites/default/files/documents/seed-certification-0.pdf
http://odishaseedsportal.nic.in/SeedPortalData/Resource%20Material/INDIAN-MINIMUM-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://dl.sciencesocieties.org/publications/books/tocs/cssaspecialpubl/theroleofseedce

XII. 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/SeedCertification Manual.pdf

Lecture Schedule
Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Genesis of seed Industry in India; seed quality control — concept and objectives	02
2.	Regulatory mechanisms — Seed Act (1966) — Seed Rules (1968) — statutory bodies — Central Seed Committee — Central Seed Certification Board	04
3.	Seed Control Order (1983) — New Policy on Seed Development (1988) — Exim Policy — National Seed Policy (2002) — Plant Quarantine Act.	03
4.	Introduction to WTO and IPR — UPOV and its role — OECD seed certification schemes	03
5.	PPV & FR Act (2001) and Rules (2003) — Seed Bill (2004 and 2011)	03
6.	Seed certification system in SAARC countries, Europe, Canada, Australia and USA.	02
7.	Seed certification — history and objectives; general and specific crop standards, field and seed standards	03

8.	Seed certification agency — role of certification agency/ department and seed certification officers	02
9.	Phases of seed certification; field inspection — counting procedures — liable for rejection (LFR) — downgrading and partial rejection — reporting.	03
10.	Post-harvest inspection — construction of seed lot number; seed sampling — testing — labeling, sealing and grant of certificate	02
11.	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	03
12.	Role of seed analyst and seed inspector in quality regulation.	02
	Total	**32**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Preparation of sowing report — varieties — transplanted and direct sown crops and hybrids; Verification of sowing report — seed certification procedures	2
2.	Field inspection — estimation of area and isolation distance, stages of inspection for varieties and hybrids — procedures	2
3.	Practicing field counting procedures — methods for row planting, broadcasted — varieties; Practicing field counting procedures — direct sown and transplanted crops — varieties	2
4	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	2
5.	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	2
6.	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	2
7.	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	3
8.	Procedure to issue tag, specification, bagging, tagging, labelling and sealing	1
	Total	**16**

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

II. Course Code : SST 508

III.Credit Hours: 3 (2+1)

IV.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.

V. Aim of the course

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

V. 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.

VII. 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.

VIII. Teaching methods

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

IX. 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.

XI. Suggested Reading

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

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

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

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

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

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

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

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

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

XI. 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& versionId=45008917+251246346
http://www.worldseed.org/wp-content/uploads/2017/01/Seed-Production-Good-practice-10.01.17-final.pdf

XII. Suggested websites

http://www.fao.org/3Za-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-2015-update.pdf

https://www.carolinafarmstewards.org/wpcontent/uploads/2012/05/Seed Processing and StorageVer_1pt3.pdf

Lecture Schedule
Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Seed processing — objectives and principles; processing sequence — threshing, shelling, ginning, extraction methods,	02
2.	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.	03
3.	Online seed processing — elevators and conveyers — processing plant — specifications, design and layout	02
4.	Mechanical injury — causes and detection — management.	03
5.	Seed treatment — methods	02
6.	Pre and mid storage seed treatments, seed treating formulations and equipments	02
7.	Packaging materials — types — bagging and labelling; seed blending — principle and methods	03
8.	Seed storage — purpose and importance — factors affecting storage, optimum condition for storage of different seeds	03
9.	Storage principles — Harrington's thumb rule — concepts and	03

	significance of moisture equilibrium — maintenance of safe seed moisture	
10.	Physical, physiological, biochemical and molecular changes during seed storage	02
11.	Storage behaviour of orthodox and recalcitrant seeds — prediction of viability — viability nomograph,	02
12.	Methods of seed storage — modified atmospheric storage — ultra dry storage — vacuum storage — cryopreservation — germplasm storage — gene banks — NBPGR, IPGRI and National seed storage laboratory.	03
13.	Seed storage godown — structure — maintenance — sanitation.	02
	Total	**32**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Seed extraction — wet and dry methods; Seed processing sequence for different crops	2
2.	Design of processing plant — equipments — estimation of processing efficiency	1
3.	Seed drying methods — principle and methods; Practicing seed grading — upgrading techniques	3
4	Delinting methods — assessment of mechanical damage; Visit to seed processing unit	2
5.	Seed packaging — effect of packaging materials on seed longevity; Prediction of viability during storage — viability nomograph and accelerated ageing test	2
6.	Assessing physical changes during seed storage; Assessing physiological changes during seed storage; Assessing biochemical changes during seed storage	2
7.	Storage behaviour of recalcitrant seeds; Pre-storage seed treatments — protectants — antioxidants — halogens; Practicing seed blending methods	3
8.	Seed storage godown — sanitation, fumigation — visit to seed storage godown and cold storage unit	1
	Total	**16**

I. Course Title : Seed Quality Testing and Enhancement*

II. Course Code : SST 509

III.Credit Hours : 2 (1+1)

IV. 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.

V. Aim of the course

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

V. 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 electro-magnetic 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.

VII. 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.

VIII. Teaching methods

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

IX. 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.

X. Suggested Reading

Agrawal PK. 1993. *Hand book of Seed Testing*. Ministry of Agriculture, GOI, New Delhi Agrawal RL. 1997. *Seed Technology*. Oxford & IBH.

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

Chakrabarthi SK. 2010. *Seed Production and Quality Control*. Kalyani Publishers. New Delhi.

Chalam GV Singh A and Douglas JE. 1967. *Seed Testing Manual.* ICAR and United States Agency for International Development, New Delhi.

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

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. ISTA. 1999. *Seed Science and Technology*, 27th supplement.

Renugadevi J, Srimathi P, Renganayaki PR and Manonmani V. 2012. *A Hand book of Seed Testing.* Agrobios. Jodhpur, Rajasthan.

Tridevi PC. 2011. *Seed Technology and Quality Control.* Pointer Publication. Jaipur, Rajasthan.

Vasudevan SN, Doddagowder SR, Rakesh CM and Patil SB. 2013. *Seed Testing and Quality Control.* Agrotech Publications, Udaipur, Rajasthan.

XI. Suggested e-books

http://odishaseedsportal.nic.in/SeedPortalData/Resource%20Material/INDIAN MINIMUMSEEDCERTIFICATIONSTANDARDS.pdf. www.kopykitab.com/Seed-Testing-and-Quality-Control-by-Vasudevan-SN https://www.jstor.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_RODUCTION_ITS_TESTING_AND_CERTIFICATION_STANDARD
https://www.seedtest.org/upload/cms/user/ISTAMethodValidationforSeedTesting-V1.01.pdf
https://www.intechopen.com/books/new-challenges-in-seed-biology-basic-and-translational-research-driving-seed-technology/recent-advances-in-seed-enhancements

XII. 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

Lecture Schedule

Theory

Sr. No.	Topic	No. of Lecture(s)
1.	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	02
2.	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.	02
3.	Seed germination test — requirements, media and methods — seedling evaluation, tolerance and reporting results; viability test (TZ test) —	01

	principle, procedure and evaluation	
4.	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.	02
5.	Genetic purity assessment — laboratory methods — physical, chemical, biochemical and molecular tests — growth chamber and field testing (Grow Out Test) methods; testing of GM seeds.	01
6.	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.	02
6.	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 electro-magnetic seed treatments — principles and methods — seed pelleting and coating principles, purpose and methods.	03
7.	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	03
	Total	**16**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Seed testing — sampling and dividing methods; Determination of seed test weight and heterogeneity test	1
2.	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	3
3.	Genetic purity assessment — laboratory and conventional methods — image analysis for seed quality	2
4	Conducting different seed health tests to identify bacteria, fungi and insects	2
5.	Visit to seed testing laboratory	1
6.	Seed enhancement techniques — practicing physical treatments and water floatation techniques; Seed coating and pelleting — uses of adhesives and filler materials	2

7.	Performing seed priming — hydro, halo and bio-priming — solid matrix priming	2
8.	Practicing seed infusion and microbial inoculation treatments; Practicing pre-germination technique;	2
9.	Studying integrated seed treatment/ designer seed treatment	1
	Total	**16**

I. Course Title : Seed Technology of Tree Species

II. Course Code : SST 510

III.Credit Hours : 2 (1+1)

IV.Why this course?

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

V. Aim of the course

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

V. Theory

Unit I

Importance of tree seeds — seed quality in plantation establishment — scope of seed production in tree species; seed structure and its significance in natural regeneration of forest species.

Unit II

Reproductive biology — angiosperms and gymnosperms — reproductive age — seasonal influence on flowering — reproductive efficiency; factors influencing seed set — pollination — pollinating agents — self incompatibility — seed dispersal — mode and mechanism of dispersal.

Unit III

Seed stand — selection and delineation — seed production area — seed zone — selection criteria for candidate, plus and elite tree; seed orchards — definition — types — seedling and clonal seed orchard — pollen dilution zone — seed orchard establishment and management; OECD certification programmes for forest reproductive materials and seeds — ISTA certification standards for tree species.

Unit IV

Physiological maturity — maturity indices — determining optimum harvestable maturity; seed collection — methods — factors influencing seed collection — precautions in collection of recalcitrant seeds; seed extraction — methods — wet, dry and cone extraction; drying — critical moisture content — seed processing; dormancy — types of dormancy in tropical, sub tropical and temperate tree seeds — dormancy breaking treatments; recalcitrant seeds — mechanism.

Unit V

Seed production and handling techniques in important tree borne oil seeds *(Madhuca, Pongamia, Azadirachta, Simaruba, Callophyllum),* timber trees (Teak, Sandal, Pine, Cedar, Sal, Shisham), fuel wood *(Acacias, Azadirachta),* pulp wood (Bambusa, *Ailanthus, Casuarina, Melia, Eucalyptus),* fodder *(Leucaena, Albizzia)* and ornamental *(Cassia, Delonix)* tree species.

VII. Practical

- Study of tree seed structure — internal and external structures;
- Study on phenology of different tree species;
- Selection procedure of candidate and plus trees;
- Assessment of seed set, physiological and harvestable maturity;
- Assessing natural regeneration in different tree species;
- Study on seed dispersal methods and dispersal distance in different species;
- Seed collection techniques in important tree species — seed collection — orthodox and recalcitrant seeds — safety measures during collection;
- Seed extraction methods — wet and dry extractions — fruits, pods, cones, etc.;
- Study on different seed drying methods and precautions;
- Practicing seed grading and upgrading techniques;
- Practicing seed dormancy breaking methods;
- Germination improvement treatments for elite seedling production;
- Study on storage of recalcitrant seed;
- Estimation of critical moisture content for safe storage;
- Visit to seed production area and seed orchard;
- Visit to tree seed processing unit.

VIII. Teaching methods

- Classroom lectures
- Power point presentations
- Student assignments and presentation
- Group exercise
- Laboratory experiments
- Field visit to seed orchard

IX. Learning outcome

Knowledge of the seed biology of a tree species enable to produce good quality seeds, handling and prevent loss of seeds. The knowledge on sexual life cycle enables them to plan for genetic improvement, production, collection, conditioning, storage, and planting of the seeds.

X. Suggested Reading

Dennis AJ, Schepp EN, Green RJ and West cott DA. 2007. *Seed Dispersal.* Agrobios, Jodhpur.

Khanna LS. 1993. *Principles and Practices of Silviculture.* Khanna Bandhu, Dehradun, India.

Lars Schmidt 2000. *Guide to Handling of Tropical and Sub Tropical Forest Seed.* Danida Forest Seed Centre, Denmark.

Negi SS. 1998. *Forest Tree Seed.* International Book Distributors, Dehradun, India.

Ram Prasad and Khandya AK. 1992. *Handling of Forestry Seeds in India.* Associated Publishers, New Delhi.

Sivasubramaniam K, Raja K and Geetha R. 2012. *Recalcitrant Seeds - Causes and Effects.* Sathish Serial Publishing House. Azadpur, New Delhi.

Umarani R and Vanangamudi K. 2004. *An Introduction to Tree Seed Technology.* InternationalBook Distributors, Dehradun.

Vanangamudi K, Natarajan K, Saravanan J, Natarajan N, Umarani R, Bharathi A and SrimathiP. 2007. *Advances in Seed Science and Technology: Forest Tree Seed Production* (Vol. 4).Agrobios, Jodhpur

Willan RL. 1985. *A guide to Forest Seed Handling.* FAO, Rome

Zoebel B and Talbert TT. 1984. *Applied forest Tree Improvement.* Joh willey and Sons, New Yark.

XI. Suggested e-books

http://www.fao.org/3/a-ah803e.pdf http://www.fao.org/3/ad232e/AD232E01.htm
https://www.springer.com/gp/book/9783540490289
http://www.fao.org/docrep/006/ad232e/ad232e00.htm
http://envis.nic.in/ifgtb/pdfs/Tree%20Seed%20Management.pdf
https://www.forestry.gov.uk/PDF/FCBU054.pdf/$FILE/FCBU054.pdf
https://www.forestry.gov.uk/PDF/FCBU059.pdf/$FILE/FCBU059.pdf

XII. Suggested websites

www.ista.org.in
ifgtb.icfre.org/index.php
http://www.kfri.res.in/research.asp
http://www.fao.org/3/ad232e/AD232E21.htm
https://www.srs.fs.usda.gov/pubs/gtr/gtr_so107.pdf
http://www.sfri.nic.in/pdf_files/Seed%20Technology.pdf

Lecture Schedule

Theory

Sr. No.	Topic	No. of Lecture(s)
1.	Importance of tree seeds — seed quality in plantation establishment — scope of seed production in tree species	01
2.	Seed structure and its significance in natural regeneration of forest species.	01
3.	Reproductive biology — angiosperms and gymnosperms — reproductive age — seasonal influence on flowering — reproductive efficiency	02
4.	Factors influencing seed set — pollination — pollinating agents — self incompatibility — seed dispersal — mode and mechanism of dispersal.	02
5.	Seed stand — selection and delineation — seed production area — seed zone — selection criteria for candidate, plus and elite tree	01
6.	Seed orchards — definition — types — seedling and clonal seed orchard — pollen dilution zone — seed orchard establishment and management;	01
7.	OECD certification programmes for forest reproductive materials and seeds — ISTA certification standards for tree species.	01

8.	Physiological maturity — maturity indices — determining optimum harvestable maturity	01
9.	Seed collection — methods — factors influencing seed collection — precautions in collection of recalcitrant seeds; seed extraction — methods — wet, dry and cone extraction; drying — critical moisture content — seed processing	02
10.	Dormancy — types of dormancy in tropical, sub tropical and temperate tree seeds — dormancy breaking treatments; recalcitrant seeds — mechanism.	02
11.	Seed production and handling techniques in important tree borne oil seeds *(Madhuca, Pongamia, Azadirachta, Simaruba, Callophyllum),* timber (Teak, Sandal, Pine, Cedar, Red sanders, Shisham), fuel wood *(Acacias, Azadirachta),* pulp wood (Bambusa, *Ailanthus, Casuarina, Melia, Eucalyptus),* fodder *(Leucaena, Albizzia)* and ornamental *(Cassia, Delonix)* tree species.	02
	Total	**16**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Study of tree seed structure — internal and external structures; Study on phenology of different tree species; Selection procedure of candidate and plus trees	2
2.	Assessment of seed set, physiological and harvestable maturity; Assessing natural regeneration in different tree species	2
3.	Study on seed dispersal methods and dispersal distance in different species; Seed collection techniques in important tree species — seed collection — orthodox and recalcitrant seeds — safety measures during collection	3
4	Seed extraction methods — wet and dry extractions — fruits, pods, cones, etc.; Study on different seed drying methods and precautions	2
5.	Practicing seed grading and upgrading techniques; Practicing seed dormancy breaking methods	2
6.	Germination improvement treatments for elite seedling production; Study on storage of recalcitrant seed	2
7.	Estimation of critical moisture content for safe storage	1
8.	Visit to seed production area and seed orchard; Visit to tree seed processing unit	2
	Total	**16**

I. Course Title : Seed Industry and Marketing Management

II. Course Code : SST 511

III. Credit Hours : 2 (1+1)

IV. 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.

V. Aim of the course

To empower the students to become seed entrepreneurs by imparting knowledge on seed industry management and marketing strategies.

VI. 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 chain 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.

VII. 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.

VIII. Teaching methods

- Classroom lectures
- Survey
- Student assignment and presentation
- Economic analysis
- Group discussion
- Swot analysis
- Seed industry visit and interaction sessions

IX. 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.

X. Suggested Reading

Acharya SS and Agarwal NL. 2004. *Agricultural Marketing in India*. 4th Ed. Oxford and IBH.

Broadway AC and Broadway A. 2003. *A Text Book of Agri-business Management.*

Kalyani Singh AK 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.

Singh G and Asokan SR. 1991. *Seed Industry in India: A Management Perspective* Oxford &IBH Publishing Co Pvt. Ltd., New Delhi.

Singh S. 2004. *Rural Marketing - Focus on agricultural Inputs.* Vikas Publishing House.

XI. 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=vPVlBos4WkYC
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. 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/

Lecture Schedule

Theory

Sr. No.	Topic	No. of Lecture(s)
1.	Introduction to seed industry — genesis, growth and structure of seed industry — mission and objectives	02
2.	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.	02
3.	Seed industry — organization set up and functions — public, private, MNC's, seed corporations	01
4.	Structure of small, medium and large seed industries, components of seed industry — public private partnership	01
5.	Custom seed production — risk management — human resource — infrastructure — processing unit — storage go down	01
6.	Seed production and distribution systems in state and central government; seed supply chain systems — seed production and distribution	02
7.	Planning, organization and coordination, staffing, assembling of resources; cost of seed production — overhead charges	01
8.	Seed marketing—definition—importance—role of marketing; type of markets — domestic and global market — problems and perspectives	01
9.	Marketing policies — seed marketing schemes — marketing channels, responsibilities of dealers — marketing mix.	01
10.	Seed demand forecasting — purpose — methods and techniques; indenting and seed dispatch procedures and forms — seed store records — maintenance	02
11.	Missing link in seed supply chain; market intelligence — SWOT analysis; seed cost analysis	01
12.	Seed pricing — policy — components of seed pricing — factors — local market rate (LMR) — fixation of procurement and sale price of seed.	01
	Total	**16**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Data collection on status of Indian and global seed industry; Assessing the factors influencing farmers preference and assessment of seed demand and supply	2
2.	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	3
3.	Exercise on fixing seed procurement and sale price; Study of marketing channels — domestic and international	2
4	Maintenance of carryover seeds — Assessing risk factors in seed industry and their management	1
5.	Survey and interaction with seed dealers and distributors	2
6.	Visit to state seed corporations; Visit to MNCs and expert discussion	2
7.	Case studies and SWOT analysis	1
8.	Visit to modern seed processing unit and advanced seed storage complex	1
9.	Custom seed production, contract farming and procurement — procedures; Planning and preparation of project proposal for setup of a seed industry	2
	Total	**16**

I. Course Title : Seed Health Testing and Management

II. Course Code : SST 512

III. Credit Hours : 2 (1+1)

IV. Why this course?

Seeds are the foundation for crop production and seed health is related to food production in many ways. Healthy seeds, free from seed transmitted pathogens, are a prerequisite for sustainable food production. Seeds are routinely tested to prevent and control plant pests and pathogens that may affect seed quality, seed movement when introduced into new territories. A seed health test is also frequently a phyto-sanitary requirement imposed by national plant protection authorities. This course aids in timely detection and management of seed borne pest and diseases and supply of pest and disease free seeds in market.

V. Aim of the course

To acquaint the students with principle and practices of seed health testing and management of seed borne pathogens and storage insects.

VI. Theory

Unit I

History and economic importance of seed health in seed industry and plant quarantine — important seed borne and seed transmitted pathogens — role of microorganisms in seed quality deterioration — storage and field fungi — effect of storage fungi on seeds — factors influencing storage fungi and management.

Unit II

Transmission of pathogens — mode and mechanism — seed certification standards; mycotoxins — types and its impact on plant, animal and human health; seed health testing methods — direct examination, incubation, serological and molecular methods.

Unit III

Production of disease free seeds in agricultural and horticultural crops; management of seed borne pathogens — plant quarantine — Indian system and networking, post-entry quarantine and international systems — Pest Risk Analysis (PRA); Sanitary and Phytosanitary System (SPS) — certificates; International Seed Health Initiative (ISHI) on seed health standards.

Unit IV

Storage pests — insects, mites, rodents and their development — economic importance; insect infestation — factors influencing, sources and kinds, biochemical changes in stored seeds due to insect infestation; detection methods and estimation of storage losses; types of seed storage structures — domestic and commercial.

Unit V

Fumigation — principles and techniques — type of fumigants; preservatives and seed protectants on seed quality — non-chemical methods for managing seed storage pests — controlled and modified atmospheric storage — trapping devices — IPM for seed storage.

VII.Practical

- Detection of seed borne pathogens — direct examination;
- Detection of seed borne pathogens — incubation methods;
- Detection of seed borne pathogens — serological methods;
- Detection of seed borne pathogens — molecular methods;
- Study on seed transmission of seed borne fungi, bacteria and viruses;
- Identification of storage fungi;
- Management of seed borne pathogens — seed treatment methods;
- Identification of storage insects — internal and external feeders influencing insects;
- Study on the effect of pre harvest spray on field carryover storage pests;
- Estimation of storage losses due to pests;
- Methods of detection of insect infestation;
- Management of storage pests — pesticides, dose determination, preparation of solution and application;
- Management of storage pests — non-chemical management methods;
- Demonstration of controlled atmospheric storage;
- Safe handling and use of fumigants and insecticides;
- Visit to seed storage godowns.

VIII. Teaching methods

- Classroom lectures
- Power point presentations
- Student assignment and presentation
- Laboratory experiments
- Hands on training.

IX. Learning outcome

Successful completion of this course will provide knowledge on production of healthy seeds by timely detection and management of seed borne pathogens and storage pests to meet phyto-sanitary requirements.

X. Suggested Reading

Agarwal VK and Sinclair JB. 1996. *Principles of Seed Pathology*. Edition, CRC Press Inc. BocaRaton, FL.

Athanassiou CG and Arthur FH. 2018. *Recent advances in stored product protection.* Springer-Verlag, Germany

Cotton, RT. 2007. *Insect Pests of Stored grain and Grain products.* Burgess Publ. Co.,Minneopolis, Minn., USA

Karuna V. 2007. *Seed Health Testing.* Kalyani Publishers, New Delhi.

Karuna V. 2009. *Fundamentals of Seed Pathology*. Kalyani Publishers, New Delhi.

Neergaard P. 1979. *Seed Pathology*. Vol. 1. The Macmillan Press Ltd.

Ranjeet K. 2017. *Insect Pests of Stored grain - Biology, Behaviour and Management Strategies.* Apple Academic Press, New York, USA.

XI. Suggested e-books

https://link.springer.com/book/10.1007/978-1-349-02842-9
https://www.crcpress.com/Principles-of-Seed-Pathology/Agarwal-Sinclair/p/book/9780429152856
https://books.google.co.in/books/about/Seed_Pathology.html?id=lvVJAAAAYAAJ&redir_esc=y https://www.taylorfrancis.com/books/9781315365695
https://www.ebooks.com/en-us/610606/insects-of-stored-products/david-rees/
https://www.elsevier.com/books/insects-and-seed-collection-storage-testing-and-certification/kozlowski/978-0-12-395605-7

XII. Suggested websites

www.tnagrisnet.tn.gov.in/ www.storedgrain.com.au/
https://openlibrary.org/subjects/seed_pathology
http://ciat-library.ciat.cgiar.org/articulos_ciat/2015/12620.pdf
www.grainscanada.gc.ca/en/
https://entomology.ca.uky.edu/ef145
http://www.fao.org/3/t1838e/T1838E00.htm#Contents
https://www.agric.wa.gov.au/pest-insects/insect-pests-stored-grain

Lecture Schedule

Theory

Sr. No.	Topic	No. of Lecture(s)
1.	History and economic importance of seed health in seed industry and plant quarantine	01
2.	Important seed borne and seed transmitted pathogens — role of microorganisms in seed quality deterioration	01
3.	Storage and field fungi — effect of storage fungi on seeds — factors influencing storage fungi and management.	01
4.	Transmission of pathogens — mode and mechanism	01
5.	Seed certification standards; mycotoxins — types and its impact on plant, animal and human health	01
6.	Seed health testing methods — direct examination, incubation, serological and molecular methods	02
7.	Production of disease free seeds in agricultural and horticultural crops; management of seed borne pathogens; plant quarantine	02
8.	Indian system and networking, post-entry quarantine and international systems — Pest Risk Analysis (PRA)	01
9.	Sanitary and Phytosanitary System (SPS) — certificates; International Seed Health Initiative (ISHI) on seed health standards	01
10.	Storage pests — insects, mites, rodents and their development — economic importance	01
11.	Insect infestation — factors influencing, sources and kinds, biochemical changes in stored seeds due to insect infestation; detection methods and estimation of storage losses; types of seed storage structures — domestic and commercial.	02
12.	Fumigation — principles and techniques — type of fumigants; preservatives and seed protectants on seed quality	01

13.	Non-chemical methods for managing seed storage pests — controlled and modified atmospheric storage — trapping devices — IPM for seed storage.	01
	Total	**16**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Detection of seed borne pathogens — direct examination; Detection of seed borne pathogens — incubation methods; Detection of seed borne pathogens — serological methods; Detection of seed borne pathogens — molecular methods	4
2.	Study on seed transmission of seed borne fungi, bacteria and viruses; Identification of storage fungi	2
3.	Management of seed borne pathogens — seed treatment methods; Identification of storage insects — internal and external feeders influencing insects	2
4	Study on the effect of pre harvest spray on field carryover storage pests; Estimation of storage losses due to pests	2
5.	Methods of detection of insect infestation; Management of storage pests — pesticides, dose determination, preparation of solution and application; Management of storage pests — non-chemical management methods	3
6.	Demonstration of controlled atmospheric storage; Safe handling and use of fumigants and insecticides	2
7.	Visit to seed storage godowns	1
	Total	**16**

Course Title with Credit Load Ph.D. in Seed Science and Technology (SST)

Course No.	Course Title	Credits
Major Courses (Min. 12 Credits from below courses including * marked courses)		
SST 601*	Hybrid Seed Production Technology	3 (2+1)
SST 602	Organic Seed Production	2 (1+1)
SST 603	Physiology and Biochemistry of Seeds	2 (1+1)
SST 604*	Genetic Purity and DUS Testing	3 (2+1)
SST 605	Seed Vigour and Crop Productivity	2 (1+1)
SST 606*	Advances in Seed Science	2 (2+0)
SST 607	Advances in Seed Quality Enhancement	2 (1+1)
SST 608	Germplasm Conservation Techniques	2 (1+1)
SST 609	Seed Ecology	2 (1+1)
SST 610	Seed Planning, Trade and Marketing	2 (1+1)
Minor Courses (Min. 6 Credits from below disciplines)		
GPB	Genetics and Plant Breeding	
BIOCHEM	Biochemistry	
STAT**	Statistics	
PL PATH	Plant Pathology	
PL PHY	Plant Physiology	
HORT	Horticulture	
FOR	Forestry	
Supporting Courses (Min. 5 Credits from below discipline)		
ENT	Entomology	
GPB	Genetics and Plant Breeding	
STAT	Statistics	
BIOCHEM	Biochemistry	
Non Credit Common Courses (Min. 5 Credits from below courses)		
PGS -501	Library and Information Services	1 (0+1)
PGS -504	Basic Concepts in Laboratory Techniques	1 (0+1)
PGS -502	Technical Writing & Communication Skills	1 (0+1)
PGS-503	Intellectual Property and its Management in Agriculture	1 (1+0)
PGS-505	Agricultural Research, Research Ethics and Rural Development Programmes	1 (1+0)
PGS-506	Disaster Management	1 (1+0)
Compulsory Seminar and Research		
SST -691	Seminar I	1 (0+1)
SST -692	Seminar II	1 (0+1)
SST-699	Research	75
	Total Credits	**100**

Comprehensive (Pre qualifying) examination	Non Credit of 100 marks	Satisfactory/Non satisfactory

***Compulsory Major Courses**

**** Interested students may registered if offered**

Note: Ph. D students may be exempted from NCCC if already completed in Master degree

Course Contents Ph.D. in Seed Science and Technology (SST)

I. Course Title : Hybrid Seed Production Technology*
II. Course Code : SST 601
III. Credit Hours : 3 (2+1)

IV. 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.

V. Aim of the course

To provide students a comprehensive knowledge and practical exposure on hybrid seed production techniques in agricultural and horticultural crops.

VI. 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.

VII. 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, Pearlmillet and Sorghum;
- Practicing supplementary pollination — Rice and Sunflower;
- Practicing field inspection in hybrid seed production plot — crops planted in ratio — Sunflower, Pearlmillet, 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.

VIII. Teaching methods

- Classroom lectures
- Power point presentation
- Student assignment and presentation
- Demonstration
- Field visits

IX. 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.

X. Suggested Reading

Agarwal RL. 2012. *Seed Technology*. 3rd Ed. Oxford & IBH Publishers, New Delhi.

Basra A. 1999. *Heterosis and Hybrid Seed Production in Agronomic Crops*. CRC Press., Florida, United States.

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

Dar SH. 2018. *Methods of Hybrid Seed Production in Major Crops*. Educreation Publishing, Chhattisgarh.

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

Hebblethwaite PD. 1980. Seed Production. Butterworth Heinemann Ltd., London, UK.

Joshi AK and Singh BD. 2004. *Seed Science and Technology*. Kalyani Publishers, New Delhi.

Krishnan M. 2012. *Plant breeding and Hybrid Seed Production.* Domin and Publishers &Distributors, New Delhi, India.

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

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

McDonald MF and Copeland LO. 2012. *Seed Production: Principles and Practices.* Springer Science and Business Media, Boston, United States.

Mondal SS, Saha M and Sengupta K. 2009. *Seed Production of Field Crops.* New India Publishing Agency, New Delhi.

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

Singhal NC. 2003. *Hybrid Seed Production.* Kalyani Publishers., New Delhi, India.

Singhal NC. 2003. *Hybrid Seed Production in Field Crops.* Kalyani Publications, New Delhi.

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

Vanangamudi K, Prabhu M, Kalaivani S, Bhaskaran M and Manonmani V. 2010. *Vegetable Hybrid seed Production and Management.* Agrobios., Jodhpur, India.

XI. 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_Flowers
http://www.worldcat.org/title/seed-production-principles-andractices/oclc
https://libgen.is/search.php?req=Raymond+A++T+George&column=author
https://libgen.is/search.php?req=Raymond%20A%20%20T%20George&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

XII. 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

Lecture Schedule

Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Introduction — history — scope — importance of hybrid development — national and international scenario of seed industry	02
2.	Popular public sector hybrids in various crops. Heterosis —	03

	definition — expression — types — utilization of heterosis in hybrid development, hybrid vigour and seed vigour	
3.	Types of hybrids — intra-specific, inter-specific hybrids, single, double, three way cross, top cross hybrids	03
4.	Apomixes; generation system of seed multiplication in different types of hybrids	02
5.	Development and maintenance of inbred lines — male sterile — maintainer lines — fertility restoration — transgenic hybrids — principles and method of development.	02
6.	Breeding tools — genetic mechanism — male sterility — types: CMS, GMS, CGMS, TGMS, PGMS	02
7.	Barnase and Barstar system — Pistillateness — self incompatibility. Manual creation of male sterility — emasculation and pollination — gametocides — mode of action, mechanism	04
8.	Synchronization of flowering — problems — methods to achieve synchrony — planting ratio and supplementary pollination methods.	03
9.	Techniques of hybrid seed production in major agricultural crops — cereals (wheat, rice)	01
10.	Techniques of hybrid seed production in major agricultural crops — Millets (Maize, Sorghum, Bajra), Pulses (Red gram), Oilseeds (Sunflower, Castor, Mustard), Cotton and Forage crops.	04
11.	Hybrid seed production techniques in horticultural crops — Tomato, Brinjal, Chilli, Bhendi, Onion, Bitter Gourd, Bottle Gourd, Ridge Gourd	03
12.	Hybrid seed production techniques in horticultural crops Cucumber, Melon, Cabbage, Cauliflower, Potato, Coconut And Papaya.	03
	Total	**32**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Characteristics features of parental lines and their hybrids; Floral biology of Rice, Maize, Pearlmillet, Sunflower, Castor and Cotton	2
2.	Study on floral biology of vegetable crops — Solanaceous and other vegetables; Study on floral biology of Cucurbitaceous crops	2
3.	Production and maintenance of A, B and R lines	1
4	Practicing planting design and border rows — Rice, Maize, Pearlmillet, Sunflower and Red Gram; Brinjal and Chillies; Practicing planting design and border rows in Tomato, Cotton and Cucurbitaceous vegetables	2
5.	Manipulation for synchronization — Rice, Sunflower, Pearlmillet and Sorghum	1
6.	Practicing supplementary pollination — Rice and Sunflower; Practicing field inspection in hybrid seed production plot — crops	2

	planted in ratio — Sunflower, Pearlmillet, Sorghum, etc	
7.	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	2
8.	Visit to hybrid seed production fields; Visit to potato seed production plots	2
9.	Determination of cost benefit of hybrid seed production; Visit to seed Industry and assessing problems and perspectives in hybrid seed production.	2
	Total	**16**

I. Course Title : Organic Seed Production

II. Course Code : SST 602

III. Credit Hours : 2 (1+1)

IV. 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.

V. Aim of the course

To make students to understand the concept of organic farming, principles and practices of organic seed production, certification and marketing.

VI. 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.

VII. 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.

VIII. Teaching methods

- Classroom lectures
- Group assignments and presentation
- Laboratory and field experiments
- Demonstration
- Field visits

IX. Learning outcome

After completion of this course, students will gain knowledge, skill and confidence to take up organic seed production for sustainable agriculture.

X. Suggested Reading

Bryan Connolly B, Langer J and Lawn CR. 2011. *Organic Seed Production and Saving: The Wisdom of Plant Heritage*. Chelsea Green Publishing, Vermont, USA.

Gehlot D. 2010. *Organic Farming: Components and Management*. Agrobios., Jodhpur, India.

Gehlot D. 2012. *Organic Farming: Standards, Accreditation, certification and Inspection*. Agrobios., Jodhpur, India.

Panda SC. 2012. *Soil Management and Organic farming*, Agrobios., Jodhpur, India.

Panda SC. 2013. *Principles and Practices of organic Farming*. Agrobios., Jodhpur, India.

Suresh N and Deshmukh. 2010. *Organic Farming: Principles, Prospects and Problems*. Agrobios., Jodhpur, India.

White JM. 1995. *Organic Vegetable Production*. UF/IFAS Coop. Ext. Serv., HS720., Florida, United States.

XI. 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/apedawebsite/organic/organic.../english_organic_sept05.pd

https://ncof.dacnet.nic.in/Training./Training...in/Cert_and_Inspection_manual.pdf

https://www.ebooks.com/en-us/96381019/organic-seed-production-and-saving/bryan-connolly-jocelyn-langer-c-r-lawn/

XII. 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

Lecture Schedule

Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Organic farming — definition, genesis, concepts and principles; importance of organic farming and organic seed; organic seed — strategies, problems and perspectives	02
2.	Organic seed vs conventional seed; organic seed production — factors influencing seed production — soil health — GMO elements of seed.	02
3.	Techniques of organic seed production — selection of land — pre requisite for seed production — conversion period — soil amendments — green manures	02
4.	Multi-varietal seed techniques — organic sources of manures — bulky, concentrated and liquid manures, biofertilizers and biocontrol agents — organic seed treatment	02
5.	Organic weed management practices — manual and mechanical methods — mulching — thermal weed control; growth promoting substances — *panchakavya*, fish amino acid, etc	01
6.	Organic plant protection measures — herbal insecticides — IPM strategies; post harvest techniques — drying, processing and grading; organic seed treatment and storage.	02
7.	Organic certification application — registration — verification of records; organic seed certification — tagging; role of organizations in production and marketing of organic seed	02
8.	National and international organizations involved — public, private — NGOs — International Federation of Organic Agriculture Movement (IFOAM) — basic standards and EU regulations — organic seed marketing.	01
9.	Crop specific organic seed production and post harvest seed management techniques for major food crops, vegetables and fruit crops	01
10.	Economics of organic seed production and demand for organic seed.	01
	Total	**16**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Studying the field and seed standards for organic seed production; Collection and identification of organic manures and liquids	2
2.	Preparation of organic products for soil application; Preparation of *panchakavya*, starter solutions and vermiwash; Organic priming of seeds with *panchakavya*a nd vermiwash; Preparation of leaf extracts and starter solutions and preparation of organic products for foliar application	3
3.	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	3
4	Assessing the storage behaviour of organically treated seeds; Selection of suitable container and dry leaves or shrubs for enhanced storability	2
5.	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	3
6.	Visit to organic farm and seed production field; Visit to Department of organic certification; Visit to organic retail shops.	3
	Total	**16**

I. Course Title : Physiology and Biochemistry of Seeds
II.Course Code : SST 603
III.Credit Hours : 2 (1+1)

IV.Why this course?

Seed is a biological entity and the seed contains all micro and macro nutrients in the form of stored food, toxic compounds and secondary metabolites. Seeds are accumulated with these materials during development and maturation and it gets depleted during deterioration and storage. The developing seed embryo attains capacity to produce a new plant by utilizing these resources. Understanding the mechanism of accumulation of food reserves and pattern of its utilization during germination will enable the students to take up research on seed dormancy, germination and quality enhancement.

V. Aim of the course

To provide insight knowledge on physiological and biochemical events governing seed quality and it survival.

V. Theory

Unit I

Seed development and maturation — role of cell organelles — embryogeny — translocation of assimilates — synthesis of starch, protein, lipid, secondary metabolites and toxic compounds — possible alteration in metabolic pathway.

Unit II

Development of embryo, endosperm and seed coat — translocation of assimilates and food reserves; desiccation tolerance — mechanism, hypothesis, role of LEA proteins; development of hard seeds — mechanisms and factors.

Unit III

Seed dormancy — types — physiology and biochemistry of seed dormancy induction and release — hormonal regulation of seed dormancy — environmental control — genetic inheritance and control of dormancy; physiology of orthodox, recalcitrant and intermediate seeds.

Unit IV

Seed germination — acquisition of viability and capacity of germination during development — genetics of germination acquisition; types of germination — phases of germination — requirements — imbibition — enzyme activation and hormonal regulation — respiration — mitochondrial activity and ATP synthesis — protein and nucleic acid synthesis — metabolism of starch, protein, lipid — physiology of embryo growth and development.

Unit V

Seed deterioration — theories, causes — ultra-structural, cell membrane and functional changes; biochemical changes — enzyme activity, storage reserves and genetic changes; lipid peroxidation — biological effects — free radicals and secondary products.

VII. Practical

- Study on the pattern of seed development and maturation;
- Study on the structural changes during seed maturation;
- Estimation of seed moisture content, fresh and dry weight and acquisition of germination and dormancy;
- Estimation of different hormones during seed development and maturation — GA and ABA;
- Estimation of phenolic compounds during seed maturity;
- Estimation of food reserves accumulation — starch, protein and oil at different stages of maturity;
- Study on the pattern of seed development in recalcitrant seeds;
- Studying the germination behaviour of different type of seeds;
- Study on imbibition pattern and soaking injury in seeds;
- Estimation of enzymes in dormant and non-dormant seeds;
- Estimation of hormones in dormant and non-dormant seeds;
- Studying the effect of light and temperature on dormancy;
- Study on deterioration pattern of orthodox and recalcitrant seeds;
- Estimation of lipid peroxidation product and free fatty acid;
- Studying the cytological and chromosomal changes in deteriorated seeds;
- Estimation of volatile aldehydes during seed storage and deterioration.

VIII. Teaching methods

- Classroom lectures
- Assignments and presentations
- Field and laboratory experiments

IX. Learning outcome

Completion of this course will enable the students to understand the mechanism of seed development, regulation of dormancy, germination and deterioration and help them to understand the mysteries in seed to address the problems in quality seed production and storage.

XI. Suggested Reading

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

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

UK. Bewley JD and Black M. 1982. *Physiology and Biochemistry of Seeds in Relation to Germination*(Vol. I & II). Springer Verlage, Berlin Heldelberg, New York, United States.

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

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

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

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

Khan AA. 1977. *Physiology and Biochemistry of Seed Dormancy and Germination.* North Holland Co, Amsterdam, New York, United States.

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

Mayer AM and Mayber AP. 1989. *Germination of Seeds.* Pergamon Press, Oxford, United Kingdom.

Ovcharov KE. 1977. *Physiological Basis of Seed Germination*, Amerind Publishing Co, New Delhi and New York, United States.

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

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

Vanangamudi K. 2006. *Seed Physiology*. Associated Publishing Company, New Delhi, India.

XI. Suggested e-books

http://agris.fao.org/agris-search/search.do?recordID=US201300553998
http://www.worldcat.org/title/physiological-basis-of-seed-germination-fiziologicheskie-osnovy-vskhozhesti-semyan/oclc/19369598 https://www.springer.com/in/book/9783642686450
https://link.springer.com/chapter/10.1007/978-1-4615-1747-4_2
https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/desiccation-tolerance
https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/embryogenesis
https://www.cell.com/current-biology/comments/S0960-9822(17)30562-6
https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1365-3040.2012.02542.x
https://dl.sciencesocieties.org/publications/books/pdfs/cssaspecialpubl/physiologyofsee/frontmatter

XII. Suggested websites

http://www.seedbiology.de/dormancy2.asp http://www.seedbiology.de/dormancy.asp
https://www.ncbi.nlm.nih.gov/pubmed/22620982 https://www.britannica.com/science/germination
http://sbc.ucdavis.edu/Research_pages/Seed_physiology_and_technology/
http://www.biologyreference.com/Re-Se/Seed-Germination-and-Dormancy.html
https://www.intechopen.com/books/advances-in-seed-biology/seed-dormancy
https://courses.lumenlearning.com/wm-biology2/chapter/development-seeds-fruit
www.iari.res.in/index.php?option=com_content&view=article&id=449&Itemid=137

Lecture Schedule

Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Seed development and maturation — role of cell organelles — embryogeny — translocation of assimilates	01
2.	Synthesis of starch, protein, lipid, secondary metabolites and toxic compounds — possible alteration in metabolic pathway.	02

3.	Development of embryo, endosperm and seed coat — translocation of assimilates and food reserves; desiccation tolerance	02
4.	Mechanism, hypothesis, role of LEA proteins; development of hard seeds — mechanisms and factors	02
5.	Seed dormancy — types — physiology and biochemistry of seed dormancy induction and release	01
6.	Hormonal regulation of seed dormancy — environmental control — genetic inheritance and control of dormancy; physiology of orthodox, recalcitrant and intermediate seeds.	02
7.	Seed germination — acquisition of viability and capacity of germination during development — genetics of germination acquisition; types of germination — phases of germination — requirements — imbibition — enzyme activation and hormonal regulation	03
8.	Respiration — mitochondrial activity and ATP synthesis — protein and nucleic acid synthesis — metabolism of starch, protein, lipid — physiology of embryo growth and development.	01
9.	Seed deterioration — theories, causes — ultra-structural, cell membrane and functional changes; biochemical changes	01
10.	Enzyme activity, storage reserves and genetic changes; lipid peroxidation — biological effects — free radicals and secondary products..	01
	Total	**16**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Study on the pattern of seed development and maturation; Study on the structural changes during seed maturation	2
2.	Estimation of seed moisture content, fresh and dry weight and acquisition of germination and dormancy; Estimation of different hormones during seed development and maturation — GA and ABA; Estimation of phenolic compounds during seed maturity; Estimation of food reserves accumulation — starch, protein and oil at different stages of maturity	4
3.	Study on the pattern of seed development in recalcitrant seeds; Studying the germination behaviour of different type of seeds; Study on imbibition pattern and soaking injury in seeds	2
4	Estimation of enzymes in dormant and non-dormant seeds; Estimation of hormones in dormant and non-dormant seeds	2
5.	Studying the effect of light and temperature on dormancy; Study on deterioration pattern of orthodox and recalcitrant seeds	2
6.	Estimation of lipid peroxidation product and free fatty acid; Studying the cytological and chromosomal changes in deteriorated seeds	2
7.	Estimation of volatile aldehydes during seed storage and deterioration	2
	Total	**16**

I. Course Title : Genetic Purity and DUS Testing*
II. Course Code : SST 604
III.Credit Hours : 3 (2+1)

IV. 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 and 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.

V. Aim of the course

To impart knowledge on various methods of genetic purity assessment and DUS testing for protection of plant varieties.

VI. 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 and FR) Act 2001 — objectives, salient features, Farmer's Rights, Breeder's Rights, Researcher's Rights — PPV and 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.

VII. 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 seed protein 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.

VIII. Teaching methods

- Classroom lectures
- Power point presentations
- Field and laboratory experiments
- Demonstration
- Field visits

IX. 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.

X. Suggested Reading

Anon. 2016. *Manual of Seed Certification Procedures.* Directorate of Seed Certification, Coimbatore, Tamil Nadu. Chakrabarthi SK. 2010. *Seed Production and Quality Control.* Kalyani Publishers, New Delhi.

Choudhary DR. 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.

Joshi AK and Singh BD. 2004. *Seed Science and Technology*, Kalyani Publishers, New Delhi, India.

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

Mishra DK, Khare D, Bhale, MS and Koutu GK. 2011. *Handbook of Seed Certification.* Agrobios, Jodhpur, Rajasthan.

Ramamoorthy K, Sivasubramaniam K and Kannan M. 2006. *Seed Legislation in India.* Agrobios, Jodhpur, Rajasthan.

Trivedi PC. 2011. *Seed Technology and Quality Control.* Publications, Jaipur, Rajasthan.

XI. 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

XII. 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/tgpdocs/en/tgp_6_section_2.pdf
https://www.upov.int/publications/en/tg_rom/introduction.html

Lecture Schedule
Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Genetic purity — importance — factors influencing genetic purity; genetic/ cultivar purity test — objectives — principles — methods; laboratory tests — green house and field plot methods	01
2.	Grow — out test, seed and seedling growth tests; chemical and biochemical methods; anthocyanin pigmentation, secondary compounds, Phenol, Peroxidase and Fluorescence tests — Chromatography techniques.	02
3.	Electrophoretic analysis of Proteins and Isozymes	02
4.	DNA finger printing methods — RAPD, AFLP, SSR, SNP and other markers	02
5.	Computer based machine vision technique and image analysis for varietal identification.	02
6.	Genesis of Plant Variety Protection (PVP); International Union for Protection of New Varieties of Plants (UPOV) and its functions	02
7.	GATT agreement in relation to plant variety protection; Protection of Plant Varieties and Farmer's Rights (PPV and FR) Act 2001	02
8.	Objectives, salient features, Farmer's Rights, Breeder's Rights, Researcher's Rights — PPV and FRA Rules 2003.	02
9.	Criteria for protection of new varieties of plants; Distinctness,	03

	Uniformity and Stability (DUS) testing — principles and procedures, guidelines, sample size, test duration, testing option	
10.	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.	03
11.	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	04
12.	Assessment of DUS characters of major crops based on morphological, biochemical and molecular markers — Tomato, Brinjal, Onion, Potato, Chilli, Bhendi, Cucurbits, Cole crops	03
13.	Assessment of DUS characters of major crops based on morphological, biochemical and molecular markers sugarcane, cotton, flower, fruit and tree species;	02
14.	Statistical procedure — computer software for DUS testing;	01
15.	Guidelines for registration of germplasm — impact of plant variety protection on seed industry growth	01
	Total	**32**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	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	2
2.	Chromatography analysis of secondary compounds; Electrophoretic analysis of seed protein and isozymes	2
3.	DNA fingerprinting using PCR techniques	1
4	DUS testing based on morphological descriptors of plant — Rice and Millets; DUS testing based on morphological descriptors of plant — pulses and oil seeds	2
5.	DUS testing based on morphological descriptors of plant — vegetable crops; DUS testing based on morphological descriptors of plant — flower, fruit and tree species;	2
6.	Recording observations and interpretation of data; Tree method of classification of varieties/ cultivars; Chemical and biochemical test applicable for DUS testing	2
7.	Practical exercise on recording DUS characteristics, statistical analysis and interpretation in major agricultural crops	2
8.	Practical exercise on recording DUS characteristics, statistical analysis and interpretation in major horticultural crops	2
9.	Visit to DUS test centers	1
	Total	**16**

I. Course Title : Seed Vigour and Crop Productivity
II. Course Code : SST 605
III. Credit Hours : 2 (1+1)

IV. Why this course?

Seed vigour is an important quality parameter needs to be assessed to estimate the real planting value of seed. Seed vigour is governed by several factors which ultimately decide the crop productivity and yield. Hence, knowledge on the concept of seed vigour and its manifestations, prediction of seed vigour in relation to crop productivity will be useful for better management of seed lots and seed crop.

