# Department of Genetics and Plant Breeding
# Chaudhary Charan Singh University, Meerut (UP)

## Programme Syllabus

## Master of Agriculture in Genetics and Plant Breeding
## (M.Sc. Ag. Genetics and Plant Breeding)

Under Choice Based Credit System (CBCS)

**(Effective from Academic Year 2022-2023)**

# ABOUT THE DEPARTMENT

Before unfolding the history of the department, we are pleased to cite here that Department of Genetics and Plant Breeding (formerly Agricultural Botany), Chaudhary Charan Singh University, Meerut, has completed a glorious journey of 50 years (1969 – 2019), and celebrated its Golden Jubilee in the year 2019.

In the year 1969, Institute of Advanced Studies was established for higher learning and research in various subjects organized into separate divisions. To fulfil these objectives, M.Phil. and Ph.D. programmes were started in several divisions including the Division of Plant Sciences comprised of the following four subjects*:* (i) Agricultural Botany (later renamed as Genetics and Plant Breeding), (ii) Agronomy, (iii) Horticulture and (iv) Botany. Thus, the department of Genetics and Plant Breeding, is one of the oldest departments of the Faculty of Agriculture and was initially engaged in teaching at M.Phil. and Ph.D. levels and research in several important areas of Genetics, Cytogenetics, Plant Breeding and Crop Biotechnology. In addition to M.Phil. and Ph.D. courses, M.Sc. (Ag.) programmes in Genetics and Plant Breeding was also started in 1973-74. Recently, M.Phil. (Genetics and Plant Breeding) Programme discontinued and therefore, currently the department is running two programmes including M.Sc. (Ag.) Genetics and Plant Breeding, and Ph.D. (Genetics and Plant Breeding).

Professor R.B. Singh was the first Head of the Department, but he left in 1972. Subsequently, the department was headed for short periods by Professor H.K. Srivastava (1973-74) and Dr. G. S. Kalra (1975-76). Thereafter, Professor P.K. Gupta was appointed as Professor and Head of the Department, who guided the department for a long period of 20 years (1976 to1996). During this period, the department made remarkable progress both in the areas of teaching and research. On the retirement of Professor Gupta, Prof. S. P. Singh took over as head of the department and steered the department for the next 10 years (1996 to 2006). Subsequently, Prof. H. S. Balyan (2006-2010,13) and Prof. B. Ramesh (2010-13,14) headed the department for about eight years. During this period the gains made in the past in the areas of teaching and research were consolidated and new infrastructure in the forms of teaching and research laboratories, modern classrooms was created and several new and sophisticated equipments were acquired to aid teaching and research in the new and emerging areas of Genetics, Genomics, Plant Breeding, Biotechnology and Bioinformatics. After the retirement of Prof. Balyan and Prof. B. Ramesh in 2014, Prof. P. K. Sharma took over as the Head of the Department and was engaged in further development of the department. All the current and erstwhile faculty of the Department have a high foreign exposure and Prof. P.K. Gupta, Prof. H.S. Balyan, Prof. P.K. Sharma and Prof. Shailendra Sharma have been in foreign laboratories of repute (Canada, Germany, Japan, USA, U.K.,) under long-term fellowship programs of Govt. of India or the abroad. Currently, there are six regular faculty members and three Emeritus Professors in Department: Dr. P.K. Sharma as Professor (on leave), Dr S.S. Gaurav as Professor and Dean, Faculty of Agriculture, Dr. Shailendra Sharma as Professor and Head of department, Dr. Rahul Kumar as Professor, Dr. D. Pratap as Sr. Assistant Professor and Dr. Sachin Kumar as Assistant Professor. In addition, Dr. P.K. Gupta, Dr. S.P. Singh, and Dr. H.S. Balyan as Emeritus Professors. Both Professor Gupta and Professor Balyan are continuing in the Department as Honorary University Emeritus Professor and INSA Senior Scientists and are engaged in both teaching and research.

In the light of the tremendous advances made in biological sciences all over the world, as also the requirement of this region, the courses and research priorities in the department have been regularly modified, and newer courses of contemporary scientific importance like Applications of Computer Technology in Agriculture and Bioinformatics and Crop Biotechnology, Genomics and Proteomics were introduced in M.Sc. (Ag.) programme. The course curriculum for M.Phil./PhD. programmes have also been modified from time to time and presently the emphasis is on courses related to Statistical Methods, Mutation Research, Crop Biotechnology, Quantitative Genetics, Molecular Breeding, Bioinformatics and Cytogenetics, which also represent the core and major thrust areas of research in the department.

During the last 20 years, the department has become known both at the national and international levels for its outstanding contributions in development and use of molecular markers and quantitative trait loci (QTL) analyses towards understanding the genetic control of important agronomic traits in wheat and other crop plants. The department has also made a mark around molecular marker assisted (MAS) breeding for grain quality improvement in wheat. MAS-derived lines are being used by several institutions in their molecular breeding programmes for improving grain quality in wheat and several of the MAS derived lines are also being evaluated in All India Coordinated Wheat Improvement Programme for their suitability for release as improved wheat varieties. A mungbean variety MUM-2, resistant to mungbean yellow mosaic virus (MYMV), developed by the department was released in 1992 for commercial cultivation in four states i.e., Uttar Pradesh, Delhi, Punjab, and Rajasthan.