V. Aim of the course

To impart knowledge on seed vigour, vigour test, impact of seed vigour on seed production, storage and seed management.

VI. Theory

Unit I

Seed vigour — importance, concepts, definitions, vigour *vs* viability, historical development — ISTA vigour committee. Factors influencing seed vigour — genetic, agronomic, biotic and abiotic factors.

Unit II

Seed vigour and senescence — sequence of vigour loss — manifestations of seed vigour — physical, physiological, biochemical and molecular manifestations; vigour in relation to seed dormancy and germination; vigour in relation to value for cultivation and use.

Unit III

Vigour tests — history — definition — characteristics — types — direct and indirect tests — physical test — x-ray radiography, seed size; physiological test — seedling first count, radicle emergence, speed of germination, seedling measurement; stress tests — brick gravel test, cool test, cold test, paper piercing test, ethanol, ammonium chloride and NaCl soak tests, accelerated ageing test, exhaustion test, controlled deterioration test, osmotic stress test.

Unit IV

Chemical and biochemical tests — electrical conductivity test, free sugars and amino acids, tetrazolium chloride test, respiration quotient, GADA test, free fatty acid, DPPH, respiratory and hydrolytic enzymes tests, modern vigour tests — machine vision, Q2 analyzer — standardization of vigour test.

Unit V

Influence of seed vigour — crop growth, field emergence, productivity and storage; vigour of vegetative propagules; role of seed vigour in field emergence, crop growth, yield and productivity. Seed vigour improvement and management techniques — pre-sowing and pre-storage — mid storage methods to improve seed vigour.

VII. Practical

- Collection and evaluation of germination of seed lots with different vigour status;

- Evaluation of seed vigour by physical vigour test — seed size, colour, weight — turbidity test;
- Evaluation of seed vigour by physiological vigour test — imbibition pattern, speed of emergence, radicle emergence, germination, seedling measurement and computation of various index;
- Conducting different stress tests — brick gravel and paper piercing tests;
- Conducting accelerated ageing and controlled deterioration test;
- Conducting chemical stress test — NH_4Cl, NaCl, mannitol, PEG test;
- Special vigour tests — cool germination test — cold test — anaerobic test;
- Biochemical vigour test — electrical conductivity, free sugars and amino acid test in seed leachate;
- Estimation of dehydrogenase enzyme activity;
- Estimation of free fatty acids in seed lots in varying vigour levels;
- Bio-assay test for seed vigour;
- Estimation of volatile aldehydes in different crop seeds with varying vigour;
- Correlation studies between field emergence and different vigour tests;
- Seed vigour on field establishment, population maintenance and crop growth and productivity;
- Pre-sowing vigour management techniques;
- Pre-storage and mid storage vigour management techniques.

VIII. Teaching methods

- Classroom lectures
- Assignment and presentation
- Slides/ video shows
- Practical exercise
- Hands on training

IX. Learning outcome

This course will enable the students to understand the concept of seed vigour and enhance the analytical skills to predict and assess the vigour accurately so as to adjust the seed lots for its value for cultivation and usage.

X. Suggested Reading

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

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

Chakrabarthi SK. 2010. *Seed Production and Quality Control.* Published by Kalyani Publisher., New Delhi, India.

Chalam GV, Singh A and Douglas JE. 1967. *Seed Testing Manual.* ICAR and United States Agency for International Development, New Delhi.

David R Murray. 1985. *Seed Physiology.* Saunders College Publishing/ Har court Brac.

International Seed Testing Association. 2018. *Handbook on Seedling Evaluation*, 4th Edition, Published by ISTA, Zurichstr, Switzerland. ISTA. 1999. *Seed Science and Technology*, 27th supplement.

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

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

Maiti RK, Sarkar NC and Singh VP. 2006. *Principles of post harvest seed physiology and technology*. Agrobios., Jodhpur, India.

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

Roberts EH. 1972. *Viability of Seeds*. Springerlink, New York.

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

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

Trivedi PC. 2011. *Seed Technology and Quality Control Pointer Publications.*, Jaipur, India.

Vasudevan SN, Doddagowder SR, Rakesh CM and Patil SB. 2013. *Seed Testing and Quality Control*. Agrotech Publications, Udaipur, Rajasthan.

XI. Suggested e-books

https://link.springer.com/chapter/10.1007/978-94-009-2764-3_71
https://link.springer.com/chapter/10.1007/978-1-4684-7747-4_8
https://link.springer.com/chapter/10.1007/978-1-4615-1783-2_7
https://doi.org/10.1079/9780851993959.0073
https://www.researchgate.net/publication/326255175_Seed_Vigour_Testing Principle and Methods
https://www.springer.com/in/book/9789400956872
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4233836/
https://link.springer.com/chapter/10.1007/978-1-4615-1783-2_8
http://www.worldcat.org/title/techniques-in-seed-science-and-technology/oclc/60047727
http://wrap.warwick.ac.uk/74767/1/WRAP_0380014-lf-271115-revised_darwin_review_for_ submission.pdf

XII. Suggested websites

www.ista.org.in
www.cambridge.org
www.tandfonline.com
www.seednet.gov.in
www.seedtest.org
https://academic.oup.com/jxb/article/67/3/567/2893341
http://www.scielo.br/pdf/sa/v72n4/0103-9016-sa-72-4-0363.pdf
https://www.researchgate.net/publication/284279769_Seed_vigour_and crop
_establishment_Extending_performance_beyond_adaptation
https://www.semanticscholar.org/paper/Seed-vigour-and-crop-establishment%3A -extending-
Finch-Savage-Bassel/a5af7beae17bd31058db0f645edd647cbb9e 9c2b

Lecture Schedule

Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Seed vigour — importance, concepts, definitions, vigour *vs* viability, historical development — ISTA vigour committee	01
2.	Factors influencing seed vigour — genetic, agronomic, biotic and abiotic factors.	01

3.	Seed vigour and senescence — sequence of vigour loss — manifestations of seedvigour — physical, physiological, biochemical and molecular manifestations	02
4.	Vigour in relation to seed dormancy and germination; vigour in relation to value for cultivation and use	01
5.	Vigour tests — history — definition — characteristics — types — direct and indirect tests — physical test — x-ray radiography, seed size.	02
6.	Physiological test — seedling first count, radicle emergence, speed of germination, seedling measurement;	01
7.	Stress tests — brick gravel test, cool test, cold test, paper piercing test, ethanol, ammonium chloride and NaCl soak tests, accelerated ageing test, exhaustion test, controlled deterioration test, osmotic stress test.	02
8.	Chemical and biochemical tests — electrical conductivity test, free sugars and amino acids, tetrazolium chloride test, respiration quotient, GADA test, free fatty acid, DPPH, respiratory and hydrolytic enzymes tests	02
9.	Modern vigour tests — machine vision, Q2 analyzer — standardization of vigour test.	01
10.	Influence of seed vigour — crop growth, field emergence, productivity and storage; vigour of vegetative propagules.	01
11.	Role of seed vigour in field emergence, crop growth, yield and productivity. Seed vigour improvement and management techniques — pre-sowing and pre-storage — mid storage methods to improve seed vigour.	02
	Total	**16**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Collection and evaluation of germination of seed lots with different vigour status; Evaluation of seed vigour by physical vigour test — seed size, colour, weight — turbidity test; Evaluation of seed vigour by physiological vigour test — imbibition pattern, speed of emergence, radicle emergence, germination, seedling measurement and computation of various index	3
2.	Conducting different stress tests — brick gravel and paper piercing tests; Conducting accelerated ageing and controlled deterioration test; Conducting chemical stress test — NH_4Cl, NaCl, mannitol, PEG test; Special vigour tests — cool germination test — cold test — anaerobic test	3
3.	Biochemical vigour test — electrical conductivity, free sugars and amino acid test in seed leachate	2
4	Estimation of dehydrogenase enzyme activity; Estimation of free fatty acids in seed lots in varying vigour levels; Bio-assay test for seed	2

	vigour	
5.	Estimation of volatile aldehydes in different crop seeds with varying vigour; Correlation studies between field emergence and different vigour tests	2
6.	Seed vigour on field establishment, population maintenance and crop growth and productivity	2
7.	Pre-sowing vigour management techniques; Pre-storage and mid storage vigour management techniques	2
	Total	**16**

I. Course Title : Advances in Seed Science*

II. Course Code : SST 606

III. Credit Hours : 2 (2+0)

IV. 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.

V. Aim of the course

To impart knowledge on the recent developments in various frontier areas of seed science and their application in seed technology.

V. 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.

VII. Teaching methods

- Classroom lectures
- Power point presentations
- Student assignment and presentations

VIII. Learning outcome

After completion of this course the students will be able to take up research on seed biotechnology.

IX. Suggested Reading

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

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

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

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

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

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

Figeys D. 2005. Industrial Proteomics: Applications for Biotechnology and Pharmaceuticals (No. TP248. 65. P76 I535 2005). United States.

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

Lombardo L. 2014. Genetic Use Restriction Technologies: a review. *Plant biotechnology journal.* **12**(8): 995-1005.

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

Nicolas G, Bradford KJ, Come D and Pritchard HW. 2003. *The Biology of Seeds: Recent Research Advances.* Proceedings.

Patterson SD and Aebersold RH. 2003. Proteomics: the first decade and beyond. Nature genetics. **33**(3s): 311.

Rakshit A and Singh HB. 2018. *Advances in Seed Priming.* Springer Nature Singapore Ltd., Singapore.

Redenbaugh K. 1993. *Synseeds: Application of Synthetic Seeds to Crop Improvement.* CRC Press, London, UK.

X. 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.researchgate.net/publication/240592094_Black_M_Bewley_JD_eds_2000_Seed_techno logy_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-Snchez/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-articles-ppts-list.php
https://libgen.is/book/index.php?md5=F63727B21E14953F0003168A2452B3FE
https://www.researchgate.net/publication/228621809_Techniques_for_detecting_genetically_ modified_crops_and_productshttps://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= iBtfDwAAQBAJ&printsec=frontcover&source=kp_read_button&redir_esc= y#v=onepage&q&f=false

XI. Suggested websites

https://www.sbc.ucdavis.edu
https://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

Lecture Schedule
Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Physiological and molecular aspects of seed development — gene expression during seed development — selective elimination of cells — theories and concepts	03
2.	Physiological and molecular regulation of germination and dormancy; desiccation and stress tolerance — gene expression — mechanism — structural changes in membranes of developing seeds.	03
3.	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	04

	Repeats (CRISPR) *Cas* — gene editing	
4.	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	04
5.	Somatic embryogenesis — principles and methods of production of synthetic/ somatic seeds — merits and demerits	03
6.	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	04
7.	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..	04
8.	Recent accomplishments in seed enhancement research — seed coating, pelleting and priming techniques	02
9.	Physiological, molecular and sub-cellular basis of seed priming	01
10.	Detection and identification of seed borne diseases and insect pests through advanced techniques — ELISA and PCR based techniques.	04
	Total	**32**

I. Course Title : Advances in Seed Quality Enhancement
II. Course Code : SST 607
III. Credit Hours : 2 (1+1)

IV. Why this course?

Quality seed is a vital input for sustainable crop production and food security. Seed enhancement through various techniques can overcome germination constraints by uniform stands, earlier crop development and better yields. Understanding of the principles and mechanisms involved in seed quality improvement would enable to modulate the performance of seed in field.

V. Aim of the course

To impart knowledge on seed quality enhancement techniques and their associated quality changes in seed.

VI. Theory

Unit I

Seed quality — importance and enhancement — principles, concept, significance, strategies; types of seed enhancement — physical, physiological and biological enhancement techniques.

Unit II

Physical seed quality enhancement — concept and principles of grading — upgrading — magnetic, electromagnetic, irradiation, coating, pelleting, colouring; plasma treatment — thermal and cold plasma — treatment; application of nano formulations — concepts — principles — mode of action on improving germination.

Unit III

Physiological methods of seed quality enhancement — seed priming — principles, methods, mode of action — physiological, biochemical and molecular mechanism of priming techniques; seed infusion — principles and methods, mode of action — imparting abiotic stress tolerance — hardening — principles and methods.

Unit IV

Application of biological formulations — bacterial, fungal agents — concepts, formulations and compatibility; methods of application — growth promotion — protection — control over pest and disease infection and mode of action; designer/ smart seed — concept, methods, applicability to different crops.

Unit V

Effect of different treatments on crop establishment and modulation of seedling growth — crop geometry, phenology and yield improvement; storability of primed, coated and pelleted seeds — pre-storage and mid-storage enhancement techniques — hydration-dehydration techniques, moisture equilibrium drying and halogenations — principles, methods and application.

VII. Practical

- Physical seed quality up gradation — specific gravity separator, density grading, floatation technique;

- Practicing seed pelleting — methods of pelleting for different crop species;
- Performing seed coating — polymer, colouring and nano emulsion coating;
- Study on the effect of magnetic and electromagnetic seed treatment on seed germination and vigour;
- Practicing seed priming — hydro, osmo, halo and solid matrix priming methods;
- Nutrient and bio priming and assessing the performance of primed seeds;
- Assessing the storability of primed seed;
- Study on seed hardening on the performance of seed under abiotic stress;
- Preparation of designer/ smart seed for different crops;
- Biological seed treatment — biological formulations, bacteria, fungi, protectants and bio fertilizers;
- Study on the effect of biological seed treatment on seedling growth and disease incidence;
- Estimating the microbial population in biologically treated seeds;
- Assessing the storability and vigour potential of treated seeds;
- Performing mid-storage seed treatment — hydration-dehydration, moisture equilibrium and drying;
- Halogenation of seeds and their effect on seed performances;
- Assessing the performance of treated seeds under field condition.

VIII. Teaching methods

- Classroom lectures
- Student assignments and presentation
- Field and laboratory experiments
- Demonstration

IX. Learning outcome

This course enable the students to understand the mechanism of seed quality improvement, stress tolerance, population maintenance, crop geometry and yield improvement due to various enhancement techniques.

X. Suggested Reading

Bewley JD, Bradford KJ, Hilhorst HWM and Nonogaki H. 2013. *Seeds: Physiology of Development, Germination and Dormancy*, Third Edition. Springer, New York, United States.

Doijode SD. 2006. *Seed Quality in Vegetable Crops. In: Handbook of Seed Science and Technology.*

Basra AS (Ed.). The Haworth Press, New York, United States. pp. 677—702. Filatova I, Azharonok V, Lushkevich V, Zhukovsky A, Gadzhieva G, Spasic K, Zivkovic S, Puac

N, Lazovic S, and Malovic G. 2013. *Plasma Seeds Treatment as a Promising Technique for Seed Germination Improvement.* 31st International Conference on Phenomena in IonizedGases, Granada, Spain.

Glick BR. 2012. *Plant Growth-Promoting Bacteria: Mechanisms and Applications*. Hindawi Publishing Corporation, Scientifica.

Halmer P. 2003. 'Methods to improve seed performance.' In: Benech-Arnold RL, Sanchez RA(Eds.). *Seed Physiology, Applications to Agriculture*. Food Product Press, New York, UnitedStates.

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

McDonald MF and Copeland LO. 2012. *Seed Production: Principles and Practices*. Springer Science and Business Media., Boston, United States.

Thomas B, Murphy DJ and Murray BG. 2003. *Encyclopedia of Applied Plant Sciences* (3 volume set). Elsevier Science, Netherland.

XI. Suggested e-books

https://www.springer.com/gp/book/9781461446927
https://link.springer.com/chapter/10.1007/978-1-4615-1619-4_13
https://www.intechopen.com/recent-advances-in-seed-enhancements
https://link.springer.com/content/pdf/bfm%3A978-981-13-0032-5%2F1.pdf
https://www.researchgate.net/publication/297732007_Advances_in_Seed_ Enhancements
https://www.researchgate.net/publication/309040118_Recent_Advances_in_Seed_ Enhancements
https://www.cambridge.org/core/journals/seed-science-research/article/seedenhancements/738B47B10C1C1B12C3D14D42E0B0A6C8
http://www.scientificpub.com/book-details/Seed-Quality-Enhancement-Principles-and-Practices-113.html

XII. Suggested websites

http://seedres.in/
http://agritech.tnau.ac.in/
http://www.bioline.org.br/pdf?cj17015
https://www.seedtest.org/en/home.html
www.niab.com/pages/id/24/Seed_Quality
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4109073/
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4746480/
https://content.ces.ncsu.edu/seed-and-seed-quality
http://greenpathindustries.com/plasma-seed-treatment/

Lecture Schedule
Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Seed quality — importance and enhancement — principles, concept, significance, strategies	01
2.	Types of seed enhancement — physical, physiological and biological enhancement techniques.	01
3.	Physical seed quality enhancement — concept and principles of grading — upgrading — magnetic, electromagnetic, irradiation, coating, pelleting, colouring	02
4.	Plasma treatment — thermal and cold plasma — treatment; application of nano formulations — concepts — principles — mode	01

	of action on improving germination	
5.	Physiological methods of seed quality enhancement — seed priming — principles, methods, mode of action — physiological, biochemical and molecular mechanism of priming techniques	02
6.	Seed infusion — principles and methods, mode of action — imparting abiotic stress tolerance — hardening — principles and methods.	02
7.	Application of biological formulations — bacterial, fungal agents — concepts, formulations and compatibility	01
8.	Methods of application — growth promotion — protection — control over pest and disease infection and mode of action; designer/ smart seed — concept, methods, applicability to different crops.	02
9.	Effect of different treatments on crop establishment and modulation of seedling growth — crop geometry, phenology and yield improvement; storability of primed, coated and pelleted seeds	02
10.	Pre-storage and mid-storage enhancement techniques — hydration-dehydration techniques, moisture equilibrium drying and halogenations — principles, methods and application	02
	Total	**16**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Physical seed quality up gradation — specific gravity separator, density grading, floatation technique; Practicing seed pelleting — methods of pelleting for different crop species; Performing seed coating — polymer, colouring and nano emulsion coating	3
2.	Study on the effect of magnetic and electromagnetic seed treatment on seed germination and vigour; Practicing seed priming — hydro, osmo, halo and solid matrix priming methods	2
3.	Nutrient and bio priming and assessing the performance of primed seeds; Assessing the storability of primed seed; Study on seed hardening on the performance of seed under abiotic stress	2
4	Preparation of designer/ smart seed for different crops; Biological seed treatment — biological formulations, bacteria, fungi, protectants and bio fertilizers	3
5.	Study on the effect of biological seed treatment on seedling growth and disease incidence; Estimating the microbial population in biologically treated seeds	2
6.	Assessing the storability and vigour potential of treated seeds; Performing mid-storage seed treatment — hydration-dehydration, moisture equilibrium and drying	2
7.	Halogenation of seeds and their effect on seed performances; Assessing the performance of treated seeds under field condition	2
	Total	**16**

I. Course Title : Germplasm Conservation Techniques
II. Course Code : SST 608
III. Credit Hours : 2 (1+1)

IV. Why this course?

Genetic resources are backbone for crop improvement. The tolerance of wild relatives to biotic and abiotic stress is gaining attention of plant breeders for transformation of genes. Hence, the young generation should be exposed to availability of various genetic resources and its conservation techniques for future use.

V. Aim of the course

To impart technical knowledge to students on the current issues and techniques of germplasm conservation for sustainable utilization in agriculture.

VI. Theory

Unit I

Biological diversity in India — importance — need for conservation — concept of natural reserves and gene banks; post-exploration handling of germplasm collections, preservation of seed and plant specimens, importance and use of herbaria; *in-situ* conservation — components — biosphere reserve — natural park; factors influencing conservation; *in-situ* conservation — national programmes — on farm conservation.

Unit II

Ex-situ conservation — components — plant genetic resources conservation in gene banks — national gene banks — gene repositories — seed gene bank — types of collections — base, active and working collections — *perma-frost* seed conservation — guidelines for sending seeds to gene bank; handling of orthodox and recalcitrant seeds for conservation — clonal repositories.

Unit III

Methods of *in-vitro* conservation — short, medium and long term, concept of active and base *in-vitro* genebank; *in-vitro* storage — culture maintenance — problems and perspectives — gene bank maintenance for temperate and tropical fruit crops, spices, tubers, bulbs, medicinal and aromatic plants; conservation of embryos and ovules, meristem, cell/ suspension cultures — protoplast and callus cultures — pollen culture — micro propagation techniques — genetic stability under long term storage.

Unit IV

Cryopreservation — principle and method — handling of orthodox and recalcitrant seeds for cryopreservation — cryoprotectants — desiccation, rapid freezing, slow freezing, vitrification techniques, encapsulation and dehydration techniques; application of cryopreservation techniques for agricultural, horticultural and forest crops.

Unit V

Gene bank standards for various crops — monitoring viability of stored seed samples — multiplication and regeneration of stored germplasm materials — National and International organizations — NBPGR and NPGRI — roll and functions; Dooms-day safe seed vault — Biodiversity International — conservation guidelines.

VII. Practical

- Study on *In-situ* conservation methods and case studies;
- Plant exploration, germplasm collection and documenting passport data;
- *Ex-situ* conservation techniques for long term conservation of germplasm collections;
- Preparation and handling of materials, packaging and documentation;
- Preparation of seed album and herbarium specimens for ex-situ conservation;
- Planning and designing of cold storage units and facilities for gene bank;
- Conservation protocols for orthodox seeds;
- Study of conservation protocols for recalcitrant seeds;
- Conservation techniques for vegetative propagules/ clones;
- Cryopreservation techniques — encapsulation, dehydration, freezing, thawing methods;
- Cryopreservation of *in-vitro* cultures — meristem, embryo, cell suspension and pollen cultures;
- Study on freezing and vitrification techniques;
- Conservation technique of forest tree species;
- Study on *in-vitro* cryo-gene banking and database management;
- Visit to national and regional seed gene banks;
- Visit to on-farm conservation sites and Botanical Survey of India.

VIII. Teaching methods

- Classroom lectures
- Student assignment and presentation
- Practical experiments
- Exposure/ field visits

IX. Learning outcome

This course will enable the students to understand the techniques of germplasm preservation and long term storage of gene pool and seeds.

X. Suggested Reading

Basra AS (Ed.). 1995. *Seed Quality: Basic Mechanisms and Agricultural Implications*. Food Product Press, USA.

Brush SB. 1999. *Genes in the field: On-farm Conservation of Crop Diversity*. Lewis Publishers,

Boca Raton, Florida, USA. Choudhary DR. 2009. *Guidelines for Storage and Maintenance of Registered Plant Varieties inthe National Gene Bank*. Published by Protection of Plant Varieties and Farmer's Rights Authority. Ministry of Agriculture and Farmers Welfare, GoI, New Delhi.

Gupta D. 2009. *Seeds: Their Conservation Principles and Practices*. Sathish Serial Publishing House. New Delhi.

Jarvis DI, Meyer L, Klemick H, Guarino L, Smale M, Brown AHD, Sadiki M and Sthapit B.2000. *A Training Guide for In-situ Conservation On-farm*. Version 1. International Plant Genetic Resources Institute, Rome, Italy.

Joshi AK and Singh BD. 2004. *Seed Science and Technology*, Kalyani Publishers, New Delhi.

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

McDonald MF and Copeland LO. 2012. *Seed Production: Principles and Practices.* Springer Science and Business Media., Boston, USA.

Meerabi G and Pullaiah T. 2015. *Plant Biodiversity Conservation and Management*, Daya Publishing House, Delhi.

Rao NK, Hanson J, Dulloo ME, Ghosh K, Nowell A and Larinde M. 2006. *Manual of Seed Handling in Genebanks.* Bioversity International, Rome.

Vernoy R, Shrestha P and Sthapit B. 2015. *Community Seed Banks: Origins, Evolution and Prospects*, Oxford, Routledge, UK.

XI. Suggested e-books

https://www.springer.com/gp/book/9783319225203
https://www.onlinelibrary.wiley.com/doi/10.1002/9781118316467.ch4
https://www.trove.nla.gov.au/work/10718000?q&versionId=12505038
http://www.libgen.io/book/index.php?md5=E4F14ADA7E2D7F05B1E7CA5C6EF F18E5
http://www.libgen.io/book/index.php?md5=ACEC8DC5834E84F9C13ACB780FA 760BC
http://www.libgen.io/book/index.php?md5=582A419EE2C82B58B98BFD7D856FDB91
http://www.libgen.io/book/index.php?md5=719F94827A8976F06BF2E6DC6FB9C093
http://www.cure.edu.uy/sites/default/files/04Libro%20Advances%2Bin% 2BPlant%202016.pdf
https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/germplasm-conservation
https://www.crcpress.com/Seed-Quality-Basic-Mechanisms-and-Agricultural-Implications/Gough/p/book/9781560228509
https://www.bioversityinternational.org/fileadmin/_migrated/uploads/tx_news/Establishment_and_management_of_field_genebank_786.pdf

XII. Suggested websites

http://www.nbpgr.ernet.in/ http://www.bioversityinternational.org
http://www.nap.edu/read/2116/chapter/7 http://www.ncbi.nlm.nih.gov/pubmed/18080461
http://www.regjeringen.no/en/topics/food-fisheries-and-agriculture/svalbard-global-seed -vault/id462220/

Lecture Schedule

Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Biological diversity in India — importance — need for conservation	01
2.	Concept of natural reserves and gene banks; post-exploration handling of germplasm collections, preservation of seed and plant specimens, importance and use of herbaria; *in-situ* conservation — components — biosphere reserve — natural park; factors influencing conservation; *in-situ* conservation — national programmes — on farm conservation.	02
3.	*Ex-situ* conservation — components — plant genetic resources	02

	conservation in gene banks — national gene banks — gene repositories — seed gene bank	
4.	Types of collections — base, active and working collections — *perma-frost* seed conservation — guidelines for sending seeds to gene bank; handling of orthodox and recalcitrant seeds for conservation — clonal repositories.	02
5.	Methods of *in-vitro* conservation — short, medium and long term, concept of active and base *in-vitro* genebank; *in-vitro* storage — culture maintenance — problems and perspectives	02
6.	Gene bank maintenance for temperate and tropical fruit crops, spices, tubers, bulbs, medicinal and aromatic plants; conservation of embryos and ovules, meristem, cell/ suspension cultures — protoplast and callus cultures — pollen culture — micro propagation techniques — genetic stability under long term storage.	02
7.	Cryopreservation — principle and method — handling of orthodox and recalcitrant seeds for cryopreservation — cryoprotectants — desiccation, rapid freezing, slow freezing, vitrification techniques, encapsulation and dehydration techniques; application of cryopreservation techniques for agricultural, horticultural and forest crops.	02
8.	Gene bank standards for various crops — monitoring viability of stored seed samples — multiplication and regeneration of stored germplasm materials	01
9.	National and International organizations — NBPGR and NPGRI — roll and functions; Dooms-day safe seed vault — Biodiversity International — conservation guidelines	02
	Total	**16**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Study on *In-situ* conservation methods and case studies; Plant exploration, germplasm collection and documenting passport data	2
2.	*Ex-situ* conservation techniques for long term conservation of germplasm collections	1
3.	Preparation and handling of materials, packaging and documentation; Preparation of seed album and herbarium specimens for ex-situ conservation	2
4	Planning and designing of cold storage units and facilities for gene bank; Conservation protocols for orthodox seeds	2
5.	Study of conservation protocols for recalcitrant seeds; Conservation techniques for vegetative propagules/ clones	2
6.	Cryopreservation techniques — encapsulation, dehydration, freezing, thawing methods; Cryopreservation of *in-vitro* cultures — meristem, embryo, cell suspension and pollen cultures	3

7.	Study on freezing and vitrification techniques; Conservation technique of forest tree species; Study on *in-vitro* cryo-genebanking and database management	2
8.	Visit to national and regional seed gene banks; Visit to on-farm conservation sites and Botanical Survey of India	2
	Total	**16**

I. Course Title : Seed Ecology

II. Course Code : SST 609

III. Credit Hours : 2 (1+1)

IV. Why this course?

Seed is highly influenced by ecological situation in which the seed is produced. Seed also possess several adaptive mechanisms to escape from unfavourable environmental/ ecological situations. Study of underlying mechanisms and ecological significances of the seeds will be useful to the students to carryout research as well as production of quality seeds at different ecological conditions. This course also deals with the ecological strategies acquired by the seed for successful perpetuation.

V. Aim of the course

To study the influence of ecology on seed production, reproductive biology, seed dispersal, longevity and adoptation mechanisms and to study the effect of pollutants on seed production and quality.

VI. Theory

Unit I

Introduction to ecology — seed ecology — importance — genetic effects — geographic adaptation of native and invasive species; ecological factors on seed germination and regeneration; reproductive allocation — reproductive effort; flowering phenology, assessment of resource allocation — positional and azimuth influence on flowering and reproduction; influence of climate change on reproduction, seed formation, germination and dormancy.

Unit II

Seed dispersal — definition — modes of dispersal, dispersal dynamics, aerial seed dispersal, pre and post dispersal hazards, seed predators and ecological significance. Seed polymorphism — types, causes, consequences on seedling adaptation.

Unit III

Soil seed bank — definition — classification — soil seed bank dynamics. Thermodynamic models — population dynamics in soil seed bank — seed longevity and germination models in soil seed bank — weed seed ecology and longevity — long term experiments in buried seeds; ecological significance of seed dormancy and seed polymorphism.

Unit IV

Influence of environment on seed germination — allelopathy, temperature, light, moisture and gaseous environment — eco-physiological role in seed storage.

Unit V

Effect of pollutants — air, water and soil pollutants on seed germination and seedling establishment — factors limiting seedling establishment — problem soils and seed management techniques — climate change and seed production — management strategies to overcome the effect of climate change on seed production and germination.

VII. Practical

- Understanding flowering phenology of different crop species;
- Study of seed dispersal mechanism of different crop species;
- Study on agents and distance of dispersal of different crop species;
- Studies on pre and post dispersal hazards;
- Assessing the natural regeneration in relation to ecology;
- Assessing the problems related to natural regeneration;
- Experiment on naturally buried seeds — dormancy and longevity;
- Studies on effect of environmental factors on seed germination and dormancy;
- Influence of seed polymorphism on germination and dormancy;
- Assessing the allelopathy effect on seed germination in crop species;
- Effect of soil pollutants on seed germination;
- Effect of air pollutants on germination of crop seeds;
- Effect of water pollutants on growth on seed quality;
- Seed management practices for polluted environment and climate change effects;
- Visit to *in-situ* and *ex-situ* conservation sites;
- Visit to biological hotspots.

VIII. Teaching methods

- Classroom lectures
- Student assignment and presentation
- Practical experiments
- Exposure/ field visits

IX. Learning outcome

This course will make the students to understand the problems in natural regeneration, storage and dormancy and to address these problems.

X. Suggested Reading

Baskin CC and Baskin JM. 1998. *Seeds: Ecology, Biogeography, and Evolution of Dormancy and Germination.*

Elsevier, Netherlands. Fenner M and Ken Thompson. 2005. *The Ecology of Seeds.* Cambridge University Press, London, United Kingdom.

Heydecker W. (Ed.). 1985. *Seed Ecology*. Penn State University Press.

Kozolowski TT. 1972. *Seed Biology* Vol. II, Academic Press., New York and London.

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

Sinclair TR and Gardner FP. 1977. *Principles of Ecology in Plant Protection.* CAB International, Wallingford, United Kingdom.

XI. Suggested e-books

https://www.springer.com/gp/book/9780412259302
https://www.cabi.org/bookshop/book/9781845936549
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2000770/
https://www.link.springer.com/chapter/10.1007/978-94-009-4844-0_4
http://www.libgen.io/book/index.php?md5=0CE8B3A7FC6224F8467E8D344B590741

http://www.libgen.io/book/index.php?md5=4AA6FDA278BAA40C1B47BA1EB9E8BC4
http://www.libgen.io/book/index.php?md5=31A06377ADC97C71831D82D4516A4DD7
http://www.libgen.io/book/index.php?md5=97028932B0E1278AE3BE17D231B41F23
http://www.ideal.egranth.ac.in/cgi-bin/koha/opacdetail.pl?biblionumber=116395&shelfbrowse_itemnumber=244623
http://fes.org.in/source-book/ecological-restoration-source-book.pdf?file=ZG93bmxvYWQvd3AxOS5wZGY=?file=ZG93bmxvYWQvd3AxOS5wZGY=
https://www.researchgate.net/profile/Arvind_Singh56/post/I_would_like_to_know_what_is_the_ecological_restoration_of_a_forest_and_why_is_it_so_important/attachment/59d641aa79197b807799d9af/AS%3A435934916288512%401480946391722/download/1.pdf

XII. Suggested Websites

https://nieindia.org
http://www.uky.edu/hort/Propagation-Seed-Ecology
https://ecology.uni-hohenheim.de https://www.biologie.uni-regensburg.de/seed ecology
https://researchonline.jcu.edu.au/52954/
http://agris.fao.org/agris-search/search.do?recordID=US201600101233
https://www.oxfordbibliographies.com/view/document/obo-9780199830060/obo-9780199830060-0086.xml

Lecture Schedule

Theory

Sr. No.	Topic	No. of Lecture (s)
1.	Introduction to ecology — seed ecology — importance — genetic effects — geographic adaptation of native and invasive species	02
2.	Ecological factors on seed germination and regeneration; reproductive allocation — reproductive effort; flowering phenology, assessment of resource allocation.	02
3.	Positional and azimuth influence on flowering and reproduction; influence of climate change on reproduction, seed formation, germination and dormancy	01
4.	Seed dispersal — definition — modes of dispersal, dispersal dynamics, aerial seed dispersal, pre and post dispersal hazards, seed predators and ecological significance.	02
5.	Seed polymorphism — types, causes, consequences on seedling adaptation.	01
6.	Soil seed bank — definition — classification — soil seed bank dynamics. Thermodynamic models — population dynamics in soil seed bank .	02
7.	Seed longevity and germination models in soil seed bank — weed seed ecology and longevity — long term experiments in buried seeds; ecological significance of seed dormancy and seed polymorphism.	02
8.	Influence of environment on seed germination — allelopathy, temperature, light, moisture and gaseous environment — eco-physiological role in seed storage	01
9.	Effect of pollutants — air, water and soil pollutants on seed	01

	germination and seedling establishment — factors limiting seedling establishment	
10.	Problem soils and seed management techniques — climate change and seed production — management strategies to overcome the effect of climate change on seed production and germination.	02
	Total	**16**

Practical

Sr. No.	**Topic**	**No. of Practical (s)**
1.	Understanding flowering phenology of different crop species; Study of seed dispersal mechanism of different crop species; Study on agents and distance of dispersal of different crop species; Studies on pre and post dispersal hazards	3
2.	Assessing the natural regeneration in relation to ecology; Assessing the problems related to natural regeneration; Experiment on naturally buried seeds — dormancy and longevity	3
3.	Studies on effect of environmental factors on seed germination and dormancy; Influence of seed polymorphism on germination and dormancy	2
4	Assessing the allelopathy effect on seed germination in crop species	1
5.	Effect of soil pollutants on seed germination; Effect of air pollutants or germination of crop seeds; Effect of water pollutants on growth on seed quality	3
6.	Seed management practices for polluted environment and climate change effects	2
7.	Visit to *in-situ* and *ex-situ* conservation sites; Visit to biological hotspots	2
	Total	**16**

I. Course Title : Seed Planning, Trade and Marketing

II. Course Code : SST 610

III.Credit Hours : 2 (1+1)

IV. 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.

V. Aim of the course

To impart knowledge on planning seed production programmes, national and international movement of seeds and marketing strategies.

VI. 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 *suigeneris* 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 polices — 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.

VII. 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;

VIII. Teaching methods

- Classroom lectures
- Students assignment and presentations
- Group discussions
- Field visits and industry visits

IX. Learning outcome

Completion of this course will enable the students to gain knowledge and to start successful seed business.

X. Suggested Reading

Acharya SS and Agarwal NL. 2004. *Agricultural Marketing in India*, 4th Ed. Oxford and IBH.

Agrawal RL. 1996. *Seed Technology*. Oxford, IBH Publishing Co., New Delhi, India.

Broadway AC and Broadway A. 2003. *A Text Book of Agri-business Management.*

Dadheech PK. 1996. *Seed Programming, Management System and Concepts.* Lok Sahitna Kendra, Jodhpur.

Feistrizer P and Fenwickkelly A. 1978. *Improved Seed Production.* FAO, Rome, Italy.

Gurudev Singh and Asokan SR. 1997. *Management of Seed Production Activity*. Oxford andIBH Publishing Co., New Delhi, India.

Joshi AK and Singh BD. 2004. *Seed Science and Technology*. Kalyani Publishers, New Delhi, India.

Kalyani Singh AK and Pandey S. 2005. *Rural Marketing.* New Age Publications.

Krishnasamy V, Ponnuswamy AS, Balamurugan P, Srimathi P, Natarajan N and Raveendran TS. 2004. *Compendium on Seed Science and Technology*. Directorate of Publications, Tamil Nadu Agricultural University, Coimbatore, India.

Kugbei S. 2008. *Seed Economics.* Scientific Publishers, Jodhpur.

Singh G and Asokan SR. 1992. *Seed Replacement Rate: Some Methodological Issues.* Indian Institute of Management, Ahmedabad, India.

Singh S. 2004. *Rural Marketing - Focus on agricultural Inputs.* Vikas Publishing House.

XI. 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-lauching-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=vPVlBos4WkYC
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. 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/

Lecture Schedule
Theory

Sr. No.	Topic	No. of Lecture (s)
1.	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	02
2.	Seed production programmes — characters, types; planning and organizing seed programmes in public and private sectors —	02

	small, medium, large and more advanced seed programmes — local, national and international seed programmes	
3.	Seed demand forecasting — purpose — methods and techniques — factors determining seed demand — seed multiplication ratio, seed replacement rate and variety replacement rate	01
4.	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.	02
5.	New seed policy — genesis — functions; WTO — Indian seed industry — patenting and *suigeneris* system — The Seeds Bill, 2004 and 2011.	01
6.	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.	02
7.	Seed production and quality control systems in SAARC Nations and other developed countries	01
8.	Quarantine measures — procedures, guidelines and certificates in international seed movement and trade.	01
9.	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	01
10.	Marketing polices — seed marketing schemes, marketing channels — responsibilities of dealers — marketing mix; handling and management of sales return seed stocks	01
11.	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.	02
	Total	**16**

Practical

Sr. No.	Topic	No. of Practical (s)
1.	Data collection on status of Indian and global seed industry	1
2.	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	4
3.	Assessment of seed demand — demand forecasting methods; Assessment of seed multiplication ratio, seed replacement rate and	2

	variety replacement rates for different crops	
4	Study on the economics of seed production and marketing; Exercise on fixing procurement and sale price of seeds	2
5.	Study of seed marketing channels — survey and interaction with seed dealers and distributors	1
6.	Visit to plant quarantine station and study of quarantine requirements and certificates for domestic and international seed trade	1
7.	Visit to modern seed processing unit, advanced seed storage complex and interactions; Visits to state seed corporations; Visit to MNCs and expert discussion	3
8.	Case studies and SWOT analysis; Planning for establishment of new seed ventures and project preparations	2
	Total	**16**

Supporting courses:

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

Course No.	Course Title	Credits
PGS -501	Library and Information Services	1 (0+1)
PGS- 504	Basic Concepts in Laboratory Techniques	1 (0+1)
PGS -502	Technical Writing & Communication Skills	1 (0+1)
PGS-503	Intellectual Property and its Management in Agriculture	1 (1+0)
PGS-505	Agricultural Research, Research Ethics and Rural Development Programmes	1 (1+0)
PGS-506	Disaster management	1 (1+0)

Ph.D. in Seed Science and Technology (SST)

Course No.	Course Title	Credits
PGS -501	Library and Information Services	1 (0+1)
PGS- 504	Basic Concepts in Laboratory Techniques	1 (0+1)
PGS -502	Technical Writing & Communication Skills	1 (0+1)
PGS-503	Intellectual Property and its Management in Agriculture	1 (1+0)
PGS-505	Agricultural Research, Research Ethics and Rural Development Programmes	1 (1+0)
PGS-506	Disaster management	1 (1+0)

Note: Ph. D students may be exempted from Non Credit Compulsory Courses if already completed in Master degree

Restructured and Revised Syllabus

M.Sc. & Ph. D.(Agriculture)

In

Plant Genetic Resources

Broad Subject coordinator

Plant Genetic Resources
(Dr. J. E. Jahagirdar)
Associate Dean,
Govt. College of Agriculture KINI
Osmanabad (VNMKV., Parbhani)

Discipline coordinator

Plant Genetic Resources
(Dr. R. B. Ghorade)
Head,
Deptt. of Agril. Botany,
Dr. PDKV., Akola

CONTENTS

Preamble
(Plant Genetic Resources)

Plant Genetic Resources (PGR) constitute the basic raw material required essentially for the crop improvement programmes. Agro-biodiversity is the key to success of any programme. The Indian sub-continent is a centre of diversity for several of our crop plants assuming significance globally. Over the last four decades, national and international communities have repeatedly emphasized the use of PGRs for Food and Agriculture (PGRFA). PGR management encompasses assembling and conserving PGRFA, adding value to them through characterization and evaluation, quarantine, supply of pest-free samples, biosecurity. In a latest study by CGIAR gene banks, the scenario has changed due to "highly politicized nature of access and benefit sharing issues at the international, national and local levels". At ICAR level emphasis has been laid on enhanced utilization of Crop Wild Relatives, effective characterisation and documentation, conservation in gene banks, streamlining of germplasm exchange within the purview of national interest, resolution of controversial issues and implementation of multi-lateral system to develop a good vision for agrobiodiversity management.

In view of the current scenario, need for specialised human resource for teaching cutting edge technology with application of basic as well as applied aspects like germplasm assemblage, handling, access to users with benefits, long term gene banking of international standards, biotechnology, pre-breeding for utilizing wild species for future crop improvement, Increasing entrepreneurship, etc., would warrant students to have strong knowledge of practical and management skills which will help them to face the competitiveness in public and private sector.

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

Emphasis was laid on basic concepts of Germplasm Exploration and Plant Systematics, Plant Diversity and Conservation, Genetic Enhancement for PGR Utilization, Genomics in PGR management, as well as the innovative developments for M.Sc. and Phenomics and Genomics for PGR Utilization, Plant Taxonomy, Ecogeography and Ecology for Ph.D. courses. The latest state of the art technologies including biotechnology and molecular biology will enable a complete coverage of the subjects. The basic courses have therefore been kept as compulsory courses which need to be taken by all the students irrespective of the subject specialization or stream from which they entered into PG education. The genomic revolution has generated detailed population genetic data. Big data samples of complete genome sequences of many individuals from natural populations of many species have transformed population genetics inferences on samples of loci to population genomics. Molecular analyses of these is essentially to be taught to students. Hence basic concepts of genetics to develop analytical, quantitative and problem-solving skills in classical and molecular genetics for PGR management is incorporated. One of the courses would be to provide knowledge in genomic tools and their application in PGR exploration, collection, conservation and utilization. To provide knowledge in genomic tools and their application in plant genetic resource exploration, collection, conservation and utilization, one course on plant genomics have been framed to develop high-throughput genome-wide-scale technologies, tools and methodologies to elucidate the basics of genetic traits/ genetic diversity in organisms.

In the era of Intellectual Property Rights (IPRs) it is imperative to teach concepts and instruments of, plant breeder's rights, farmer's rights, access and benefit sharing, international treaties and national legislation related to plant genetic resources which would be done through one course. In addition to conventional hybridization, there is a need for precise tools to decipher the molecular basis of genetic diversity through mapping and sequencing. In one of the courses students would be taught basics of genome structure and organization, generation of molecular markers-basic principles, molecular marker techniques, data handling and analysis of GM. Another course would deal with germplasm data base management using modern tools and softwares. To educate about protecting the economy, environment and plant health from pests and disease including preventing new pests and diseases from arriving, and helping to control outbreaks when they do occur, biosecurity issues for India would be taught.

By intensive discussion with the core faculty, PGR experts and based on the feedback from faculty of ICAR-National Bureau of Plant Genetic Resources, the entire syllabus was restructured with the improvement in existing courses as well addition of new courses. The syllabus was suitably finalized with the view to equip the students to aspire knowledge and skill sets and mould towards entrepreneurship and build themselves to prepare for global competiveness.

The curricula and syllabi were discussed at length in the BSMA Committee meetings and workshops. The opinions and suggestions invited from institutions, eminent scientists and other stakeholders were also reviewed by the committee. The new look and restructured PG programmes in PGR have been designed keeping in view latest international commitments, role of private sector, modern research tools and their applications, supplementary skills required, and to enhance the global competitiveness and employability of our students. Considerable efforts have, therefore gone in for the preparation of this document.

Many existing courses were upgraded with addition and deletion as per the need of the present situation. The new courses that have been incorporated based on their importance and applied aspects both at national and international level are Genetic Enhancement for PGR Utilization; Genomics in PGR management; Phenomics and Genomics for PGR Utilization; Concepts in Conservation Genetics; Genomic tools and current applications.

Committee on Plant Sciences

ICAR-BSMA Broad Subject	ICAR-BSMA Approved Disciplines	Degree Programmes		Broad Subject Coordinator (Chairman of all Disciplines' Sub Committees	Discipline Coordinator (Secretary of respective Discipline Sub-Committee)
Plant Sciences	Genetics and Plant Breeding	M.Sc. (Agri.)	Ph.D.	Dr. J.E. Jahagirdar ADP, CoA, Osmanabad (VNMKV, Parbhani) E-mail: Mobile:	Dr. H.V. Kalpande Head, Dept. of Agril. Botany, VNMKV, Parbhani
	Seed Science and Technology	M.Sc. (Agri.)	Ph.D.		Dr. V.R. Shelar, SRO, STRU, MPKV, Rahuri
	Plant Physiology	M.Sc. (Agri.)	Ph.D.		Dr. R.S. Wagh Prof ,MPKV, Rahuri
	Plant Genetic Resources	M.Sc. (Agri.)	Ph.D.		Dr. R.B. Ghorade Head, (Ag Botany) Dr.PDKV, Akola

Implementation of New Curriculum

The universities offering PG programmes in Plant Sciences need to be supported for establishing specialized laboratories equipped with state-of-the art equipment's for conducting practical classes especially, Genetics and Plant Breeding, Seed Science and Technology, Plant Physiology. One time catch up grant should be awarded to each SAU, offering PG programmes in Forestry for meeting expenditure for upgrading the course requirements.

Faculty training and retraining should be an integral component. For imparting total quality management, a minimum of two faculty in each department under an SAU should be given on job training in reputed national and international institutes. To execute the new PG and Ph.D. programmes in different discipline of Plant Sciences in effective manner, special funds from ICAR would be required for outsourcing of faculty from Indian/Foreign Universities for some initial years.

The already existing M.Sc. and Ph.D. Programmes in Plant Sciences like: Genetics and Plant Breeding, Seed Science and Technology, Plant Physiology and Plant Genetic Resources etc. will be considered at par with the recommended M.Sc. & Ph.D. programme by Vth Deans Committee for admission and employment.

Expected Outcome

- Revamping of post graduate programme in whole of Plant Sciences throughout the country.
- Imparting quality education.

- Development of technical manpower to cater the need of governments, corporate sector and research organization in India and abroad.
- Exposure to the faculty in the latest technical knowhow.

Organization of Course Contents & Credit Requirements

Minimum Residential Requirement:
M.Sc.: 4 Semesters
Ph.D.: 6 Semesters

Name of the Departments / Divisions

- Genetics and Plant Breeding (GPB)
- Seed Science and Technology (SST)
- Plant Physiology (Plant Physiology)
- Plant Genetic Resources(PGR)

Nomenclature of Degree Programme

(a) M.Sc. Programmes
i) M.Sc. (Agriculture) in GPB
ii) M.Sc. (Agriculture) in SST
iii) M.Sc. (Agriculture) in Plant Physiology
iv) M.Sc. (Agriculture) in PGR

(b) Ph.D. Programmes
i) Ph.D. (Agriculture) in GPB
ii) Ph.D. (Agriculture) in SST
iii) Ph.D. (Agriculture) in Plant Physiology
iv) Ph.D.(Agriculture) in PGR

i) Code Numbers

- All courses are divided into two series: 500-series courses pertain to Master's level, and 600- series to Doctoral level.
- Credit Seminar for Master's level is designated by code no. 591, and the Two Seminars for Doctoral level are coded as 691 and 692, respectively
- Deficiency courses will be of 400 series.
- Master's research: 599 and Doctoral research: 699

Course Contents
The contents of each course have been organized into:

- Objective – to elucidate the basic purpose.
- Theory units – to facilitate uniform coverage of syllabus for paper setting.
- Suggested Readings – to recommend some standard books as reference material. This does not obviously exclude such a reference material that may be recommended according to the advancement and local requirement.

- A list of international and national reputed journals pertaining to the discipline is provided at the end which may be useful as study material for 600/700 series courses as well as research topics.
- Lecture schedule and practical schedule has also be given at the end of each course to facilitate the teacher to complete the course in an effective manner.

Eligibility for Admission

- **Master's Degree Programme**

(i) **B.Sc. Agriculture (4 year programme)/B.Sc. (Hons.) Agriculture**
B.Sc. (Agri.)/ B.Sc.(Hons.) Agriculture/B.Sc. (Hort.)*/B.Sc. (Hons.) Horticulture/ B.Sc.(Forestry)*/ B.Sc.(Hons.) Forestry or equivalent degree with four years duration of agriculture related Universities and having the Common Entrance Test in Agriculture conducted by competent authority.

(Note: - In case B.Sc. Agriculture/B.Sc. (Hons.) Agriculture candidates are not available; B.Sc. Forestry/ B.Sc. Horticulture. may be considered subjected to completion of deficiency package)

Doctoral Degree Programme

(i) Master Degree in the concerned Department/Discipline of Plant Sciences and having appearing the Common Entrance Test of PGR subject conducted by competent authority.

S. N.	Name of Department	Specialization in Ph. D Agriculture	Eligibility criteria
1.	Genetics and Plant Breeding (GPB)	Ph.D. Agriculture (Genetics and Plant Breeding)	M.Sc. (Agriculture) in GPB
2.	Seed Science and Technology (SST)	Ph.D. Agriculture (Seed Science and Technology)	M.Sc. (Agriculture) in SST
3.	Plant Physiology (Plant Physiology)	Ph.D. Agriculture (Plant Physiology)	M.Sc. (Agriculture) in Plant Physiology
4.	Plant Genetic Resources (PGR)	Ph.D. Agriculture (Plant Genetic Resources)	M.Sc. (Agriculture) in PGR

Credit Requirements

Course Details	Master's Degree	Doctoral Degree
Major Courses	20	15
Minor Courses	08	06
Supporting / Optional	06	05
Common PGS Courses	05	-
Seminar	01	02
Research	30	75
Total	**70**	**100**

M.Sc. Agriculture (Plant Genetic Resources)
Course Structure

LIST OF CORE COURSES/ DEPARTMENT WISE SPECIALIZATION/ COMPULSORY/SUPPORTING COURSES

1. M.Sc. Agriculture (Plant Genetic Resources)

Course Code	Course Title	Credit Hours
PGR-501*	Germplasm Exploration and Plant Systematics	2+1
PGR-502*	Plant Diversity and Conservation	2+1
PGR-503*	Germplasm Characterization and Evaluation	1+1
PGR-504	Genetic Enhancement for PGR Utilization	1+1
PGR-505*	Economic Botany	2+1
PGR-506	Information Management in PGR	1+1
PGR-507*	PGR Exchange and Quarantine	2+1
PGR-508	Genomics in PGR management	1+1
PGR-509	Plant Biosecurity	1+0
PGR-510	Principles of Genetics for PGR Management	2+0
PGR-511	Principles of Plant Breeding for PGR Management	1+1
PGR-512	Concepts in Conservation Genetics	1+1
PGR-591	Seminar	0+1
	Total	**15+10= 25**
PGR-599	Thesis/Research	0 + 30

***Compulsory Course**

Common Courses: (Non Credit)

Course code	Semester	Course Title	Credits
PGS -501	I	Library and Information Services	1+0
PGS-502	I	Technical Writing and Communications Skills	1+0
PGS -503	II	Intellectual Property and its management in Agriculture	1+0
PGS- 504	II	Basic Concepts in Laboratory Techniques	1+0
PGS -505	III	Agricultural Research, Research Ethics and Rural Development Programmes	1+0
PGS -506	III	Disaster Management	1+0

Minor Disciplines:

1. Genetics & Plant Breeding
2. Seed Science and Technology
3. Plant Physiology
4. Molecular Biology and Biotechnology

Supporting Courses:

1. Agricultural Statistics
2. Biochemistry

Compulsory Non Credit Deficiency Courses
(Those who are non-Agriculture Graduates)

Course Code	Semester	Course Title	Credit Hrs.
GPB121	II	Fundamentals of Genetics	3(2+1)
BOT121	II	Fundamentals of Crop Physiology	2(1+1)
GPB232	III	Fundamentals of Plant Breeding	2(1+1)
GPB243	IV	Principles of Seed Technology	3(1+2)
GPB355	V	Crop Improvement–I (Kharif Crops)	2(1+1)
BOT353	V	Intellectual Property Right	1(1+0)
GPB366	VI	Crop Improvement–II(Rabi crops)	2(1+1)

Students from Horticulture and Forestry stream will be required to completed Noncredit deficiency courses (6 to 10 credits) from the above courses related to the discipline in which admitted and as decided by the Student Advisory committee.

Ph.D. Agriculture
Course Structure

1. Ph. D. Agriculture (Plant Genetic Resources)

Course Code	Course Title	Credit Hours
PGR 601*	Recent Advances in Germplasm Conservation	1+1
PGR 602*	Phenomics and Genomics for PGR Utilization	1+1
PGR 603*	Economic Botany and Crop Diversification	1+1
PGR 604	PGR Policies and Regulatory Mechanisms	1+0
PGR 605	Molecular Population Genetics in PGR Management	2+1
PGR 606	Plant Taxonomy, Ecogeography and Ecology	1+1
PGR 607	In-situ on farm conservation	1+1
PGR 608	Genomic tools and current applications	2+1
PGR 609*	Intellectual Property Rights and Regulatory Mechanisms (e-course)	1+0
PGR 691	Seminar I	0+1
PGR 692	Seminar II	0+1
	Total	**12+9=21**
PGR 699	Thesis/Research	0+75

***Compulsory Courses**

Minor Disciplines:

1. Genetics & Plant Breeding
2. Seed Science and Technology
3.Plant Physiology
4. Molecular Biology and Biotechnology

Disciplines for Supporting Courses:

1. Genetics & Plant Breeding
2. Seed Science and Technology
3. Plant Physiology
4. Molecular Biology and Biotechnology
5. Agricultural Statistics

Detailled Course Contents

PGR -501 Germplasm Exploration and Plant Systematics* 3 (2+1)

Objective

The course is designed to make students understand reconstruction of the evolutionary history and classification of plants into taxonomic groups, introduce the students to the theory and practice behind systematic conduct of exploration, Eco geographic survey, sampling strategies, post-harvest methods.

Theory

Unit I

History of germplasm exploration, distribution and extent of prevalent genetic diversity; phyto-geographical regions/ ecological zones and associated diversity; Geo-Spatial analysis using GIS (Geographical Information System) tools for mapping eco-geographic distribution of diversity, threatened habitats, remote sensing, use of drones, need for collection missions, Planning and execution, Use of floras, Concept of population and gene pool; gene pool sampling in self- and cross-pollinated and vegetatively propagated species, non-selective, random and selective sampling strategies, coarse and fine grid surveys, planning collection and analyses of ecogeographic data, assessing the threats of genetic erosion.

Unit II

Ethnobotanical aspects of PGR, crop botany, farming systems, collecting wild relatives of crop plants; Post-exploration handling of germplasm collections, preservation of specimens, importance and use of herbaria and preparation of herbarium specimens.

Unit III

Crop Systematics, nomenclature; International code for binomial nomenclature, systems of classification; concept of species and taxa, biosystematics and terminologies
for plant description, Classical and modern species concepts, differentiation and evolution of species: speciation, variation within species, phenotypic plasticity.

Unit IV

Taxonomy of higher/ cultivated plants: use of taxonomic literature such as floras, manuals, monographs, indices, catalogues and dictionaries, concept and methods of herbarium and field study, criteria used for classification, identification of plants of economically important families, floristic and monographic works, Modern trends in plant taxonomy – Chemotaxonomy, Numerical taxonomy and Cytotaxonomy; Cronquist system – Angiosperm Phylogeny (AGP) Group classification; molecular systematics – Primary and Secondary metabolites – Semantides; global taxonomic initiatives-barcoding, taxonomic databases.

Practical

- Plant exploration and germplasm collecting, documenting passport data, use of flora and maps, collecting vegetatively propagated species;
- Local field visit for recording of ethnobotanical information/ notes, herbarium collection, report writing on germplasm collecting missions;
- Post exploration handling;
- Collecting wild relatives of crop plants';
- Preparation, maintenance and use of herbarium, Ecogeographical surveys and inventory, Use of GIS in biodiversity mapping and collecting;
- Estimation of genetic diversity in traditional agroecosystems on farm, matrix ranking of farmer selection criteria;
- Classical and modern species concepts and biosystematics, Morphology and

anatomy;
• Comparative studies on phytochemistry, Chemotaxonomy;
• Floristic and monographic work; Practical methods for elucidating and proving hypotheses relating to plant speciation, Numerical taxonomy-practice and procedures, Intraspecific categories in relation to population biology, Taxonomic databases and documentation methods in relation to PGR, Taxonomy of crop plants, cultivated species, domesticated species, wild-cultivated continuum, problems and their resolution, newer methods of analysis and interpretation;
• Visit to Biosphere reserves/ renovated degraded ecosystems and Farmer's fields for landraces, visit to NBAGR/ NBPGR Regional stations.

Lecture Schedule
Theory

S. N.	Topic	No. of lectures
1.	History of germplasm exploration, distribution and extent of prevalent genetic diversity; phyto-geographical regions/ ecological zones and associated diversity	2
2.	Geo-Spatial analysis using GIS (Geographical Information System) tools for mapping eco-geographic distribution of diversity, threatened habitats, remote sensing, use of drones, need for collection missions, Planning and execution, Use of floras.	3
3.	Concept of population and gene pool; gene pool sampling in self- and cross-pollinated and vegetatively propagated species, non-selective, random and selective sampling strategies,	3
4.	Coarse and fine grid surveys, planning collection and analyses of eco geographic data, assessing the threats of genetic erosion.	2
5.	Ethno botanical aspects of PGR, crop botany, farming systems, collecting wild relatives of crop plants	2
6.	Post-exploration handling of germplasm collections, preservation of specimens, importance and use of herbaria and preparation of herbarium specimens.	1
7.	Crop Systematics, nomenclature; International code for binomial nomenclature, systems of classification	2
8.	Concept of species and taxa, biosystematics and terminologies for p description.	2
9.	Classical and modern species concepts, differentiation and evolution of species: speciation, variation within species, phenotypic plasticity.	2
10.	Taxonomy of higher/ cultivated plants: use of taxonomic literature such as floras, manuals, monographs, indices, catalogues and dictionaries,	3
11.	Concept and methods of herbarium and field study,	2
12.	Criteria used for classification, identification of plants of economically important families, floristic and monographic works	2
13.	Modern trends in plant taxonomy – Chemotaxonomy, Numerical taxonomy and Cytotaxonomy	1
14.	Cronquist system – Angiosperm Phylogeny (AGP) Group classification	2
15.	Molecular systematics – Primary and Secondary metabolites – Semantides	2
16.	Global taxonomic initiatives- barcoding, taxonomic databases.	1

		Total	**32**

Practical Schedule

S. N.	Topic	No. of Practicals
1.	Plant exploration and germplasm collecting, documenting passport data, use of flora and maps, collecting vegetatively propagated species	1
2.	Local field visit for recording of ethnobotanical information/ notes, herbarium collection, report writing on germplasm collecting missions	2
3.	Post exploration handling	1
4.	Collecting wild relatives of crop plants'	1
5.	Preparation, maintenance and use of herbarium, Ecogeographical surveys and inventory, Use of GIS in biodiversity mapping and collecting	2
6.	Estimation of genetic diversity in traditional agroecosystems on farm, matrix ranking of farmer selection criteria.	2
7.	Classical and modern species concepts and biosystematics, Morphology and anatomy	1
8.	Comparative studies on phytochemistry, Chemotaxonomy	1
9.	Floristic and monographic work; Practical methods for elucidating and proving hypotheses relating to plant speciation, Numerical taxonomy-practice and procedures	2
10.	Infraspecific categories in relation to population biology, Taxonomic databases and documentation methods in relation to PGR, Taxonomy of crop plants, cultivated species, domesticated species, wild-cultivated continuum, problems and their resolution, newer methods of analysis and interpretation	2
11.	Visit to Biosphere reserves/ renovated degraded ecosystems and Farmer's fields for landraces, visit to NBAGR/ NBPGR Regional stations	1
	Total	**16**

Suggested Reading

Barrough PA. 1986. Principles of Geographic Information System for Land Resources Assessment. Oxford University Press, Oxford, UK.

Brown AHD, Frankel OH, Marshall DR and Williams JT. 1989. *The Use of Plant Genetic Resources*. Cambridge University Press.

Brown AHD, Clegg MT, Kahler AL and Weir BS. (eds.) 1990.*Plant population genetics, breeding,and genetic resources*. Sinauer Associates, USA.

Chapman and Hall. 1992. *Global biodiversity: Status of the Earth's living resources*. World Conservation Monitoring Centre, London .xx + 594 pp

.Curran PJ 1985.*Principles of Remote Sensing*. Longman Inc., New York.

Davis PH and Heywood VH. 1963. *Principles of Angiosperm Taxonomy*. Oliver & Boyd, UK.556 p.

Greuter W, Barrie FR, Burdet HM, Chaloner WG, Demoulin V, Hawksworth DL, JorgensonPM, Nicolson DH, Silva PC, Trehane P and Mcneill J. 1994. *International Code of Botanical Nomenclature*. Regnum Veg. 131, Koeltz. Sci. Books, Konigstein, Germany.389 p.

Frankel OH and Michaele ES. 1987. *Conservation and evolution*, Cambridge University Press.

Halewood M, Noriega I and Louafi S. 2013.*Crop Genetic Resources as a Global commons:* Challenges in International Law and Governance.

Harlan, J.R. 1992. Crops and Man (Second Edition), American Society of Agronomy Inc., Crop Science Society of America Inc., Madison, Wisconsin, USA.
Jackson M, Ford-Lloyd B and Parry M. (editors) 2014. *Plant Genetic Resources and Climate Change*.
Jain SK and Rao RR. 1976. *A Handbook of Field and Herbarium Methods*. Today &Tomorrow's Printers & Publishers, New Delhi, India. 157 p.
Lawrence GHM. 1951. *Taxonomy of Vascular Plants*, Indian ed., 1964. Oxford and IBM
Publishing Co., Calcutta, India.323 p.
Maheshwari JK. 1963.*The Flora of Delhi*. Publications and Information Directorate, CSIR, New Delhi. 447 p
.Meerabi G and Pullaiah T. 2015.*Plant Biodiversity Conservation and Management*. Daya Publishing House, Delhi.
Porter CL. 1959. *Taxonomy of Flowering Plants*. W.H. Freeman and Co. Inc., USA. 452 p.
Redden R, Yadav SS, Maxted N, Dullo ME, Guarino L and Smith P. 2015. *Crop Wild Relatives and Climate Change*. Willey-Blackwell.
Zeven AC and De wet JMJ. 1982. *Dictionary of Cultivated Plant and their Regions of Diversity*. Pudoc, Wageningen: Centre for Agricultural Publishing and Documentation.

PGR-502* Plant Diversity and Conservation* 3 (2+1)

Objective
The students will grasp the science underpinning biodiversity and agro-biodiversity, concept of PGR, threats to diversity and impact of biotic homogenization for the diversity crisis, concerned legal issues and data recording, various concepts and approaches of plant conservation.

Unit I
Biodiversity an overview: genetic, species and ecosystem diversity, higher plant diversity, species richness and endemism, biospheres, Gene centres, importance of Indian gene centre. Origin and history of agriculture, conservation and agricultural development, the central role of agro-biodiversity: trends and challenges, centers of crop plant origin and diversity, dynamics of domestication, plant domestication and evolution of crop plants, Crop Wild Relatives, patterns of variation, classification of cultivated plants, concept of gene pool, geographical distribution of crops of Indian origin.

Unit II
Status and trends of agro biodiversity; Global challenges and conservation of agro biodiversity-in-situ, ex-situ, Impact of climate change on agrobiodiversity, managing plant genetic resources: Basic science issues; Institutional aspects of managing agrobiodiversity, PGR networks.

Unit III
Agrobiodiversity and livelihoods: Food and nutrition systems, Traditional knowledge, TKDL, Farmers' seed systems and participatory breeding, Valuing PGR and ecosystem services; Value chains of neglected and underutilized (potential crop)species, community biodiversity management.

Unit IV
IPR for innovative entrepreneurship International framework and PGR networks; International treaties and policies in relation to agro-biodiversity conservation, sustainable use and germplasm exchange, CBD, UPOV, ITPGRFA, Nagoya protocol, National policies and legal frame work, Biodiversity Act, PPV and FR Act, Global Plan of action, germplasm registration, IP issues with respect to ITKs and communities, safe guarding biodiversity, case studies, digital sequence information vs tangible genetic resources, recent advances in biotechnology and synthetic biology, new forms of life and threats to biodiversity.

Unit V

In situ and ex situ conservation: concept of biosphere reserves, gene sanctuaries, on-farm conservation, seed gene banks, Perma-frost conservation, field genebanks, botanical gardens, herbal gardens, in vitro repositories and cryo-genebanks; short-,medium- and long-term conservation, concept of base, active and working collections. Importance of seed gene banks; seed structure and function; seed storage behavior, physiological and genetic changes during storage, theories of ageing, viability equations, dormancy. Genebank standards for various crops, ISTA, AOSA, Bioversity International guidelines; monitoring viability of stored samples; strategies for reviva land rescue of rare genetic material. Multiplication and regeneration of stored germplasm, Principles and practices of germplasm regeneration and maintenance, breeding systems and mode of reproduction; maintaining sufficiently large populations for effective conservation of farmer landraces.

Unit VI

History and principles of plant tissue culture, Laboratory requirement and general techniques, Tissue culture media, Cellular totipotency, Clonal propagation and clonal multiplication, Somatic embryogenesis, Soma clonal variation, Meristem culture and virus elimination, Cell culture, Anther and pollen culture, Genetic engineering, In vitro collecting of plant germplasm, in vitro techniques in germplasm exchange, In vitro conservation strategies, Concept of in vitro active, base genebank and DNA genebank, Introduction to plant cryopreservation, Cryopreservation techniques, Cryopreservation of vegetative propagules and in vitro explants, Genetic stability.

Unit VII

Complementary strategies for conservation, scientific basis of In situ on-farm conservation; social and cultural context, economic analysis in on-farm conservation, factors influencing farmer variety choice, the value of local crop diversity to markets and to farmers, Community seed genebanks, Institutional frameworks for the implementation of on-farm conservation.

Practical

- Legal issues and FAO code of conduct;
- Seed structure and morphology;
- Seed germination and seedling evaluation;
- Seed viability test, seed sampling and purity analysis, seed dormancy and dormancy breaking treatments, moisture testing methods;
- Vigour testing methods and seed leachate analysis, accelerated aging of seeds and their assessment, seed processing and storage in Gene Bank;
- Preparation of stock solutions, media preparation, preparation of explants and culture initiation in monocots and dicots;

- Meristem isolation and culture establishment, subculture of shoots in monocots and dicots, hardening and field establishment of plantlets;
- Preparation of cryoprotectant solutions and regrowth media, isolation of in vitro explants and pre-treatment, cryopreservation of in vitro cultures- vitrification based techniques, Encapsulation-dehydration technique, etc.

Lecture Schedule

Theory

S. N.	Topic	No. of lectures
1.	Biodiversity an overview: genetic, species and ecosystem diversity, higher plant diversity, species richness and endemism, biospheres	2
2.	Gene centres, importance of Indian gene centre.	1
3.	Origin and history of agriculture, conservation and agricultural	1

	development, the central role of agro-biodiversity	
4.	trends and challenges, centers of crop plant origin and diversity, dynamics of domestication, plant domestication and evolution of crop plants	1
5.	Crop Wild Relatives, patterns of variation, classification of cultivated plants, concept of gene pool, geographical distribution of crops of Indian origin	1
6.	Status and trends of agro biodiversity; Global challenges and conservation of agro biodiversity-in-situ, ex-situ, Impact of climate change on agro biodiversity, managing plant genetic resources	2
7.	Basic science issues; Institutional aspects of managing agro biodiversity, PGR networks.	1
8.	Agro biodiversity and livelihoods: Food and nutrition systems, Traditional knowledge, TKDL, Farmers' seed systems and participatory breeding, Valuing PGR and ecosystem services	1
9.	Value chains of neglected and underutilized (potential crop) species, community biodiversity management	1
10.	IPR for innovative entrepreneurship International framework and PGR networks	1
11.	International treaties and policies in relation to agro-biodiversity conservation, sustainable use and germplasm exchange, CBD, UPOV, ITPGRFA, Nagoya protocol, National policies and legal frame work, Biodiversity Act, PPV and FR Act	3
12.	Global Plan of action, germplasm registration, IP issues with respect to ITKs and communities, safe guarding biodiversity, case studies, digital sequence information vs tangible genetic resources, recent advances in biotechnology and synthetic biology, new forms of life and threats to biodiversity.	1
13.	In situ and ex situ conservation: concept of biosphere reserves, gene sanctuaries, on-farm conservation, seed gene banks, Perma-frost conservation, field gene banks, botanical gardens, herbal gardens, in vitro repositories and cryo-gene banks	2
14.	short-, medium- and long-term conservation, concept of base, active and working collections.	1
15.	Importance of seed gene banks; seed structure and function; seed storage behavior, physiological and genetic changes during storage, theories of ageing, viability equations, dormancy.	1
16.	Genebank standards for various crops, ISTA, AOSA, Bioversity International guidelines; monitoring viability of stored samples; strategies for revival and rescue of rare genetic material. Multiplication and regeneration of stored germplasm	2
17.	Principles and practices of germplasm regeneration and maintenance, breeding systems and mode of reproduction; maintaining sufficiently large populations for effective conservation of farmer landraces.	1
18.	History and principles of plant tissue culture, Laboratory requirement and general techniques, Tissue culture media,	1
19.	Cellular totipotency, Clonal propagation and clonal multiplication, Somatic embryogenesis, Somaclonal variation, Meristem culture and virus elimination	1

20.	Cell culture, Anther and pollen culture	1
21.	Genetic engineering, In vitro collecting of plant germplasm, in vitro techniques in germplasm exchange, In vitro conservation strategies,	1
22.	Concept of in vitro active, base gene bank and DNA gene bank	1
23.	Introduction to plant cryopreservation, Cryopreservation techniques, Cryopreservation of vegetative propagules and in vitro explants, Genetic stability.	1
24.	Complementary strategies for conservation, scientific basis of In situ on-farm conservation	1
25.	social and cultural context, economic analysis in on-farm conservation, factors influencing farmer variety choice, the value of local crop diversity to markets and to farmers	1
26.	Community seed gene banks, Institutional frameworks for the implementation of on-farm conservation.	1
	Total	**32**

Practical Schedule

S. N.	Topic	No. of Practical
1.	Legal issues and FAO code of conduct	2
2.	Legal issues and FAO code of conduct	2
3.	Seed germination and seedling evaluation	2
4.	Seed viability test, seed sampling and purity analysis, seed dormancy and dormancy breaking treatments, moisture testing methods	2
5.	Vigour testing methods and seed leachate analysis, accelerated aging of se and their assessment, seed processing and storage in Gene Bank	2
6.	Preparation of stock solutions, media preparation, preparation of explants culture initiation in monocots and dicots	2
7.	Meristem isolation and culture establishment, subculture of shoots in mono and dicots, hardening and field establishment of plantlets	2
8.	Preparation of cryoprotectant solutions and regrowth media, isolation o vitro explants and pre-treatment, cryopreservation of in vitro cultu vitrification basedtechniques, Encapsulation-dehydration technique, etc.	2
	Total	**16**

Suggested Reading

Barbara MR, Chin HF and Normah MN. 2013. *Conservation of Tropical Plant Species*, Springer. Frankel OH and Hawks JG. 1975. *Crop Genetic Resources for Today and Tomorrow*. Cambridge University Press.

Bewley JD and Black M. 1994.*Seeds: Physiology of Development and Germination*. SecondEdition. Plenum Press, New York and London. pp. 445.

Benson EE. (ed.). 1999. *Plant Conservation Biotechnology*. Taylor and Fancis Ltd. London.

Bhojwani, Bhojwani SS and Razdan MK. 1983.*Plant Tissue Culture: Theory and Practice*. Elsevier Science Publishing Co. Inc. New York.

Bhojwani SS and Razdan MK. 1983.*Plant Tissue Culture: Theory and Practice*. Elsevier Science Publishing Co. Inc. New York.

Bhojwani SS and Dantu PK. 2013.*Plant Tissue Culture*: *An introductory text*. Springer.

Bonner FT. 1990. 'Storage of seeds: Potential and limitation of germplasm conservation.' *Forest Ecology and Management.*

Chaudhury R and Malik SK. 2017.*Cryopreservation of Plant Species: Practical Approaches* from Handling to Cryo banking. ICAR-NBPGR, New Delhi.52 p.

Dodds JH. (eds.) 1991.In vitro Methods for *Conservation of Plant Genetic Resources*. Chapman and Hall, London.

Engels JMM. 1995. *In situ conservation and sustainable use of plant genetic resources for foodand agriculture in developing countries*. IPGRI/ DSE.

Engelmann F and Takagi H. (eds). 2000. *Cryopreservation of Tropical Plant Germplasm – Current Research Progress and Application*, IPGRI, Rome/ JIRCAS/Japan.

Ellis RH, Hong TD and Roberts EH.1985a. *Handbook of Seed Technology for Genebank* .Volume II. Principles and Methodology. International Board for Plant Genetic Resources, Rome.

Ellis RH, Hong TD and Roberts EH. 1985b. *Handbook of Seed Technology for Genebank .Compendium of Specific Germination Information and Test Recommendations.*
International Board for Plant Genetic Resources, Rome.

Ford-Lloyd BV, Newburry JH and Callow JA.(eds.) 1998.*Biotechnology and Plant Genetic Resources*: Conservation and Use. CABI, Wellingford.

Guriano L, Ramanatha Rao V and Reid R. 1995.*Collecting plant genetic diversity-Technical Guidelines*. CAB International, Wallingford, UK.

Hong TD and Ellis RH. 1996. A protocol to determine seed storage behaviour. International Plant Genetic Resources Institute IPGRI Technical Bulletin No. 1, Rome.

Jarvis D, Staphit B and Sears L. 2000.*Conserving agricultural biodiversity in situ: a scientific basis for sustainable agriculture*. IPGRI, Rome, Italy.

Kartha KK. (ed.). 1995. *Cryopreservation of Plant Cells and Organs*. CRC Press, Boca Rataon, Florida.

Maxted N, Ford-Lloyd BV and Hawkes JG. 1997. *Plant Genetic Conservation: The In situ Approach* .Chapman & Hall, London.

McNeely JA. 1988. *Economic and biological diversity: developing and using economic incentivesto conserve biological resources*. International Union for Conservation of Nature and Natural Resources, Gland.

Plucknett DL, Smith NJH and Williams JT. 1987.*Genebanks and the World's Food*. Princeton University Press.

Razdan MK and Cocking EC.(eds.) 2000.*Conservation of Plant Genetic Resources In vitro*, Vol.2: Applications and Limitations. Science Publishers, Inc. USA.

Redden R, Yadav SS, Maxted N, Dulloo ME, Guarino L and Smith P. (eds.) 2015. *Crop wild relatives and climate change*. Wiley-Blackwell. 400 p. ISBN: 978-1-118-85433-4.

e-resource
www.iucnredlist.org

PGR -503 Germplasm Characterization and Evaluation* 2(1+1)

Objective

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

Theory
Unit I
Understanding genetic diversity in crop plants; Crop descriptors, descriptor states; germplasm characterization/ evaluation procedures; evaluation of germplasm for specific traits; Measuring diversity using agro-morphological data, statistical procedures to measure population genetic variation, markers and their use in PGR, evaluation of biotic and abiotic stresses, Principles and methods for formulating core and mini core collections and their validation, Web based tools for management of data.
Unit II
Principles and practices of germplasm regeneration and maintenance, breeding systems and mode of reproduction; maintaining sufficiently large populations foreffective conservation of farmer landraces, evaluation and maintenance of wildrelatives of crop plants. Genetic enhancement, Use of CWRs genetic resources for crop improvement.
Unit III
High throughput phenotyping systems- imaging and image processing concepts for automated germplasm characterization (phenotyping) – evaluation for nutritional traits, resistance traits - Biochemical and molecular markers for characterization

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

Lecture Schedule

Theory

S. N.	Topic	No. of lectures
1.	Understanding genetic diversity in crop plants; Crop descriptors, descriptor states; germplasm characterization/ evaluation procedures; evaluation of germplasm for specific traits	2
2.	Measuring diversity using agro-morphological data, statistical procedures to measure population genetic variation.	1
3.	Markers and their use in PGR, evaluation of biotic and abiotic stresses.	1
4.	Principles and methods for formulating core and mini core collections and their validation, Web based tools for management of data.	2
5.	Principles and practices of germplasm regeneration and maintenance,	1
6.	Breeding systems and mode of reproduction; maintaining sufficiently large populations for effective conservation of farmer landraces, evaluation and maintenance of wild relatives of crop plants.	3
7.	Genetic enhancement, Use of CWRs genetic resources for crop improvement.	2
8.	High throughput phenotyping systems- imaging and image processing concepts for automated germplasm characterization (phenotyping).	2
9.	Evaluation for nutritional traits, resistance traits -Biochemical and molecular markers for characterization.	2
	Total	**16**

Practical Schedule

S. N.	Topic	No. of Practicals
1.	Field layout and experimental designs	2
2.	Recording field data on germplasm evaluation in different agri-horticultural crops	3
3.	Post-harvest handling	3
4.	Evaluating quality traits, biochemical and phyto-chemical evaluation of cro germplasm, data processing	4
5.	Documentation, analysis of diversity and cataloguing, data analysis, viabilit equations, sampling strategies, data documentation, cataloguing, biochemic analyses of samples.	4
	Total	**16**

Suggested Reading

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

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

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

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

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

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

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

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

Tripathi K, Bhardwaj R, Bhalla S, Kaur V, Bansal R, Yadav R, Gangopadhyay KK, Kumar A and Chaudhury R. 2018. *Plant Genetic Resources Evaluation: Principles and Procedures*.

Indian Council of Agricultural Research-National Bureau of Plant Genetic Resources(ICAR-NBPGR), New Delhi. vi+50 p.

PGR -504Genetic enhancement for PGR Utilization 2(1+1)

Objective

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

Theory

Unit I

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

Unit II

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

Unit III

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

Practical

• Characterization of CWRs by visiting the fields;

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

Lecture Schedule
Theory

S. N.	Topic	No. of lectures
1.	Concepts of gene pools; Introduction, potential of pre-breeding.	2
2.	Role of crop wild relatives, semi exotics, creating and managing variation, b concepts to set up a successful pre-breeding programme.	1
3.	Understanding crop adaptation, handling and maintenance of CWRs.	1
4.	Synchronization of flowering, overcoming impediments to flowering through photoperiodic adjustments, role of other barriers to flowering.	1
5.	Role of amphidiploids, semi exotics and other unadapted germplasm.	1
6.	Identifying desirable traits in natural populations, screening for biotic and abiotic stress resistance traits	2
7.	Screening of nutritionally important traits, genetic analysis to understand the inheritance of novel traits.	1
8.	Parental selection for pre-breeding, search for superior genotypes, breeding methods for trait transfer; moving the genes – unadapted to adapted	1
9.	Wide hybridization, Incongruity and its management.	1
10.	Modern tools for incongruity management, cytogenetical approaches for gene transfer such as alien addition and substitution	1
11.	Segregating populations and their management in wide crosses, purging the undesirable traits.	1
12.	Testing and improving the adaptability of wide cross derivatives, cytological studies	1
13.	Florescence microscopy, embryo rescue methods	1
14.	Pollen physiology and storage, pollen storage methods to facilitate wide hybridization, pre- and postzygotic barriers.	1
	Total	**16**

Practical Schedule

S. N.	Topic	No. of Practical
1.	Characterization of CWRs by visiting the fields.	2
2.	Screening methods for special traits-biotic and abiotic resistance.	2
3.	Screening for nutritional traits.	2
4.	Cross ability studies in CWRs of cereals, legumes, oilseeds, vegetables. Assessment of pre and post-zygotic barriers in wide hybridization crosses.	4
5.	Pollen storage studies.	2
6.	Special requirements for growing CWRs, inducing flowering by manipulating day length, temperature, chemical spraying, etc.	4

	Total	**16**

Suggested Reading

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

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

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

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

Goodman, RM. 2004. Encyclopedia of plant and crop science. Marcel Dekker Inc., Switzerland. Kimber, G and Feldman, M. 1987. Wild Wheat: An introduction. Special report 353, College of Agriculture, University of Missouri-Columbia.

Lynch, M. and Walsh, B. 1998. Genetics and analysis of quantitative traits. Sinauer Associates Inc., MA, USA.
Murphy, D. 2007. Plant breeding and biotechnology: Societal context and the future of agriculture. Cambridge University Press, Cambridge, UK.

Ram JS. 2010. Plant Cytogenetics. CRC Press
.
Ramanatha Rao V, Brown AHD, Jackson M. 2001. Managing Plant Genetic Diversity. CABI Publication.

Sharma S, Upadhyaya HD, Varshney RK, et al. 2013. 'Pre-breeding for diversification of primary gene pool and genetic enhancement of grain legumes.' *Frontiers in Plant Science* 4: 309.Yunbi Xu. 2010. Molecular plant breeding, CABI publishers

e-Resources

https://www.integratedbreedPlaning.net/pre-breeding-effective-use-plant-geneticresourceshttp://www.croptrust.org/http://www.bioversityinternational.org/training/trainingmaterials/pre_breeding.htmhttp://www.grdc.com.au/director/research/prebreeding.

PGR -505 Economic Botany * 3 (2+1)

Objective

The student will learn concept of economic botany and relationship between human and plants including cultivation and economic uses in everyday life.

Theory

Unit I

Introduction to economic botany, Origin of agriculture, domestication and adaptations of cultivated plants, classification into crop groups, reproductive systems and breeding behaviour of crop plants.

Unit II

Origin, evolution, botany, cultivation, use, genetic resource management and utilization of important crops, viz., cereals, pseudo-cereals, millets, legumes, forage and fodder crops, oil yielding plants, fibre yielding plants, under-utilized and underexploited plants, new and potential crops, processing and use of crop residues.

Unit III

Important taxa in horticulture, floriculture and agro-forestry. Origin, evolution, botany, cultivation, use, genetic resource management and utilization of geneticdiversity of important crops, viz., vegetable crops, fruits and nuts, medicinal and aromatic plants, spices and condiments, beverages, fumitory and masticatory plants, rubber yielding plants, wood and timber yielding taxa, cellulose, starch and sugar yielding plants, insecticidal and herbicidal plants, important taxa in agro-forestry, flavouring agents, gums and resins.

Practical

• Botanical micro techniques for the study of structure, development and biochemical status of plant parts;
• Identification of economically important plant parts in different groups of plant soil yielding plants, cereals, millets, legumes, spices, condiments, woods, timber and industrial crops, medicinal and aromatic plants and fumitory, masticatory plants;
• Structure of economic plant parts-root, stem, leaves, fruits, seeds, recognizing the grains;
• Case studies on adaptations during domestication;
• Histochemical localization of chemical constituents in economically important plant parts e.g. starch-sugars, Proteins-lipids; and studies on sugar, starch, cellulose, fibers, gums, rubber and resins;
• Visit to Museum of economic products in other Institutes, visit to industrial units processing the economic products.

Lecture Schedule

Theory

S. N.	Topic	No. of lectures
1.	Introduction to economic botany, Origin of agriculture.	2
2.	Domestication and adaptations of cultivated plants, classification into crop groups.	3
3.	Reproductive systems and breeding behaviour of crop plants.	3
4.	Origin, evolution, botany, cultivation, use, genetic resource management and utilization of important crops, viz., cereals, pseudo-cereals, millets, legumes, forage and fodder crops, oil yielding plants, fibre yielding plants, under-utilized and under exploited plants.	4
5.	New and potential crops, processing and use of crop residues.	3
6.	Important taxa in horticulture, floriculture and agro-forestry.	3
7.	Origin, evolution, botany, cultivation, use, genetic resource management and utilization of genetic diversity of important crops, viz., vegetable crops, fruits and nuts.	4
8.	Medicinal and aromatic plants, spices and condiments, beverages, fumitory and masticatory plants, rubber yielding plants.	4
9.	Wood and timber yielding taxa, cellulose, starch and sugar yielding plants	3
10.	Insecticidal and herbicidal plants, important taxa in agro-forestry,	3

	flavouring agents, gums and resins.	
	Total	**32**

Practical Schedule

S. N.	Topic	No. of Practical
1.	Botanical micro techniques for the study of structure, development and biochemical status of plant parts.	2
2.	Identification of economically important plant parts in different groups of plant soil yielding plants, cereals, millets, legumes, spices, condiments, woods, timber and industrial crops, medicinal and aromatic plants and fumitory, masticatory plants.	3
3.	Structure of economic plant parts-root, stem, leaves, fruits, seeds, recognizing the grains.	2
4.	Case studies on adaptations during domestication.	4
5.	Histo chemical localization of chemical constituents in economically important plant parts e.g. starch-sugars, Proteins-lipids; and studies on sugar, starch, cellulose, fibers, gums, rubber and resins	3
6.	Visit to Museum of economic products in other Institutes, visit to industrial units processing the economic products.	2
	Total	**16**

Suggested Reading

Atkinson ET. 1980. *The Economic Botany of the Himalayas*.

Brown AHD, Frankel OH, Marshall DR and Williams JT. 1989.*The use of plant genetic resources.* Cambridge University Press

Burkill IH. 1951-52.Habits of man and the origins of the cultivated plants of the old World. *Proceeding Linnean Society of London*, 164: 12-42.

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

George W. 2014.*Dictionary of Economic Products of India*. Cambridge University Press.

Hanelt P. 2001.*Mansfeld'sencyclopedia of agricultural and horticultural crops*, vol 3. Institute of Plant and Genetics and Crop Plant Research (eds) Springer, Berlin.

Harlan JR. 1992. *Crops and Man* (Second Edition). American Society of Agronomy Inc., Crop Science Society of America Inc., Madison, Wisconsin, USA.

Hill AF. 1952. *Economic Botany*: *A Textbook of Useful Plants and Plant Products*. Second Edition. New York Toronto London McGraw-hill Book Company, Inc.

Kochhar SL. 2012. *Economic Botany in the Tropics*. Paperback, Fourth edition. Laxmi Publications.

Maiti RK and Singh VP. 2006. *An Introduction to Modern Economic Botany*. Eastern Book Corporation, Delhi.

Mehra KL and Arora RK. 1982. *Plant Genetic Resources of India: their diversity and conservation*. NBPGR, New Delhi.

Morton JF. 1987. *Fruits of warm climates. Creative Resource Systems*. Inc. NC Miami, FL.

Paroda RS and Arora RK (eds.). 1991. *Plant Genetic Resources: Conservation and Management.* NBPGR, New Delhi.

Purseglove W. 1981.*Tropical Crops. Dicotyledons*. The English Language Book Society and Longman.

Purseglove W. 1981.*Tropical Crops. Monocotyledons*. The English Language Book Society and Longman
.
Schery RW. 2001. *Plants for Man*

Simpson BB and Ogorzaly M. 2013. Plants in Our World: Economic Botany, McGraw-HillEducation, New York, NY.
Simpson BB, Molly Ogorzaly, Simpson Beryl. 2001. *Economic Botany: Plants in Our World.* Mcgraw-hill Science/ engineering/ math.

Swaminathan MS and Jana S (eds.). 1992. *Biodiversity: implication for global food security*.Mc MIllan Press.

Wealth of India: Raw material series, CSIR, India

PGR -506 Information Management in PGR2(1+1)

Objective
To train students in germplasm database management using modern tool sand softwares.

Theory
Unit I
Documentation of germplasm collections, principles of documentation of information in genebanks, concept of data base creation and management; Relational Database Management Systems; Web based PGR networks.

Unit II
Statistical techniques in management of germplasm, developing core collection, estimating sample size during plant explorations, impact of sampling on population structure.

Unit III
Sequential sampling for viability estimation, introduction of binomial, normal and negative cumulative normal, use of Probit scales, viability equations and nomograms, estimation of sample size for storage and viability testing. Germplasm documentation; basics of computer and

operating systems, database management system- PGR Portal, Cryodatabase, *In vitro* genebank database, use of statistical softwares, pictorial and graphical representation of data; Introduction to communication network.

Unit IV

Introduction to database management and DBMS, Introduction to Perl and Bioperl. Collection and storage of sequences, NCBI-providing access to biomedical and genomic information.

Practical

- Experimental designs and data analysis;
- Viability equations, sampling strategies, data documentation;
- Cataloguing;
- PGR portal, Cryo database management;
- Writing programmes in Perl for bioinformatics applications.

Lecture Schedule

Theory

S. N.	Topic	No. of lectures
1	Documentation of germplasm collections, principles of documentation of information in gene banks.	1
2	Concept of data base creation and management; Relational Database Management Systems.	1
3	Web based PGR networks.	1
4	Statistical techniques in management of germplasm, developing core collection, estimating sample size during plant explorations, impact of sampling on population structure.	2
5	Sequential sampling for viability estimation, introduction of binomial, normal and negative cumulative normal.	2
6	Use of Probit scales, viability equations and nomograms, estimation of sample size for storage and viability testing.	2
7	Germplasm documentation; basics of computer and operating systems.	1
8	Database management system- PGR Portal, Cryo database, *In vitro* gene bank database.	1
9	Use of statistical softwares, pictorial and graphical representation of data	1
10	Introduction to communication network.	1
11	Introduction to database management and DBMS.	1
12	Introduction to Perl and Bioperl. Collection and storage of sequences.	1
13	NCBI-providing access to biomedical and genomic information.	1
	Total	**16**

Practical Schedule

S. N.	Topic	No. of Practical
1.	Experimental designs and data analysis.	4
2.	Viability equations, sampling strategies, data documentation.	3
3.	Cataloguing	2
4.	PGR portal, Cryo database management.	3

5.	Writing programmes in Perl for bioinformatics applications.	4
	Total	**16**

Suggested Reading

AgrawalRC,ArchakSandTyagiRK.2012.*An over view of biodiversity information with special reference*toPGR.ComputerandElectronicsinAgriculture84:92-99.

ArchakSandAgrawalRC.2013.*PGR informatics* at the NBPGR: *Status, challenges and future*.

In A road map for implementing the MLS of ABS in India (Eds. Halewood, M,Brahmi,

P.Mathur,PNandBansal,KC).BioversityInternational,RomeandNBPGR,NewDelhi.

Painting K A, Perry MC,DenningRAandAyadWG.1993.*Guide Book for Genetic Resources Documentation*. IPGRI, Rome, Italy.

Puzone L and Th.Hazekamp.1996. Characterization and Documentation of Genetic Resources Utilizing Multimedia Database.

Rana R S,Sapra R L,Agrawal RC and Gambhir R.1991.*PlantGenetic Resources*. Documentation and Information Management, NBPGR, New Delhi.

PGR -507 PGR Exchange and Quarantine *3 (2+1)

Objective

To impart knowledge on safe exchange of germplasm nationally and internationally Along with the quarantine related issues which are either legislative or technical.

Theory

Unit I

History, principles, objectives and importance of plant introduction, pre-requisite and conventions for exchange of PGR, national and international legislations and policies.

Unit II

Principles, objectives and relevance of plant quarantine, regulations and plant quarantine set up in India, pest risk analysis, pest and pathogen information database; quarantine in relation to integrated pest management, symptoms of pest damage, economic significance of seed-borne pests (insects, mites, nematodes, fungi, bacteria, viruses, phytoplasma, viroids, weeds, etc.), detection and identification of pests including use of recent techniques like ELISA, PCR, etc.

Unit III

Salvaging techniques for infested/ infected germplasm, post-entry quarantine operation, seed treatment and other prophylactic treatments and facilities, domestic quarantine; seed certification; international linkages in plant quarantine, weaknesses and future thrust. Symptoms of pest damage, pests of quarantine significance for India, sampling of bulk material for quarantine, Plant Quarantine/ biosecurity system in other countries, case histories of alien invasive species.

Unit IV

Genetically Modified Organisms (GMOs) or Genetically Engineered Plants (GEPs), Concepts of biosafety, risk analysis and consequences of spread of GE crops on the environment; Treaties and multilateral agreements governing trans-boundary movement of GEPs or GMOs, Indian regulatory system for biosafety.

Practical

- Inventory of IQ/ EQ samples;
- Joint inspection for pest detection;
- Detection of pests of quarantine significance (Conventional, Electron microscopy, ELISA and molecular techniques);
- Primer designing;
- Pest risk analyses, quarantine in relation to integrated pest management; salvaging of infested/ infected germplasm;
- Seed treatment and other prophylactic treatments and facilities; domestic quarantine; seed-health certification.

Theory Schedule

S. N.	Topic	No. of lectures
1.	History, principles, objectives and importance of plant introduction.	2
2.	Pre-requisite and conventions for exchange of PGR.	1
3.	National and international legislations and policies.	2
4.	Principles, objectives and relevance of plant quarantine, regulations and plant quarantine set up in India.	3
5.	Pest risk analysis, pest and pathogen information database; quarantine in relation to integrated pest management.	2
6.	Symptoms of pest damage, economic significance of seed-borne pests (insects, mites, nematodes, fungi, bacteria, viruses, phytoplasma, viroids, weeds, etc.).	3
7.	Detection and identification of pests including use of recent techniques like ELISA, PCR, etc.	3
8.	Salvaging techniques for infested/ infected germplasm.	1
9.	Post-entry quarantine operation, seed treatment and other prophylactic treatments and facilities, domestic quarantine; seed certification.	2
10.	International linkages in plant quarantine, weaknesses And future thrust.	2
11.	Symptoms of pest damage, pests of quarantine significance forIndia, sampling of bulk material for quarantine.	2
12.	Plant Quarantine/ biosecurity system in other countries, case histories of alien invasive species.	3
13.	Genetically Modified Organisms (GMOs) or Genetically Engineered Plants (GEPs).	1
14.	Concepts of biosafety, risk analysis and consequences of spread of GE crops on the environment.	3
15.	Treaties and multilateral agreements governing trans-boundary movement of GEPs or GOMs	1
16.	Indian regulatory system for biosafety.	1
	Total	**32**

Practical Schedule

S. N.	Topic	No. of Practicals
1.	Inventory of IQ/ EQ samples.	2
2.	Joint inspection for pest detection.	2
3.	Detection of pests of quarantine significance (Conventional, Elec microscopy, ELISA and molecular techniques).	3
4.	Primer designing	2
5.	Pest risk analyses, quarantine in relation to integrated pest managem salvaging of infested/ infected germplasm.	3
6.	Seed treatment and other prophylactic treatments and facilities; domestic quarantine; seed-health certification.	3
	Total	**16**

Suggested Reading

Albrechsten SE. 2006. *Testing methods for seed-transmitted viruses*: *principles and protocols.*UK: CAB International, Wallingford. 268 p.

Bhalla S, Chalam VC, Tyagi V, Lal A, Agarwal PC and Bisht IS. 2014. Teaching Manual on Germplasm Exchange and Plant Quarantine. ICAR-NBPGR, New Delhi, India p. 340+ viii.

Bhalla S, Chalam VC, Lal A, and Khetarpal RK. 2009. *Practical Manual on Plant Quarantine*. National Bureau of Plant Genetic Resources, New Delhi, India.204p+viii.

Bhalla S, Chalam VC, Singh B, Gupta K and Dubey SC. 2018. Biosecuring Plant Genetic Resources in India: Role of Plant Quarantine. ICAR-NBPGR, New Delhi vi+216 p.

Chalam VC, Dubey SC, Murali Krishna C, Bhalla S and Singh K (eds.). 2018. *Transboundary Movement of Living Modified Organisms: Strengthening Capacities of Enforcement Agencies*. ICAR-National Bureau of Plant Genetic Resources and Ministry of Environment, Forest and Climate Change, New Delhi, India. vi+159 p. ISBN 978-81-937111-2-5

Gupta K and Dubey SC. 2017.'Biosecurity policies influencing international exchange of PGR.' *Indian Journal of Plant Genetics Resources* 30: 258-266.

Khetarpal RK, Lal A, Varaprasad KS, Agarwal PC, Bhalla S, Chalam VC and Gupta K. 2006. Quarantine for Safe Exchange of Plant Genetic Resources. In: *Hundred Years of Plant Genetic Resources Management in India* (eds. AK Singh, Kalyani Srinivasan, Sanjeev Saxena andBS Dhillon), National Bureau of Plant Genetic Resources, New Delhi, pp 108-139.

Richardson MJ. 1990. An Annotated list of seed-borne diseases (Fourth Edition). International Seed Testing Association, P.O. Box 412.CH 8046 Zurich, Switzerland.

PGR -508 : Genomics in PGR management 2(1+1)

Objective

Students would be taught basics of genome structure and organization, generation of molecular markers-basic principles, molecular marker techniques, data handling and analysis of GM.

Theory

Unit I

Structure and function of DNA, genome organization, tools and techniques for genetic manipulation, Introduction to genetic markers, classification and comparison of markers, basis for DNA polymorphism and principles of generating molecular markers- RFLP, PCR, sequencing, next generation sequencing techniques, molecular marker techniques eg. RAPD, ISSR, AFLP, etc.; STMS, SNPs markers, GBS, GWAS, data handling and statistical analysis.

Unit II

Overview of molecular marker applications and recent advances, genetic diversity analysis using molecular markers, DNA Fingerprinting and cultivar identification.

Unit III

Introduction to transgenic, development of genetically modified crops, monitoring strategies and methods for detecting transgenic, Genome Editing.

Practical

- DNA isolation and purification, DNA quantification;
- RAPD, ISSR, STMS, SCAR, SRAP;
- Data Analysis.

Theory Schedule

S. N.	Topic	No. of lectures
1	Structure and function of DNA, genome organization, tools and techniques for genetic manipulation,.	2
2	Introduction to genetic markers, classification and comparison of markers,	1
3	Basis for DNA polymorphism and principles of generating molecular markers- RFLP.	2
4	PCR, sequencing, next generation sequencing techniques, molecular marker techniques eg. RAPD, ISSR, AFLP, etc.; STMS, SNPs markers, GBS, GWAS, data handling and statistical analysis.	3
5	Overview of molecular marker applications and recent advances.	1
6	Genetic diversity analysis using molecular markers.	2
7	DNA Fingerprinting and cultivar identification	2
8	Introduction to transgenic, development of genetically modified crops, monitoring strategies and methods for detecting transgenic, Genome Editing.	3
	Total	**16**

Practical Schedule

S. N.	Topic	No. of Practicals
1	DNA isolation and purification.	4
2	DNA quantification;	4
3	RAPD, ISSR, STMS, SCAR, SRAP.	4
4	Data Analysis.	4
	Total	**16**

Suggested Reading

BD Singh and Singh AK (Eds). 2015. *Marker-assisted Plant Breeding: Principles and Practices*. Springer.

Henry RJ. (Editor). 2001. *Plant Genotyping*: The DNA *Fingerprinting of Plants*, CABI Publishing.

Henry R (ed.) 2013. *Molecular Markers in Plants*. Wiley and Blackwell Publication, Iowa USA, 196 p.

Lewin B. 2008. Genes IX. Jones and Bartlett.

Karp A, Isaac PG and Ingram DS. 1998. *Molecular Tools for Screening Biodiversity– Plants and Animals*. Chapman and Hall, London.

Tuberosa R, Graner A and Frison E (eds.). 2014. Genomics of Plant Genetic Resources, Volume1. Managing, Sequencing and Mining Genetic Resources. Springer Science, New York,825 p.

Varshney RK and Tuberosa R (eds.) 2007. Genomics-Assisted Crop Improvement Vol 2: Genomics Applications in Crops. Springer Dordrecht, The Netherlands, 509 p.

PGR -509 : Plant Biosecurity 1(1+0)

Objective

To educate about protecting the economy, environment and plant health from pests and disease including preventing new pests and diseases from arriving, and helping to control outbreaks when they do occur.

Theory

Unit I

History of biosecurity, concept of biosecurity, components of biosecurity, Quarantine, Invasive Alien Species, biowarfare,/resurgence of insects, pests and diseases.

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.

Lecture Schedule

Theory

S. N.	Topic	No. of lectures
1	History of biosecurity, concept of biosecurity, components of biosecurity,	1
2	Quarantine, Invasive Alien Species, biowarfare,/ resurgence of insects, pests and diseases	2
3	National Regulatory Mechanism and International Agreements/ Conventions, viz., Agreement on Application of Sanitary and Phytosanitary (SPS)Measures/World Trade Organization (WTO)	2
4	Convention on Biological Diversity (CBD), International Standards for Phytosanitary Measures	1
5	Pest risk analysis, risk assessment models, pest information system, early warning and forecasting system	2
6	Use of Global Positioning System (GPS) and Geographic Information System (GIS) for plant biosecurity, pest/ disease and epidemic management,	2
7	Strategies for combating risks and costs associated with agroterrorism event.	2
8	Mitigation planning, integrated approach for biosecurity.	1
9	Biosafety, policies and regulatory mechanism.	1
10	Cartagena Protocol on Biosafety and its implications.	1
11	Issues related to release of genetically modified crops	1
	Total	**16**

PGR -510 : Principles of Genetics for PGR Management 2+0

Objective

To understand basic concepts of genetics and to develop analytical, quantitative and problem-solving skills in classical and molecular genetics for PGR management.

Theory

Unit I

History and role of genetics in crop improvement, polyploidy, mutation, genetic diversity in PGR, genetic principles of diversity and its distribution, evolution of crop plants through ploidy manipulation.

Unit II

Cytology-euploidy, haploid, diploid, polyploids, chimeras, role of polyploids in crop breeding, evolutionary advantages of auto polyploids vs allopolyploids, Role of aneuploids in basic and applied aspects of crop breeding, apomixis, haploids and their uses, modes of reproduction, male sterility, CMS, heterosis and hybrid development.

Unit III

Methods of studying polymorphism, Overview of molecular marker applications and recent advances, genetics of mitochondria and chloroplast, extra chromosomal inheritance, eugenics, epigenetics, basics of genome structure and organization, generation of molecular markers-RFLP, PCR, sequencing; principles, merits and demerits of RAPD, ISSR, SSR, SCAR, SCOT, SRAP, AFLP, SNP.

Unit IV

Population-Mendelian Population, random mating population, frequencies of genes and genotypes, causes of change, Hardy-Weinberg equilibrium.

Theory Schedule

S. N.	Topic	No. of lectures
1	History and role of genetics in crop improvement,	1
2	Polyploidy, mutation, genetic diversity in PGR	2
3	Genetic principles of diversity and its distribution.	2
4	Evolution of crop plants through ploidy manipulation	1
5	Cytology-euploidy, haploid, diploid, polyploids, chimeras, role of polyploids in crop breeding,	2
6	evolutionary advantages of auto polyploids vs allopolyploids	1
7	Role of aneuploids in basic and applied aspects of crop breeding	3
8	Apomixis, haploids and their uses, modes of reproduction, male sterility, CMS, heterosis and hybrid development	3
9	Methods of studying polymorphis	2
10	Overview of molecular marker applications and recent advances	2
11	Genetics of mitochondria and chloroplast, extra chromosomal inheritance	2
12	Eugenics, epigenetics, basics of genome structure and organization	2
13	Generation of molecular markers-RFLP, PCR, sequencing; principles, merits and demerits of RAPD, ISSR, SSR, SCAR, SCOT, SRAP, AFLP, SNP.	3
14	Population-Mendelian Population, random mating population.	3
15	Frequencies of genes and genotypes, causes of change,	2
16	Hardy-Weinberg equilibrium	1
	Total	**32**

Suggested Reading

Griffin HG and Griffin AM. 1994. PCR Technology: Current Innovations. CRC Press, London.

Hancock JF. 2004. Plant Evolution and Origin of crop species, 2nd edition. CABI.

Henry RJ (Editor). 2001. Plant Genotyping: The DNA Fingerprinting of Plants. Publisher: CABI Publishing.

Karp A, Isaac PG and Ingram DS. 1998. Molecular Tools for Screening Biodiversity – Plants and Animals. Chapman and Hall, London.

Miller AJ. 2007. Crop Plants: Evolution. John Wiley and Sons.

PGR -511 : Principles of Plant Breeding for PGR Management 2 (1+1)

Objective

To impart theoretical knowledge and practical skills about plant breeding objectives in PGR management especially for germplasm maintenance, regeneration and pre-breeding.

Theory

Unit I

Objectives of plant breeding genetic basis of breeding self and cross pollinated crops, nature of variability, components of variation, genotype-environment interaction, general and specific combining ability, self-incompatibility and male sterility in crop plant and their commercial exploitation.

Unit II

Principles of breeding for biotic and abiotic stresses, Breeding self-pollinated and cross pollinated crops, pureline theory; pureline selection and line breeding, pedigree, bulk, backcross, single seed descent and multiline method. Breeding methods in asexually/clonally propagated crops, clonal selection. Concept of plant ideotype and its role in crop improvement. Participatory Plant Breeding, Plant breeders' rights and regulations for plant variety protection and farmers rights, DUS testing.

Unit III

Molecular breeding-molecular markers, fundamental concepts in the development of molecular markers, types (isozymes, RFLP, RAPD AFLP), mapping populations RILs, NILs, DH, Backcross), their merits and demerits, markers assisted selection, linkage disequilibrium and the concept tomarker-traitassociation-casestudies,markerassistedpre-breedingprogrammes.

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 infield crops.

Theory Schedule

S. N.	Topic	No. of lectures
1	Objectives of plant breeding genetic basis of breeding self- and cross-pollinated crops,	1
2	Nature of variability, components of variation, genotype- environment interaction,	1
3	General and specific combining ability,	1
4	Self-incompatibility and male sterility in crop plant and their commercial exploitation.	1
5	Principles of breeding for biotic and abiotic stresses,.	1
6	Breeding self-pollinated and cross pollinated crops, pureline theory; pureline selection	1
7	Line breeding, pedigree, bulk, backcross, single seed descent and	2

	multiline method.	
8	Breeding methods in sexually /clonally propagated crops, clonal selection.	2
9	Concept of plant ideotype and its role in crop improvement.	1
10	Participatory Plant Breeding, Plant breeders' rights and regulations for plant variety protection and farmers rights, DUS testing	1
11	Molecular breeding-molecular markers, fundamental concepts in the development of molecular markers, types (isozymes, RFLP, RAPD AFLP),	2
12	Mapping populations RILs, NILs, DH, Backross),their merits and demerits,.	1
13	Markers assisted selection, linkage disequilibrium and the concept to marker-trait association-case studies, marker assisted pre-breeding programmes	1
	Total	**16**

Practical Schedule

S. N.	Topic	No. of Practicles
1	Floral biology in self and cross pollinated species, selfing and crossing techniques	4
2	Selection methods in segregating populations and evaluation of breeding material. Analysis of variance (ANOVA)	4
3	Estimation of heritability and genetic advance, maintenance of experimental records;	4
4	Learning techniques in hybrid seed production using male-sterility infield crops	4
	Total	**16**

Suggested Reading

AllardRW.1981.*PrinciplesofPlantBreeding*.JohnWiley&Sons.ChopraVL.2001.*BreedingField Crops*.Oxford&IBH.

ChopraVL.. *Plan tBreeding*. Oxford & IBH.

PoehlmanJMandBorthakurDN.1972*BreedingAsianFieldCrops*.Oxford&IBH.

RoyD.2003.PlantBreeding,AnalysisandExploitationofVariation.NarosaPubl.House.SharmaJR.2001.PrinciplesandPracticeofPlantBreeding.TataMcGraw-Hill.

SimmondsNW.1990.*PrinciplesofCropImprovement*.EnglishLanguageBookSocietySingh BD.2006*PlantBreeding*.KalyaniPublishers,NewDelhi.

PGR -512 : Concept in Conservation Genetics 2 (1+1)

Objective

Conservation genetics focuses on processes within small and fragmented populations and on practical approaches to minimize deleterious effects on them. This course will introduce students to the relatively young discipline of conservation genetics with the basic understanding on genetic and epigenetic principles. Emphasis will be placed on general principles rather than specific experimental procedure. A Basic knowledge of Mendelian genetics and simple statistics is a prerequisite for registering this course.

Theory

Unit I

Genetic material, cell division, chromosomes, nucleic acids, biological significanceofDNA,MendelianprinciplesIandII,calculationofgeneticratios, Chi Square method, dominance, Gene Interaction, multiple alleles, sex determination, extranuclear inheritance, quantitative inheritance, linkage and recombination, genetic map, environmental effects – external and internal, phenol copies, concordance, discordance, epigenetics, environmental epigenetics, DNA methylation, dification, gene environment sepigene environment, epigenetic inheritance.

Unit II

Modern Synthesis Theory – Endangered and extinct species – causes of extinctions–Structure and content of conservation genetics–genetics and extinction–Limitations ofGenetics in Conservation Biology.

Unit III

Hardy Weinberg Principle, proportions – deviations from Hardy Weinberg equilibrium, Inbreeding – Assortative and dissassortive mating, extensions of Hardy –Weinberg equilibrium, evolutions in large population, natural selection and adaptation, directional, stabilizing and disruptive selection, mutation, migration and their interaction, evolution in small population, genetic drift, in breeding ,inbreeding depression, outbreeding, outbreeding depression, population fragmentation, geneflow.

Unit IV

Genetically viable populations, reproductive fitness, population viability analysis, recovery of endangered species/ threatened population, legal issues related to endangered species and their protection, minimum viable population, recovery of endangered species, legal issues related to endangered species and their protection.

Practical

- Deriving Hardy Weinberg equilibrium, problems on Hardy Weinberg equilibrium, calculation of gene frequencies, autosomal loci with two alleles, estimation of gene frequencies, auto somalloci with multiple alleles, estimation of gene frequencies;
- Sex linked loci, estimation of inbreeding co-efficient – problems in epigenetics, genetic variability of threatened populations, hybridization and introgression analysis;
- Plant forensics, storage of plant genetic samples for time-series analyses.

Lecture Schedule

Theory

S. N.	Topic	No. of lectures
1	Genetic material, cell division, chromosomes ,nucleic acids, biological significance of DNA,	2
2	Mendelian principles I and II, calculation of genetic ratios, Chi Square method, dominance,	1

3	Gene Interaction, multiple alleles, sex determination, extra nuclear inheritance,	1
4	Quantitative inheritance, linkage and recombination, genetic map,	1
5	Environmental effects – external and internal, phenol copies, concordance, discordance, epigenetics, environmental epigenetics,	1
6	DNA methylation, dification, gene environment vs epi gene environment, epigenetic inheritance.	1
7	Modern Synthesis Theory – Endangered and extinct species – causes of extinctions–Structure and content of conservation genetics–genetics and extinction–	1
8	Genetic versus demographic and environmental factors in conservation biology Limitations of Genetics in Conservation Biology.	1
9	Hardy Weinberg Principle, proportions – deviations from Hardy Weinberg equilibrium.	1
10	Inbreeding – Assortative and dissassortive mating, extensions of Hardy –Weinberg equilibrium,	1
11	Evolutions in large population, natural selection and adaptation, directional, stabilizing and disruptive selection, mutation, migration and their interaction	1
12	Evolution in small population, genetic drift, inbreeding, inbreeding depression, outbreeding, outbreeding depression, population fragmentation, gene flow.	1
13	Genetically viable populations, reproductive fitness, population viability analysis,	1
14	Recovery of endangered species/ threatened population, legal issues related to endangered species and their protection, minimum viable population	1
15	Recovery of end angered species, legal issues related to endangered species and their protection.	1
	Total	**16**

Practical Schedule

S. N.	Topic	No. of Practicals
1	Deriving Hardy Weinberg equilibrium, problems on Hardy Weinberg equilibrium,	3
2	Calculation of gene frequencies, autosomal loci with two alleles, estimation of gene frequencies, autosomal loci with multiple alleles, estimation of gene frequencies.	3
3	Sex linked loci, estimation of inbreeding co-efficient – problems in epigenetics,	3
4	Genetic variability of threatened populations.	2
5	Hybridization and introgression analysis.	3
6	Plant forensics, storage of plant genetic samples fort time-series	2

	analyses.	
	Total	**16**

- **Suggested Reading**

Allendorf.FW.2007 .*Conservation and the genetics of populations*. Blackwell Publishing Ltd, Australia.

Frankham R, Ballou J D and Briscoe D A. 2004.Aprimer *of Conservation Genetics*. Cambridge University Press

Frankham R, Ballou J D and Briscoe D A.2009.*An Introduction to Conservation Genetics*, 2nd edition. 2009. Cambridge University Press: Cambridge, UK.

Höglund J.2009. *Evolutionary Conservation Genetics*. Oxford University Press, USA.

Strickberger M W.1996.*Genetics*, *Prentice Hall of India* Pvt Limited.

Tollefsbol T. 2017. *Hand book of Epigenetics*, Elsevier.

e-Resources

http://www.scu.edu.au/research/cpcg/http://genetics.for
estry.ubc.ca/cfcg/

Ph.D. Agriculture (Plant Genetic Resources)

Course Contents

PGR- 601*Recent advances in Germplasm Conservation 1+1

Objective
To provide knowledge on advances in seed physiology, biology and banking to lead to retention of high seed quality during conservation and all aspects of conservation science and technology.

Theory

Unit I

Seed development and maturation; Seed storage behavior: physiological and molecular basis of desiccation sensitivity; Dormancy, seed germination- mobilization of reserves and their control processes; Viability and vigour-principle and testing procedures; Seed testing for inadvertent introduction of transgenes.

Unit II

Seed storage for long-term conservation and factors affecting seed longevity; seed processing for short, medium and long-term storage, artificial aging and controlled deterioration test; ultra-desiccation techniques for germplasm conservation, richness index, ecological correlates of ex-situ seed longevity, permafrost conservation, maintenance of Seed Gene bank, status of global seed gene banks.

Unit III

In-vitro techniques in PGR management, In-vitro methods of clonal propagation, In-vitro collecting and germplasm exchange, Meristem culture and virus elimination, somaclonal variation, application of somatic embryogenesis in PGR, Methods of in-vitro conservation- short, medium-term and long term, Concept of active and base in-vitro gene bank, Status of World cryo- and cryo-gene banks, embryo rescue technique, history and principles of cryopreservation, cryo protectants-role and applicability, freezing injury and factors affecting cryoprotection, methods of cryopreservation-conventional and vitrification based techniques, varied application of cryopreservation, handling difficult-to store non orthodox seeds, embryonic axes, pollen and dormant buds, Management of in-vitro, cryo and DNA gene bank- Practical considerations, Monitoring genetic stability of in-vitro conserved and cryopreserve edgermplasm, database management for in-vitro and cryopreserved germplasm

Practical

• Seed morphology and structure;

• Desiccation rates and freezing to low and ultra-low temperatures, seed storage behavior determination in sample seeds, seed viability and vigour tests;

• Seed longevity and accelerated ageing test in different types of seeds, handling hard seededness and physiological immaturity;

• Post harvest handling methods of difficult-to-store seeds, dormant buds, and pollen, ultra-desiccation of seeds, biochemical tests of seed deterioration;

• Preparation of stock solutions, culture media, cryoprotectant solutions and Re growth media,

- Isolation of explants and in vitro culturing in growth retarding media for slow growth conservation, meristem isolation in dicots and monocots;

• Pretreatments, preculturing, cryoprotectant treatments varying temperature and durations, cold hardening- plants and explants, cryopreservation techniques encapsulation-dehydration, vitrification, encapsulation-vitrificaion, droplet freezing,

thawing- slow and fast, recovery and regrowth- media, light conditions;

• In vitro-cryo-gene banking and database management, morphological and molecular markers for assessing genetic stability-demonstration.

Theory Schedule

S. N.	Topics	No. of Lectures
UNIT I		
1	Seed development and maturation.	1
2	Seed storage behaviour: physiological and molecular basis of desiccation sensitivity; Dormancy.	1
3	Seed germination- mobilization of reserves and their control processes.	1
4	Viability and vigour-principle and testing procedures.	1
5	Seed testing for inadvertent introduction of transgenes.	1
UNIT II		
6	Seed storage for long-term conservation and factors affecting seed longevity; seed processing for short, medium and long-term storage.	1
7	Artificial aging and controlled deterioration test; ultra-desiccation techniques for germplasm conservation, richness index, ecological correlates of ex-situ seed longevity, permafrost conservation,	1
8	Maintenance of Seed Genebank, status of global seed gene banks.	1
UNIT III		
9	In-vitro techniques in PGR management, In-vitro methods of clonal propagation, In-vitro collecting and germplasm exchange.	1
10	Meristem culture and virus elimination, somaclonal variation, application of somatic embryogenesis in PGR.	1
11	Methods of in-vitro conservation- short, medium-term and long term, Concept of active and base in-vitro gene bank.	1
12	Status of World cryo- and cryo-gene banks.	1
13	Embryo rescue technique, history and principles of cryopreservation, cryo protectants-role and applicability, freezing injury and factors affecting cryoprotection, methods of cryopreservation-conventional and vitrification based techniques, varied application of cryopreservation.	1
14	Handling difficult-to store non orthodox seeds, embryonic axes, pollen and dormant buds, Management of in-vitro, cryo and DNA gene bank-Practical considerations.	1
15	Monitoring genetic stability of in-vitro conserved and cryopreserve edgermplasm.	1

16	Database management for in-vitro and cryopreserved germplasm.	1
	Total	**16**

Practical Schedule

S.N.	Topics	No of Practicals
1	Seed morphology and structure.	2
2	Desiccation rates and freezing to low and ultra-low temperatures, seed storage behaviour determination in sample seeds, seed viability and vigour tests.	2
3	Seed longevity and accelerated ageing test in different types of seeds, handling hard seededness and physiological immaturity;	2
4	Post-harvest handling methods of difficult-to-store seeds, dormant buds, andpollen, ultra-desiccation of seeds, biochemical tests of seed deterioration.	2
5	Preparation of stock solutions, culture media, cryoprotectant solutions and regrowth media, isolation of explants and in vitro culturing in growth retarding media for slow growth conservation, meristem isolation in dicots and monocots.	2
6	Pre-treatments, preculturing, cryoprotectant treatments varying temperature and durations, cold hardening- plants and explants, cryopreservation techniques encapsulation-dehydration, vitrification, encapsulation-vitrification, droplet freezing, thawing- slow and fast, recovery and regrowth- media, light conditions.	4
7	In vitro-cryo-gene banking and database management, morphological and molecular markers for assessing genetic stability-demonstration.	2
	Total	**16**

Suggested Reading

Barbara MR, Chin HF and Normah MN. 2013. Conservation of Tropical Plant Species. Springer.

Bewley JD and Black M. 1994.*Seeds Physiology of Development and Germination*, Second Edition. Plenum Press, New York and London.

Chaudhury R and Malik SK. 2017.*Cryopreservation of Plant Species*: *Practical Approaches from Handling to Cryobanking*. ICAR-NBPGR, New Delhi.52 p.

Chaudhury R, Pandey R, Malik SK, Bhag Mal (eds). 2003. *In vitro* Conservation and Cryopreservation of Tropical Fruit Species. IPGRI Office for South Asia, New Delhi, India/NBPGR, New Delhi, India, 293 pp.

Cromarty A. 1984. Techniques of drying seeds, pp 88-125.*Seed Management Techniques for Genebank* (JB Dicke, S Linington and JT Williams, eds). International Board on Plant Genetic Resources, Rome.

Cromarty A, Ellis RH and Robert EH. 1982. *The Design of Seed Storage Facilities for Genetic Conservation*, Revised 1985. International Board on Plant Genetic Resources, Rome.

Ellis RH, Hong TD and Roberts EH.1985a. Handbook of Seed Technology for Genebank Volume II. Principles and Methodology. International Board for Plant Genetic Resources, Rome.

Ellis RH, Hong TD and Roberts EH. 1985b. Handbook of Seed Technology for Genebank Compendium of Specific Germination Information and Test Recommendations.
International Board for Plant Genetic Resources, Rome.

Ellis RH. 1988. The viability equation, seed viability monographs, and practical advice on seed storage. *Seed Science and Technology* 16: 29-50.

Hong TD and Ellis RH. 1996. A protocol to determine seed storage behaviour. International Plant Genetic Resources Institute IPGRI Technical Bulletin No1, Rome.

Mandal BB, Chaudhury R, Engelmann F, Bhag Mal, Tao KL and Dhillon BS (editors). 2003.Conservation Biotechnology of Plant Germplasm. NBPGR, New Delhi, India/ IPGRI, Rome, Italy, 293 pp.

Reed BM. 2008. Cryopreservation—Practical Considerations. In: Reed B.M. (eds) Plant Cryopreservation: A Practical Guide. Springer, New York, NY
Roberts EH. 1972. *Viability of Seeds.* Chapman and Hall, London.

PGR- 602* Phenomics and Genomics for PGR Utilization 1+1

Objective
To impart theoretical and practical knowledge on recent advances in crop germplasm evaluation and use. To teach current advances in genomic technologies in use for breeding, phylogenetic analyses, understanding genetic value, facilitating germplasm selection in genebanks, and develop practical skills in phenotyping and genotyping.

Theory

Unit I

Advances in phenotyping to overcome limitations in use of germplasm collections; advanced methodology of germplasm evaluation and predictive methods for identification of useful germplasm, phenomics facility, quantitative imaging techniques using remote sensing. Experimental designs, analyses of evaluation data and database management.

Unit II

Evaluation of crop germplasm for agronomic traits: Evaluation against biotic/ abiotic stresses; quality attributes and other value addition traits. Management and

utilization of crop germplasm, germplasm registration, Core and mini core collections; Germplasm enhancement/ pre-breeding and use of wild relatives in crop improvement, embryo rescue method, pollen physiology and storage, integration of big data into breeding programs, harmonising agro-biodiversity conservation and agricultural development, New crops of the future, biofortified crops.

Unit III

Uses and applications of molecular markers in PGR – analysis of genetic diversity, identification of gaps in collection, molecular cytology, Establishment of core and mini-core collections using molecular markers, Identification of desirable genes and alleles, germplasm characterization, trait mapping, genome sequencing, High throughput genotyping – GBS, association mapping studies: GWAS, molecular tagging of QTLs, FIGS.

Practical

- Management and utilization of crop germplasm: Exercise for developing core set;
- Validation using molecular markers;
- Evaluation of crop germplasm for value addition;
- Evaluation of crop germplasm against biotic/ abiotic stresses;
- Evaluation of germplasm for quality traits;
- Biochemical/ Molecular characterisation of germplasm.

Theory Schedule

S. N.	Topics	No. of Lectures
UNIT I		
1	Advances in phenotyping to overcome limitations in use of germplasm collections.	1
2	Advanced methodology of germplasm evaluation and predictive methods for identification of useful germplasm.	1
3	Phenomics facility, quantitative imaging techniques using remote sensing.	1
4	Experimental designs, analyses of evaluation data and database management.	1
UNIT II		
5	Evaluation of crop germplasm for agronomic traits: Evaluation against biotic/ abiotic stresses; quality attributes and other value addition traits.	1
6	Management and utilization of crop germplasm, germplasm registration.	1
7	Core and mini core collections.	1
8	Germplasm enhancement/ pre-breeding and use of wild relatives in crop improvement.	1
9	Embryo rescue method, pollen physiology and storage, integration of big data into breeding programs.	1

10	Harmonising agro-biodiversity conservation and agricultural development.	1
11	New crops of the future, biofortified crops.	1
UNIT III		
12	Uses and applications of molecular markers in PGR – analysis of genetic diversity ,identification of gaps in collection, molecular cytology.	1
13	Establishment of core and mini-core collections using molecular markers.	1
14	Identification of desirable genes and alleles, germplasm characterisation, trait mapping, genome sequencing.	1
15	High throughput genotyping – GBS, association mapping studies.	1
16	GWAS, molecular tagging of QTLs, FIGS.	1
	Total	**16**

Practical Schedule

S. N.	**Topics**	**No. of Practicals**
1	Management and utilization of crop germplasm.	2
2	Exercise for developing core set.	2
3	Validation using molecular markers.	2
4	Evaluation of crop germplasm for value addition	3
5	Evaluation of crop germplasm against biotic/ abiotic stresses.	3
6	Evaluation of germplasm for quality traits.	2
7	Biochemical/ Molecular characterisation of germplasm.	2
	Total	**16**

Suggested Reading

Brown AHD, Clegg MT, Kahler AL and Weir BS (eds.). 1990. *Plant population genetics, breeding ,and genetic resources*, Sinauer Associates, USA.

Brown AHD, Frankel OH, Marshall DR and Williams JT. 1989. *The use of plant genetic resources*. Cambridge University Press.

Frankel OH and Hawks JG. 1975. *Crop genetic resources for today and tomorrow*. Cambridge University Press.

Frankel OH and Michaele ES. 1987. *Conservation and evolution*. Cambridge University Press.

Frankel R and Galun E. 1977.*Pollination mechanisms, reproduction and plant breeding*. Genetic Data Analysis II: methods for Discrete Population Genetic Data. Sinauer Associates, Massachusetts, USA.

Griffin HG and Griffin AM. 1994. PCR *Technology: Current Innovations*. CRC Press, London.

Harlan JR. 1992. *Crops and Man* (Second Edition). American Society of Agronomy Inc., Crop Science Society of America Inc., Madison, Wisconsin, USA.

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

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

Hillis, D and Moritz C. 1990.Molecular Systematics. Sinauer Associates, USA.

IPGRI. 1997. Regeneration of accessions in seed collections: a decision guide: Handbook forgene banks No. 5. Karp A, Isaac PG and Ingram DS. 1998. *Molecular Tools for Screening Biodiversity – Plants and Animals*. Chapman and Hall, London.

Lynch M and Walsh B. 1998. *Genetics and analysis of quantitative traits*. Sinauer Associates, Massachusetts, USA.

Peterson WW, Marie-Noelle N and Robert JH. 2018. Role of genomics in promoting the utilization of plant genetic resources in genebanks. *Briefings in Functional Genomics* 17(3): 198–206.

Stoskopf NC. 1993. *Plant Breeding: theory and practice*. Westview Press.

Tanksley SD and OrtonTJ. 1983. *Isozymes in Plant Genetics and Breeding*, Part A and B. Elsevier SciencePublication, Amsterdam.

Varshney RK, Mahendar T, Aggarwal RK, et al. 2007. Genic Molecular Markers in Plants: Development and Applications. In: Varshney RK, Tuberosa R. (eds). *Genomics-Assisted Crop Improvement*. Dordrecht: Springer Netherlands, 13–29.

PGR- 603* Economic Botany and Regulatory Mechanisms 1+1

Objective

To apprise students about economic uses of plants including in fields such as Ethnopharmacology as well as potential/ new commercial crops.

Theory

Unit I

Structure, development and chemical constituents of plant parts- cereals, pulses and oilseeds, vegetables, fruits, nuts.

Unit II
Origin, history, evolution, domestication, botany, genetic resources activities, cultivation, production and utilization of various crops- cereals, pulses and oilseeds, vegetables, fruits, nuts, ornamental plants, underutilized plants.
Unit III
Economic uses and commercial importance of crop plants- cereals, pulses and oilseeds, vegetables, fruits, nuts, ornamental plants, underutilized plants, fodder and forage crops. Current topics on potential crops, biofortified crops, lost and neglected crops, revival of lesser known crops, the marketing of potential crops.
Unit IV
Importance of plants with respect to society and environment- Social and religious significance of plants in environmental amelioration. Case studies of massive economic gains due to use of lesser known crops/ genes in history of agriculture.

Practical
• Structure, development and chemical constituents of plant parts-cereals;
• Structure, development and chemical constituents of plant parts-pulses and oilseeds;
• Structure, development and chemical constituents of plant parts-vegetables, fruits, nuts;
• Structure, development and chemical constituents of plant parts-ornamental plants, underutilized plants.

Theory Schedule

S. N.	Topics	No. of Lectures
UNIT I		
1	Structure, development and chemical constituents of plant parts-cereals, pulses and oilseeds, vegetables, fruits, nuts.	2
UNIT II		
2	Origin, history, evolution, domestication, botany, genetic resources activities, cultivation.	2
3	Production and utilization of various crops- cereals, pulses and oilseeds, vegetables, fruits, nuts, ornamental plants, underutilized plants.	3
UNIT III		
4	Economic uses and commercial importance of crop plants- cereals, pulses and oilseeds, vegetables, fruits, nuts, ornamental plants, underutilized plants, fodder and forage crops.	3
5	Current topics on potential crops, biofortified crops, lost and neglected crops, revival of lesser known crops, the marketing of potential crops.	2
UNIT IV		
6	Importance of plants with respect to society and environment- Social and religious significance of plants in environmental amelioration.	2
7	Case studies of massive economic gains due to use of lesser known crops/ genes in history of agriculture.	2
	Total	**16**

Practical Schedule

S. N.	Topics	No. of Practicals
1	Structure, development and chemical constituents of plant parts-cereals.	4
2	Structure, development and chemical constituents of plant parts-pulses and oilseeds.	4
3	Structure, development and chemical constituents of plant parts-vegetables, fruits, nuts.	4
4	Structure, development and chemical constituents of plant parts-ornamental plants, underutilized plants.	4
	Total	**16**

Suggested Reading

Beryl Brintnall Simpson. 2013. *Plants in Our World: Economic Botany*. McGraw-Hill Education, 2014, New York, NY.

Beryl Brintnall Simpson, Molly Ogorzaly, Simpson Beryl. 2001. Economic Botany: Plants in Our World. Mcgraw-Hill Science/ engineering/ math.

Brown AHD, Frankel OH, Marshall DR and Williams JT. 1989. *The use of plant genetic resources*, Cambridge University Press

Burkill IH 1951-52 Habits of man and the origins of the cultivated plants of the old World. *Proceeding Linnean Society of London*, 164: 12-42.

Commercial products of India. Watt, Sir George.
Economic Botany. By Hill, Albert R

Frankel OH and Hawks JG. 1975. *Crop genetic resources for Today and Tomorrow*. Cambridge University Press.

George Watt (2014) Dictionary of Economic Products of India. Cambridge University Press.
Wealth of India CSIR

Hanelt P. 2001. Institute of Plant and Genetics and Crop Plant Research (eds) Mansfeld's *encyclopedia of agricultural and horticultural crops*, vol 3. Springer, Berlin.

Harlan JR. 1992. *Crops and Man* (Second Edition). American Society of Agronomy Inc., Crop Science Society of America Inc., Madison, Wisconsin, USA

Hill Albert F. 1952. *Economic Botany: A Textbook of Useful Plants and Plant Products*, Second Edition. New York Toronto London McGraw-Hill Book Company, Inc.

Kochhar SL. 2012. *Economic Botany in the Tropics, Paperback*, Fourth edition. Laxmi Publications.

Maiti RK and Singh VP. 2006. *An Introduction to Modern Economic Botany*. Eastern Book Corporation, Delhi.

Mehra KL and Arora RK. 1982. *Plant genetic resources of India*: *their diversity and conservation*. NBPGR, New Delhi.

Morton JF 1987. *Fruits of warm climates Creative Resource* Systems. Inc. N.C., Miami, FL.

Paroda RS and Arora RK (eds.). 1991. *Plant genetic resources: conservation and management.* NBPGR, New Delhi

Purseglove W. 1981.*Tropical Crops. Dicotyledons*. The English Language Book Society and Longman.

Purseglove W. 1981.*Tropical Crops. Monocotyledons*. The English Language Book Society and Longman.

Sturtevant's notes on edible plants. Hedrick UP.

Swaminathan MS and Jana S (eds.). 1992. *Biodiversity: implication for global food security*. Mc Millan Press.

PGR- 604 PGR Policies and Regulatory Mechanisms 1+0

Objective
To educate students about concepts and instruments of intellectual property rights, plant breeder's rights, farmer's rights, access and benefit sharing, international treaties and national legislation related to plant genetic resources.

Theory
Unit I
Concept of intellectual property, need for IP protection, Dimensions and nature of IPR, conflicting community interest with private right. Forms of IPR, patents, copyright, trademark, design, trade secret/ confidential information, GI registration. Process of obtaining an IPR, World Intellectual Property Organization, Patent Cooperation Treaty (PCT)
Unit II
Plant breeder's rights, protection of plant varieties, UPOV; registration of plant varieties and essentially derived varieties, duration and effect of registration; traditional knowledge systems, farmer's rights, folklore, code of conduct, access and benefit sharing; compulsory license; plant varieties protection appellate tribunal.
Unit III
International instruments concerning agro-biodiversity, Convention on Biological Diversity (CBD), FAO and global system of PGR, the International Treaty on Plant Genetic Resources for food and agriculture (ITPGR), Global Plan of Action, TRIPS agreement and IPR protection of life

forms, geographical appellations. Patent Information Search, Patent Drafting, Opinion on Patentability, Patent Infringement.

Unit IV

Multilateral agreement on trade in goods – relevance to agriculture, Agreement on Agriculture (AOA); agreement on application of sanitary and phytosanitary measures (SPS), international plant protection convention, agreement on Technical Barriers to Trade (TBT). Plant quarantine, biosafety related issues.

Unit V

National legislations related to biodiversity conservation and IPR protection.

Theory Schedule

S. N.	Topics	No. of Lectures
UNIT I		
1	Concept of intellectual property, need for IP protection, dimensions and nature of IPR, conflicting community interest with private right.	2
2	Forms of IPR, patents, copyright, trademark, design, trade secret/ confidential information, GI registration. Process of obtaining an IPR.	2
3	World Intellectual Property Organization, Patent Cooperation Treaty (PCT).	1
UNIT II		
4	Plant breeder's rights, protection of plant varieties, UPOV.	1
5	Registration of plant varieties and essentially derived varieties, duration and effect of registration; traditional knowledge systems, farmer's rights, folklore, code of conduct, access and benefit sharing; compulsory license; plant varieties protection appellate tribunal.	2
UNIT III		
6	International instruments concerning agro-biodiversity, Convention on Biological Diversity (CBD), FAO and global system of PGR.	1
7	The International Treaty on Plant Genetic Resources for food and agriculture (ITPGR), Global Plan of Action, TRIPS agreement and IPR protection of life forms, geographical appellations.	1
8	Patent Information Search, Patent Drafting, Opinion on Patentability, Patent Infringement.	1
UNIT IV		
9	Multilateral agreement on trade in goods – relevance to agriculture, Agreement on Agriculture (AOA); agreement on application of sanitary and phytosanitary measures (SPS).	1
10	International plant protection convention, agreement on Technical Barriers to Trade (TBT).	1
11	Plant quarantine, biosafety related issues.	1

UNIT V		
12	National legislations related to biodiversity conservation and IPR protection.	2
	Total	**16**

Suggested Reading

Anonymous. *Providing Protection For Plant Genetic Resources*: *Patents, Sui Generis Systems and Bio partnerships*. Kluwer Academic Press, ISBN: 9041188754; Distributer: Landmark Ltd.

Kate KT and Laird SA. 1999. *The Commercial Use of Biodiversity: Access to Genetic Resources and Benefit Sharing*. Earthscan, London.

Michael M. et al. 2005. *Valuation and Conservation of Biodiversity: Interdisciplinary Perspectives on the Convention on Biological Diversity*. Springer.
Srivastava SK. 2016. *Commercial Use of Biodiversity: Resolving the Access and Benefit Sharing Issues*. SAGE Publications, India, Pvt. Ltd.

e-resources

http://www.icar.org.in/files/reports/other-reports/icar-ipmttcguide.pdf
http://www.wto.org
http://www.geographicindications.com
http://www.cbd.int www.patentoffice.nic.in
http://www.uspto.gov
http://www.wipo.int
http://www.nif.org.in
http://www.fao.org/Legal/treaties/Treaty-e.htm
http://www.plantauthority.gov.in
http://www.nbaindia.org

PGR- 605 Molecular Population Genetics in PGR Management 2+1

Objective

Students would be provided insights into organization and structure of genetic variation in plant populations and practical skills in molecular diversity analyses.

Theory

Unit I

The genetic structure of populations – Genetic transmission in populations, the Hardy-Weinberg principle and estimating allele frequencies, testing of departures from Hardy-Weinberg proportions, inbreeding and self-fertilization, analyzing the genetic structure of populations: Bayesian F-statistics, Nei's Gst, Weir &Cockerham's, the Wahlund Effect and Wright's F-statistics.

Unit II

Natural selection, genetic drift, mutations – The genetics of natural selection, estimating viability, Selection at one locus with many alleles, fertility selection and sexual selection, Selection component analysis, genetic drift- mutation, migration and genetic drift, selection and genetic drift; the coalescent.

Unit III

Quantitative genetics – introduction to quantitative genetics, resemblance among relatives, partitioning variance, evolution of quantitative traits, simultaneous evolution of several quantitative traits, mapping quantitative trait loci, introduction to linkage disequilibrium and association analysis.

Unit IV

Molecular evolution – introduction to molecular population genetics, the neutral theory of molecular evolution, patterns of nucleotide and amino acid substitutions, detecting selection on nucleotide polymorphisms; patterns of selection on nucleotide polymorphisms, Tajima's D, Fay's and Wu's H, and Zeng et.al's E, introduction to population genomics and challenges.

Unit V

Evolution in multigene families, phylo-geography, analysis of molecular variance (AMOVA), nested clade analysis, basics of cladistic analysis.

Practical

- Calculating gene and genotypic frequencies;
- Testing of HWE;
- Estimation of allele frequencies under forces of selection, mutation and migration;
- Calculation of inbreeding coefficient;
- Estimation of linkage disequilibrium;
- Quantifying genetic variation at the molecular level, analysis of molecular variance;
- Hypothesis testing in molecular evolution, estimation of evolutionary parameters.

Theory Schedule

S. N.	Topics	No. of Lectures
UNIT I		
1	The genetic structure of populations – Genetic transmission in populations.	2
2	The Hardy-Weinberg principle and estimating allele frequencies, testing of departures from Hardy-Weinberg proportions.	2
3	Inbreeding and self-fertilization, analyzing the genetic structure of populations.	2
4	Bayesian F-statistics, Nei's Gst, Weir &Cockerham's, the Wahlund Effect and Wright's F-statistics.	2
UNIT II		
5	Natural selection, genetic drift, mutations – The genetics of natural selection, estimating viability.	3
6	Selection at one locus with many alleles, fertility selection and sexual selection, Selection component analysis.	2
7	Genetic drift- mutation, migration and genetic drift, selection and genetic drift; the coalescent.	3
UNIT III		
8	Quantitative genetics – introduction to quantitative genetics, resemblance among relatives, partitioning variance.	3

9	Evolution of quantitative traits, simultaneous evolution of several quantitative trait.	1
10	Mapping quantitative trait loci, introduction to linkage disequilibrium and association analysis.	1
UNIT IV		
11	Molecular evolution – introduction to molecular population genetics, the neutral theory of molecular evolution.	2
12	Patterns of nucleotide and amino acid substitutions, detecting selection on nucleotide polymorphisms.	2
13	Patterns of selection on nucleotide polymorphisms.	1
14	Tajima's D, Fay's and Wu's H, and Zeng et al's E, introduction to population genomics and challenges.	2
UNIT V		
15	Evolution in multigene families, phylo-geography.	1
16	Analysis of molecular variance (AMOVA).	1
17	Nested clade analysis, basics of cladistic analysis.	2
	Total	**32**

Practical Schedule

S. N.	Topics	No. of Practicals
1	Calculating gene and genotypic frequencies.	2
2	Testing of HWE.	2
3	Estimation of allele frequencies under forces of selection, mutation and migration.	2
4	Calculation of inbreeding coefficient.	2
5	Estimation of linkage disequilibrium.	2
6	Quantifying genetic variation at the molecular level, analysis of molecular variance.	2
7	Hypothesis testing in molecular evolution.	2
8	Estimation of evolutionary parameters.	2
	Total	**16**

Suggested Reading

Cutter A D. 2019. A *Primer of Molecular Population Genetic*. Oxford University Press.
Hartl D L and Clark AG. 2006.*Principles of Population Genetics*, 4th Ed. Sinauer Associates, Sunderland, MA.
Matthew B. Hamilton. 2009. *Population Genetics*, 1st Ed. Wiley-Blackwell.
Matthew W. Hahn. 2018. *Molecular Population Genetics*, Oxford University Press.
Casillas S and Barbadilla A. 2017.*Molecular Population, Genetics 205*: 1003–1035.

PGR- 606 Plant Taxonomy, Eco geography and Ecology 1+1

Objective

To educate students about interdisciplinary scientific study of the distributions, abundance and relations of organisms and their interactions with the environment, and the study of ecosystems. To provide information on ecogeographic surveys, sampling strategies and legal issues involved in germplasm collecting. To teach taxonomic data bases and documentation systems.

Theory

Unit I

Origin and diversity of life, speciation, biosystematics, basic elements of plant ecology, ecological components, population ecology- populations and life history, growth and limits. Community ecology-species interactions, role of interactions and structure.

Unit II

Ecosystems-concept of ecosystems, ecological balance, vegetation dynamics, productivity and nutrient cycling. Conservation ecology, seed ecology, nature conservation and environmental management, ecosystem restoration, biogeography and evolution. Biodiversity functioning- genetic adaptations, population irruptions/crisis in nature, community change and ecosystem regulation. Biodiversity conservation-geographical patterns in biodiversity, habitat fragmentation and conservation areas. Biodiversity management and exploitation-biodiversity resources and their harvesting, impact of physical and biotic factors on sustainability-case studies, impact of biotic and climatic factors on biomes and biodiversity-pollution and over-exploitation.

Unit III

Genetic diversity of PGR, genetic principles of diversity and its distribution. Indicators of diversity, assessing the threats of genetic erosion; eco-geographic surveys: planning, collection and analysis of eco-geographic data, outputs of eco-geographic surveys.

Unit IV

Differentiation and evolution of species and biosystematics, Modern evidences: morphology and anatomy; embryology and palynology; Modern evidences: Biogeography and Cytotaxonomy; Modern evidences: Comparative studies on phytochemistry, Chemo-taxonomy; Molecular taxonomy; Hybrids, domesticated species, wild-cultivated continuum.

Unit V

Sampling strategies theory and practice, strategies for wilds species; Germplasm collecting: legal issues and the FAO code of conduct, participatory approaches to collecting including indigenous knowledge, Traditional knowledge systems. Taxonomic databases and documentation systems.

Practical

- Concepts and methods for computing biodiversity, Alpha and beta models, , calculation of species richness and endemism;
- Field visits to protected areas- biospheres /national parks, understanding various ecosystems;
- Geospatial analysis and use of GIS;
- Identification and learning the use of CWR so various families, survey of local biodiversity (field study), ecological status of various species (field study);
- Population and community patters- case studies on local flora;
- Identification of alien species and their impact assessment, study of protected areas,

restoration of threatened and native species, bioresources and their harvesting, classical and modern species concepts and biosystematics, morphology and anatomy;

- Comparative studies on phytochemistry, chemotaxonomy, floristic and monographic work;
- Practical methods for elucidating and proving hypotheses relating to plant speciation, Numerical taxonomy- practice and procedures; biosystematics studies and their role in improving plant taxonomies, intraspecific categories in relation to population biology, taxonomic databases, wild-cultivated continuum, problems and their resolution, newer methods of analysis and interpretation.

Theory Schedule

S. N.	Topics	No. of Lectures
UNIT I		
1	Origin and diversity of life, speciation, bio systematics. Basic elements of plant ecology, ecological components, population ecology- populations and life history, growth and limits.	1
2	Community ecology-species interactions, role of interactions and structure.	1
UNIT II		
3	Ecosystems-concept of ecosystems, ecological balance, vegetation dynamics, productivity and nutrient cycling.	1
4	Conservation ecology, seed ecology, nature conservation and environmental management, ecosystem restoration, bio geography and evolution.	1
5	Biodiversity functioning- genetic adaptations, population irruptions/crisis in nature, community change and ecosystem regulation.	1
6	Biodiversity conservation-geographical pattern sin biodiversity, habitat fragmentation and conservation areas.	1
7	Biodiversity management and exploitation-biodiversity resources and their harvesting, impact of physical and biotic factors on sustainability-case studies.	1
8	Impact of biotic and climatic factors on biomes and biodiversity-pollution and over-exploitation.	1
UNIT III		
9	Genetic diversity of PGR, genetic principles of diversity and its distribution. Indicators of diversity, assessing the threats of genetic erosion; eco-geographic surveys: planning, collection and analysis of eco-geographic data, outputs of eco-geographic surveys.	1
UNIT IV		
10	Differentiation and evolution of species and bio systematics. Modern evidences: morphology and anatomy; embryology and palynology	1
11	Modern evidences: Biogeography and Cytotaxonomy.	1

12	Modern evidences: Comparative studies on phyto chemistry, Chemo-taxonomy.	1
13	Molecular taxonomy; Hybrids, domesticated species, wild-cultivated continuum.	1
UNIT V		
14	Sampling strategies theory and practice, strategies for wilds species.	1
15	Germplasm collecting: legal issues and the FAO code of conduct, participatory approaches to collecting including indigenous knowledge.	1
16	Traditional knowledge systems. Taxonomic data bases and documentation systems.	1
	Total	**16**

Practical Schedule

S. N.	**Topics**	**No. of Practicals**
1	Concepts and methods for computing biodiversity, Alpha and beta models, calculation of species richness and endemism.	2
2	Field visits to protected areas-biospheres/national parks, understanding various ecosystems.	2
3	Geospatial analysis and use of GIS.	2
4	Identification and learning the use of CWR so various families, survey of local biodiversity (field study), ecological status of various species (field study).	2
5	Population and community patters-case studies on local flora.	1
6	Identification of alien species and their impact assessment, study of protected areas, restoration of threatened and native species, bio resources and their harvesting, classical and modern species concepts and biosystematics, morphology and anatomy.	2
7	Comparative studies on phyto chemistry, chemotaxonomy, floristic and mono graphic work.	1
8	Practical methods for elucidating and proving hypotheses relating to plants speciation.	2
9	Numerical taxonomy-practice and procedures; biosystematics studies and their role in improving plant taxonomies, infraspecific categories in relation to population biology, taxonomic databases, wild-cultivated continuum, problems and their resolution, newer methods of analysis and interpretation.	2
	Total	**16**

Suggested Reading

Ananthakrishanan.1989. *Bioresource ecology*, Oxford &IBH Pub. Co. (New Delhi).

Brummitt R K and Powell C E.1992. *Authors of Plant Names*. Royal Botanic Gardens, Kew, London, UK.732p.

Hermann R. 1980 .Ecology: A *textbook. Springer*.

Heywood V H. 1973. *Taxonomy and Ecology*. Academic Press London.

Hollingsworth P M, Bateman RM and Gornall RJ (eds.).1999. *Molecular Systematic and Plant Evolution*. Taylor and Francis, London and NewYork.485p.

Iriondo etal. 2008. *Conserving Plant Genetic Diversity in Protected Areas: Population management of* CWR. CAB International, Wallingford, UK.

Kumar HD. 1992.Modern concepts of ecology. Vikas Publishing Hous (New Delhi),

Meffe and Carroll 1997. *Principles of Conservation Biology*, 2nd edition. Publisher: Sinauer Associates.

Paroda RS and Arora RK (eds.)1991. *Plant genetic resources :conservation and management* .NBPGR, New Delhi.

Swaminathan MS and Jana S (eds.). 1992. *Biodiversity: implication for global food security*. McMillan Press.

Trehane P, Bricknell CD, Baum BR, Hetterscheid WLA, Leslie AC, McNeill J, Spongberg SA and Vrugtman F. 1995. *The International Code of Nomenclature for Cultivated PlantsRegnum*Veg.133.QuarterjackPublishing,Wimborne,UK.175p.

Vavilov NI 1887-1943. Origin and Geography of Cultivated Plants. English ed.: Translated byLove,D.1992.Camb.UniversityPress,Cambridge,UK.498p.

Watt G 1889-1896. *A Dictionary of Economic Products of India*.7vols., Repr. 1972. Calcutta, India.

Woodbury AM. 1954. *Principle of general ecology*. Blakiston, New York.

PGR- 607 In-situ on farm conservation 1+1

Objective

To impart knowledge about in-situ and/ On-farm conservation of crop diversity and type of information required for such an approach.

Theory

Unit I

Conservation strategies (in-situ, Ex-situ community conservation), In situ conservation of wild species in nature reserves, In situ conservation of crop diversity on-farm.

Unit II

Phytogeographic surveys and inventory, estimation of genetic diversity, population biology, concept of minimum viable population, population viability and population genetics theory, designation of gene management zones (GMZs)/ gene sanctuaries, management and monitoring of

GMZs, threat of genetic erosion, conservation agency priorities, biologically important species, National action plan for agrobiodiversity, Delhi Declaration on Agrobiodiversity.

Unit III

Social, cultural and economic factors influencing crop genetic diversity, Agroecosystem factors: natural and farmer-managed, agro morphological characters, farmer selection and maintenance, the genetics structure of crop landraces and the challenge to conserve them in situ on-farms, seed systems: formal vs informal.

Unit IV

Institutional frameworks for the implementation of on-farm conservation, identification of target crops, site selection, community sensitization, participatory plant breeding, sampling, structuring, documentation and presenting information for action plans, increasing crop genetic diversity's competitiveness for farmers, improvising the material and farmers 'access to genetic materials, increasing consumer demand, the role of policy, deciding on an appropriate initiative, evaluating benefit-enhancement options, role of Geographical Indications (GI) in agri-horticultural crops.

Practical

- Floristic surveys and inventory (wild species in nature reserves and crop species in traditional agro-ecosystems), questionnaire preparation;
- Visit to commercial units processing native crops, and to on farm fields and to community seed banks in villages;
- The genetic structure of crop landraces and the challenge to conserve them in situ on-farm at selected sites.

Theory Schedule

S. N.	Topics	No. of Lectures
UNIT I		
1	Conservation strategies (in-situ, Ex-situ community conservation), Insitu conservation of wild species in nature reserves, In situ conservation of crop diversity on-farm.	2
UNIT II		
2	Phytogeographic surveys and inventory, estimation of genetic diversity, population biology, concept of minimum viable population, population viability and population genetics theory.	1
3	Designation of gene management zones (GMZs)/ gene sanctuaries, management and monitoring of GMZs, threat of genetic erosion, conservation agency priorities, biologically important species.	2
4	National action plan for agro biodiversity, Delhi Declaration on Agrobiodiversity.	1
UNIT III		
5	Social, cultural and economic factors influencing crop genetic diversity.	1
6	Agroecosystem factors: natural and farmer-managed, agromorphological	2

	characters, farmer selection and maintenance, the genetics structure of crop landraces and the challenge to conserve them in situ on-farms, seed systems: formal vs informal.	
UNIT IV		
7	Institutional frameworks for the implementation of on-farm conservation.	1
8	Identification of target crops, site selection, community sensitization, participatory plant breeding, sampling, structuring, documentation and presenting information for action plans.	2
9	Increasing crop genetic diversity's competitiveness for farmers, improvising the material and farmers 'access to genetic materials, increasing consumer demand, the role of policy, deciding on an appropriate initiative, evaluating benefit-enhancement options.	2
10	Role of Geographical Indications (GI) in agrihorticultural crops.	2
	Total	**16**

Practical Schedule

S. N.	**Topics**	**No. of Practicals**
1	Floristic surveys and inventory (wild species in nature reserves and crop species in traditional agro-ecosystems).	4
2	Questionnaire preparation.	4
3	Visit to commercial units processing native crops, and to on farm fields and to community seed banks in villages.	4
4	The genetic structure of crop landraces and the challenge to conserve them insitu on-farm at selected sites.	4
	Total	**16**

Suggested Reading

Brush SB 1999. *Genes in the field: On-farm Conservation of Crop Diversity*. Lewis Publishers, Boca Raton, Florida, USA.

Jarvis D I, Meyer L, Klemick, H, Guarino, L, Smale M, Brown, AHD, Sadiki, M and Sthapit B. 2000. A Training Guide for In situ Conservation On-farm. Version 1.International Plant Genetic Resources Institute, Rome, Italy.

Maxted N, Dulloo ME, Ford-Lloyd BV (eds.) 2016.Enhancing Crop Genepool Use: Capturing Wild Relative and Landrace Diversity for Crop Improvement. CAB International, Wallingford, UK.

Jarvis D, Hodgkin T, Brown AHD, Tuxill JD, Loìpez Noriega I, Smale M, Shtapit B, Samper S.2016.

Crop Genetic Diversity in the Field and on the Farm. Principles and Applications in

Research Practices. Yale Agrarian Studies Series. Bioversity International, Maccarese /Swiss Agency for Development and Cooperation (SDC), Bern/ Yale University Press, New Haven.

Maxted N, Dulloo ME, Ford-Lloyd BV, Frese L, Iriondo JM, Pinheiro de Carvalho MAA (eds.).2012.Agrobiodiversity Conservation: Securing the Diversity of Crop Wild Relatives and Landraces. CAB International, Wallingford.

Maxted N, Guarino L, Myer L, Chiwona EA. 2002. Towards a methodology for on-farm conservation of plant genetic resources. Genetic Resources and Crop Evolution 49: 31-46.

Vernoy, R, Shrestha P and Sthapit B. 2015. Community Seed Banks: Origins, Evolution and Prospects. Oxford, Routledge.

PGR- 608 Genomic Tools and Current Applications 2+1

Objective
To provide knowledge in genomic tools and their application in plant genetic resource exploration, collection, conservation and utilization.

Theory
Unit I
Genomics: Basic concept, structural, comparative and functional genomics, genomic tools, TILLING ,Eco TILLING, Genome duplication and ploidy variation, application of genomic tools in PGR valuation, conservation and utilization.
Unit II
DNA barcoding: Basic concept, methodologies, utility of DNA barcoding in specie delineation, plant exploration and collection, conservation and utilizing species in widening gene pool of major crops.
Unit III
DNA markers: Types, application in assessment of diversity in germplasm, DNA finger printing and genetic identity analysis, allele mining, development and validation of coresets, genetic association studies and genomic selection in germplasm collections.

Practical
- Gene based screening of trait-specific germplasm using linked molecular markers;
- Amplification and sequencing of DNA barcoding loci for species identification in crops;
- Allele mining in trait-specific germplasm for quality traits in crops;
- DNA fingerprinting for identity analysis in crops, molecular markers for designation and validation of germplasm core-sets.

Theory Schedule

S. N.	Topics	No. of Lectures
UNIT I		
1	Genomics: Basic concept.	2
2	Structural, comparative and functional genomics.	2
3	Genomic tools.	2
4	TILLING ,Eco-TILLING.	3
5	Genome duplication and ploidy variation.	2
6	Application of genomic tools in PGR valuation, conservation and utilization.	2

UNIT II		
7	DNA barcoding: Basic concept, methodologies, utility of DNA barcoding in specie delineation.	4
8	Plant exploration and collection, conservation and utilizing species in widening genepool of major crops.	3
UNIT III		
9	DNA markers: Types, application in assessment of diversity in germplasm.	3
10	DNA fingerprinting and genetic identity analysis.	3
11	Allele mining, development and validation of coresets.	3
12	Geneticassociationstudiesandgenomicselectioningermplasmcollections.	3
	Total	**32**

Practical Schedule

S. N.	Topics	No. of Practicals
1	Gene based screening of trait-specific germplasm using linked molecular markers.	2
2	Amplification and sequencing of DNA barcoding loci for species identification in crops.	3
3	Allele mining in trait- specific germplasm for quality traits in crops.	4
4	DNA fingerprinting for identity analysis in crops.	3
5	Molecular markers for designation and validation of germplasm core-sets.	4
	Total	**16**

Suggested Reading

Fleury D, Jefferies S, Kuchel Hand Langridge P. 2010.

Review Paper: Genetic and genomic tools to improve drought tolerance in wheat. *Journal of Experimental Botany* 61: 3211–3222.

Gupta PK, Kulwal PL and Jaiswal V.2014.Association Mapping in Crop Plants: Opportunities and Challenges: *Advances in Genetics*85:109-147.

Henry R(ed.) 2013. *Molecular Markers in Plants*. Wiley and Blackwell Publication, Iowa USA,196p.

Pérez-de-Castro AM, Vilanova S, Cañizares J, *etal*.2 012. Application of genomic tools in plant breeding. *Current Genomics* 13:179-195.

Primrose SB and Twyman RM. 2006. *Principles of Gene Manipulation and Genomics: Part III Genome Analysis, Genomics, and Beyond*. 7thEdition, Blackwell, Malden, USA, pp. 323-481.

Sucher NA, Hennell JR and Carles MC (eds.) 2012.*Plant DNA Finger printing and Barcoding: Methods and Protocols*. Humana Press, Springer Science, New York,201p.

Tuberosa R, Graner A and Frison E (eds.) 2014. *Genomics of Plant Genetic Resources, Volume1. Managing, Sequencing and Mining Genetic Resources*. Springer Science, New York,825p.

Varshney RK and Uberosa R (eds.) 2007. *Genomics-Assisted Crop Improvement Vol2: Genomics Applications in Crops*. Springer Dordrecht, The Netherlands,509p

PGR- 609* Intellectual Property Rights and Regulatory Mechanisms (e-course) 1+0

Objective

To educate students about concepts and instruments of intellectual property rights, plant breeder's rights, farmer's rights, access and benefit sharing, international treaties and national legislation related to plant genetic resources.

Theory

Unit I

Concept of intellectual property, need for IP protection, Dimensions and nature ofI PR, conflicting community interest with private right. Forms of IPR, patents, copyright, trademark, design, trade secret/ confidential information, GI registration. Process of obtaining an IPR, World Intellectual Property Organization, Patent Cooperation Treaty (PCT).

Unit II

Plant breeder's rights, protection of plant varieties, UPOV; registration of plant varieties and essentially derived varieties, duration and effect of registration ;traditional knowledge systems, farmer's rights, folklore, code of conduct, access and benefit sharing; compulsory license; plant varieties protection appellate tribunal; finance, accounts and audit; infringement, offenses, penalties and procedure.

Unit III

International instruments concerning agro-biodiversity, Agenda 21, Convention on Biological Diversity (CBD), FAO and global system of PGR, the International Treaty on Plant Genetic Resources for food and agriculture (ITPGR), Global Plan of Action, TRIPS agreement and IPR protection of life forms, geographical appellations.

Unit IV

Multilateral agreement on trade in goods – relevance to agriculture, Agreement on Agriculture (AOA); agreement on application of sanitary and phytosanitary measures(SPS Agreement), international plant protection convention, agreement on technical barriers to trade (TBT); Plant quarantine, biosafety related issues.

Unit V

National legislations related to biodiversity conservation and IPR protection, Patent Information Search, Patent Drafting, Opinion on Patentability, Patent Infringement

Theory Schedule

S. N.	Topics	No. of Lectures
UNIT I		
1	Concept of intellectual property, need for IP protection, Dimensions and nature of IPR, conflicting community interest with private right.	1

2	Forms of IPR, patents, copyright, trademark, design, trade secret/ confidential information.	1
3	GI registration. Process of obtaining an IPR, World Intellectual Property Organization.	1
4	Patent Cooperation Treaty (PCT).	1
UNIT II		
5	Plant breeder's rights, protection of plant varieties, UPOV.	1
6	Registration of plant varieties and essentially derived varieties duration and effect of registration; traditional knowledge systems farmer's rights, folklore, code of conduct, access and benefit sharing compulsory license; plant varieties protection appellate tribunal finance, accounts and audit; infringement, offenses, penalties and procedure.	2
UNIT III		
7	International instruments concerning agro-biodiversity, Agenda 21, Convention on Biological Diversity (CBD).	1
8	FAO and global system of PGR, the International Treaty on Plant Genetic Resources for food and agriculture (ITPGR), Global Plan of Action.	1
9	TRIPS agreement and IPR protection of life forms, geographical appellations.	1
UNIT IV		
10	Multilateral agreement on trade in goods – relevance to agriculture.	1
11	Agreement on Agriculture (AOA); agreement on application of sanitary and phytosanitary measures(SPS Agreement), international plant protection convention, agreement on technical barriers to trade (TBT).	2
12	Plant quarantine, biosafety related issues.	1
UNIT V		
13	National legislations related to biodiversity conservation and IPR protection.	1
14	Patent Information Search, Patent Drafting, Opinion on Patentability, Patent Infringement.	1
	Total	**16**

Suggested Reading

Kate KT and Laird SA. 2002. *The Commercial Use of Biodiversity: Access to Genetic Resources and Benefit Sharing*. Earthscan.

Markussen M et al. 2005 Valuation and Conservation of Biodiversity: Inter disciplinary Perspectives on the Convention on Biological Diversity, Springer.

Marin PLC. 2002. *Providing Protection For Plant Genetic Resources: Patents, Sui Generis System And Biopartnerships*. Publisher: Kluwer Law International, ISBN: 9041188754; Distributer: Landmark Ltd.

e-Resources

http://www.icar.org.in/files/reports/other-reports/icar-ipmttcguide.pdf
http://www.wto.org;
http://www.geographicindications.com;
http://www.cbd.int;
http://www.patentoffice.nic.in;
http://www.uspto.gov;
http://www.wipo.int;
http://www.nif.org.in;
http://plantauthority.gov.in
http://nbaindia.org

Restructured and Revised Syllabus

M.Sc. & Ph. D. (Agriculture)
In
Plant Physiology

Discipline Co-Coordinator
Plant Physiology
Dr. D. V. Deshmukh
Assistant Breeder (JAF)
AINP on Jute and Allied Fibres,
MPKV, Rahuri.

Discipline coordinator
Plant Physiology
Dr. R. S. Wagh
Cotton Breeder
Cotton Improvement Project,
MPKV, Rahuri.

Broad Subject coordinator
Plant Science
Dr. J. E. Jahagirdar
Associate Dean,
College of Agriculture, Osmanabad,
VNMKV., Parbhani

CONTENT

DISCIPLINE: PLANT PHYSIOLOGY

1. Preamble

The last decade witnessed phenomenal progress in science and technology resulting in the accruement of significant new scientific developments in plant sciences, more specifically on plant growth, development and productivity. This necessitates restructuring the curriculum and the syllabus to enable graduate students to be abreast with the developments through providing comprehensive exposure to the M.Sc and Ph.D. students, on new developments in different areas of plant sciences. With this background the structure of curriculum for M.Sc. and Ph.D. program and syllabi for the courses needs to be developed keeping in view the mandate of agriculture universities and crop specific ICAR institutes.

Genetic enhancement to achieve crop improvement is the major mandate of state agricultural universities (SAU) and crop specific institutes. The emphasis has systematically shifted towards improving specific physiological traits and mechanisms to enhance crop productivity, yield potentials, adaptation to stresses, etc. Yet another major mandate is to optimize agronomic inputs for yield enhancement to rationalize utilization of natural resources. As the crop improvement success heavily depends on improving physiological processes, plant/crop physiology will immensely contribute to the envisaged goals. With this background the M.Sc and Ph.D. students must be provided with adequate exposure and trainings on plant/crop physiology to complement national and state level crop improvement and crop production programs. The focus is to restructure the course content and syllabi of physiology courses to achieve these objectives. While restructuring and modifying the course curriculum it is necessary to take into cognisance the recent developments in molecular biology, genomics and phenomics which provide options to identify traits and their genetic enhancement. Besides potential interventions, the restructured courses should provide insight based on sound physiological process which now provided options to regulate the plant growth and productivity. Therefore, emphasis is on,

- Providing basic knowledge on plant physiological processes and plant responses to environment and other constraints
- Providing exposure to undertake programs for crop improvement by exploiting well characterized physiological processes
- Provides exposure on potential interventions based on principals of plant physiology to improve growth and productivity

2. Committee on Plant Sciences

ICAR-BSMA Broad Subject	ICAR-BSMA Approved Disciplines	Degree Programmes		Broad Subject Coordinator (Chairman of all Disciplines' Sub-Committees)	Discipline Coordinator (Secretary of respective Discipline Sub-Committee)
Plant Sciences	Genetics and Plant Breeding	M.Sc. (Agri.)	Ph.D.	Dr. J.E. Jahagirdar ADP, CoA, Osmanabad (VNMKV, Parbhani)	Dr. H.V. Kalpande Head, Dept. of Agril. Botany, VNMKV, Parbhani
	Seed Science and Technology	M.Sc. (Agri.)	Ph.D.		Dr. V.R. Shelar, SRO, STRU, MPKV, Rahuri
	Plant Physiology	M.Sc. (Agri.)	Ph.D.		Dr. R.S. Wagh, Cotton Breeder Prof ,MPKV, Rahuri
	Plant Genetic Resources	M.Sc. (Agri.)	Ph.D.		Dr. R.B. Ghorade Head, Dept. Agril. Botany Dr.PDKV, Akola

3. Sub-Committee constituted for the finalization of common syllabi in Plant Physiology discipline.

Sr.No	Name	Sub-Committee
1	Dr. R. S. Wagh, Cotton Breeder, MPKV, Rahuri	Discipline Coordinator
2	Dr. D. V. Deshmukh, Assistant Breeder (JAF), AINP on Jute and Allied Fibres, MPKV, Rahuri	Discipline Co-Coordinator
3	Dr.PDKV.Akola	Member
4	Dr.BSKKV Dapoli	Member
5	VNMKV, Parbhani	Member

4. Implementation of New Curriculum

The Universities offering PG programmes in Plant Physiology need to be supported for establishing specialized laboratories equipped with state-of-the art equipment's for conducting practical classes especially, basic fundamentals of plant physiology, nutrient management, basic plant processes (Transpiration, photosynthesis, respiration, nitrogen metabolism, lipid biochemistry), abiotic stress management, climate change and physiology of growth and development.

One-time catch-up grant should be awarded to each SAU, offering PG programmes in Genetics and Plant Breeding for meeting expenditure for upgrading the course requirements.

Faculty training and retraining should be an integral component. For imparting total quality management, a minimum of two faculties in each department under SAU should be given on job training in reputed national and international institutes. To execute the new PG and Ph.D. programmes in Genetics and Plant Breeding discipline in effective manner, special funds from ICAR would be required for outsourcing of faculty from Indian/Foreign Universities for some initial years.

The already existing M.Sc. and Ph.D. Programmes in Plant Physiology will be considered atpar with the recommended M.Sc. & Ph.D. programme by Vth Deans Committee for admission and employment.

Expected Outcome

- Revamping of post graduate programme in whole of Plant Physiology throughout the country.
- Imparting quality education.
- Developmentoftechnicalmanpowertocatertheneedoffarmersgovernments,corporate sector and research organization in India and abroad.
- Exposure to the faculty in the latest technical knowhow.

5. Organization of Course Contents & Credit Requirements

Minimum Residential Requirement: M.Sc.:- Semesters
Ph.D.:- 6Semesters

Name of the Departments/Divisions: Plant Physiology

Nomenclature of Degree Programme

- **M.Sc. Programmes:** M.Sc.(Agriculture) Plant Physiology
- **Ph.D. Programmes:** Ph.D.(Agriculture) Plant Physiology

Code Numbers

- All courses are divided into two series: 500-series courses pertain to Master‟s level, and 600-series to Doctoral level.
- Credit Seminar for Master's level is designated by code no. 591 and the Two

Seminars for Doctoral level are coded as 691 and 692, respectively.
- Master's research: 599 and Doctoral research: 699.
- Deficiency courses will be of 400 series.

Course Contents
The contents of each course have been organized into:
- Objective– to elucidate the basic purpose.
- Theory units–to facilitate uniform coverage of syllabus for paper setting.
- Suggested readings – to recommend some standard books as reference material. This does not obviously exclude such a reference material that may be recommended according to the advancement and local requirement.
- A list of International and National reputed Journals pertaining to the discipline is provided at the end which may be useful as study material for 500/600 series courses as well as research topics.
- Lecture schedule and practical schedule has also been given at the end of each course to facilitate the teacher to complete the course in an effective manner.

6. Eligibility for Admission Master's Degree Programme
Masters Degree Programme
B.Sc. (Agri.)/ B.Sc.(Hons.)Agriculture**,** B.Sc. (Hort.)/ B.Sc.(Hons.) Horticulture / B. Sc. (Forestry) / B.Sc. (Hons.) Forestry under 10+2+4 system with minimum of 5.50/10 or equivalent percentage of marks or equivalent degree with four years duration of agriculture related Universities and having the Common Entrance Test in Agriculture conducted by competent authority.

Doctoral Degree Programme
Master‟s degree in concerned discipline with minimum of 6.50/10 or equivalent percentage of marks and based on CET score. CET conducted by MAUEB or AIEEA–ICAR, Agricultural Universities (AUs) which have expressed their willingness to utilize NTA scores for their PG admissions. If required the scores will be provided by NTA.
(i) Master Degree in the concerned Department/ Discipline of Plant Physiology and having appearing the Common Entrance Test of Plant Physiology subject conducted by competent authority.

Sr. No	**Name of Department**	**Specialization in Ph. D Agriculture**	**Eligibility criteria**
1.	Plant Physiology	Ph.D (Agriculture) Plant Physiology	M.Sc. (Agri) Plant Physiology

7. Credit Requirements

Course Details	**Master's Degree**	**Doctoral Degree**
Major Courses	20	15
Minor Courses	08	06
Supporting/Optional	06	05
Common PGS Courses	05	---
Seminar	01	02
Research	30	75
Total	**70**	**100**

Remedial Non Gradial Courses

Students who have not been exposed to respective disciplines in their Bachelor's programme, shall be required to undergo introductory courses in which admission is sought at Masters level during the first year of their study along with undergraduate degree program. The number of courses and credits (10 to 15 credits) required to be completed will be decided by the SAC.

List can be included

Major courses:

From the Discipline in which a student takes admission.

Minor courses:

From the subjects closely related to a student's major subject and which are required for the support of research problem.

These courses could be from any discipline within the faculty.

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. **These courses could also be from any discipline outside the faculty also.**

Major Minor and Supporting Courses Example

Major	**Minor**	**Supporting**	**Compulsory**
Plant Physiology	Biochemistry Agronomy Seed Science and Technology	Statistics Vegetable Science Seed Science and Technology	E courses

- All masters degree program should have minimum of **three compulsory courses** having **9/ 12 credits** (as given in BSMA report)
- All doctoral degree programs should have **2 compulsory courses with 5/6 credits** (as given in BSMA report)

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.
- Rational and balanced Distribution of Courses in Even and Odd semesters
- As per recommendations of the National Education Policy-2020, the courses have been categorized as Major and Minor/Optional courses by following the spirit of Choice Based Credit System (CBCS), the students are given opportunity to select courses from any discipline/department enabling the multi-disciplinary approach

8. Residential requirements

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

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

9. Evaluation of course work, comprehensive examination and thesis evaluation

- For M.Sc. multiple levels of evaluation (First Test, Midterm and Final semester) is desirable
- For Ph.D. two levels of evaluation (Midterm and Final semester) is desirable. However, the course teacher may be given freedom to evaluate in terms of assignment/ class seminar/first test as desired.

M.Sc : No Comprehensive qualifying Exam
Ph.D : 2 papers for Written Comprehensive qualifying examination (after completion of 80 % of major and minor courses separately)

Question paper setting : External

Evaluation : Internal

Qualifying Viva : External

- The comprehensive oral examination should be by an external expert along with the Student Advisory committee 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 and Student Advisory committee .

Examination system and Weight age

Each of the courses shall be of 100 marks (Theory and practical combined). The mode of evaluation and weightage for each course shall be as shown in table below. The score secured by candidate out of total of 100 marks in a course shall be converted to equivalent grade under 10.00 point system to represent the grade point for that course.

Masters	Doctoral
(1) Course work **Theory- Midterm – 30 %** **Semester end Theory- 70 %** **Practical- Class room Record – 5 %** **Assignments – 10 %** **SE practical – 35%** **2) written Comprehensive qualifying examination(after completion of 80 % of core and optional courses separately)**	**(1) Course work** **Theory- Midterm – 30 %** **Semester end Theory - 70 %** **Practical- Class room Record – 5 %** **Assignments – 10 %** **SE practical – 35%** **2) written Comprehensive qualifying examination(after completion of 80 % of core and optional / minor courses separately)**

Allotment of students to the retiring persons
(As per the PG Teachers recognition rule)

- 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.

Thesis Evaluation

M. Sc.: 1. External Examiner 2. **Viva-voce :** Internal nominated by Dean PGS

Ph. D.: External by two subject experts
Viva-voce : External by one of the thesis evaluator.

Prevention of plagiarism (As per PG regulations)

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.

Publication (As per PG regulations)

M.Sc. : One research papers out of research work

Ph.D : Two research papers out of research work

The paper must be Published / Submitted through Chairman SAC on or before or the submission of thesis

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.
- An optional internship/ in-plant training (called as IDEA) in addition to thesis/ research work is recommended which will give the students an opportunity to have a real-time hands-on experience in the industry for conduct of Research work / Skill development.

Credit distribution in such IDEA will be 25 (Thesis) + 5 (IDEA) or 30 credits of Thesis work

IDEA credits to be allotted only with the organizations with which the MOU are signed by the SAU

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

- A provision may be made to enable the project personnel (SRF/ RA) to register for Ph.D. However, this can be done only if they are selected based on some selection process such as walk-in-interview.
- For registration project personal for Ph.D. the research topic could be based on the project under which the candidate registers. And the provision of SRF and JRF exist in the project funded by the external agency.
- This will not be applicable for inhouse/ institutional funded projects.
- The candidates need to submit the declaration stating that the project work shall not be compromised because of Ph.D. programme. Further, in order to justify the project work and Ph.D. programme, the number of course credits should not be more than 8 in a semester for the project personnel (SRF/ RA) who intend to register for Ph.D.

Teaching assistantship

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.

The selection will only on basis of merit

- Each Ph.D. student may be allowed to take a maximum of 16 classes in a month to UG students.
- The process of selection and 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

10. List of core courses/ department wise specialization/ compulsory/ supporting courses
a) M.Sc. (Ag) in Plant Physiology (Major)

Course Code	Course Title	Credit Hours
PP 501*	Principles of Plant Physiology-I: Plant Water Relations and Mineral Nutrition	2+1
PP 502*	Principles of Plant Physiology-II: Metabolic Processes and Growth Regulation	2+1
PP 503*	Plant Developmental Biology: Physiological and Molecular Basis	2+1
PP 504	Physiological and Molecular Responses of Plants to Abiotic Stresses	2+1
PP 505	Hormonal Regulation of Plant Growth and Development	2+1
PP 506	Physiological and Molecular Mechanisms of Mineral Nutrient Acquisition and their Functions	2+1
PP 507	Photosynthetic Processes, Crop Growth and Productivity and Concepts of Crop Modelling	2+1
PP 508	Physiology of Field Crops	2+0
PP 509	Physiology of Horticulture Crops	2+0
PP 510*	Seed Physiology	2+1
PP 511	Phenotyping Physiological Processes	2+0
PP 512	Crop Growth Regulation and Management	2+0
PP 591	Master's Seminar	1+0
PP 599	Master's Research	0+30

***Compulsory Courses**

Common Courses: (Non-Credit)

Course code	Semester	Course Title	Credits
PGS501	I	Library and Information Services	0+1=1
PGS502	I	Technical Writing and Communications Skills	0+1=1
PGS504	I	Basic Concepts in Laboratory Techniques	0+1=1
PGS503	II	Intellectual Property and its management in Agriculture	1+0=1
PGS505	III	Agricultural Research, Research Ethics and Rural Development Programmes	1+0=1
PGS-506	III	Disaster Management	1+0=1

Minor courses

1. Biochemistry
2. Agronomy
3. Seed Science and Technology
4. Genetics and Plant Breeding
5. Plant Biotechnology

Suggested Minor Courses:

Course code	Course Title	Credits
BIOCHEM 501	Basic biochemistry	3 + 1 = 4
AGRON 501	Modern Concepts in Crop Production	3 + 0 = 3
SST 501	Seed Developmental Biology	1 + 1 =2
	Total	**7 + 2 = 9**

Supporting/optional courses

1. Biochemistry
2. Seed Science and Technology
3. Horticulture
4. Statistics

Suggested Supporting Courses:

Course code	Course Title	Credits
STAT 511	Experimental design	2 + 1 = 3
VSC 503 **SST 503**	Growth and Development of Vegetable Crops **OR** Seed production principles & techniques in field crops Seed Production	2 + 1 = 3 2 + 1 = 3
	Total	**4 + 2 = 6**

Compulsory Non Credit Deficiency Courses
(Those who are non-Agriculture Graduates)

Course Code	Semester	Course Title	Credit Hrs.
BOT 121	II	Fundamentals of Crop Physiology	2 (1+1)

Students from Horticulture and Forestry stream will be required to complete Non credit deficiency courses (6 to 10 credits) from the above courses related to the discipline in which admitted and as decided by the Student Advisory committee.

b) Ph.D.(Agriculture) Plant Physiology

Course Code	Course Title Credit	Hours
PP 601	Functional Genomics and Genes Associated with a Few Physiological Processes	2+0
PP 602*	Signal Perceptions and Transduction and Regulation of Physiological Processes	2+0
PP 603	Molecular Approaches for Improving Physiological Mechanisms Through Trait Introgression	2+1
PP 604	Plant Phenomics – Next Generation Phenomics Platforms	2+0
PP 605	Experimental Techniques to Characterize Plant Processes for Crop Improvement	0+2
PP 606	Global Climate Change and Crop Response	2+0
PP 607*	Physiological and Molecular Aspects of Source-sink Capacity for Enhancing Yield	3+0
PP 608	Seed and Fruit Growth and their Quality Improvement	2+0
PP 609	Plant-microbe Interactions	2+1
PP 610	Weed Biology and Physiology of Herbicide Action	2+0
PP 691	Doctoral Seminar I	1+0
PP 692	Doctoral Seminar II	1+0
PP 699	Doctoral Research	0+75

***Core courses**

Common Courses: (Non-Credit)

Course code	Semester	Course Title	Credits
PGS501	I	Library and Information Services	0+1=1
PGS502	I	Technical Writing and Communications Skills	0+1=1
PGS504	I	Basic Concepts in Laboratory Techniques	0+1=1
PGS503	II	Intellectual Property and its management in Agriculture	1+0=1

PGS505	III	Agricultural Research, Research Ethics and Rural Development Programmes	1+0=1
PGS-506	III	Disaster Management	1+0=1

Note: Ph.D. students may be exempted from Non Credit Compulsory Courses (NCCC) if already studied during Master's degree.

Minor Disciplines:

1. Biochemistry
2. Genetics and Plant Breeding
3. Horticulture
4. Agronomy
5. Plant Biotechnology

Suggested minor courses

Course Code	Semester	Course Title	Credit Hrs
BIOCHEM 603	I	Biochemistry Of Biotic And Abiotic Stresses	3+0=3
GPB 605*	II	Genomics in Plant Breeding	3+0=3
		Total	**6+0=6**
Note: Apart from above courses student shall register courses from Any other discipline within faculty as per student advisory committee recommendation.			

Disciplines for Supporting/ optional Courses:

1. Biochemistry
2. Seed Science and Technology
3. Horticulture
4. Agronomy

Suggested supporting and optional courses:

Course Code	Semester	Course Title	Credit Hrs
SST 603	I	Physiology and Biochemistry of Seeds	1+1=2
BIOCHEM 605	II	Concepts And Aplication Of Omics In Biological Science	3+0=3
		Total	**4+1=5**
Note: Apart from above courses student shall register courses from Any other discipline within faculty as per student advisory committee recommendation.			

Credit requirements: M. Sc. (Agriculture) Plant Physiology

	Doctoral Programme
(i) Course work Major courses	**14+6=20**
Minor courses	**6 + 2 = 8**
Supporting courses	**4 + 2 = 6**
Common courses	**0 + 5 = 5**
Seminar	0 + 1 = 1
(ii) Thesis Research	0 + 30 = 30
Total	**25 + 45 = 70**

Credit requirements: Ph. D. Plant Physiology

	Doctoral Programme
(i) Course work Major courses	 12
Minor courses	06
Supporting courses	05
Common courses	–
Seminar	02
(ii) Thesis Research	75
Total	**100**

11. Course Structure for M. Sc. (Agriculture) Plant Physiology: Semester wise core Courses offered based on credit requirement (Major/ Minor/ Supporting/ Non credit compulsory courses/ common courses/ Seminar/ Research and Thesis writing)

Corse Code	Title	Credits	Nature
Major			
PP 501*	Principle of Plant Physiology-I: Plant water relations	2 + 1 = 3	Major + Minor
PP 502*	Principle of Plant Physiology-II: Metabolic processes and growth regulation	2 + 1 = 3	Major
PP 503*	Plant developmental biology: Physiological and molecular basis	2 + 1 = 3	Major
PP 504	Physiological and molecular responses of plants to abiotic stresses	2 + 1 = 3	Major
PP 505	Hormonal regulation of plant growth and development	2 + 1 = 3	Major + Supporting
PP 508	Physiology of field crops	2 + 0 = 2	Major + Supporting
PP 510*	Seed Physiology	2 + 1 = 3	Major + Minor
	Total	**14+6=20**	
Minor			
BIOCHEM 501	Basic biochemistry	3 + 1 = 4	
AGRON 501	Modern Concepts in Crop Production	3 + 0 = 3	
SST 501	Seed Developmental Biology	1 + 1 =2	
	Total	**7 + 2 = 9**	
Supporting			
STAT 511	Experimental design	2 + 1 = 3	
VSC 503 **SST 503**	Growth and Development of Vegetable Crops **OR** Seed production principles & techniques in field crops Seed Production	2 + 1 = 3 2 + 1 = 3	
	Total	**4 + 2 = 6**	
Non credit compulsory courses/ common courses			
	Library & Information Services	0 + 1 = 1	
	Tech. Writing & Communication Skill	0 + 1 = 1	
	IPR & It's management in Agriculture	0 + 1 = 1	
	Basic Concepts in Library Techniques	0 + 1 = 1	
	Agril. Res., Res. Ethics & Rural Dev. Program	0 + 1 = 1	
	Total	**0 + 5 = 5**	
Seminar			
PP 591	Seminar	**0 + 1 = 1**	
Research and Thesis writing			
PP 599	**Thesis/ Research**	**0+30= 30**	
	Total course and credit loads	**25 + 46 = 71**	

Masters Degree - Course Structure and Syllabus

Course Title: Principles of Plant Physiology I - Plant Water Relations and Mineral Nutrition

Course Code : PP 501* **Credit Hours: 2+1**

Objective

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.

Theory

Block 1: Plant Water Relations

Unit 1: Soil and Plant Water Relations

Water and its importance; Molecular structure of water; Properties and functions of water. Concept of water potential; Plant cell and soil water potential and their components; Methods to determine cell and soil water potential; Concept of osmosis and diffusion. Soil physical properties and water availability in different soils; Water holding capacity and approaches to improve WHC; Concept of FC and PWP; Water holding polymers and their relevance.

Unit 2: Water Absorption and Translocation

Root structure and functions; Root architecture and relevance in water mining; Mechanism of water absorption and translocation; Theories explaining water absorption and translocation; Aquaporins. Mycorrhizal association and its relevance in water mining.

Unit 3: Transpiration and Evaporative Cooling

Evaporation and transpiration; relevance of transpiration; factors regulating transpiration; Measurement of transpiration; approaches to minimize evaporation and transpiration; Concept of CCATD and its relevance. Energy balance: Solar energy input and output at crop canopy level. Stomata- its structure, functions and distribution; Molecular mechanisms of stomatal opening and closing; Concept of guard cell turgidity; role of K and other osmolytes; role of ABA in stomatal closure; Guard cells response to environmental signals; Signaling cascade associated with stomatal opening and closure. Antitranspirants and their relevance in agriculture.

Unit 4: Water Productivity and Water Use Efficiency

WUE and its relevance in water productivity; Transpiration efficiency, a measure of intrinsic WUE; Approaches to measure WUE; Stomatal and mesophyll regulation on WUE; Passioura’s yield model emphasizing WUE.

Unit 5: Moisture Stress and Plant Growth

Physiology of water stress in plants; Effect of moisture stress at molecular, cellular, organ and plant level. Drought indices and drought tolerance strategies. Drought tolerance traits.

Block 2: Mineral Nutrition

Unit 1: Nutrient Elements and Their Importance

Role of mineral nutrients in plant’s metabolism; Essential elements and their classification; beneficial elements; factors influencing the nutrients availability; critical levels of nutrients. Functions of mineral elements in plants. Deficiency and toxicity symptoms in plants.

Unit 2: Nutrient Acquisition

Mechanism of mineral uptake and translocation; Ion transporters; genes encoding for ion transporters; localization of transporters; xylem and phloem mobility; Nutrient transport to grains at maturity; Strategies to acquire and transport minerals under deficient levels. Role of mycorrhiza, root exudates and PGPRs in plant nutrient acquisition.

Unit 3: Concept of Foliar Nutrition

Foliar nutrition; significance and factors affecting total uptake of minerals; Foliar nutrient droplet size for effective entry; role of wetting agents in entry of nutrients.

LECTURE SCHEDULE

Lecture No.	Name of the topic	Weightage
	Block 1: Plant Water Relations	
	Unit 1: Soil and Plant Water Relations	**18**
1	Water and its importance; Molecular structure of water; Properties and functions of water.	4
2	Concept of water potential; Plant cell and soil water potential and their components;	4
3 &4	Methods to determine cell and soil water potential; Concept of osmosis and diffusion. Soil physical properties and water availability in different soils;	6
5 & 6	Water holding capacity and approaches to improve WHC; Concept of FC and PWP; Water holding polymers and their relevance.	4
	Unit 2: Water Absorption and Translocation	**10**
7& 8	Root structure and functions; Root architecture and relevance in water mining; Mechanism of water absorption and translocation;	5
9	Theories explaining water absorption and translocation; Aquaporins. Mycorrhizal association and its relevance in water mining.	5
	Unit 3: Transpiration and Evaporative Cooling	**15**
10	Evaporation and transpiration; relevance of transpiration; factors regulating transpiration; Measurement of transpiration; approaches to minimize evaporation and transpiration;	3
11	Concept of CCATD and its relevance. Energy balance: Solar energy input and output at crop canopy level. Stomata- its structure, functions and distribution;	4
12 & 13	Molecular mechanisms of stomatal opening and closing; Concept of guard cell turgidity; role of K and other osmolytes; role of ABA in stomatal closure;	4
14 & 15	Guard cells response to environmental signals; Signaling cascade associated with stomatal opening and closure. Antitranspirants and their relevance in agriculture.	4
	Unit 4: Water Productivity and Water Use Efficiency	**15**
16 &17	WUE and its relevance in water productivity; Transpiration efficiency, a measure of intrinsic WUE	7

18 & 19	Approaches to measure WUE; Stomatal and mesophyll regulation on WUE; Passioura's yield model emphasizing WUE.	8
	Unit 5: Moisture Stress and Plant Growth	**10**
20 & 21	Physiology of water stress in plants; Effect of moisture stress at molecular, cellular, organ and plant level.	6
22	Drought indices and drought tolerance strategies. Drought tolerance traits.	4
	Block 2: Nutrient Acquisition	
	Unit 1: Nutrient Elements and Their Importance	**10**
23	Role of mineral nutrients in plant's metabolism; Essential elements and their classification; beneficial elements;	4
24 & 25	Factors influencing the nutrients availability; critical levels of nutrients. Functions of mineral elements in plants. Deficiency and toxicity symptoms in plants.	6
	Unit 2: Nutrient Acquisition	**12**
26	Mechanism of mineral uptake and translocation; Ion transporters;	3
27 & 28	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.	5
29	Role of mycorrhiza, root exudates and PGPRs in plant nutrient acquisition.	4
	Unit 3: Concept of Foliar Nutrition	**10**
30 & 31	Foliar nutrition; significance and factors affecting total uptake of minerals;	5
32	Foliar nutrient droplet size for effective entry; role of wetting agents in entry of nutrients.	5
	Total	**100**

Practical

Expt. No.	**Title of the experiment**
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
10	Measurement of CCATD and its relevance
11	Demonstration and use of anti-transpirants to reduce transpiration
12	Influence of potassium and ABA on stomatal opening and closing respectively
13	Deficiency and toxicity symptoms of nutrients
14	Effect of water stress on plant growth and development

Suggested Reading

Vilalta JM and Forner NG. 2017. *Water potential regulation, stomatal behaviour and hydraulic transport under drought: deconstructing the iso/anisohydricconcept Plant, Cell and Environment* 40, 962–976

Mangrich AS, Cardoso EMC, Doumer ME, Romão LPC, Vidal M, Rigol A, Novotny EH. *Improving the Water Holding Capacity of Soils of Northeast Brazil by Biochar Augmentation*. Chapter 16, pp 339–354.

McElrone AJ, Choat B, Gambetta GA and Brodersen CR. 2013. *Water Uptake and Transport in Vascular Plants*. *Nature Education Knowledge* 4(5): 6

Hodson RC and J Acuff. 2006. *Water transport in plants: anatomy and physiology*. Pages 163-183, *Tested Studies for Laboratory Teaching*, Volume 27 (M.A. O'Donnell, Editor). Proceedings of the 27th Workshop/Conference of the Association for Biology Laboratory Education (ABLE), 383 pages.

Chater CCC, Caine RS, Fleming AJ, Gray JE. 2017. *Plant Physiology*, 174 (2) 624-638; DOI: 10.1104/pp.17.00183

Dietrich P, Sanders D, Hedrich R. 2001. *The role of ion channels in light dependent stomatal opening*, *Journal of Experimental Botany*, Volume 52, Issue 363, Pages 1959–1967, https:// doi.org/10.1093/jexbot/52.363.1959

Sreeman SM, Vijayaraghavareddy P, Sreevathsa R, Rajendrareddy S, Arakesh S, Bharti P, Dharmappa P, Soolanayakanahally R. 2018. *Introgression of Physiological Traits for a Comprehensive Improvement of Drought Adaptation in Crop Plants*. *Front. Chem*. 6, 92.

Seyed Yahya Salehi-Lisar Hamideh Bakhshayeshan-Agdam, (2016). Drought Stress in Plants: Causes, Consequences, and Tolerance. Drought Stress Tolerance in Plants, Vol 1 pp 1-16

Pandey R. 2015. *Mineral Nutrition of Plants*. 10.1007/978-81-322-2286-6_20.

Barker AV and DJ Pilbeam. 2015. Handbook of Plant Nutrition, Second Edition. Books in Soils, Plants, and the Environment Series, the 2nd Edition, CRC Press.

Vatansever R, Ozyigit II and Filiz E. 2017. *Essential and beneficial trace elements in plants,and their transport in roots: a review. Applied biochemistry and biotechnology* 181(1), 464- 482..

Tahat MM and Sijam K. 2012. *Arbuscularmycorrhizal fungi and plant root exudates bio-communications in the rhizosphere. African Journal of Microbiology Research*, 6(46), 7295- 7301.

Rajasekar MD, Nandhini DU and Suganthi S. 2017. *Supplementation of Mineral Nutrients through Foliar Spray – A Review. Int.J.Curr.Microbiol.App.Sci.* 6(3): 2504-2513.https:// doi.org/10.20546/ijcmas.2017.603.283

Tarek A and Hassan ER. 2017. *Foliar application: from plant nutrition to biofortification*. Environment, Biodiversity and Soil Security. 10.21608/jenvbs.2017.1089.1006.

General Source of Information

- Taiz T, Zeiger E and Max Mller IM, 2018, *Fundamentals of Plant Physiology*
- Taiz L and Zeiger E. 2015. *Plant Physiology and development*.6th Ed
- Salisbury FB and Ross C. 1992 (4th Ed.) *Plant Physiology*
- Epstein E and Bloom AJ. 2004. *Mineral nutrition of plants: principles and perspectives*.2nd Ed.
- Hopkins WG and Huner NPA. 2004. *Introduction to Plant Physiology*
- Kramer, P. J., *Water relations of plants*
- Kirkham, M. B., *Principles of soil and plant water relations*
- Hopkins WG, 2008, *Introduction to Plant Physiology*

Course Title: Principles of Plant Physiology-II: Metabolic Processes and Growth Regulation

Course Code : PP 502* **Credit Hours:** 2+1=3

Objective

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.

Theory

Block 1: Metabolic Processes and Growth Regulation

Unit 1: Carbon Metabolism – Photochemical Processes

- Chloroplast ultrastructure with special mention of lamellar system
- Excitation, electron and proton transfers and their relevance in energy conservation
- Concepts of pigment systems and generation of powerful reductant and oxidant
- Water oxidation, Water-water cycle and other aspects of electron transfer

Unit 2: Carbon Metabolism: Biochemical Processes

- CO_2 diffusion mechanisms and diffusive conductances, concept of Ci determining Photosynthesis
- RuBisCO enzyme kinetics and Calvin cycle mechanisms, Regulation of Calvin cycle and metabolite fluxes
- Photorespiration: the advantages and inefficiencies of photosynthesis because of photorespiration
- Concepts of CO_2 concentrating mechanisms (CCM) and spatial and temporal differences in carboxylation
- Ecological aspects of $C_4$and CAM photosynthesis
- Product synthesis, Starch and Sucrose biosynthesis

Unit 3: Carbon Metabolism: Respiration

- Mitochondrial organization and functions
- Aspects of Glycolysis, TCA cycle and mitETC.
- Relevance of growth and maintenance respiration
- Concepts of CN resistance respiration – Alternate and SHAM sensitive ETC

Unit 4: Product Synthesis and Translocation Leading to Crop Growth

- Phloem loading and sugar transporting, concepts of bi-directional transport of sugars and other metabolites
- Source-Sink relationship and modulation of photosynthesis
- Concepts and definitions of Growth and Differentiation
- Growth and yield parameters, NAR, CGR, HI and concepts of LAI, LAD

Unit 5: Nitrogen Assimilation and Protein Synthesis

- Developments in d-nitrgen fixation
- Nitrate reduction and assimilation GS-GOGAT process for amino acid synthesis
- Inter-Dependence of carbon assimilation and nitrogen metabolisms

Unit 6: Lipid Metabolism and Secondary Metabolites

- Storage, protective and structural lipids.
- Biosynthesis of fatty-acids, diacyl and triacyl glycerol, fatty acids of storage lipids.
- Secondary metabolites and their significance in plant defense mechanisms.

Unit 7: Hormonal Regulation of Plant Growth and Development

- Growth promoting and retarding hormones: biosynthesis, transport, conjugation
- Mode of action of these hormones and their application in plant physiology

Unit 8: Synthetic Growth Promoters

- Different synthetic hormones: Salicylic acid, strigolactones etc
- Roles and biological activities of various synthetic hormones
- Commercial application of hormones to maximize growth and productivity

Unit 9: Morphogenesis and Reproductive Phase

- Photoperiodism: Phytochromes, their structure and function
- Circadian rhythms,
- Blue light receptors: Cryptochrome and morphogenesis.
- Vernalization and its relevance in germination.

LECTURE SCHEDULE

Lecture No.	Name of the topic	Weigh tage
	Block 1: Metabolic Processes and Growth Regulation	
	Unit 1: Carbon Metabolism – Photochemical Processes	**12**
1	Chloroplast ultrastructure with special mention of lamellar system	4
2	Excitation, electron and proton transfers and their relevance in energy conservation	4
3	Concepts of pigment systems and generation of powerful reductant and oxidant	4
4	Water oxidation, Water-water cycle and other aspects of electron transfer	4
	Unit 2: Carbon Metabolism: Biochemical Processes	**15**
5	CO_2 diffusion mechanisms and diffusive conductances, concept of Ci determining Photosynthesis	3
6	RuBisCO enzyme kinetics and Calvin cycle mechanisms, Regulation of Calvin cycle and metabolite fluxes	3
7	Photorespiration: the advantages and inefficiencies of photosynthesis because of photorespiration	3
8	Concepts of CO_2 concentrating mechanisms (CCM) and spatial and temporal differences in carboxylation	3
9	Ecological aspects of C_4 and CAM photosynthesis Product synthesis, Starch and Sucrose biosynthesis	3
	Unit 3: Carbon Metabolism: Respiration	**13**
10	Mitochondrial organization and functions	3
11 & 12	Aspects of Glycolysis, TCA cycle and mitETC	4
13	Relevance of growth and maintenance respiration	3
14	Concepts of CN resistance respiration – Alternate and SHAM sensitive ETC	3
	Unit 4: Product Synthesis and Translocation Leading to Crop Growth	**15**
15	Phloem loading and sugar transporting, concepts of bi-directional transport of sugars and other metabolites	4
16	Source-Sink relationship and modulation of photosynthesis	3
17	Concepts and definitions of Growth and Differentiation	4
18	Growth and yield parameters, NAR, CGR, HI and concepts of LAI, LAD	4

	Unit 5: Nitrogen Assimilation and Protein Synthesis	**10**
19	Developments in d-nitrgen fixation	3
20	Nitrate reduction and assimilation GS-GOGAT process for amino acid synthesis	4
21	Inter-Dependence of carbon assimilation and nitrogen metabolisms	3
	Unit 6: Lipid Metabolism and Secondary Metabolites	**10**
22	Storage, protective and structural lipids.	3
23	Biosynthesis of fatty-acids, diacyl and triacyl glycerol, fatty acids of storage lipids	4
24	Secondary metabolites and their significance in plant defense mechanisms	3
	Unit 7: Hormonal Regulation of Plant Growth and Development	**07**
25	Growth promoting and retarding hormones: biosynthesis, transport, conjugation	3
26	Mode of action of these hormones and their application in plant physiology	4
	Unit 8: Synthetic Growth Promoters	**09**
27	Different synthetic hormones: Salicylic acid, strigolactones etc	3
28	Roles and biological activities of various synthetic hormones	3
29	Commercial application of hormones to maximize growth and productivity	3
	Unit 9: Morphogenesis and Reproductive Phase	**09**
30	Photoperiodism: Phytochromes, their structure and function	3
31	Circadian rhythms, Blue light receptors: Cryptochrome and morphogenesis	3
32	Vernalization and its relevance in germination.	3
	Total	**100**

Practical

Expt. No.	**Title of the experiment**
1	Radiant energy measurements
2	Separation and quantification of chlorophylls
3	O_2 evolution during photosynthesis
4	Anatomical identification of C_3 and C_4 plants
5	Measurement of gas exchange parameters, conductance, photosynthetic rate, photorespiration
6	Measurement of respiration rates
7	Estimation of reducing sugars, starch
8	Estimation of NO_3, free amino acids in the xylem exudates, quantification of soluble proteins
9	Bioassays for different growth hormones- Auxins, Gibberellins, Cytokinins, ABA and ethylene
10	Demonstration of photoperiodic response of plants in terms of flowering

Suggested Reading

Kirchhoff H. 2019. *Chloroplast ultrastructure in plants*, New Phytologist. Doi.org/10.1111/ nph.15730

Jafari T, Moharreri E, Amin A, Miao R, Song W and Suib S. 2016. *Photocatalytic water splitting—the untamed dream: a review of recent advances*. *Molecules*, *21*(7), 900.

Jensen E, Cle´ment R, Maberly SC, Gontero B. 2017. *Regulation of the Calvin –Benson–Bassham cycle in the enigmatic diatoms: biochemical and evolutionary variations on an original theme. Phil. Trans. R. Soc. B* 372: 20160401. doi.org/10.1098/rstb.2016.0401

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.

Hagemann M, Weber AP and Eisenhut M. 2016. *Photorespiration: origins and metabolic integration in interacting compartments*. *Journal of experimental botany*, 67(10), 2915.

Kühlbrandt W. 2015. *Structure and function of mitochondrial membrane protein complexes*. *BMC biology*, 13(1), 89.

Liesche J., and Patrick, J. 2017. *An update on phloem transport: a simple bulk flow under complex regulation*. *F1000Research*, 6.

Jensen KH, Berg-Sørensen K, Bruus H, Holbrook NM, Liesche J, Schulz A and Bohr T. 2016. *Sap flow and sugar transport in plants*. *Reviews of modern physics*, 88(3), 035007.

Julius BT, Leach KA, Tran TM, Mertz RA and Braun DM. 2017. *Sugar transporters in plants: new insights and discoveries*. Plant and Cell Physiology, 58(9), 1442-1460.

Rao DLN. 2014. *Recent advances in biological nitrogen fixation in agricultural systems*. In *ProcIndianNatlSciAcad*(Vol. 80, (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), 4041-4062.

Mus, F., Crook, M. B., Garcia, K., Costas, A. G., Geddes, B. A., Kouri, E. D.andUdvardi, M.

K. 2016. *Symbiotic nitrogen fixation and the challenges to its extension to nonlegumes. Appl. Environ. Microbiol.*, *82*(13), 3698-3710.

Pagare S, Bhatia M, Tripathi, N., Pagare, S., and Bansal, Y. K. 2015. *Secondary metabolites of plants and their role: Overview*. *Curr Trends Biotechnol Pharm*, 9(3), 293-304.

Jain C, Khatana S and Vijayvergia R. 2019. *Bioactivity of secondary metabolites of various plants: a review. Int J Pharm Sci and Res* 10(2): 494-04. doi: 10.13040/IJPSR.0975- 8232.10(2).494-04..

Li, C., Li, J., Chong, K., Harter, K., Lee, Y., Leung, J.,and Schroeder, J. 2016. *Toward a molecular understanding of plant hormone actions*. *Molecular plant*, 9(1), 1-3.

Eckardt, N. A. 2015. *The plant cell reviews dynamic aspects of plant hormone signaling and crosstalk.*

Jiang, K., andAsami, T. 2018. *Chemical regulators of plant hormones and their applications in basic research and agriculture*. *Bioscience, biotechnology, and biochemistry*, 82(8), 1265- 1300.

Zwanenburg, B., Pospíšil, T., and Zeljkoviæ, S. Æ. 2016. *Strigolactones: new plant hormones in action. Planta*, 243(6), 1311-1326.

Kumar, R., Khurana, A., and Sharma, A. K. 2014. *Role of plant hormones and their interplay in development and ripening of fleshy fruits. Journal of experimental botany, 65*(16), 4561- 4575.

Gururani, M., Mohanta, T., and Bae, H. 2015. *Current understanding of the interplay between phytohormones and photosynthesis under environmental stress. International journal of molecular sciences, 16*(8), 19055-19085.

Song, Y. H., Shim, J. S., Kinmonth-Schultz, H. A., and Imaizumi, T. 2015. *Photoperiodic flowering: time measurement mechanisms in leaves. Annual review of plant biology, 66*, 441-464.

Sanchez, S. E., and Kay, S. A. 2016. *The plant circadian clock: from a simple timekeeper to a complex developmental manager. Cold Spring Harbor perspectives in biology, 8*(12), a027748.

General Text books

- *Taiz, Lincoln, Zeiger. 2007 Plant Physiology, Eduardo Original American edition Sinauer Associates, Inc., 2006; 4th ed., XXVI, ISBN: 978-3-8274-1865-4; © Springer.*
- *Plant Physiology* Frank Boyer Salisbury and Cleon Ross.
- *Introduction to Plant Physiology* (Wie)by William G. Hopkins.

Course Title: Plant Developmental Biology: Physiological and Molecular Basis

Course Code : PP 503* **Credit Hours:** 2+1=3

Objective

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.

Theory

Block 1: Plant Developmental Biology

Unit 1: Evolutionary Development of Plants and Role of Environment

Plant development and plasticity, evolution, Biodiversity. Novel features of plant growth and development, Concept of plasticity-evolution and biodiversity, Model plants for study; Environment and development. Developmental stages and program; Cell-cycle, totipotency and regeneration.

Unit 2: Physiological and Molecular Determinants of Seed Biology

Seed development- Physiology of seed development, role of hormones in embryo development; seed development and maturation. Seed dormancy- Physiological and molecular mechanism of seed dormancy regulation. Seed germination- seed structure and Hormonal regulation of germination, Mobilization of food reserves during seed germination.

Unit 3: Vegetative Growth and Organ Development

Regeneration and totipotency- organ differentiation and development – role of hormones-developmental control genes in crop plants. Meristems in plant development. Shoot, Leaf, Trichome and stomate development and differentiation. Axillary shoot branching; Bud dormancy and growth**.** Root development; Nodule development; Tuber development- hormonal control, signaling and molecular regulation- genes involved. Vascular bundle development- xylem and phloem differentiation.

Unit 4: Physiological and Molecular Aspects of Reproductive Growth and Development

Floral Induction and Development: Molecular and physiological mechanism of transition -vegetative to reproductive phase- floral organ initiation and development their controls. Development of male and female gametophyte; gametophytic mutants: pollen-stigma interaction- Pollen germination and tube growth; role of imprinting; Male sterility: and fertility restoration; Self incompatibility; Sterility and fertility restoration, Maternal gene effects, Zygotic gene effects. Sex determination in plants, mate choice in plants. Embryo and endosperm development- fertilization, role of imprinting; Parthenocarpy and apomixes

Unit 5: Ripening and Senescence

Fruit development, enlargement, maturation and ripening; climacteric and non-climacteric fruit ripening mechanism. Hormonal, biochemical & Molecular aspects of fruit ripening. Senescence and its regulation; Hormonal and environmental control of senescence; PCD in the life cycle of plants.

Unit 6: Physiological and Molecular Regulation of Plant Development Influenced by Light and Temperature

Light control of plant development: Phytochromes and cryptochromes, phototropins, their structure, biochemical properties and cellular distribution. Molecular mechanisms of light perception, signal transduction and gene regulation. Photoperiodism and its significance, vernalization and hormonal control. Circadian rhythms-biological clocks and their genetic and molecular determinants. Thermomorphogenesis- Thermoperiodism

Block 2: Application of Morphogenesis and its Practical Application

Unit 1: Tissue culture and micro-propagation

Applications of tissue culture for plant production, callus induction, somatic embryogenesis, regeneration from different explants. Micro-propogation, tip and axillary node culture of commercially important crops, hardening and ex-vitro establishment, concept of somatic hybridization and protoplast culture.

Unit 2: Application of *in-vitro* techniques for crop improvement

Development of somoclones, identification and exploitation of somoclonal variants.

Haploid production, pollen/anther, ovule/ovary culture. Production of secondary metabolites by tissue culture, concept of bio-fermenters. Plant transformation, development of transgenic plants and their characterization. Germplasm storage, cryopreservation and regulation

LECTURE SCHEDULE

Lecture No.	Name of the topic	Weightage
	Block 1: Plant Developmental Biology	
	Unit 1: Evolutionary Development of Plants and Role of Environment	**12**
	Plant development and plasticity, evolution, Biodiversity.	3
	Novel features of plant growth and development	5
	Concept of plasticity-evolution and biodiversity, Model plants for study;	4
	Environment and development. Developmental stages and program; Cell-cycle, totipotency and regeneration	4

	Unit 2: Physiological and Molecular Determinants of Seed Biology	**10**
	Seed development- Physiology of seed development, role of hormones in embryo development; seed development and maturation	3
	Seed dormancy- Physiological and molecular mechanism of seed dormancy regulation	3
	Seed germination- seed structure and Hormonal regulation of germination, Mobilization of food reserves during seed germination	4
	Unit 3: Vegetative Growth and Organ Development	**13**
	Regeneration and totipotency- organ differentiation and development – role of hormones- developmental control genes in crop plants	4
	Meristems in plant development. Shoot, Leaf, Trichome and stomate development and differentiation. Axillary shoot branching; Bud dormancy and growth	3
	Root development; Nodule development; Tuber development- hormonal control, signaling and molecular regulation- genes involved	3
	Vascular bundle development- xylem and phloem differentiation	3
	Unit 4: Physiological and Molecular Aspects of Reproductive Growth and Development	**15**
	Floral Induction and Development: Molecular and physiological mechanism of transition -vegetative to reproductive phase- floral organ initiation and development their controls.	5
	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.	5
	Sex determination in plants, mate choice in plants. Embryo and endosperm development- fertilization, role of imprinting; Parthenocarpy and apomixes	5
	Unit 5: Ripening and Senescence	**12**
	Fruit development, enlargement, maturation and ripening; climacteric and non- climacteric fruit ripening mechanism	5
	Hormonal, biochemical & Molecular aspects of fruit ripening	3
	Senescence and its regulation; Hormonal and environmental control of senescence; PCD in the life cycle of plants	4
	Unit 6: Physiological and Molecular Regulation of Plant Development Influenced by Light and Temperature	**13**
	Light control of plant development: Phytochromes and cryptochromes, phototropins, their structure, biochemical properties and cellular distribution	4
	Molecular mechanisms of light perception, signal transduction and gene regulation	3
	Photoperiodism and its significance, vernalization and hormonal control	3
	Circadian rhythms-biological clocks and their genetic and molecular determinants. Thermomorphogenesis- Thermoperiodism	3
Block 2: Application of Morphogenesis and its Practical Application		
	Unit 1: Tissue culture and micro-propagation	**12**

	Applications of tissue culture for plant production, callus induction, somatic embryogenesis, regeneration from different explants	6
	Micro-propogation, tip and auxillary node culture of commercially important crops, hardening and ex-vitro establishment, concept of somatic hybridization and protoplast culture	6
	Unit 2: Application of *in-vitro* techniques for crop improvement	**13**
	Development of somoclones, identification and exploitation of somoclonal variants	4
	Haploid production, pollen/anther, ovule/ovary culture. Production of secondary metabolites by tissue culture, concept of bio-fermenters	4
	Plant transformation, development of transgenic plants and their characterization. Germplasm storage, cryopreservation and regulation	5
	Total	**100**

Practical

S No.	Title of the experiment
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 inhbibitor 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 auxiliary 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 tumefacines* and *Agrobacterium rhizogenes* for production of transgenic
14	Molecular characterization of transgenic- PCR, southern blotting, gene expression

Suggested Reading

Niklas KJ. *Plant Evolution- An Introduction to the History of Life*.

Bahadur *B et al*. (eds.), *Plant Biology and Biotechnology:* Volume I: Plant Diversity, Organization, Function and Improvement

Jong MD and Leyser O. *Developmental Plasticity in Plants*. Cold Spring Harbor Symposia on Quantitative Biology. 63-73.

Inze D and Veylder LD. 2006. *Cell Cycle Regulation in Plant Development*. Annu. Rev. Genet. 2006. 40: 77–105

J. Derek Bewley *et al*., Seeds-Physiology of Development, Germination and Dormancy.

Kent J. Bradford and Hiroyuki Nonogaki (2007). *Seed Development, Dormancy and Germination*. Blackwell publishing.

Evans MMS and Barton MK. 1997. *Genetics Of Angiosperm Shoot Apical Meristem Development. Annu. Rev. Plant Physiol. Plant Mol. Biol.* 48: 673–701.

Jiang K and Feldman LJ. 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.

Tooke F and Battey N. 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. Condic (2014). *Totipotency*: *What It Is and What It Is Not. Stem Cells And Development*. 23(8). 796- 812.

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.

John R. Pannel. (2017). *Plant Sex Determination. Current Biology* 27, R191–R197.

Johnson MA *et al*. 2019. *A Fruitful Journey: Pollen Tube Navigation from Germination to Fertilization. Annu*. Rev. Plant Biol. 70: 20.1–20.29

Callow JA. *Advances in Botanical Research- Incorporating Advances in Plant Pathology* Vol. 44, Developmental Genetics Of The Flower.

Jack T. 2004. *Molecular and Genetic Mechanisms of Floral Control*. The Plant Cell. 16: S1– S17.

Koltunow AM and Grossniklaus U. 2003. *APOMIXIS: A Developmental Perspective. Annu. Rev. Plant Biol*. 54: 547–74.

Vernonica E. Franklin-Tong. *Self-Incompatibility in Flowering Plants-Evolution, Diversity,and Mechanisms*, Springer

Thomas H. 2013. *Senescence, ageing and death of the whole plant. New Phytologist*. 197: 696–711.

Lam E, Fukuda H and Greenberg J. *Programmed cell death in higher plants*. Reprinted from Plant Molecular Biology, Volume 44 (3).

Pua EC and Davey MR. *Plant Developmental Biology - Biotechnological Perspectives*.

Meng Chen. 2004. *Light Signal Transduction In Higher Plants Annu. Rev. Genet*. 38: 87–117.

Fankhauser C and Chory J. 1997. *Light Control Of Plant Development Annu. Rev. Cell Dev. Biol*. 13: 203–229.

Mieke de Wit. 2016. *Light-Mediated Hormonal Regulation of Plant Growth and Development.Annu. Rev. Plant Biol*. 67: 22.1–22.25

Franklin KA and Wigge PA. *Temperature and Plant Development*. Wiley Blackwell.

Franklin KA *et al*. 2014. *Interaction of light and temperature signaling. Journal of Experimental Botany*. 65(11): 2859–2871.

Bhojwani SS and Razdan MK. *Plant tissue culture: theory and practice, a revised edition*. Elsiver publication.

Bhojwani SS, Dantu SS and Kumar P. *Plant Tissue Culture: An Introductory Text*.

George EF and Hall MA. *Plant Propagation by Tissue Culture* 3rd Edition.

Krishna H, Alizadeh M, Singh D, Singh U, Chauhan N, Eftekhari M and Sadh RK. 2016. *Somaclonal variations and their applications in horticultural crops improvement. 3 Biotech*, 6(1), 54.

Evans DA. 1989. *Somaclonal variation-genetic basis and breeding applications. Trends in genetics*, 5, 46-50.

Benson EE, Dumet DJ and Harding K. 2009. *Cryopreservation of plant cells, tissues and organs. Encyclopedia of Industrial Biotechnology: Bioprocess, Bioseparation, and Cell Technology*, 1-22.

Schumacher HM, Westphal M and Heine-Dobbernack E. 2015. *Cryopreservation of plant cell lines. In Cryopreservation and Freeze-Drying Protocols* (pp. 423-429). Springer, New York, NY.

Kalaiselvi R, Rajasekar M and Gomathi S. 2017. *Cryopreservation of plant materials-a review*. IJCS, 5(5), 560-564.

Murovec J and Bohanec B. 2012. *Haploids and doubled haploids in plant breeding*. Intechopen. DOI: 10.5772/29982

Germanà MA. 2011. *Anther culture for haploid and doubled haploid production*. Plant Cell, Tissue and Organ Culture. Volume 104, Issue 3, pp 283–300

Ren J, Wu P, Trampe B, Tian X, Lübberstedt T and Chen S. 2017. *Novel technologies in doubled haploid line development. Plant biotechnology journal*, 15(11), 1361-1370.

Dunwell JM. 2010. *Haploids in flowering plants: origins and exploitataion. Plant Biotechnol* J. 8(4): 377-424. doi: 10.1111/j.1467-7652.2009.00498.x

Ferrie MR and Caswell KL. 2011. *Isolated microspore culture techniques and recent progress for haploid and doubled haploid plant production*. Plant Cell, Tissue and Organ Culture. Volume 104, Issue 3, pp 301–309

Thijs S, Sillen W, Rineau F, Weyens N and Vangronsveld J. 2016. *Towards an enhanced understanding of plant–microbiome interactions to improve phytoremediation: engineering the metaorganism. Frontiers in Microbiology*, 7, 341.

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.
- Bewley JD *et al*., *Seeds-Physiology of Development, Germination and Dormancy*.
- Jong MD and Leyser O. *Developmental Plasticity in Plants. Cold Spring Harbor Symposia on Quantitative Biology*. 63-73.
- Bae G and Choi G. 2008. *Decoding of Light Signals by Plant Phytochromes and Their Interacting Proteins*. Annu. Rev. Plant Biol. 59: 281–311
- Willemsen V and Scheres B. 2004. *Mechanisms of pattern formation in plant embryogenesis*. *Annu. Rev. Genet*. 38: 587–614
- MomokoIkeuchi *et al*. 2016. *Review- Plant regeneration: cellular origins and molecular mechanisms*. *Development*, 143: 1442-1451.
- Pannel JR. 2017. *Plant Sex Determination. Current Biology* 27, 191–197.
- Vernonica E. Franklin-Tong. *Self-Incompatibility in Flowering Plants -Evolution,*

Diversity, and Mechanisms. Springer.
- Dijk PV and Damme JV. 2000. *Apomixis technology and the paradox of sex. Trends in Plant Sciences* 5(2): 81-84.

Course Title: Physiological and Molecular Responses of Plants to Abiotic Stresses

Course Code : PP 504 **Credit Hours:** 2+1=3

Objective

This course aims to describe students the abiotic-stress physiology and their effects on plant growth and productivity. This will also help students gain insights into latest developments in stress physiology and stress tolerance mechanisms, approaches for crop improvement under stressful environment.

Theory

Block 1: Abiotic Stresses

Unit 1: Introduction to Abiotic Stresses

Abiotic stresses major constraints to realize potential yields of crop plants, yield losses. Drought prone areas in India- Frequency of occurrence of drought, Rainfed- kharif, Rabi, Areas affected by salinity, heavy metals, water logging, high temperature scenario due to global warming.

Block 2: Drought Stress

Unit 1: Moisture Stress Responses in Plants

Drought-characteristic features; water potential in the soil-plant-air continuum. Physiological and biochemical processes affected by drought.Oxidative stress-generation of ROS and other cytotoxic compounds, their effect on cellular process. Effect on total carbon gain- decrease in photosynthetic area and function, protein turn over and lipid characters, phenology-reproductive aspects, critical stages.

Unit 2: Stress Perception and Molecular Responses of Plants to Drought Stress

Stress perception andsignal transduction leading to expression of regulatory genes, stress specific kinases, stress specific transcription factors, functional genes associated with adaptive mechanisms.

Unit 3: Plant Adaptive Mechanisms to Drought

(a) Escape and desiccation avoidance mechanism

Concept of stress escape- exploiting genetic variability in phenology, Drought avoidance mechanisms- Maintenance of cell turgor, water mining by root characters. Moisture conservation- Regulation of transpiration- traits reducing heat load, Stomatalfactors guard cell metabolism, moisture conservation by waxes. Water use efficiency (WUE) and concept of water productivity- regulation of transpiration efficiency-stomatal conductance, mesophyll efficiency, relevance of WUE and Passioura’s model.

(b) Desiccation tolerance- Concept of acquired tolerance

Decreased turgor mediated upregulation of cellular tolerance mechanisms, Osmolytes, managing cytotoxic compounds, ROS, RCC, scavenging - enzymatic and non-enzymatic, protein turnover, stability, chaperones, membrane stability, photo- protection of chlorophylls.

Unit 4: Approaches to Improve Drought Tolerance

Development of genetic resources- donor genotypes for specific traits, Genomic resources- genes, QTL's regulating adaptive mechanisms, Conventional, transgenic and molecular breeding approaches to improve relevant adaptive traits, concept of trait introgression.

Block 3: Salt, Heavy Metal, Water Logging, Temperature and Light Stress

Unit 1: Salt Stress

Soil salinity-Effect of salt stress, ionic and osmotic effects; species variation in salt tolerance; glycophytes and halophytes, Salt tolerance mechanisms - exclusion, extrusion and compartmentalization, Signaling during salt stress – SOS pathway, Approaches to improve salt tolerance.

Unit 2: Heavy Metal Stress and Water Logging

Heavy metal toxicity in plants (eg., Al, Cd), tolerance mechanisms and approaches to improve. Plant response to water logging, role of hormones- ethylene, mechanism of tolerance and approaches to improve.

Unit 3: Temperature and Light Stress

High and low temperatures; effect on plants; adaptive mechanisms, evaporation cooling, concept of cellular tolerance, protein stability, chaperones, HSPs, HSFs, membranes. High light and high ionizing radiation- photo oxidation and photo- inhibition; mechanisms of tolerance, plant adaptation to low light, concept of shade avoidance response (SAR).

LECTURE SCHEDULE

Lecture No.	Name of the topic	Weightage
	Block 1: Abiotic Stresses	
	Unit 1: Introduction to Abiotic Stresses	**10**
1	Abiotic stresses major constraints to realize potential yields of crop plants, yield losses	4
2&3	Drought prone areas in India- Frequency of occurrence of drought, Rainfed- kharif, Rabi, Areas affected by salinity, heavy metals, water logging, high temperature scenario due to global warming	6
	Block 2: Drought Stress	
	Unit 1: Moisture Stress Responses in Plants	**15**
4	Drought-characteristic features; water potential in the soil-plant-air continuum	3
5	Physiological and biochemical processes affected by drought	3
6	Oxidative stress- generation of ROS and other cytotoxic compounds, their effect on cellular process	4
7&8	Effect on total carbon gain- decrease in photosynthetic area and function, protein turn over and lipid characters, phenology-reproductive aspects, critical stages	5
	Unit 2: Stress Perception and Molecular Responses of Plants to Drought Stress	**12**
9&10	Stress perception and signal transduction leading to expression of regulatory genes	5
11&12	Stress specific kinases, stress specific transcription factors, functional genes associated with adaptive mechanisms	7
	Unit 3: Plant Adaptive Mechanisms to Drought	**20**

13	**a) Escape and desiccation avoidance mechanism** Concept of stress escape- exploiting genetic variability in phenology, Drought avoidance mechanisms- Maintenance of cell turgor, water mining by root characters.	4
14	Moisture conservation- Regulation of transpiration- traits reducing heat load, Stomatalfactors guard cell metabolism, moisture conservation by waxes.	4
15	Water use efficiency (WUE) and concept of water productivity- regulation of transpiration efficiency-stomatal conductance, mesophyll efficiency, relevance of WUE and Passioura's model.	4
16	**b) Desiccation tolerance- Concept of acquired tolerance** Decreased turgor mediated upregulation of cellular tolerance mechanisms, Osmolytes, managing cytotoxic compounds,	4
17	ROS, RCC, scavenging - enzymatic and non-enzymatic, protein turnover, stability, chaperones, membrane stability, photo- protection of chlorophylls.	4
	Unit 4: Approaches to Improve Drought Tolerance	**11**
18 &19	Development of genetic resources- donor genotypes for specific traits	4
20&21	Genomic resources- genes, QTL's regulating adaptive mechanisms, Conventional, transgenic and molecular breeding approaches to improve relevant adaptive traits, concept of trait introgression	7
Block 3: Salt, Heavy Metal, Water Logging, Temperature and Light Stress		
	Unit 1: Salt Stress	**10**
2	Soil salinity-Effect of salt stress, ionic and osmotic effects; species variation in salt tolerance; glycophytes and halophytes	4
23&24	Salt tolerance mechanisms - exclusion, extrusion and compartmentalization, Signaling during salt stress – SOS pathway, Approaches to improve salt tolerance	6
	Unit 2: Heavy Metal Stress and Water Logging	**11**
25&26	Heavy metal toxicity in plants (eg., Al, Cd), tolerance mechanisms and approaches to improve.	6
27&28	Plant response to water logging, role of hormones- ethylene, mechanism of tolerance and approaches to improve	5
	Unit 3: Temperature and Light Stress	**11**
29&30	High and low temperatures; effect on plants; adaptive mechanisms, evaporation cooling, concept of cellular tolerance, protein stability, chaperones, HSPs, HSFs, membranes	6
31&32	High light and high ionizing radiation- photo oxidation and photo-inhibition; mechanisms of tolerance, plant adaptation to low light, concept of shade avoidance response (SAR)	5
	Total	100

Practical

S No.	**Title of the experiment**
1	Measurement of soil and plant water status
2	Drought stress imposition and measurement of physiological and biochemical changes in plants under stress –gas exchange and fluorescence measurements
3	Determination of water use efficiency as a drought resistant trait

4	Drought Susceptibility Index (DSI) -precise field technique to identify productive genotypes under stress
5	Approaches to quantify root characters
6	Determination of stomatal parameters and canopy temperature as a reflection of transpiration and root activity
7	Determination of Salinity Tolerance Index
8	Studying acclimation response - Temperature induction response
9	Heat tolerance and membrane integrity- Sullivans heat tolerance test
10	Quantification of osmolytes – proline under stress
11	Oxidative stress imposition- Quantification of oxidative stress
12	Quantification of ROS under stress
13	Estimation of ABA content in leaf and root tissues under stress
14	Determination of Sodium and Potassium in plant tissue grown under salt stress
15	Estimation of antioxidant enzymes

Suggested Reading

Plant Physiology Book by Eduardo Zeiger and Lincoln Taiz.

Plant Physiology Book by Frank B. Salisbury, Cleon W. Ross Salisbury, Frank B

Pereira A. 2016. *Plant Abiotic Stress Challenges from the Changing Environment. Front. Plant Sci*. 7: 1123. doi: 10.3389/fpls.2016.01123

Sergey Shabala, 2012. *Plant Stress Physiology*.

https://www.mapsofindia.com/maps/india/drought-prone-areas.html

Abid M, Ali S, Qi LK, Zahoor R, Tian Z, Jiang D, Snider JL and Dai T. 2018. *Physiological and biochemical changes during drought and recovery periods at tillering and jointing stages in wheat (Triticum aestivum L.). Scientific Reports*, 8(1), p.4615.

Fathi, Amin and Barari, Davood. 2016. *Effect of Drought Stress and its Mechanism in Plants*. *International Journal of Life Sciences*. 10. 1. 10.3126/ijls.v10i1.14509.

Pareek A, Sopory SK, Bohnert HJ and Govindjee 2010. *Abiotic Stress Adaptation in Plants*, Springer, The Netherlands.

Dumont S and Rivoal J. 2019. *Consequences of oxidative stress on plant glycolytic and respiratory metabolism*. Frontiers in plant science, 10.

Mittler R. 2002. *Oxidative stress, antioxidants and stress tolerance. Trends in Plant Science*, 7(9), pp.405-410.

Demidchik V. 2015. *Mechanisms of oxidative stress in plants: from classical chemistry to cell biology. Environmental and experimental botany*, 109, pp.212-228.

Das K and Roychoudhury A. 2014. *Reactive oxygen species (ROS) and response of antioxidants as ROS-scavengers during environmental stress in plants*. *Frontiers in Environmental Science*, 2, p.53.

Yadav P, Kumar S and Jain V. 2016. *Recent Advances in Plant Stress Physiology*. Daya Publishing House, New Delhi.

http://threeissues.sdsu.edu/three_issues_droughtfacts03.html

Rout GR and Das AB. 2013. *Molecular Stress physiology of plants*. Springer, India.

Mahalingam, Ramamurthy (Ed.) 2015. *Combined Stresses in Plants Physiological, Molecular, and Biochemical Aspects*

Lata C and Muthamilarasan M and Prasad M. 2015. *Drought Stress Responses and Signal Transduction in Plants. In elucidation of abiotic stress signaling in plants* (PP.195-225).

Springer, New York,Ny. DOI: 10.1007/978-1-4939-2540-7_7.

Zhu JK. 2016. *Abiotic stress signaling and responses in plants. Cell*, 167(2), pp.313-324.

Osakabe Y, Yamaguchi-Shinozaki K, Shinozaki K and Tran LSP. 2013. Sensing *the environment: key roles of membrane-localized kinases in plant perception and response to abiotic stress. Journal of experimental Botany*, 64(2), pp.445-458.

Xiong L and Zhu JK. 2001. *Abiotic stress signal transduction in plants: molecular and genetic perspectives. Physiologia Plantarum*, 112(2), pp.152-166.

Gill SS, Anjum NA, Gill R and Tuteja N, 2016. *Abiotic Stress signaling in plants–an overview. Abiotic Stress Response in Plants*, 3, pp.1-12.

de Vasconcelos MWPL, Menguer PK, Hu Y, Revers LF and Sperotto RA. 2016. Stress signaling responses in plants. *BioMed Research International*, 2016.

Khan, A., Pan, X., Najeeb, U., Tan, D.K.Y., Fahad, S., Zahoor, R. and Luo, H., 2018. *Coping with drought: stress and adaptive mechanisms, and management through cultural and molecular alternatives in cotton as vital constituents for plant stress resilience and fitness. Biological research* 51(1), p.47.

Abobatta Waleed. 2019. *Drought adaptive mechanisms of plants -a review. Adv.Agr.Environ Sci*., 2(1). 42-45. DOI: 10.30881/aaeoa.00021.

Basu S, Ramegowda V, Kumar A and Pereira A. 2016. *Plant adaptation to drought stress. F1000Research*, 5.

Gilbert ME and Medina V. 2016. *Drought adaptation mechanisms should guide experimental design. Trends in Plant Science*, 21(8), pp.639-647.

Kamanga RM, Mbega E, Ndakidemi P. 2018. *Drought Tolerance Mechanisms in Plants: Physiological Responses Associated with Water Deficit Stress in Solanum lycopersicum. Adv Crop Sci Tech* 6: 362. DOI: 10.4172/2329-8863.1000362

Farrant, Jill and Cooper, Keren and Nell J. 2012. Desiccation tolerance.

M.A., Wani, S.H., Bhattacharjee, S., Burritt, D.J., Tran, L.-S.P. (Eds.) *Drought Stress Tolerance in Plants*, Vol 1, Physiology and Biochemistry, Editors: Hossain.

Prakash M and Dr K Balakrishnan. 2014. *Abiotic Stress tolerance in crop plants*. Satish Serial Publishing House. Delhi. ISBN: 978-93-81226-92-6.

Kumar S, Muthappa (Ed.) 2017. *Plant Tolerance to Individual and Concurrent Stresses*

Fernando VD and Schroeder DF. 2016. *Role of ABA in Arabidopsis salt, drought, and desiccation tolerance. In Abiotic and Biotic Stress in Plants-Recent Advances and Future Perspectives*. IntechOpen.

Le Gall H, Philippe F, Domon JM, Gillet F, Pelloux and Rayon C. 2015. Cell wall metabolism in response to abiotic stress. Plants, 4(1), pp.112-166.

Hasanuzzaman M, Nahar K, Alam M, Roychowdhury R and Fujita M. 2013. Physiological, biochemical, and molecular mechanisms of heat stress tolerance in plants. International *Journal of Molecular Sciences*, 14(5), pp.9643-9684.

Khan MIR, Fatma M, Per TS, Anjum NA and Khan NA. 2015. *Salicylic acid-induced abiotic stress tolerance and underlying mechanisms in plants. Frontiers in Plant Science*, 6, p.462.

Tuberosa R and Silvio S. 2006. *Genomic based approaches to improve drought tolerance in crops. Trends Plant Sci*. 11. 1260-1285.

Ali A, Ali Z, Quraishi UM, Kazi AG, Malik RN, Sher H and Mujeeb-Kazi A. 2014. *Integrating physiological and genetic approaches for improving drought tolerance in crops. In Emerging technologies and management of crop stress tolerance* (pp. 315-345). Academic Press.

Sahebi M, Hanafi MM, Rafii MY, Mahmud TMM, Azizi P, Osman M, Abiri R, Taheri S, Kalhori N, Shabanimofrad M and Miah G. 2018. *Improvement of drought* *tolerance in rice (Oryza sativa L.): Genetics, genomic tools, and the WRKY gene family*. BioMed research international, 2018.

Manavalan LP, Guttikonda SK, Phan Tran LS and Nguyen HT. 2009. *Physiological and molecular approaches to improve drought resistance in soybean. Plant and Cell Physiology*, 50(7), pp.1260-1276.

Shah AA, Salgotra RK, Wani SA and Mondal SK. 2017. *Breeding and genomics approaches to increase crop yield under drought stress in climate change scenario. European Journal of Experimental Biology*, 7(4), pp.1-7.

Dixit S, Yadaw RB, Mishra KK and Kumar A. 2017. *Marker-assisted breeding to develop the drought-tolerant version of Sabitri, a popular variety from Nepal. Euphytica*, 213(8), p.184.

Mir RR, Zaman-Allah M, Sreenivasulu N., Trethowan R and Varshney RK. 2012. *Integrated genomics, physiology and breeding approaches for improving drought tolerance in crops. Theoretical and Applied Genetics*, 125(4), pp.625-645.

Singla-Pareek SL, Reddy MK and Sopory SK. 2001. *Transgenic approach towards developing abiotic stress tolerance in plants. Proceedings: Indian National Science Academy* Part B, 67(5), pp.265-284.

Gupta B and Huang B. 2014. *Mechanism of salinity tolerance in plants: physiological, biochemical, and molecular characterization*. *International journal of genomics*, 2014.

Zhu JK. 2001. *Plant salt tolerance. Trends in plant science*, 6(2), pp.66-71.

Moghimi A, Yang C, Miller ME, Kianian SF and Marchetto PM. 2018. *A novel approach to assess salt stress tolerance in wheat using hyperspectral imaging.* Frontiers in plant science, 9.

Isayenkov SV and Maathuis FJ. 2019. *Plant Salinity Stress: Many Unanswered Questions Remain. Frontiers in plant science*, 10.

Tuteja N. 2007. *Mechanisms of high salinity tolerance in plants. In Methods in enzymology* (Vol. 428, pp. 419-438). Academic Press.

Carillo P, Annunziata MG, Pontecorvo G, Fuggi A and Woodrow P. 2011. *Salinity stress and salt tolerance. In Abiotic stress in plants-mechanisms and adaptations*. IntechOpen.

Saiema R and Asiya H, Mohamed A , Muneeb R and Siddiqi OT and Parvaiz A. 2013. *Salt Stress: Causes, Types and Responses of Plants*. 10.1007/978-1-4614-4747-4_1.

Negrão S, Schmöckel SM and Tester M. 2017. *Evaluating physiological responses of plants to salinity stress. Annals of Botany*, 119(1), pp.1-11.

Fukao T, Barrera-Figueroa BE, Juntawong P and Peña-Castro JM. 2019. *Submergence and Waterlogging Stress in Plants: A Review Highlighting Research Opportunities and Understudied Aspects. Frontiers in Plant Science*, 10, p.340.

Emamverdian A, Ding Y, Mokhberdoran F and Xie Y. 2015. *Heavy metal stress and some mechanisms of plant defense response. The Scientific World Journal*, 2015.

Mani A and Sankaranarayanan K. 2018. *Heavy Metal and Mineral Element-Induced Abiotic Stress in Rice Plant. In Rice Crop-Current Developments.* IntechOpen.

Barceló Juan and Poschenrieder Charlotte. 2008. *Plant Water Relations as Affected by Heavy Metal Stress: A Review. Journal of Plant Nutrition*. 13. 1-37. 10.1080/01904169009364057.

Yamauchi T, Colmer TD, Pedersen O, Nakazono M, *Plant physiology*. 2018. *Regulation of root traits for internal aeration and tolerance to soil water logging-flooding stress*. 176(2) 1118-1130. DOI: 10.1104/pp.17.01157.

Szymañska R, Elesak I, Orzechowska A and Kruk J. 2017. *Physiological and biochemical responses to high light and temperature stress in plants. Environmental and Experimental Botany* 139: 165-177.

Nahar K, Hasanuzzaman M, Ahamed KU, Hakeem KR, Ozturk M and Fujita M. 2015. *Plant responses and tolerance to high temperature stress: role of exogenous phytoprotectants. In Crop production and global environmental issues* (pp. 385-435). Springer, Cham.

Mathur S, Agrawal D and Jajoo A. 2014. *Photosynthesis: response to high temperature stress. Journal of Photochemistry and Photobiology B: Biology*, 137, pp.116-126.

Ort DR. 2001. *When there is too much light. Plant physiology*, 125(1), pp.29-32.

Demmig-Adams B and Adams Iii WW. 1992. *Photoprotection and other responses of plants to high light stress. Annual review of plant biology*, 43(1), pp.599-626.

Dietz KJ. 2015. *Efficient high light acclimation involves rapid processes at multiple mechanistic levels. Journal of Experimental Botany*, 66(9), pp.2401-2414.

Course Title: Hormonal Regulation of Plant Growth and Development

Course Code : PP 505 **Credit Hours:** 2+1=3

Objective

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.

Theory

Block 1: Plant Growth and Development: Hormonal Regulation

Unit 1: Introduction to Plant Hormones

Growth, differentiation and development regulated by plant growth substances, Definition and classification of growth regulating substances: Classical hormones, Definition and classification of growth regulating substances: Endogenous growth substances other than hormones, Synthetic chemicals.

Unit 2: Plant Hormones – Discovery and Metabolism

Discovery, biosynthetic pathways and metabolism of Auxin, Discovery, biosynthetic pathways and metabolism of Gibberellins, Discovery, biosynthetic pathways and metabolism of Cytokinins, Discovery, biosynthetic pathways and metabolism of Abscisic acid, Discovery, biosynthetic pathways and metabolism of Ethylene, Discovery, biosynthetic pathways and metabolism of Brassinosteroids, Discovery, biosynthetic pathways and metabolism of Strigolactones.

Unit 3: Physiological Role of Hormones in Plant Growth and Development

Physiological functions of Auxin and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Gibberellins and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Cytokinins and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Abscisic acid and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of

Ethylene and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Brassinosteroidsand Strigolactones and use of mutants and transgenic plants in elucidating the physiological functions, Discovery, biosynthetic pathways metabolism and physiological roles of Salicylic acid and Peptide hormones.

Unit 4: Endogenous Growth Substances other than Hormones

Discovery, biosynthetic pathways metabolism and physiological role of Polyamines and Karrikins, Discovery, biosynthetic pathways metabolism and physiological roles of Jasmonates and Tricontanol, Discovery, biosynthetic pathways metabolism and physiological roles of systemins Concept of death hormone, Recent developments in elucidating responses of Salicylic acid, Peptide hormones and Polyamines at physiological and molecular level, Recent developments in elucidating responses of Jasmonates, Systemins, Karrikins and Tricontanol at physiological and molecular level.

Unit 5: Hormone Signaling

Hormone signal perception, transduction - Receptors, components and mechanism (Auxin, Gibberellin, Cytokinin, ABA and Salicylic acid), Hormone signal perception, transduction - Receptors, components and mechanism (Ethylene, Jasmonate, Brassinosteroids and strigolactones), Advances in elucidating the structure and function of receptors and signaling components of important hormones.

Unit 6: Key Genes Regulating Hormone Levels and Functions

Genomics approaches to regulate hormone metabolism and its effect on plant growth and development – case studies.

Unit 7: Crosstalk of Hormones in Regulation of Plant Growth and Development Processes

Crosstalk of Hormones in Regulation of Plant Growth and Development Processes: Floral transition, reproductive development, Shoot and root apical meristem development

Unit 8: Practical Utility of Growth Regulators in Agriculture and Horticulture

Practical Utility of Growth Regulators in Agriculture and Horticulture: Rooting of cuttings, Vine and brewing industry, Promotion of gynoecious flowers, hybrid rice production, induction of flowering in pine apple, cucurbits, Practical Utility of Growth Regulators in Agriculture and Horticulture: Delaying of senescence and ripening, Production of dwarf plants for ornamental purpose, As herbicides, Reduction in flower and fruit drop.

LECTURE SCHEDULE

Lecture No.	Name of the topic	Weightage
Block 1: Plant Growth and Development: Hormonal Regulation		
	Unit 1: Introduction to Plant Hormones	11
1	Growth, differentiation and development regulated by plant growth substances	4
2 & 3	Definition and classification of growth regulating substances: Classical hormones, Definition and classification of growth regulating substances	4
4	Endogenous growth substances other than hormones, Synthetic chemicals	3
	Unit 2: Plant Hormones – Discovery and Metabolism	**14**
5	Discovery, biosynthetic pathways and metabolism of Auxin	3
6 & 7	Discovery, biosynthetic pathways and metabolism of Gibberellins,	4

	Discovery, biosynthetic pathways and metabolism of Cytokinins	
8 & 9	Discovery, biosynthetic pathways and metabolism of Abscisic acid, Discovery, biosynthetic pathways and metabolism of Ethylene	4
10	Discovery, biosynthetic pathways and metabolism of Brassinosteroids, Discovery, biosynthetic pathways and metabolism of Strigolactones	3
	Unit 3: Physiological Role of Hormones in Plant Growth and Development	**20**
11	Physiological functions of Auxin and use of mutants and transgenic plants in elucidating the physiological functions	4
12	Physiological functions of Gibberellins and use of mutants and transgenic plants in elucidating the physiological functions,	4
13	Physiological functions of Cytokinins and use of mutants and transgenic plants in elucidating the physiological functions	4
14	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	4
15&16	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	4
	Unit 4: Endogenous Growth Substances other than Hormones	**13**
17&18	Discovery, biosynthetic pathways metabolism and physiological role of Polyamines and Karrikins, Discovery, biosynthetic pathways metabolism and physiological roles of Jasmonates and Tricontanol, Discovery, biosynthetic pathways metabolism and physiological roles of systemins Concept of death hormone	7
19	Recent developments in elucidating responses of Salicylic acid, Peptide hormones and Polyamines at physiological and molecular level	3
20	Recent developments in elucidating responses of Jasmonates, Systemins, Karrikins and Tricontanol at physiological and molecular level	3
	Unit 5: Hormone Signaling	**12**
21&22	Hormone signal perception, transduction - Receptors, components and mechanism (Auxin, Gibberellin, Cytokinin, ABA and Salicylic acid)	4
23	Hormone signal perception, transduction - Receptors, components and mechanism (Ethylene, Jasmonate, Brassinosteroids and strigolactones)	4
24	Advances in elucidating the structure and function of receptors and signaling components of important hormones	4
25&26	**Unit 6: Key Genes Regulating Hormone Levels and Functions** Genomics approaches to regulate hormone metabolism and its effect on plant growth and development – case studies.	**07**
	Unit 7: Crosstalk of Hormones in Regulation of Plant Growth and Development Processes	**08**
27	Crosstalk of Hormones in Regulation of Plant Growth and Development Processes	4

28	Crosstalk of Hormones in Regulation of Floral transition, reproductive development, Shoot and root apical meristem development	4
	Unit 8: Practical Utility of Growth Regulators in Agriculture and Horticulture	**15**
29&30	Practical Utility of Growth Regulators in Agriculture and Horticulture: Rooting of cuttings, Vine and brewing industry, Promotion of gynoecious flowers, hybrid rice production, induction of flowering in pine apple, cucurbits	8
31&32	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	7
	Total	**100**

Practical

S No.	Title of the experiment
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 cytokinin by GC / GC-MS / HPLC
15	Cytokinin bioassays- effect on apical dominance and senescence / stay green

I. Suggested Reading

Davies P.J. 2004, *Plant Hormones: Biosynthesis, Signal Transduction and Action*, 2nd Edition. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Hedden, P. and Thomas, S.J. 2006. *Plant Hormone Signalling*, Blackwell Publishing Ltd., Oxford, UK.

Osborne, D.J. and McManus, M.T. 2005. *Hormones, Signals and Target Cells in Plant Development*. Cambridge University Press, New York, USA.

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*, 2nd Edition

Lincoln Taiz and Eduardo Zeiger. *Plant Physiology and Development*, 6th Edition. *Teaching Tools in Plant Biology*, The American Society of Plant Biologists *The Arabidopsis* Book(http://www.arabidopsisbook.org/)

Course Title: Physiology of Field Crops

Course Code : PP 508 **Credit Hours:** 2+0=2

Objective

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.

Theory

Block 1: Physiology of Field Crops

Unit 1: Introduction

Origin- Variability in physiology of crop plants between wild species and cultivated. Adaptability to growing environments (ecosystems), Importance in food grain contribution.

Unit 2: Crop Establishment, Crop Growth and Development

Seed characteristic features, dormancy, viability, concept of seed priming seedling establishment and crop stand. Different crop growth stages, concept of source establishment and optimum LAI, Canopy architecture, light interception/radiation use efficiency, thermal time, heat units, GDD, determining growth duration.

Unit 3: Reproductive Growth

Photo and thermo-periodic response for flowering, sink development, sink source relationship, partitioning efficiency, improvement in HI, yield determining factors, genetic gain in yield over years, structuring of ideal plant type, limitations to improve source to sink size, options to improve yield potential.

Unit 4: Seed Nutrient Quality

Seed quality, seed as a source of nutrients, seed constituents and their improvement, concept of pathway engineering to improve seed quality.

Unit 5: Plant Nutrition

Nutrient requirement, genetic variability in nutrient acquisition under constraint conditions, specific nutrient disorders.

Unit 6: Abiotic Stress Response

Response to different abiotic stresses, plant traits/mechanics to improve adaptation to realize potential yields. Global warming responses, thermomorphogenesis, approaches to overcome the constraints.

Unit 7: Crop Specific Physiological Processes and Importance

Choosing location specific crop species exposure will be given on physiological process as described above. Besides, emphasis is on providing information on crop specific features/productivity constraints.

TEACHING SCHEDULE

Lecture No.	Name of the topic	Weightage
Block 1: Physiology of Field Crops		
	Unit 1: Introduction	**10**
1&2	Origin- Variability in physiology of crop plants between wild species and cultivated.	5
3&4	Adaptability to growing environments (ecosystems), Importance in food grain contribution.	5
	Unit 2: Crop Establishment, Crop Growth and Development	**18**
5&6	Seed characteristic features, dormancy, viability, concept of seed priming seedling establishment and crop stand	6
7&8	Different crop growth stages, concept of source establishment and optimum LAI	6
9&10	Canopy architecture, light interception/radiation use efficiency, thermal time, heat units, GDD, determining growth duration.	6
	Unit 3: Reproductive Growth	**18**
11&12	Photo and thermo-periodic response for flowering, sink development, sink source relationship	6
13&14	Photo and thermo-periodic response for partitioning efficiency, improvement in HI, yield determining factors, genetic gain in yield over years	6
15&16	Photo and thermo-periodic response for genetic gain in yield over years, structuring of ideal plant type, limitations to improve source to sink size, options to improve yield potential.	6
	Unit 4: Seed Nutrient Quality	**14**
17&18	Seed quality, seed as a source of nutrients, seed constituents and their improvement	7
17&20	Concept of pathway engineering to improve seed quality	7
	Unit 5: Plant Nutrition	**12**
21&22	Nutrient requirement, genetic variability in nutrient acquisition under constraint conditions	7
23&24	Specific nutrient disorders	5
	Unit 6: Abiotic Stress Response	**15**
25&26	Response to different abiotic stresses, plant traits/mechanics to improve adaptation to realize potential yields	8
27&28	Global warming responses, thermomorphogenesis, approaches to overcome the constraints	7
	Unit 7: Crop Specific Physiological Processes and Importance	13
29&30	Choosing location specific crop species exposure will be given on physiological process as described above	7
31&32	Besides, emphasis is on providing information on crop specific features/productivity constraints	6
	Total	**100**

Suggested Reading

Grain Legumes: Ed De Ron, Antonio M. (Ed.) 2015. Springer

Legumes under Environmental Stress: Yield, Improvement and Adaptations. Eds MM Azooz P Ahmad and Hoboken, NJ: John Wiley and Sons, Ltd., 328 pages. ISBN: 978-1-118-91708- 4

Pulse Crops: Biotechnological Strategies to Enhance Abiotic Stress Tolerance. Ganeshan S, Gaur PM, Chibbar RN, Tuteja N, Gill SS, Tuteja R. chapter 17

Climate Change and Management of Cool Season Grain Legume *Crops*. Eds Yadav GS, McNeil DL, Redden R, Patil SA. Springer *Nature's pulse power: legumes, food security and climate change.* Considine MJ, Siddique

KHM and Foyer CH,· 2017 *J Exp Bot*. 68(8): 1815–1818. Published online 2017 May 11. doi: 10.1093/jxb/erx099

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. DOI 10.1093/jxb/em310

Moore PH and Botha FC. 2014. *Sugarcane: physiology, biochemistry, and functional biology*.John Wiley and Sons ISBN 978-1-118-77119-8

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. DOI 10.1007/s12355-014-0321-6

Evans, L.T., 1996. *Crop Evolution, Adaptation and Yield*. Cambridge University Press.

Jeff L. Bennetzen, j.l AND Hake, S.C. 2009. *Hand Book of Maize: Its Biology*, Springer-Verlag New York

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, A. 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 Sci* 30: 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.

Hubbart S, Peng S, Horton P, Chen Y, Murchie EH. 2007. *Trends in leaf photosynthesis in historical rice varieties developed in the Philippines since 1966; Journal of Experimental Botany*, 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 Science* 22(4): 147-161.

Kole C. 2006. *Cereals and millets. Genome Mapping and Molecular Breeding in Plants. Springer.*

Samuel A. Matz. 2006. Cereal science

Rinki, Mamrutha HM, Sareen S, Tiwari V, Singh GP. 2018. *Dissecting the physiological and anatomical basis for high yield potential in HD 2967. Vegetos*. 31: 121-124.

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 Reports* 10.1007/ s11033-019-04761-3

Tiwari R and Mamrutha HM. 2014. *Precision Phenotyping for Mapping of Traits for Abiotic Stress Tolerance in Crops. Biotechnology: Prospects and Applications.* Ed. Salar RK, Gahlawat SK, Siwach P and Duhan JS. Pp79-85. Publisher: Springer.

Sleper DA and Poehlman JM. 1995. *Breeding for field crops*

Reynolds *M. Wheat Physiological Breeding volume I and II (CIMMYT): Wheat Physiological Breeding: A Field Guide to Wheat Phenotyping*.

Mamrutha HM *et al*. 2019. *Physiological and Molecular Basis of Abiotic Stress Tolerance in Wheat*. In: Rajpal V., Sehgal D., Kumar A., Raina S. (eds) *Genetic Enhancement of Crops for Tolerance to Abiotic Stress: Mechanisms and Approaches*, Vol. I. Sustainable Development and Biodiversity, vol 20. Springer, Cham

Tiwari V. *et al*. 2017. *Managing Abiotic Stresses in Wheat.* In: Minhas P., Rane J., Pasala R. (eds) *Abiotic Stress Management for Resilient Agriculture*. Springer, Singapore

----

Course Title: Seed Physiology

Course Code : PP 510* **Credit Hours:** 2+1=3

Objective

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.

Theory

Block 1: Physiology of Seed Development

Unit 1: Introduction to Seed Physiology

Importance of seed as a propagule, seed structure and functions; chemical composition of seeds. Embryogenesis: pollination and fertilization, pollen and pistil interaction, signal for interaction; pollen load hypothesis; genetical and environmental influence on seed development. Source-Sink relationship affecting seed yield and quality. Concept of seed viability and seedling vigour and their relevance; approaches to improve the storability of seeds. Physiological and molecular mechanisms of seed germination; approaches to improve seed germination; seed size and its influence on seed germination.

Unit 2: Seed Development

Physiology and molecular mechanisms of embryo, endosperm and seed coat development; cellularization during endosperm development; morphological and cellular changes during seed coat development, anatomy and function of seed coat, programmed cell death (PCD) in seed coat, Deposition of seed storage reserves during development.

Unit 3: Seed Maturation

Seed maturation and maturation indices; physiological and anatomical changes during seed maturation; Seed drying and acquisition of desiccation tolerance in seeds; mechanisms of desiccation tolerance; role of ABA LEA's, HSP's, dehydrins and other stress proteins during seed maturation and drying, Seed abortion and approaches to reduce it.

Unit 4: Metabolism in Developing Seed

Chemical composition of seeds (carbohydrates, proteins, fats etc.), source of assimilates for seed development, pathways of movement of assimilates to developing seed, approaches to increase the chemical composition of seeds. Seed respiration and mitochondrial activity; seed respiration rate and storability of seeds. Seed ageing, Mobilization of stored resource in seeds; Chemistry of oxidation of starch, proteins and fats; Utilization of breakdown products by embryonic axis.

Block 2: Physiology of Seed Germination and Dormancy

Unit 1: Seed germination

Seed germination, types of germination, imbibition kinetics of germinating seed; Physiological events during germination: seed respiration, mitochondrial activity, mobilization of food reserve; energy utilization by the germinating seed. Environmental regulation of germination: hydro-time, thermal time and hydrothermal time models; Influence of environmental factors on germination; Role of plant hormones/PGR's during seed germination.

Unit 2: Seed Dormancy and Viability

Physiological and molecular basis of seed dormancy, hormonal regulation of dormancy, After ripening, dormancy breaking treatments; Ecological perspective of seed dormancy. Seed viability: concept and physiology of seed viability, theories of seed ageing, seed storage and regulation of storage life of seeds; methods to prolong seed viability; Conservation of orthodox and recalcitrant seeds. Seed vigour: concept, importance, measurement; Physiological, biochemical and molecular basis of seed vigour.

TEACHING SCHEDULE

Lecture No.	Name of the topic	Weight age
	Block 1: Physiology of Seed Development	
	Unit 1: Introduction to Seed Physiology	**20**
1	Importance of seed as a propagule, seed structure and functions; chemical composition of seeds.	3
2&3	Embryogenesis: pollination and fertilization, pollen and pistil interaction, signal for interaction; pollen load hypothesis; genetical and environmental influence on seed development.	5
4	Source-Sink relationship affecting seed yield and quality.	3
5	Concept of seed viability and seedling vigour and their relevance; approaches to improve the storability of seeds.	4
6&7	Physiological and molecular mechanisms of seed germination; approaches to improve seed germination; seed size and its influence on seed germination.	5
	Unit 2: Seed Development	**15**

8&9	Physiology and molecular mechanisms of embryo, endosperm and seed coat development	5
10&11	Cellularization during endosperm development; morphological and cellular changes during seed coat development	5
12&13	Anatomy and function of seed coat, programmed cell death (PCD) in seed coat, Deposition of seed storage reserves during development	5
	Unit 3: Seed Maturation	**15**
14&15	Seed maturation and maturation indices; physiological and anatomical changes during seed maturation	5
16&17	Seed drying and acquisition of desiccation tolerance in seeds; mechanisms of desiccation tolerance	5
18&19	role of ABA LEA’s, HSP’s, dehydrins and other stress proteins during seed maturation and drying, Seed abortion and approaches to reduce it	5
	Unit 4: Metabolism in Developing Seed	**20**
20&21	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	8
22&23	Seed respiration and mitochondrial activity; seed respiration rate and storability of seeds	8
24&25	Seed ageing, Mobilization of stored resource in seeds; Chemistry of oxidation of starch, proteins and fats; Utilization of breakdown products by embryonic axis	8
Block 2: Physiology of Seed Germination and Dormancy		
	Unit 1: Seed germination	**15**
26	Seed germination, types of germination, imbibition kinetics of germinating seed; Physiological events during germination	5
27	Seed respiration, mitochondrial activity, mobilization of food reserve; energy utilization by the germinating seed	5
28	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	5
	Unit 2: Seed Dormancy and Viability	**15**
29	Physiological and molecular basis of seed dormancy, hormonal regulation of dormancy, After ripening, dormancy breaking treatments, ecological perspective of seed dormancy	4
30	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	4
31	Conservation of orthodox and recalcitrant seeds	3
32	Seed vigour: concept, importance, measurement; Physiological, biochemical and molecular basis of seed vigour	4
	Total	**100**

Practical

S No.	**Title of the experiment**
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 etc.
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 ofseed 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

IX. Suggested Reading

Bewley, JD, Bradford K, Hilhorst H, Nogonaki 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 *et al*. 2017. *Seed Physiology*. Associated Publishing Company.

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

Pammenter NW 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. Vanangamudi *et al*.) TNAU, Coimbatore. 287-396.

Padmavathi SM, Prakash S, Ezhil Kumar G, Sathianarayanan and Kamaraj A. 2012. *A Text Book of Seed Science and Technology*. New India Publishing Agency, New Delhi.

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.

13. Course Structure for Ph. D. (Agriculture) Plant Physiology: Semester wise core Courses offered based on credit requirement (Major/ Minor/ Supporting/ Non-credit compulsory courses/ common courses/ Seminar/ Research and Thesis writing).

Corse Code	Title	Credits	Nature
Major			
PP 602*	Signal perception and transduction and regulation of physiological processes	2 + 0 = 2	
PP 604	Plant phenomics- Next generation phenomics platforms	2 + 0 = 2	
PP 606	Global climate change and crop response	2 + 0 = 2	
PP 607*	Physiological and molecular aspects of source- sink capacity for enhancing yield	3 + 0 = 3	
PP 608	Seed and fruit growth and their quality improvement	2 + 0 = 2	
PP 610	Weed biology and physiology of herbicide action	2 + 0 = 2	
	Total	**13+0= 13**	
Minor			
BIOCHEM 603	Biochemistry Of Biotic And Abiotic Stresses	3 + 0 = 3	
GPB 605*	Genomics in Plant Breeding	3 + 0 = 3	
	Total	**6 + 0 = 6**	
Supporting			
SST 603	Physiology and Biochemistry of Seeds	1+1=2	
BIOCHEM 605	Concepts and aplication of omics in biological science	3+0=3	
	Total	**4+1=5**	
Non credit compulsory courses/ common courses			
	Library & Information Services	0 + 1 = 1	
	Tech. Writing & Communication Skill	0 + 1 = 1	
	IPR & It's management in Agriculture	0 + 1 = 1	
	Basic Concepts in Library Techniques	0 + 1 = 1	
	Agril. Res., Res. Ethics & Rural Dev. Program	0 + 1 = 1	
	Total	**0 + 5 = 1**	
Seminars			
PP 691	Seminar-I	0 + 1 = 1	
PP 692	Seminar-II	0 + 1 = 1	
	Total	**0 + 2 = 2**	
Thesis/ Research			
PP 699	**Thesis/ Research**	**0+75 = 75**	
	Total course and credit loads	**13+6+5+ 2+ 75 = 101**	

Course Contents : Ph. D. in Plant Physiology

Course Title: Signal Perceptions and Transduction And Regulation of Physiological Processes

Course Code : PP 602* **Credit Hours:** 2+0=2

Objective

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.

Theory

Block 1: Signal Perceptions and Transduction: Regulation of Physiological Processes

Unit 1: Concept of Receptor and Ligands

Signal, signal types, long (diffusible) and short (contact) range signaling and components of signaling. Types of receptors, nature of ligands, downstream components like primary, secondary signaling components.

Unit 2: Receptors – Signal Perception and Transfer

Cell surface trans-membrane receptors- GPCRs, Receptor Tyrosine Kinases (RTKs), Receptors Serine Threonine kinases (RSTKs), Receptor-Like Kinases (RLKs), receptor two component systems. Signal transfer phosphor-relay and generation of secondary signaling components and activation of TFs or enzymes. Downstream components- G-proteins, second messengers-Cyclic AMP, Adenylate cyclase cascade, cyclic GMP, calcium-calmodulin-kinases; effector molecules (transcription factor).

Unit 3: Hormone Signaling

Hormone binding receptors-Transduction process. Effector molecules and gene expression. Specific signaling pathways of Auxins, Cytokinin, Gibberellins, Ethylene, ABA, Brassinosteroids, Salicylic Acid, Strigolactone, polyamines, Jasmonic acid, etc. which leads to formative effects. Cross talk in the signaling of different hormones-significance of studies with hormone action mutants.

Unit 4: Light Signaling

Perception of light-pigments involved- activation of phytochrome/cryptochrome (study of mutants). Light signal transduction. Multiple signaling cascades- identification of signaling components through mutant analysis-changes in gene expression.

Unit 5: Abiotic Stress Signaling and Nutrient Signalling

Sensing of environmental factors (Temperature-Osmotic-Ionic stress), Activation of specific molecules and secondary messengers, activation of downstream components-leading to stress gene expression, Case studies with different abiotic stresses, Retrograde signaling, Nitrogen fixation, nitrogen and phosphorus uptake, nutrient translocation.

Unit 6: Signaling Cascade during Developmental Events

Leaf senescence/fruit development and ripening, Tuberization, Sugar signaling. Signaling during seed germination.

Unit 7: Signal Perception and Transduction in Plant Defense Responses

General mechanisms to pathogen response, Role of salicylic acid and active oxygen species, Cross Talk Signaling- Stress matrix under field conditions, cross talk between abiotic-abiotic stress, biotic-abiotic stress signaling networks.

TEACHING SCHEDULE

Lecture No.	Name of the topic	Weightage
Block 1: Signal Perceptions and Transduction: Regulation of Physiological Processes		
	Unit 1: Concept of Receptor and Ligands	**10**
1&2	Signal, signal types, long (diffusible) and short (contact) range signaling and components of signaling.	5
3&4	Types of receptors, nature of ligands, downstream components like primary, secondary signaling components.	5
	Unit 2: Receptors – Signal Perception and Transfer	**20**
5&6	Cell surface trans-membrane receptors- GPCRs, Receptor Tyrosine Kinases (RTKs), Receptors Serine Threonine kinases (RSTKs), Receptor-Like Kinases (RLKs), receptor two component systems	7
7&8	Signal transfer phosphor-relay and generation of secondary signaling components and activation of TFs or enzymes	6
9&10	Downstream components- G-proteins, second messengers-Cyclic AMP, Adenylate cyclase cascade, cyclic GMP, calcium-calmodulin-kinases; effector molecules (transcription factor)	7
	Unit 3: Hormone Signaling	**15**
11 &12	Hormone binding receptors-Transduction process	4
13&14	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	6
15&16	Cross talk in the signaling of different hormones-significance of studies with hormone action mutants	5
	Unit 4: Light Signaling	**13**
17&18	Perception of light-pigments involved- activation of phytochrome/ cryptochrome (study of mutants)	6
19&20	Light signal transduction. Multiple signaling cascades- identification of signaling components through mutant analysis-changes in gene expression	7
	Unit 5: Abiotic Stress Signaling and Nutrient Signalling	**18**
21&22	Sensing of environmental factors (Temperature-Osmotic-Ionic stress)	5
23&24	Activation of specific molecules and secondary messengers, activation of downstream components-leading to stress gene expression	7
25&26	Case studies with different abiotic stresses, Retrograde signaling, Nitrogen fixation, nitrogen and phosphorus uptake, nutrient translocation	6
	Unit 6: Signaling Cascade during Developmental Events	**12**
27&28	Leaf senescence/fruit development and ripening, Tuberization, Sugar signaling	7
	Signaling during seed germination	5
	Unit 7: Signal Perception and Transduction in Plant Defense Responses	**12**
29&30	General mechanisms to pathogen response, Role of salicylic acid and	6

	active oxygen species	
31&32	Cross Talk Signaling- Stress matrix under field conditions, cross talk between biotic-abiotic stress, biotic-abiotic stress signaling networks	6
	Total	**100**

Suggested Reading

He, Y., Zhou, J., Shan, L. and Meng, X., 2018. *Plant cell surface receptor-mediated signaling–a common theme amid diversity*. J Cell Sci, 131(2), p.jcs209353.

Hall, M.A., Smith, A.R., Novikova, G.V. and Moshkov, I.E., 1999. *Perception and transduction of ethylene. New Comprehensive Biochemistry*, 33, 475-490.

Huber, A.E. and Bauerle, T.L., 2016. *Long-distance plant signaling pathways in response to multiple stressors: the gap in knowledge. Journal of Experimental Botany*, 67(7), 2063-2079.

Pollard, T.D., Earnshaw, W.C., Lippincott-Schwartz, J. and Johnson, G., 2016. *Cell Biology* E-Book. Elsevier Health Sciences.

Braun, Y., Smirnova, A.V., Weingart, H., Schenk, A. and Ullrich, M.S., 2007. *A temperature sensing histidine kinase—function, genetics, and membrane topology*. Methods In Enzymology: 423: 222-249. Academic Press.

Unden, G., Wörner, S. and Monzel, C., 2016. *Cooperation of secondary transporters and sensor kinases in transmembrane signalling: the DctA/DcuS and DcuB/DcuS sensor complexes of Escherichia coli. In Advances in Microbial Physiology* (Vol. 68, 139-167). Academic Press.

Ortiz-Urquiza, A. and Keyhani, N.O., 2016. Molecular genetics of *Beauveria bassiana* infection of insects. *Advances in Genetics* 94: 165-249). Academic Press.

Snijders, L. and Naguib, M., 2017. *Communication in animal social networks: a missing link. Adv Study Behav*, 49, pp.297-359.

Hedden, P. and Thomas, S.G. (eds.), 2008. *Annual Plant Reviews, Plant Hormone Signaling* 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*, 2015, 1998-2008.

Leduc, N., Roman, H., Barbier, F., Péron, T., Huché-Thélier, L., Lothier, J., Demotes-Mainard,

S. and Sakr, S., 2014. *Light signaling in bud outgrowth and branching in plants. Plants*, 3(2), 223-250.

Kami, C., Lorrain, S., Hornitschek, P. and Fankhauser, C., 2010. *Light-regulated plant growth and development*. *Current Topics in Developmental Biology* (91: 29-66). Academic Press.

Coureux, P.D. and Genick, U.K., 2007. *Triggering and Monitoring Light Sensing Reactions in Protein Crystals. Methods in Enzymology* (422: 305-337). Academic Press.

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. International Review of Cell and Molecular Biology* (301: pp. 37-94). Academic Press.

Ben-Ari, G. and Lavi, U., 2012. *Marker-assisted selection in plant breeding*. *Plant Biotechnology and Agriculture* (163-184). Academic Press.

Peleg, Z.V.I., Walia, H. and Blumwald, E. 2012. *Integrating genomics and genetics to accelerate development of drought and salinity tolerant crops*. *Plant Biotechnology and Agriculture* 271- 286. Academic Press.

Zhu, J.K., 2016. *Abiotic Stress Signaling and Responses in Plants*. Cell, 167(2): 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. International Review of Cell and Molecular Biology* (Vol. 290, pp. 167-204). Academic Press.

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) 163-192.

Sparks, E., Wachsman, G. and Benfey, P.N. 2013. *Spatiotemporal signalling in plant development. Nature Reviews Genetics* 14(9): p.631.

Rabellino, D., Boyd, J.E., McKinnon, M.C. and Lanius, R.A. 2019. *The Innate Alarm System: A Translational Approach. Stress: Physiology, Biochemistry, and Pathology* 197-212. Academic Press.

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*. *Advances in Applied Microbiology* (81: 89-132). Academic Press.

Reverchon, S., Muskhelisvili, G. and Nasser, W., 2016. *Virulence program of a bacterial plant pathogen: the Dickeya model. Progress in Molecular Biology and Translational Science* (142, 51-92). Academic Press.

Davies, P.J. ed., 2004. *Plant Hormones: Biosynthesis, Signal Transduction, Action*. Springer Science and Business Media.

Dzhavakhiya, V.G. and Shcherbakova, L.A., 2007. *Creation of disease-resistant plants by gene engineering. Comprehensive and Molecular Phytopathology* (439-466). Elsevier.

Dyakov, Y.T. and Ozeretskovskaya, O.L., 2007. *Vertical pathosystem: avirulence genes and their products. Comprehensive and Molecular Phytopathology* (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. Plant Virus–Host Interaction* (345-357). Academic Press.

General Source Information

Bogre L and Beemster G. 2008. *Plant cell monographs. Plant Growth Signaling. Signals and Signal Transduction Pathways in Plants* 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)

Sopory SK Oelmuller R, Maheswari SC. 2012. (Ed) *Signal Transduction in Plants: CurrentAdvances*; ISBN-13: 9781461355182

Wang XY, Springer, 2016. *Plant Signalling Networks: Methods and Protocols* ISBN-13: 9781493961696

Developmental and Cell Biology Series: Hormones, Signals and Target Cells in Plant Development Series Number 41, Osborne DJ, McManus MT, Cambridge University Press, ISBN-13: 9780521330763

How Plants Communicate Machajewski S. 2018, Rosen Education Service, ISBN-13: 9781538301852

Signal Transduction in Plants Aducci P (Ed), 2011, ISBN-13: 9783034899383

Reactive Oxygen Species: Signaling Between Hierarchical Levels in Plants. Schmitt FJ. Allakhverdiev SI (Eds), 2017, Wiley-Scrivener ISBN-13: 9781119184881

Biocommunication: Sign-Mediated Interactions Between Cells and Organisms Gordon R and Seckbach J (Ed). 2017. World Scientific Publishing Europe Ltd ISBN-13: 9781786340443

Annual Plant Reviews: Intracellular Signaling in Plants Hedden P, Napier R, Yang Z (Ed) 2008, Wiley-Blackwell (an imprint of John Wiley and Sons Ltd) ISBN-13: 9781405160025

Course Title: Plant Phenomics-next Generation Phenomics Platforms

Course Code : PP 604 **Credit Hours:** 2+0=2

Objective

The course aims at providing cutting edge knowledge on the current progress made in various phenotyping techniques and approaches. The students will be versed with principles of various phenotyping approaches. The aim is to provide hands- on expertise in analyzing trait diversity. Exposure will be provided on Non-invasive imaging technologies that drive the phenomics platforms. The course provides comprehensive exposure on recent developments in phenomics platforms imaging tools/techniques and recent trends in designing specific phenomics platforms e.g. drought studies/root phenotyping etc.

Theory

Block 1: Concepts of High throughput Phenotyping and its Requirement

Unit 1: Concepts of Phenotyping

The concepts of “phene and trait” analogous to gene and allele. Genome-phenome relationship, definition of phenotyping, GxE interaction on phenome.

Unit 2: Physio-Morphological Traits Associated with Crop Performance

Overview of phenotyping needs to complement genomic resources, specific traits associated with yield potential, stress adaptation (both biotic and abiotic stresses). Need for high throughput precision phenotyping approaches for basic studies and to generate genetic and genomic resources.

Unit 3: Features of Phenomic Platforms

Precision growth conditions, maintenance of light, temperature/VPD and RH to realize the potential crop growth response, Controlled environmental facilities for simulating challenging climatic conditions to phenotype diverse plant traits, Concept of sensors, diverse sensors and their utility in precise quantification of environmental variables, soil moisture sensors, Imaging to capture plant traits, image acquisition. Automated big data access, processing, etc.

Unit 4: Trends in Phenomics

Types of phenomic platforms- Laboratory, Greenhouse and the field-based platforms. Platforms designed for specific needs i.e., root phenotyping, drought studies etc., Crop specific phenotyping, mobile and stationary platforms, Global trends in establishing major phenomics platforms, and their characteristic features and impact.

Unit 5: Non-invasive Phenotyping Approaches

The concept of non-invasive capturing of plant growth and health, Imaging technologies - image acquisition, segmentation and data analysis, Critical aspects of Visual, IR Thermal, Fluorescence, NIR, Hyperspectral imaging, Development and validation of models for deriving relevant physiological traits from image phenome. Concepts of Plants to sensors and sensors to plants, Stationary and ground based tractor mounted sensors/imaging tools, Unmanned aerial vehicle (UAV) sensors, Machine learning and its integration to analyze ground and aerial based images.

Block 2: Applications of the Phenomics Platforms

Unit 1: Basic Studies to Assess the Crop Response

Functional validation of genes, chemicals and other interventions, Characterize the growth and stress response in contrasts to identify the relevance of adaptive trait.

Unit 2: Applied Studies Focused on Crop Improvement Programs Characterizing the pre-released promising lines for productivity under defined environmental variables. Phenotyping germplasm accessions, mapping populations for specific traits for mapping, Concept of Phenome Wide Association Studies (PWAS). Genomic selection, gene-based crop models to predict complex traits, Impact of phenomics platform, progress made, case studies.

TEACHING SCHEDULE

Lecture No.	Name of the topic	Weightage
	Block 1: Concepts of High throughput Phenotyping and its Requirement	
	Unit 1: Concepts of Phenotyping	**10**
1&2	The concepts of “phene and trait” analogous to gene and allele	5
3&4	Genome-phenome relationship, definition of phenotyping, GxE interaction on phenome	5
	Unit 2: Physio-Morphological Traits Associated with Crop Performance	**15**
5&6	Overview of phenotyping needs to complement genomic resources, specific traits associated with yield potential, stress adaptation (both biotic and abiotic stresses)	7
7&8	Need for high throughput precision phenotyping approaches for basic studies and to generate genetic and genomic resources	8
	Unit 3: Features of Phenomic Platforms	**20**
9&10	Precision growth conditions, maintenance of light, temperature/VPD and RH to realize the potential crop growth response	5
11&12	Controlled environmental facilities for simulating challenging climatic	5

	conditions to phenotype diverse plant traits	
13&14	Concept of sensors, diverse sensors and their utility in precise quantification of environmental variables, soil moisture sensors	5
15&16	Imaging to capture plant traits, image acquisition. Automated big data access, processing, etc.	5
	Unit 4: Trends in Phenomics	**11**
17	Types of phenomic platforms- Laboratory, Greenhouse and the field-based platforms.	3
18	Platforms designed for specific needs i.e., root phenotyping, drought studies etc.,	4
19	Crop specific phenotyping, mobile and stationary platforms, Global trends in establishing major phenomics platforms, and their characteristic features and impact.	4
	Unit 5: Non-invasive Phenotyping Approaches	**20**
20	The concept of non-invasive capturing of plant growth and health	3
21	Imaging technologies - image acquisition, segmentation and data analysis	3
22	Critical aspects of Visual, IR Thermal, Fluorescence, NIR, Hyperspectral imaging	4
23	Development and validation of models for deriving relevant physiological traits from image phenome	4
24	Concepts of Plants to sensors and sensors to plants, Stationary and ground based tractor mounted sensors/imaging tools	3
25	Unmanned aerial vehicle (UAV) sensors, Machine learning and its integration to analyze ground and aerial based images	3
Block 2: Applications of the Phenomics Platforms		
	Unit 1: Basic Studies to Assess the Crop Response	**12**
26&27	Functional validation of genes, chemicals and other interventions	6
28&29	Characterize the growth and stress response in contrasts to identify the relevance of adaptive trait	6
	Unit 2: Applied Studies Focused on Crop Improvement Programs	**12**
30	Characterizing the pre-released promising lines for productivity under defined environmental variables	4
31	Phenotyping germplasm accessions, mapping populations for specific traits for mapping, Concept of Phenome Wide Association Studies (PWAS)	4
32	Genomic selection, gene-based crop models to predict complex traits, Impact of phenomics platform, progress made, case studies	4
	Total	**100**

Suggested Reading

Pieruschka R and Poorter H. 2012. *Phenotyping plants: genes, phenes and machines. Functional Plant Biology*, 39(11), 813-820.

Noah F, Gehan MA and Baxter I. 2015. *Lights, camera, action: high-throughput plant phenotyping is ready for a close-up*. *Current Opinion in Plant Biology* 24 2015: 93-99.

Singh AK, Ganapathysubramanian B, Sarkar S and Singh A. 2018. *Deep learning for plant stress phenotyping: trends and future perspectives. Trends in Plant Science*.

Lobos GA, Camargo AV, del Pozo A, Araus JL, Ortiz R and Doonan JH. 2017. *Plant Phenotyping and Phenomics for Plant Breeding. Frontiers in Plant Science*, 8, 2181.

Walter A, Liebisch F and Hund A. 2015. *Plant phenotyping: from bean weighing to image analysis*. *Plant Methods*, 11(1): 14.

Rahnama, A., Munns, R., Poustini, K., and Watt, M. 2011. *A Screening Method to Identify Genetic Variation in Root Growth Response to a Salinity Gradient. Journal of Experimental Botany* 62(1), 69-77.

Okono R. 2010. *Practical measurement of generic drought adaptation-related traits. Drought phenotyping in crops: From theory to practice. Generation Challenge Programme,* Cornell, USA, 451-457.

Chen D, Neumann K, Friedel S, Kilian B, Chen M, Altmann T and Klukas C. 2014. *Dissecting the phenotypic components of crop plant growth and drought responses based on high- throughput image analysis*. *The Plant Cell*, 26(12), 4636-4655.

Lyu JI, Baek SH, Jung S, Chu H, Nam HG, Kim J and Lim PO. 2017. *High-throughput and computational study of leaf senescence through a phenomic approach. Frontiers in plant science*, 8, 250.

Jeudy C, Adrian M, Baussard C, Bernard C, Bernaud E, Bourion V and Lamboeuf M. 2016.

RhizoTubes as a new tool for high throughput imaging of plant root development and architecture: test, comparison with pot grown plants and validation. Plant Methods, 12(1), 31.

Großkinsky DK, Svensgaard J, Christensen S and Roitsch T. 2015. *Plant phenomics and the need for physiological phenotyping across scales to narrow the genotype-to-phenotype knowledge gap. Journal of experimental botany*, 66(18), 5429-5440.

Ubbens JR and Stavness I. 2017. *Deep Plant Phenomics: a Deep Learning Platform for Complex Plant Phenotyping Tasks. Frontiers in Plant Science*, 8, 1190.

Tardieu F, Cabrera-Bosquet L, Pridmore T and Bennett M. 2017. *Plant phenomics, from sensors to knowledge. Current Biology* 27(15), R770-R783.

Rahaman M, Chen D, Gillani Z, Klukas C and Chen M. 2015. *Advanced phenotyping and phenotype data analysis for the study of plant growth and development. Frontiers in Plant Science*, 6, 619.

Kumar J, Pratap A and Kumar S. Eds. 2015. *Phenomics in crop plants: trends, options and limitations* (No. 8, p. 296). New Delhi: Springer India.

Costa C, Schurr U, Loreto F, Menesatti P and Carpentier S. 2018. *Plant Phenotyping Research Trends, a Science Mapping Approach. Frontiers in Plant Science*, 9.

Das Choudhury S, Samal A and Awada T. 2019. *Leveraging Image Analysis for High-Throughput Plant Phenotyping. Frontiers in Plant Science*, 10, 508.

Golzarian MR, Frick RA, Rajendran K, Berger B, Roy S, Tester M and Lun DS. 2011. *Accurate inference of shoot biomass from high-throughput images of cereal plants. Plant Methods*, 7(1), 2.

https://www.fz-juelich.de/ibg/ibg-2/EN/methods_jppc/methods_node.html

Hartmann A, Czauderna T, Hoffmann R, Stein N and Schreiber F. 2011. *HTPheno: an image analysis pipeline for high-throughput plant phenotyping. BMC bioinformatics*, 12(1), 148.

Berger B, Parent B and Tester M. 2010. *High-throughput shoot imaging to study drought responses. Journal of Experimental Botany*, 61(13), 3519-3528.

Grift TE, Novais J and Bohn M. 2011. *High-throughput phenotyping technology for maize roots. Biosystems Engineering*, 110(1), 40-48.

Ge Y, Bai G, Stoerger V and Schnable JC. 2016. *Temporal dynamics of maize plant growth, water use, and leaf water content using automated high throughput RGB and hyperspectral imaging. Computers and Electronics in Agriculture*, 127; 625-632.

DominguesFranceschini M, Bartholomeus H, van Apeldoorn D, Suomalainen J and Kooistra L. 2017. *Intercomparison of unmanned aerial vehicle and ground-based narrow band spectrometers applied to crop trait monitoring in organic potato production*. Sensors, 17(6), 1428.

Busemeyer L, Mentrup D, Möller K, Wunder E, Alheit K, Hahn V and Rahe F. 2013. *BreedVision—A multi-sensor platform for non-destructive field-based phenotyping in plant breeding. Sensors* 13(3), 2830-2847.

Li, L, Zhang Q and Huang D. 2014. *A review of imaging techniques for plant phenotyping. Sensors* 14(11) 20078-20111.

Banan D, Paul R, Feldman MJ, Holmes M, Schlake H, Baxter I and Leakey AD. 2017. *High fidelity detection of crop biomass QTL from low-cost imaging in the field*. BioRxiv, 150144.

Honsdorf N, March TJ, Berger B, Tester M and Pillen K. 2014. *High-throughput phenotyping to detect drought tolerance QTL in wild barley introgression lines*. PLoS One, 9(5), e97047.

Rungrat T, Awlia M, Brown T, Cheng R, Sirault X, Fajkus J and Pogson BJ. 2016. *Using phenomic analysis of photosynthetic function for abiotic stress response gene discovery. The Arabidopsis Book/American Society of Plant Biologists*, 14.

Tanger P, Klassen S, Mojica JP, Lovell JT, Moyers BT, Baraoidan M and Leung H. 2017.*Field-based high throughput phenotyping rapidly identifies genomic regions controlling yield components in rice. Scientific Reports*, 7, 42839.

Zhang X, Huang C, Wu D, Qiao F, Li W, Duan L and Xiong L. 2017. *High-throughput phenotyping and QTL mapping reveals the genetic architecture of maize plant growth. Plant physiology*, 173(3), 1554-1564.

Campbell MT, Knecht AC, Berger B, Brien CJ, Wang D and Walia H. 2015. *Integrating image-based phenomics and association analysis to dissect the genetic architecture of temporal salinity responses in rice. Plant physiology* 168(4): 1476-1489.

Chen D, Neumann K, Friedel S, Kilian B, Chen M, Altmann T and Klukas C. 2014. *Dissecting the phenotypic components of crop plant growth and drought responses based on high- throughput image analysis*. *The Plant Cell*, 26(12), 4636-4655.

Parent B, Shahinnia F, Maphosa L, Berger B, Rabie H, Chalmers K and Fleury D. 2015. *Combining field performance with controlled environment plant imaging to identify the genetic control of growth and transpiration underlying yield response to water-deficit stress in wheat. Journal of Experimental Botany* 66(18): 5481-5492.

Araus JL and Cairns JE. 2014. *Field high-throughput phenotyping: the new crop breeding frontier. Trends in Plant Science* 19(1): 52-61.

Brown TB, Cheng R, Sirault XR, Rungrat T, Murray KD, Trtilek M and Borevitz JO. 2014. *TraitCapture: genomic and environment modelling of plant phenomic data. Current opinion in plant biology*. 18: 73-79.

Pratap A, Gupta S, Nair RM, Gupta SK, Schafleitner R, Basu PS and Mishra AK. 2019. *Using Plant Phenomics to Exploit the Gains of Genomics. Agronomy*, 9(3), 126.

Rahaman M, Chen D, Gillani Z, Klukas C and Chen M. 2015. *Advanced phenotyping and phenotype data analysis for the study of plant growth and development. Frontiers in Plant Science*. 6, 619.

Campbell ZC, Acosta-Gamboa LM, Nepal N and Lorence A. 2018. *Engineering plants for tomorrow: how high-throughput phenotyping is contributing to the development of better crops. Phytochemistry Reviews*. 17(6), 1329-1343.

Araus JL, Kefauver SC, Zaman-Allah M, Olsen MS and Cairns JE. 2018. *Translating high- throughput phenotyping into genetic gain. Trends in Plant Science* 23(5): 451-466.

General Source Information

Montes JM, Melchinger AE and Reif JC. 2007. *Novel throughput phenotyping platforms in lant genetic studies. Trends in Plant Science*, 12(10): 433-436.

Development of high throughput plant phenotyping facilities at aberystwyth (ppt)

Zhou J, Reynolds D, Websdale D, Le Cornu T, Gonzalez-Navarro O, Lister C and Clark M. 2017. *CropQuant: An automated and scalable field phenotyping platform for crop monitoring and trait measurements to facilitate breeding and digital agriculture*. BioRxiv, 161547.

Bradshaw JE. 2017. *Plant breeding: past, present and future. Euphytica*, 213(3), 60.

Lee U, Chang S, Putra GA, Kim H and Kim DH. 2018. *An automated, high-throughput plant phenotyping system using machine learning-based plant segmentation and image analysis*. *PloS one*, 13(4), e0196615.

Furbank RT and Tester M. 2011. *Phenomics–technologies to relieve the phenotyping bottleneck. Trends in Plant Science* 16(12): 635-644.

Course Title: Global Climate Change and Crop Response

Course Code : PP 606 **Credit Hours:** 2+0=2

Objective

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.

Theory

Block 1: Climate Change: Crop Response and Mitigation

Unit 1: Fundamentals of Climate Change

Definition of climate change, history and evidences of climate change and its implications. Natural and anthropogenic climate change. Sources of Greenhouse Gas (GHG) emission, Global Warming Potential of GHGs, accumulation of GHGs in the atmosphere and science behind climate change, industrial revolution and GHG build-up in the atmosphere, Energy-Emission-Economy Interactions, carbon intensity of economy, carbon equity/justice.

Unit 2: Manifestations of Climate Change

Impact on monsoons, occurrence of extreme weather events, hydrological cycle and water availability, effect on crop growing period in tropics, subtropics and temperate regions, shifts in distribution of flora and fauna, effects on biodiversity and migration of tropical plant species to higher latitudes and altitudes.

Unit 3: Major GHGs (CO_2, Methane, NO_2, etc.), their Production Rates, Monitoring and their Influence on Climate Change

GHGs: An Overview, - role of CO_2, methane and major uncertainties. Mechanism of their production and emission from various, source and sinks of GHGs; and contribution of GHGs to global warming. Techniques used in monitoring GHGs.

Unit 4: Agricultural Practices on GHG Production

Carbon footprint analysis of agriculture and various agricultural practices contribute to climate change. Impacts of natural factors and farming practices on greenhouse gas emissions. Sources of agricultural GHG emission- Agricultural Soil Management, enteric fermentation, manure management, other sources. Opportunities to reduce GHG emission from Agriculture.

Unit 5: Direct and Indirect Effects of Climate Change on Plant Processes

Problems and Prospects of Crops with changing temperature: Growth and Development of Crop plants, Thermo-morphogenesis, phenology, Physiological processes such as photosynthesis, Net carbon assimilation, C_3 and C_4 plants adaptation,Respiration, Nutrient acquisition and metabolisms, Plant water relations and Heat shock proteins, Grain/seed development: Grain Quality parameters and yield.

Unit 6: Climate Change Scenario and Impact on Crops

Different scenarios for temperature, rainfall in different agro-climatic zones of India and their impact on crop growth and productivity. Major climate change (temperature, CO_2, and rainfall) impact quantification using field or controlled environment experiments, meta-analysis and simulation models. Some examples of crop simulation models calibration and their application in short-term and long- term predictions.

Unit 7: Ozone Depletion leading to Increased Ionizing Radiations and its Implications on Crop Growth

Role of CFCs in ozone depletion, penetration of ionizing UV radiations and its implications on crop growth.

Unit 8: Long-term and Short-term Projections of Climate Change: Effects on Natural Vegetation and Ecosystems

Response of natural ecosystems to increasingatmospheric CO_2 concentration and climate warming, effect of climate change on quality of feed i.e leaf and stored grains/seeds, its implications on pollinators and pests

Unit 9: Technologies for Climate Change Mitigation in Agriculture

Agricultural biotechnology to produce crop varieties with enhanced carbon uptake. Nutrient management: Management of nitrogenous fertilizers.

Tillage/residue management:

1. Conservation tillage CO_2 mitigation technology;
2. Biochar: A potentialtechnique for carbon sequestration.

Methane mitigation using reduced tillage technology, change in methanogenic bacterial activity using electron acceptors. Carbon sequestration potential, concept and measurement.

Unit 10: Climate-resilient Agriculture

Conventional and biotechnological approaches to improve the crop adaptation to climate change. Relevance of "Genome wide mutants" to identify genes/processes for improved adaptation to changing environments.

Unit 11: Climate Change: Technologies for Crop response studies

Temperature Gradient Chambers, Temperature Gradient Greenhouses, Soil plant atmosphere research system (SPAR), Infra-red warming Technology, Free Air temperature enrichment technology, Soil Warming system etc.

Unit 12: Politics of Climate Change Negotiations

IPCC, Major International conventions/treaties, Kyoto Protocol, Paris Agreement, Global initiatives on Carbon sequestration, carbon trading.

TEACHING SHEDULE

Lecture No.	Name of the topic	Weightage
	Block 1: Climate Change: Crop Response and Mitigation	
	Unit 1: Fundamentals of Climate Change	**10**
1	Definition of climate change, history and evidences of climate change and its implications. Natural and anthropogenic climate change.	3
2&3	Sources of Greenhouse Gas (GHG) emission, Global Warming Potential of GHGs, accumulation of GHGs in the atmosphere and science behind climate change, industrial revolution and GHG build-up in the atmosphere, Energy-Emission-Economy Interactions, carbon intensity of economy, carbon equity/justice	7
	Unit 2: Manifestations of Climate Change	**08**
4&5	Impact on monsoons, occurrence of extreme weather events, hydrological cycle and water availability, effect on crop growing period in tropics, subtropics and temperate regions	4
6	Shifts in distribution of flora and fauna, effects on biodiversity and migration of tropical plant species to higher latitudes and altitudes	4
	Unit 3: Major GHGs (CO_2, Methane, NO_2, etc.), their Production Rates, Monitoring and their Influence on Climate Change	**08**
7	GHGs: An Overview, - role of CO_2, methane and major uncertainties	3
8&9	Mechanism of CO_2, methane and major uncertainties production and emission from various, source and sinks of GHGs; and contribution of GHGs to global warming. Techniques used in monitoring GHGs	5
	Unit 4: Agricultural Practices on GHG Production	**08**
10&11	Carbon footprint analysis of agriculture and various agricultural practices contribute to climate change. Impacts of natural factors and farming practices on greenhouse gas emissions	4
112&13	Sources of agricultural GHG emission- Agricultural Soil Management, enteric fermentation, manure management, other sources. Opportunities to reduce GHG emission from Agriculture	4
	Unit 5: Direct and Indirect Effects of Climate Change on Plant Processes	**10**
14	Problems and Prospects of Crops with changing temperature: Growth and Development of Crop plants	4
15&16	Thermo-morphogenesis, phenology, Physiological processes such as photosynthesis, Net carbon assimilation, C_3 and C_4 plants adaptation, Respiration, Nutrient acquisition and metabolisms, Plant water relations and Heat shock proteins, Grain/seed development: Grain Quality parameters and yield	6
	Unit 6: Climate Change Scenario and Impact on Crops	**10**

17	Different scenarios for temperature, rainfall in different agro-climatic zones of India and their impact on crop growth and productivity.	4
18&19	Major climate change (temperature, CO_2, and rainfall) impact quantification using field or controlled environment experiments, meta-analysis and simulation models. Some examples of crop simulation models calibration and their application in short-term and long- term predictions.	6
	Unit 7: Ozone Depletion leading to Increased Ionizing Radiations and its Implications on Crop Growth	**08**
20	Role of CFCs in ozone depletion	4
21	Penetration of ionizing UV radiations and its implications on crop growth	4
	Unit 8: Long-term and Short-term Projections of Climate Change: Effects on Natural Vegetation and Ecosystems	**08**
22	Response of natural ecosystems to increasingatmospheric CO_2 concentration and climate warming	4
23	Effect of climate change on quality of feed i.e leaf and stored grains/seeds, its implications on pollinators and pests	4
	Unit 9: Technologies for Climate Change Mitigation in Agriculture	**10**
24	Agricultural biotechnology to produce crop varieties with enhanced carbon uptake.	3
25	Nutrient management: Management of nitrogenous fertilizers. 1. Conservation tillage CO_2 mitigation technology; 2. Biochar: A potentialtechnique for carbon sequestration.	3
26	Methane mitigation using reduced tillage technology, change in methanogenic bacterial activity using electron acceptors. Carbon sequestration potential, concept and measurement.	4
	Unit 10: Climate-resilient Agriculture	**07**
27	Conventional and biotechnological approaches to improve the crop adaptation to climate change	3
28	Relevance of “Genome wide mutants” to identify genes/processes for improved adaptation to changing environments	4
	Unit 11: Climate Change: Technologies for Crop response studies	**07**
29	Temperature Gradient Chambers, Temperature Gradient Greenhouses	3
30	Soil plant atmosphere research system (SPAR), Infra-red warming Technology, Free Air temperature enrichment technology, Soil Warming system etc	4
	Unit 12: Politics of Climate Change Negotiations	06
31&32	IPCC, Major International conventions/treaties, Kyoto Protocol, Paris Agreement, Global initiatives on Carbon sequestration, carbon trading	6
	Total	**100**

Suggested Reading

Uprety DC and Reddy VR. 2016. *Crop responses to Global warming*, Springer publication, ISBN 978-981-10-2004-9, pp 1-125 (2016)

Torquebiau E. 2015. *Climate Change and Agriculture Worldwide* Springer Netherlands

Lipper L, McCarthy N, Zilberman D, Asfaw S, Branca. 2018. *Climate Smart Agriculture: Building Resilience to Climate Change.* Springer, FAO.

Handbook of Climate Change and Agroecosystems: The Agricultural Model Intercomparison and Improvement Project (AgMIP) in 2 parts Kindle Editionby Rosenzweig Cynthia and Hillel Daniel (Author), Cynthia Rosenzweig (Editor), 2015

Climate Smart Agriculture FAO source book, 2013

Aggarwal PK. 2009. *Climate Change and Indian Agriculture*, ICAR Publication.

Kumar N, Singh S, Aggarwal AK, Rao PK, Venkateswarlu VUM B. 2012. *Climate change and Indian Agriculture: Salient achievements from ICAR network project*. IARI Pub., 32p. available at http://www.iari.res.in/files/ClimateChange.pdf

Hebbar KB, Naresh Kumar S and Chowdappa P. 2017. *Impact of Climate Change on Plantation Crops* (Eds). P 260. Astrel International–Daya Publishing House, New Delhi, India, ISBN: 9789351248330

Kumar NS, Bandyopadhyay SK, Padaria RN, Singh AK, Rashid Md., Wasim Md., Anuja,

Kaur R, D.NSwaroopa Rani, Panda BB, Garnayak LM, Prasad S, Khanna M, Sahoo RN and Singh VV. 2014. *Climatic Risks and Strategizing Agricultural Adaptation in Climatically Challenged Regions*. IARI, New Delhi Publication. TB-ICN: 136/2014, P 106. Available at http://www.iari.res.in/files/ClimaticRisks.pdf

Lamb HH. 2013. *Climate: Present, Past and Future* (Routledge Revivals): Volume 1: Fundamentals and Climate Now. Routledge.

Nelson, G.C., Rosegrant, M.W., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringler, C., Msangi,

S., Palazzo, A., Batka, M. and Magalhaes, M., 2009. *Climate change: Impact on agriculture and costs of adaptation* (Vol. 21). Intl Food Policy Res Inst.

Lobell, D.B. and Gourdji, S.M., 2012. *The influence of climate change on global crop productivity. Plant Physiology*, 160(4). 1686-1697.

Tubiello, F.N., Soussana, J.F. and Howden, S.M., 2007. *Crop and pasture response to climate change. Proceedings of the National Academy of Sciences*, 104(50): 19686-19690.

Iizumi, T., Furuya, J., Shen, Z., Kim, W., Okada, M., Fujimori, S., Hasegawa, T. and Nishimori, M., 2017. *Responses of crop yield growth to global temperature and socioeconomic changes. Scientific Reports*, 7(1), p.7800.

Najafi, E., Devineni, N., Khanbilvardi, R.M. and Kogan, F., 2018. *Understanding the changes in global crop yields through changes in climate and technology. Earth's Future*, 6(3), 410- 427.

Wheeler, T. and Von Braun, J., 2013. *Climate change impacts on global food security. Science*, 341(6145), 508-513.

Lobell, D.B., Schlenker, W. and Costa-Roberts, J., 2011. *Climate trends and global crop production since 1980. Science*, 333(6042), pp.616-620.

Lobell, D.B. and Field, C.B., 2007. *Global scale climate–crop yield relationships and the impacts of recent warming. Environmental Research Letters*, **2**(1), 014002.

Howden, S.M., Soussana, J.F., Tubiello, F.N., Chhetri, N., Dunlop, M. and Meinke, H., 2007. *Adapting agriculture to climate change. Proceedings of the national academy of sciences*, 104(50), 19691-19696.

Sanz-Cobena, A., Lassaletta, L., Aguilera, E., Del Prado, A., Garnier, J., Billen, G., Iglesias, A., Sanchez, B., Guardia, G., Abalos, D. and Plaza-Bonilla, D., 2017. *Strategies for greenhouse gas emissions mitigation in Mediterranean agriculture: A review. Agriculture, Ecosystems and Environment* 238: 5-24.

Wollenberg, E., Richards, M., Smith, P., Havlík, P., Obersteiner, M., Tubiello, F.N., Herold, M., Gerber, P., Carter, S., Reisinger, A. and Van Vuuren, D.P. 2016. *Reducing emissions from agriculture to meet the 2 C target*. Global Change Biology **22**(12), pp. 3859-3864.

Alley, R.B. 2014. *Two-mile time machine: Ice cores,abrupt climate change and our future*: Princeton University Press.

Fan, K.S.W. 2015. *Climate change and Chinese History: A review of trends, topics and methods. Wiley Interdisciplinary Reviews. Climate Change* **6**: 225-238.

Uprety, D.C. 2014. *Greenhouse gases and Crops,* New Delhi Publishing India Group pp. 1- 427.

Uprety, D.C., Reddy, V.R. and Mura, J.D. 2019. *Climate Change and Agriculture: A HistoricalAnalysis*. Springer, Nature, Singapore Pvt. Ltd. 1-88

Crutzen, P.J. 1991. *Methane's sinks and sources*. *Nature* 350: 380-381.

Das, K. and Baruah, K.K. 2008. *A comparison of growth and photosynthetic characterstics of two improved rice cultivars on methane emission from rainfed agroecosystem of North East India*, *Agricul. Ecosyst. and Environ*. **124**: 105-113.

Das, K. and Baruah, K.K. 2008. *Methane emission associated with anatomical and morpho physiological characterstics of rice* (*Oryza sativa* L.) plant. *Physiologia Plantarum* **134**: 303- 312.

Uprety, D.C., Baruah, K.K. and Borah, L. 2011. *Methane in rice agriculture*. *J. Sci. Ind. Res.* **70**: 401-411.

Abbasi, M.K. and Adams W.A. 2000. *Gaseous N emission during simultaneous nitrification-denitrification associated with mineral N fertilization to a grassland soil under field conditions*. *Soil Biology and Biochemistry* **32**: 1251-1259.

Bhatia, A *et al.* 2010. *Mitigating nitrous oxide emission from soil under conventional and no tillage in wheat using nitrification inhibitors. Agriculture, Ecosystem and Environment,* **136** (3-4): 247-253.

Datta A, *et al.* 2011. *Greenhouse gas emissions and rice based cropping systems: Economic and Technologic challenges and Opportunities. Mittig. Adapt. Strateg. Global Change*, **16**(5): 597-615.

Uprety, D.C. 2014. *Greenhouse gases and Crops. Publishing India Group*, ISBN 978-81-928337-0-5, pp 250-308.

Adhya, T.K., Patnaik, P, Satpathy, S.N., Kumarswami, S. and Sethunathan, N. 1998. *Influence of Phosphorus application on methane emission and production in flooded paddy soils. Soil Biol. Biochem* **30**: 177-181

Babu, J.Y., Nayak, D.R. and Adhya, T.K. 2006. *Potassium application reduces Methane emission from flooded field planted to rice*. *Biol.Fertil, Soils* (2006), **42**: 532-54.

Lehmann, J., Gaunt J. and Rondon, M. 2006. *Bio char sequestration in terrestrial ecosystem-A review Mitigation and Adaptation strategies for Global change* **11**: 403-427, C. Springer.

Uprety, D.C., Dhar, S., Hongmin, D., Kimball, B.A., Garg, A and Upadhyay, J. (2012), *Technologies for Climate change Mitigation –Agriculture Sector- GEF*, TNA Guidebook series,

UNEP RISO Center, DTU, Denmark, pp 1-117.

Uprety, D.C., Baruah, K.K. and Borah, L. 2011. *Methane in rice agriculture*. *J. Sci. and Indust. Res.* **70** (6): 401-411

IPCC AR5 Reports WG I 2013

IPCC AR5 Reports WG II and III 2014

IPCC Special Reports
UNFCCC website
IPCC website
NOAA website
CCAFS website
India's Second National Communication to UNFCCC
INCCA Report, MoEF and CC
MoEF and CC website

Course Title: Physiological and Molecular Aspects of Source-sink Capacity for Enhancing Yield

Course Code : PP 607* **Credit Hours:** 3+0=3

Objective

The course addresses the recent development in photosynthetic processes that can be exploited to improve yield potential. Besides, other major emphasis is to provide exposure on recent developments in regulating the sink characters ie., yield attributes at molecular level to achieve higher potential yields.

Theory

Block 1: Source Size and Function–Basic Concepts, Physiological and Molecular Mechanisms, Genomic Resources to Regulate Source Characters

Unit 1: Source Establishment

Maximize energy capture by improved light interception, light distribution and its utilization efficiency, concepts of shade avoidance response (SAR) and option to increase, Increase canopy size by vertical expansion – concept of increasing optimum LAI levels, Concepts of semi-tall varieties with resistance to lodging: traits associated with lodging resistance, Sustain net carbon gain with age – the relevance of stay green character, photon capture and achieve high CO_2 reduction to photon ratio under low light, Options for increasing canopy photosynthesis, Relevance of maintaining cell turgor and nutrient status.

Unit 2: Source Function- Photochemical Reactions

Maximize conversion efficiency of intercepted radiation by improving net carbon gain - Emerging solutions to increase carbon fixation rate, Improve efficiency of photochemical reaction by - Engineering the pigments to expand PAR spectrum into IR range; reduce antenna size, optimize energy dissipation mechanisms; optimize components of ETC and downstream acceptors; accelerate adaptation for shifting light intensities.

Unit 3: Source Function- CO_2 Diffusion and Concentration

Enhance stomatal conductance (g_s) and mesophyll conductance (g_m) – guard cell metabolism; concepts of leaf mesophyll tissue thickness (SLW), Concepts of VPD responses of g_s to enhance duration of photosynthesis during the day, Bicarbonate transports and aquaporins; achieve higher CCM - Engineering C4 cycle, CAM, cyanobacteria, carboxysomes, algal pyrenoids.

Unit 4: Source Function- Metabolic Engineering of CO_2 Fixation

RuBisCO carbon fixation activity - Increase and optimize kinetics of RuBisCO with enhanced specificity to CO_2, Engineer RuBisCO to minimize feedback regulation by metabolite inhibitors, Increased activation state by improving stability and function of RuBisCOactivase; optimize RuBp regeneration – modulate specific enzyme levels. New concepts on photorespiratory synthetic bypass.

Unit 5: Case Studies to Improve Source Capacity

Genetic and genomic resources, genes/QTLs associated with specific yield potential traits and/or photosynthetic mechanisms, Genetic resources to improve source traits- case studies.

Block 2: Improving Sink Size and Capacity

Unit 1: Sink Establishment

Optimise duration of phenological stages related to sink establishment, genetic and environmental factors, GDD and phenology.

Unit 2: Increase the Sink Size by Enhancing the Relevant Constituent Traits

Role of hormones in regulating molecular mechanisms of yield structure development, Genomic and genetic resources developed for regulation/improvement of such traits. – Sink Size: Tillering associated traits, branching patterns/fruiting points, spikelet number, pod number, fruit number. – Sink development: Basic concepts and molecular mechanisms associated with pollination, fertilization, ovary development in determining the spikelet fertility/sterility components and strategies for engineering seed/fruit size in crop plants.

Unit 3: Genetic and Genomic Resources, Genes/ QTLs, Genetic Resourcesto Improve Sink Traits- Case Studies. Progress and status in developing genomic and genetic resources of validated genes/ QTLs to improve sink traits- Specific case studies.

Unit 4: Source to Support the Sink Capacity

Canopy architecture to support sink requirements in cereals: plant height, tillering, leaf area, shading or senescence of lower canopy leaves, canopy photosynthesis, Canopy architecture to support sink requirements in Pulses: Leaf senescence, abscission, mobilization of N and other nutrients, Symbiotic N fixation to support sink size and capacity in pulses.

TEACHING SCHEDULE

Lecture No.	Name of the topic	Weightage
Block 1: Source Size and Function–Basic Concepts, Physiological and Molecular Mechanisms, Genomic Resources to Regulate Source Characters		
	Unit 1: Source Establishment	**12**
1&2	Maximize energy capture by improved light interception, light distribution and its utilization efficiency, concepts of shade avoidance response (SAR) and option to increase	4
3&4	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	3
5&6	Sustain net carbon gain with age – the relevance of stay green character, photon capture and achieve high CO_2 reduction to photon ratio under low light, Options for increasing canopy photosynthesis, Relevance of maintaining cell turgor and nutrient status	5
	Unit 2: Source Function- Photochemical Reactions	12
7, 8 &9	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	6

	expand PAR spectrum into IR range	
10,11 &12	Reduce antenna size, optimize energy dissipation mechanisms; optimize components of ETC and downstream acceptors; accelerate adaptation for shifting light intensities	6
	Unit 3: Source Function- CO_2 Diffusion and Concentration	**10**
13&14	Enhance stomatal conductance (g_s) and mesophyll conductance (g_m) – guard cell metabolism	3
15&16	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	4
16&17	Engineering C4 cycle, CAM, cyanobacteria, carboxysomes, algal pyrenoids	3
	Unit 4: Source Function- Metabolic Engineering of CO_2 Fixation	**12**
18,19 &20	RuBisCO carbon fixation activity - Increase and optimize kinetics of RuBisCO with enhanced specificity to CO_2, Engineer RuBisCO to minimize feedback regulation by metabolite inhibitors	6
21, 22 &23	Increased activation state by improving stability and function of RuBisCOactivase; optimize RuBp regeneration – modulate specific enzyme levels. New concepts on photorespiratory synthetic bypass	6
	Unit 5: Case Studies to Improve Source Capacity	**10**
24, 25 &26	Genetic and genomic resources, genes/QTLs associated with specific yield potential traits and/or photosynthetic mechanisms	6
	Genetic resources to improve source traits- case studies	4
Block 2: Improving Sink Size and Capacity		
	Unit 1: Sink Establishment	**10**
27& 28	Optimise duration of phenological stages related to sink establishment	4
29, 30 &31	Optimise duration of phenological stages related to genetic and environmental factors, GDD and phenology.	6
	Unit 2: Increase the Sink Size by Enhancing the Relevant Constituent Traits	**14**
32 & 33	Role of hormones in regulating molecular mechanisms of yield structure development, Genomic and genetic resources developed for regulation/improvement of such traits.	4
34 &35	Sink Size: Tillering associated traits, branching patterns/fruiting points, spikelet number, pod number, fruit number	4
36, 37 &38	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	6
	Unit 3: Genetic and Genomic Resources, Genes/ QTLs, Genetic Resources to Improve	**10**
39 &40	Sink Traits- Case Studies	4

41 & 42	Progress and status in developing genomic and genetic resources of validated genes/ QTLs to improve sink traits- Specific case studies	4
	Unit 4: Source to Support the Sink Capacity	**10**
43, 44 & 45	Canopy architecture to support sink requirements in cereals: plant height, tillering, leaf area, shading or senescence of lower canopy leaves, canopy photosynthesis, Canopy architecture to support sink requirements in Pulses	6
46 & 47	Leaf senescence, abscission, mobilization of N and other nutrients, Symbiotic N fixation to support sink size and capacity in pulses	4
	Total	**100**

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

Hunter MC, Smith RG, Schipanski ME, Atwood LW and Mortensen DA. 2017. *Agriculture in 2050: Recalibrating Targets for Sustainable Intensification*. BioScience • April 2017 / Vol. 67 No. 4

PirjoPeltonen-Sainio, TapioSalo, Lauri Jauhiainen, HeikkiLehtonen, ElinaSievila¨inen. 2015. *Static yields and quality issues: Is the agri-environment program the primary driver*? Ambio 2015, 44: 544–556 DOI 10.1007/s13280-015-0637-9

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

Orta DR, Merchantd BS, Alricf J, Barkan A *et al*. 2015. *Redesigning photosynthesis to sustainably meet global food and bioenergy demand*. PNAS, 112, 8529–8536

TANG Yun-jia, Liesche J. 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

Sessa G, Carabelli M, Possenti M, Morelli G and Ruberti I. 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

Haroa RJ, Baldessaria J, Otegui ME. 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

Jiang D, Chen W, Dong J, Li J, Yang1 F, Wu Z, Zhou H, Wang W and Zhuang C. 2018. *Overexpression of miR164b-resistant OsNAC2 improves plant architecture and grain yield in rice. Journal of Experimental Botany*, vol. 69, (7) 1533–1543.

Smolikova G, Dolgikh E, Vikhnina M, Frolov A and Medvedev S. 2017. *Genetic and Hormonal Regulation of Chlorophyll Degradation during Maturation of Seeds with Green Embryos*. *Int. J. Mol. Sci*. 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

Sato T, Shimoda Y, Matsuda K, Tanaka A, Ito H. 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

Christophera M, Chenub NK, Jenningsa R, Fletchera S, Butlera D, Borrellc A, Christopher J. 2018. *QTL for stay-green traits in wheat in well-watered and water-limited environments. Field Crops Research* 217 (2018) 32–44

Thomas H and Ougham H. 2014. *The stay-green trait. Journal of Experimental Botany*, Vol. 65, No. 14, pp. 3889–3900, 2014

Kusaba M, Tanaka A, Tanaka R. *Stay-green plants: what do they tell us about the molecular mechanism of leaf senescence*. *Photosynth Res* DOI 10.1007/s11120-013-9862-x

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

South PF, Cavanagh AP, Liu HW, Ort DR. 2019. *Synthetic glycolate metabolism pathways stimulate crop growth and productivity in the field*. *Science*. DOI: 10.1126/science.aat9077

Long BM, YihHee W, Sharwood RE, Rae BD, Kaines S *et al*. *Carboxysome encapsulation of the CO2-fixing enzyme Rubisco in tobacco chloroplasts. Nature communication* DOI: 10.1038/ s41467-018-06044-0

Orr DJ, Alcântara A, Kapralov MV, Andralojc PJ, Silva EL, Parry MAJ. *Surveying Rubisco diversity and temperature response to improve crop photosynthetic efficiency. Plant Physiolocy* DoI: 10.1104/pp.16.00750.

Even AB. 2018. *Daring metabolic designs for enhanced plant carbon fixation. Plant Science* 2018 71-83

Jansson C, Vogel J, Hazen S, Brutnell T and Mockler T. 2018. *Climate-smart crops with enhanced photosynthesis. Journal of Experimental Botany*, Vol. 69, No. 16 pp. 3801–3809, 2018.

Conlan B, Birch R, Kelso C, Holland S, De Souza AP, Long SP, Beck JL, Whitney SM. 2018. *BSD is a Rubisco specific assembly chaperone, forms intermediary hetero-oligomeric complexes and is non-limiting to growth in tobacco. Plant Physiol*.

Skraly FA, Ambavaram MMR, Peoples O, Snell KD. 2018. *Metabolic engineering to increase crop yield: From concept to execution. Plant Science* 273: 23–32.

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.* 1 (1)

Khumsupan*et al*., 2019, *CRISPR/Cas in Arabidopsis: overcoming challenges to accelerate improvements in crop photosynthetic efficiencies, PhysiologiaPlantarum.*

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/plantgenome 2017.08.0073.

Sgarma *et al*. 2018. *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.

Hong *et al*. 2017. *Genome-wide identification and extensive analysis of rice-endosperm preferred genes using reference expression database, J. Plant Biol*. 60: 249-258.

Mir *et al*. *High-throughput phenotyping for crop improvement in the genomics era, Plant Science*, In press

Orezyk N *et al*. 2017. *Major genes determining yield-related traits in wheat and barley, Theor Appl Genet* 130: 1081-1098.

Savadi. 2018. *Molecular regulation of seed development and strategies for engineering seed size in crop plants- Review, Plant Growth Regulation* 84: 401–422

Sonnewald *et al*. 2018. *Next-generation strategies for understanding and influencing source–sink relations in crop plants, Current Opinion in Plant Biology*. 43: 63–70

Zhang *et al*. 2016. *OsSRT1 is involved in rice seed development through regulation of starch metabolism gene expression, Plant Science* 248: 28–36

Scheben *et al*. 2018. *Progress in single-access information systems for wheat and rice crop improvement, Briefings in Bioinformatics*. 1–7

Verma *et al*. *Rice research to break yield barriers*, Cosmos, Vol. 11, No. 1 (2015) 1–18

Li *et al*. 2018. *Systems model-guided rice yield improvements based on genes controlling source, sink, and flow. Journal of Integrative Plant Biology*, 60, (12): 1154–1180

Paul *et al*. 2018. *The Role of Trehalose 6-Phosphate in Crop Yield and Resilience, Plant Physiology* 177: 12–23.

Narnoliya *et al*. *Transcriptional Signatures Modulating SAM Morphometric and Plant Architectural Traits Enhance Yield and Productivity in Chickpea, The Plant Journal.*

Course Title: Seed and Fruit Growth and their Quality Improvement

Course Code : PP 608 **Credit Hours:** 2+0=2

Objective

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 minimizethe losses.

Theory

Block 1: Physiological and Molecular Aspects of Seed and Fruit Growth: Quality Improvement

Unit 1: Physiology of Seed Growth and Development

Mechanism of seed development and different developmental stages; synthesis, mobilization and accumulation of stored reserves, Forms of stored reserves and their localization, Sink drawing ability (SDA) and its relevance in seed growth and development, Role of plant hormones in seed growth and development and SDA.

Unit 2: Seed as a Propagule

Seed as a propagation material; seed size and seed chemical composition and their relevance in seed germination, Physiological, biochemical and molecular mechanisms and approaches to regulate seed germination, seedling emergence and establishment and seedling vigour, Physiological, biochemical and molecular mechanisms and approaches to regulate seed priming and crop establishment: seed dormancy, precocious germination and controlling pre-harvest sprouting in crops, Physiological, biochemical and molecular mechanisms and approaches to regulate seed viability, improving the viability and storability of seeds.

Unit 3: Seed as a Source of Nutrition

Seed as a source of nutrition to humans: approaches to improve the quality of seeds through synthesis of seed storage reserves and other constituents, Genes/ QTL's regulating these processes and concept of pathway engineering to improve the quantity and quality of seed constituents, Carbohydrates- Amylose and amylopectin ratios for glycemic index, resistant and digestable starch, improving dietary fibre, alter gelatinisation, Protein content, modified proteins, essential amino acids, Oil content, fatty acid composition, Omega 3 fatty acids. Carotenoids and vitamins, Biofortification strategies to enhance the grain zinc, iron, other minerals and other essential compounds, Engineering for low protease inhibitors, phytic acid, tannins, phenolic substances, lectins, oxalates as anti-nutritional factors, Case studies of improving seed nutrition components by molecular breeding and transgenic approaches.

Unit 4: Quality Deterioration during Storage

Changes in chemical composition during storage; factors influencing the deterioration of nutritional quality of seeds during storage; approaches to minimize nutritional quality deterioration, Effect of quality deterioration on human and animal health

Unit 5: Fruit Growth and Development

Flower and fruit development; concept of parthenocarpy, Physiological and biochemical changes during fruit development and chemical composition, Molecular approaches to regulate flower and fruit drop/ abscission; Role of hormones.

Unit 6: Fruit as a Source of Phytochemicals: Nutraceuticals

Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Antioxidants, Flavanoids, anthocyanins, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Vitamins- Vitamin C, Tocopherol, Carotenoids, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Alkaloids, Mangiferin, tomatins, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of DigestableFiber lycopene, stillbeans, Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Aroma, monoterpenoids and Fatty acid esters.

Unit 7: Fruit Ripening, Post Harvest Deterioration and Shelf life

Physiological and molecular mechanisms of fruit ripening, Postharvest deterioration of fruits; factors regulating fruit deterioration; hormonal and environmental aspects of reducing post harvest deterioration of fruits, Physiological and Molecular approaches to regulate fruit ripening and shelf life: Role of Ethylene and Ethylene response factors regulating specific processes of fruit ripening; Approaches to regulate specific shelf life characters, Improving fruit ripening and shelf life by molecular approaches-Case studies.

TEACHING SCHEDULE

Lecture No.	Name of the topic	Weightage
Block 1: Physiological and Molecular Aspects of Seed and Fruit Growth: Quality Improvement		
	Unit 1: Physiology of Seed Growth and Development	**10**
1	Mechanism of seed development and different developmental stages; synthesis, mobilization and accumulation of stored reserves	5
2& 3	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	5
	Unit 2: Seed as a Propagule	**17**
4& 5	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	6
6& 7	Physiological, biochemical and molecular mechanisms and approaches to regulate seed priming and crop establishment	5
8& 9	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	6
	Unit 3: Seed as a Source of Nutrition	**18**
10& 11	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	6
12& 13	Carbohydrates- Amylose and amylopectin ratios for glycemic index, resistant and digestable starch, improving dietary fibre, alter gelatinisation, Protein content, modified proteins, essential amino acids, Oil content, fatty acid composition, Omega 3 fatty acids, Carotenoids and vitamins, Biofortification strategies to enhance the grain zinc, iron, other minerals and other essential compounds	6
14& 15	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	6

	approaches	
	Unit 4: Quality Deterioration during Storage	**12**
16& 17	Changes in chemical composition during storage; factors influencing the deterioration of nutritional quality of seeds during storage	6
18& 19	Approaches to minimize nutritional quality deterioration, Effect of quality deterioration on human and animal health	6
	Unit 5: Fruit Growth and Development	**13**
20& 21	Flower and fruit development; concept of parthenocarpy, Physiological and biochemical changes during fruit development and chemical composition	7
22& 23	Molecular approaches to regulate flower and fruit drop/ abscission; Role of hormones	6
	Unit 6: Fruit as a Source of Phytochemicals: Nutraceuticals	**17**
24	Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Antioxidants, Flavanoids, anthocyanins,	4
25	Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Vitamins-Vitamin C, Tocopherol, Carotenoids	4
26	Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Alkaloids, Mangiferin, tomatins	3
27	Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of DigestableFiber lycopene, stillbeans	3
28	Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Aroma, monoterpenoids and Fatty acid esters	3
	Unit 7: Fruit Ripening, Post Harvest Deterioration and Shelf life	**13**
29	Physiological and molecular mechanisms of fruit ripening, Postharvest deterioration of fruits; factors regulating fruit deterioration	3
30	Hormonal and environmental aspects of reducing post harvest deterioration of fruits, Physiological and Molecular approaches to regulate fruit ripening and shelf life	3
31	Role of Ethylene and Ethylene response factors regulating specific processes of fruit ripening	4
32	Approaches to regulate specific shelf life characters, Improving fruit ripening and shelf life by molecular approaches-Case studies	3
	Total	**100**

Suggested Reading

Bewley, JD, Bradford K, Hilhorst H, Nonogaki H. (2013). *Seeds: Physiology of Development, Germination and Dormancy*, Springer-Verlag

Larkins BA and Vasil IK (Ed). 2010. *Cellular and Molecular Biology of Plant Seed Development*, Springer

Vanangamudi K, Natarajan K and Vanangamudi M, *Seed Physiology*, Associated Publishing Company.

Pammenter NW and Berjak P. 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..

Lee KR, Chen GQ and Kim HU. 2015. *Current progress towards the metabolic engineering of plant seed oil for hydroxy fatty acids production. Plant Cell Reports*, 34(4): 603-615.

Zhu Y, Xie L, Chen GQ, Lee MY, Loque D and Scheller HV. 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 GJ, Carter TC and Nguyen HT. 2017. *Molecular mapping and genomics of soybean seed protein: a review and perspective for the future. Theoretical and Applied Genetics* 130(10): 1975-1991.

Tien Lea D, Duc Chua H. and Quynh Lea N. 2016. *Improving nutritional quality of plant proteins through genetic engineering. Current Genomics*, 17(3): 220-229.

Mene-Saffrane, L. and Pellaud, S. 2017. *Current strategies for vitamin E biofortification of crops. Current opinion in biotechnology* 44: 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, 937.

Bohra A, Jha UC, Jha R, Naik SJS, Maurya AK and Patil PG. Chapter-1. *Genomic Interventions for Biofortifcation 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

Finkelstein JL, Haas JD and Mehta S. 2017. *Iron-biofortified staple food crops for improving iron status: a review of the current evidence, Current Opinion in Biotechnology* 44: 138–145

Sperotto RA, Ricachenevsky FK, Waldow VdA, Fett JP. *Iron biofortification in rice: It's a long way to the top, Plant Science* 190 (2012) 24–39

Lee J, Nou IS, Kim HR. 2012. *Current status in calcium biofortification of crops, J Plant Biotechnol* 39: 23–32, DOI: http://dx.doi.org/10.5010/JPB.2012.39.1.023

Sharma D, Jamr G, Singh UM, Sood S and Kumar A. 2017. *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*, doi: 10.3389/fpls.2016.02028

Gemede HF 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 IM and Oliveira JTA. 2004. *Antinutritional properties of plant lectins. Toxicon*, 44(4), pp.385-403.

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 HU, Naveed M and Basra SMA. 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.

Gillaspy G, David HB and Gruissem W. *Fruits: A Developmental Perspective, The Plant Cell*, Vol. 5, 1439-1451

Nitsch JP. 1953. *The Physiology of Fruit Growth. Annual Review of Plant Physiology*, 4(1), 199–236.doi: 10.1146/annurev.pp.04.060153.0012

Kumar R, Khurana A and Sharma AK. 2014. *Role of plant hormones and their interplay in development and ripening of fleshy fruits, Journal of Experimental Botany*, 65: 4561– 4575, https://doi.org/10.1093/jxb/eru277

Robert HS. 2019. *Molecular Communication for Coordinated Seed and Fruit Development: What Can We Learn from Auxin and Sugars? Int. J. Mol. Sci. 20*, 936.

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 AM, Kubow S, Li XQ and Donnelly DJ. 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 YW, Chuah LO, 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 DM, Katyare SS, Hegde MV 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

Yahia EM 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 MW. ed., 2015. *Postharvest biology and technology of horticultural crops: principles and practices for quality maintenance*. CRC Press.

Corpas FJ and Palma JM. 2018. *Nitric oxide on/off in fruit ripening. Plant Biology*, 20(5), 805–807.doi: 10.1111/plb.12852

Course Title: Weed Biology and Physiology of Herbicide Action

Course Code : PP 610 **Credit Hours: 2+0=2**

Objective

The course is designed to provide both basic and applied knowledge on the weeds. It will help to understand the fundamental physiology, biochemistry, and molecular biology of herbicides and their effects on plants; To study the physiological and molecular mechanisms of herbicide resistance. This course will provide knowledge on biology of weeds, classification and mode of action of herbicides, herbicide resistance and its management and environment friendly weed management strategies.

Theory

Block 1: Weed Biology

Unit 1: Weed Biology and its Importance in Weed Management

Introduction to weeds, Classification of weeds, Yield losses caused by weeds, Environmental impacts of invasive weed species, Aspects of Weed biology, Germination, Dormancy and growth behaviour of weed species, Effect of environmental factors on weeds, Adaptation of weeds to different ecologies

Unit 2: Life Cycle and Population Dynamics of Weeds

Growth duration and reproductive potential of weed species, Population dynamics, Weed Shift due to weed management, weed Seed Bank,

Unit 3: Crop Weed Competition

Understanding the nature of crop-weed competition, critical stages of crop weed competition, growth stages of weeds for improved control by herbicides

Block 2: Physiology of Herbicide Action

Unit 1: Introduction to Herbicides

Introduction, Chemistry and classification of herbicides by mechanism of action, HRAC Classification, Site of Actions, Application techniques, doses, active ingredients, formulations, Absorption and translocation of soil and foliar applied herbicides, Methods to increase the efficiency of soil and foliar applied herbicide – role of membranes, adjuvants, surfactants, synergists,

Unit 2: Mechanism of Action of Herbicides

Physiological and biochemical effects of herbicides: Effects on membrane structure and functions, cell division and cell development, Effects on chloroplast, photosynthesis, respiration, protein synthesis, synthesis of lipids, Molecular mechanism of action, Molecular mechanisms of herbicide resistance in relation to chloroplast gene expression,

Unit 3. Herbicide Resistance and its Management

Herbicide resistance-Definition, history, magnitude; Mechanisms of resistance: Target site and non-target site, cross and multiple resistances, Role of management practices on resitance development, Resistance management: Strategies; HR crops, Super weeds,

TEACHING SCHEDULE

Lecture No.	Name of the topic	Weightage
Block 1: Weed Biology		
	Unit 1: Weed Biology and its Importance in Weed Management	**18**
1& 2	Introduction to weeds, Classification of weeds, Yield losses caused by weeds	6
3& 4	Environmental impacts of invasive weed species, Aspects of Weed biology, Germination, Dormancy and growth behaviour of weed species	6
5& 6	Effect of environmental factors on weeds, Adaptation of weeds to different ecologies	6
	Unit 2: Life Cycle and Population Dynamics of Weeds	**14**
7& 8	Growth duration and reproductive potential of weed species, Population dynamics	7
9& 10	Weed Shift due to weed management, weed Seed Bank	7

	Unit 3: Crop Weed Competition	**15**
11& 12	Understanding the nature of crop-weed competition, critical stages of crop weed competition	8
13& 14	Growth stages of weeds for improved control by herbicides	7
	Block 2: Physiology of Herbicide Action	
	Unit 1: Introduction to Herbicides	**20**
15& 16	Introduction, Chemistry and classification of herbicides by mechanism of action	6
17& 18	HRAC Classification, Site of Actions, Application techniques, doses, active ingredients, formulations, Absorption and translocation of soil and foliar applied herbicides	7
19& 20	Methods to increase the efficiency of soil and foliar applied herbicide – role of membranes, adjuvants, surfactants, synergists	7
	Unit 2: Mechanism of Action of Herbicides	**18**
21& 22	Physiological and biochemical effects of herbicides	5
	Effects on membrane structure and functions, cell division and cell development, Effects on chloroplast, photosynthesis, respiration, protein synthesis, synthesis of lipids, Molecular mechanism of action	7
23& 24	Molecular mechanisms of herbicide resistance in relation to chloroplast gene expression	6
	Unit 3. Herbicide Resistance and its Management	**15**
25& 26	Herbicide resistance-Definition, history, magnitude	4
27& 28	Mechanisms of resistance: Target site and non-target site, cross and multiple resistances	5
29& 30	Role of management practices on resistance development, Resistance management: Strategies; HR crops, Super weeds	6
31& 32	Revision	
	Total	**100**

Suggested Reading

Inderjit (Ed). 2004. *Weed Biology and Management*. Springer Netherlands

Monaco, TJ, Weller SC, Ashton FM. 2002. *Weed Science: Principles and Practices*. John Wiley and Sons Inc., New York

De Prado R, Jorrin J, and Garcia-Torres L. 1997. *Weed and Crop Resistance to Herbicides*. Kluwer academic Publishers, The Netherlands.

Heap I. (2018.). *The International Survey of Herbicide Resistant Weeds*. www.weedscience.com

Herbicide Handbook of the Weed Science Society of America, 9th Edition. 2008. http://wssa.net.

Devine, M.D., Duke S.O. and Fedtke C. 1993. *Physiology of Herbicide Action*. Prentice-Hall, Inc. Englewood, NJ. 441 pp

Zimdahl, R L .2007. *Fundamentals of Weed Science* (Third Edition). Academic Press-Elsevier, USA.

----

15. Reputed journals in Plant Physiology discipline

Jrn. ID	ISSN	Name of Journal	NAAS Score
A033	0137-5881	Acta Physiologiae Plantarum	8.35
A034	1748-1708	Acta Physiologica (Acta Physiologica Scandinavica)	12.31
A057	0065-2296	Advances in Botanical Research	8.18
A067	0065-2911	Advances in Microbial Physiology	9.52
A137	0363-6143	American Journal of Physiology - Cell Physiology	10.25
A138	0193-1849	American Journal of Physiology - Endocrinology and Metabolism	10.31
A139	0193-1857	American Journal of Physiology - Gastrointestinal and Liver Physiology	10.05
A140	0363-6135	American Journal of Physiology - Heart and Circulatory Physiology	10.73
A141	1040-0605	American Journal of Physiology - Lung Cellular and Molecular Physiology	11.46
A142	1931-857X	American Journal of Physiology - Renal Physiology	9.38
A143	0363-6119	American Journal of Physiology-Regulatory Integrative and Comparative Physiology	9.62
A147	1044-1549	American Journal of Respiratory Cell and Molecular Biology	12.91
A194	0305-7364	Annals of Botany	10.36
A204	0970-9924	Annals of Plant Physiology	#
A206	0972-1959	Annals of Plant and Soil Research	5.22
A214	1081-0706	Annual Review of Cell and Developmental Biology	19.83
A215	1543-592X	Annual Review of Ecology Evolution and Systematics	19.92
A223	0066-4278	Annual Review of Physiology	20.00
A256	0969-8043	Applied Radiation and Isotopes	7.51
B008	1471-213X	BMC Developmental Biology	7.98
B049	0829-8211	Biochemistry and Cell Biology	9.63
B079	0006-3134	Biologia Plantarum	7.75
F092	1664-042X	Frontiers in Physiology	10.57
F101	1445-4408	Functional Plant Biology (Australian Journal of Plant Physiology)	9.10
I021	1054-5476	In Vitro Cellular and Developmental Biology-Plant	8.25
I324	2454-1117	International Journal of Plant and Environment	4.46
J443	0176-1617	Journal of Plant Physiology (Biochem. Physiol. Pflanzen.)	9.55
P058	1474-905X	Photochemical and Photobiological Sciences	9.98
P059	0031-8655	Photochemistry and Photobiology	9.42
P060	0099-1112	Photogrammetric Engineering and Remote Sensing	7.08
P061	0166-8595	Photosynthesis Research	9.57
P062	0300-3604	Photosynthetica	9.19
P070	0031-9317	Physiologia Plantarum	10.50
P073	0862-8408	Physiological Research	7.88
P074	0031-9333	Physiological Reviews	20.00
P076	0971-5894	Physiology and Molecular Biology of Plants	8.39
P117	0032-0889	Plant Physiology	14.34
P118	2662-253X	Plant Physiology Reports (Indian Journal of Plant Physiology)	5.50
P119	0981-9428	Plant Physiology and Biochemistry	10.27
P127	0032-079X	Plant and Soil	10.19

R074	1021-4437	Russian Journal of Plant Physiology	7.48
T089	0829-318X	Tree Physiology	10.20