In recent years, the research programmes of the department have been diversified with a focus on the understanding of the genetic and epigenetic control of the biotic (rust, spot blotch, nematode

resistance) and abiotic (drought and heat) tolerance and nutrient use efficiency (nitrogen and phosphorous use efficiency). With the establishment of Bioinformatics Infrastructure Facility in the department (with funds obtained from the Department of Biotechnology, GOI), the discovery and validation of genes in wheat has also become a major activity of several research programmes in the department. All the teaching and research activities of the department are supported by well-equipped laboratories and related infrastructure. To support the laboratory research, the department also has over 20 Acre Research Farm for conducting various types of field experiments. The students of the department have been successful in competitive exams like ICAR-ARS/NET, CSIR-JRF/NET, GATE, PCS, IFS and have obtained various scholarships from different funding agencies. Several students of the department are presently occupying prestigious and important positions in both public and private sector organizations at national and international levels. Besides India, several students, who obtained their PhD, MPhil and/or MSc (Ag.) degrees from the department are currently working in various capacities in different universities and government organizations in countries including USA, Canada, Australia etc.

For its outstanding contributions, the department was supported by the University Grants Commission (UGC) as the Department of Special Assistance Programme-Departmental Research Support (SAP-DRS) and funds were provided for strengthening teaching and research in the department. The department was also supported through its FIST programme by the Department of Science & Technology (DST) and several expensive and useful equipments were provided. This department also has a unique position in the university since it is the only department to receive support in the form of both SAP-DRS and DST-FIST programmes. For conducting research, the department has also been supported through crores of research grants both by the national and international organizations. The Department of Science & Technology, Department of Biotechnology, Biotechnology Industry Research Assistance Council (BIRAC), Government of India, ICAR-NATP, New Delhi, University Grants Commission, New Delhi, UP Council of Science & Technology, Lucknow and DAE-BRNS, Bombay are some of the organizations from India, which funded various research projects.

So far, more than 130 Ph.D., 200 M.Phil. and 380 M.Sc. (Ag.) students have successfully completed their degree programs. More than 800 publications have been published by different faculty members and students of the Department in Indian and international journals of high repute. Under CBCS mode, core course (four in each semester, total 16) and open elective courses (two: Plant Physiology, and Global Food & Nutrition Security in II and III semesters, respectively) are being offered to the students in M.Sc. (Ag.) programme.

**PROGRAMME OUTCOMES (POs)**

M.Sc. (Ag.) is a two years (four semesters) full time choice-based credit system (CBCS) course, including the thesis work. Each student must undertake research work for his/her thesis on any aspect related to the course of study and submit the same at the end of fourth semester to the Department. The students of M.Sc. (Ag.) are required to have in depth knowledge about classical and latest developments in agricultural sciences and practices. Due emphasis has been given on practical classes wherever it was felt necessary to provide opportunity to learn and do the exercises on topics covered in the theory classes. Upon completion of this programme, students will be able to explore new opportunities in agriculture sector. The students will understand crop improvement methods for a better world and will sparkle up the qualities of passion and perseverance for agricultural sciences. The objective of the programme is widening the scope of agricultural research and development. The students will be encouraged to plan the research work, use time effectively, develop an intellectual curiosity and manage small projects.

## PROGRAMME SPECIFIC OUTCOMES (PSOs)

PSO-1: The students will be able to learn the basics of classical to molecular plant breeding including genetics, plant biotechnology, qualitative and quantitative inheritance, genomics, transcriptomics, and proteomics tools/techniques.

PSO-2: The students will develop skill in self-designing, regional and crop specific plant breeding programs linking conventional and modern techniques; selection strategies for development of pre-bred genetic materials and/or new varieties.

PSO-3: The students will develop expertise in collection, investigation and analysis of data sets using statistical software; interpretation of the genetic results to arrive at meaningful conclusions.

PSO-4: The students will have insight about various biotechnological tools, tissue culture techniques, principles behind transgenic crops and its ethical implications.

PSO-5: The students will understand the importance of quantitative genetic analysis, identifying the genes and QTL analysis.

PSO-6: The students will gain proficiency in mapping population, molecular marker assisted selection and its application in crop improvement.

PSO-7: The students will understand the significance of germplasm, biodiversity conservation in relation to Plant Variety Protection and Intellectual Property Rights.

PSO-8: The students will obtain knowledge and expertise in genomics, proteomics, bioinformatics and gene editing technologies.

## Value Added Courses

Department of Genetics and Plant breeding offer following five value-added courses to enhance basics knowledge of students from agricultural or nonagricultural background. These interesting courses provided fundamental knowledge of agriculture and related fields. Certificates will be provided to student after course completion.

Semester II: Essentials of Laboratory Techniques
Semester II: Advance Bioinformatics Techniques
Semester III: Techniques in Virology
Semester IV: Techniques in Seed Science and Technology.
Semester IV: Agricultural Research and Genetic Resources

**STRUCTURE OF THE PROGRAMME**

**Department of Genetics and Plant Breeding**
**Ch. Charan Singh University, Meerut**

**Syllabus for M. Sc. (Ag.) Genetics and Plant Breeding as per CBCS w.e.f. 2022-2023**

| Course Type | Name of Course | Course Code | Credits L+P+T | Maximum Marks | | | |
|---|---|---|---|---|---|---|---|
| | | | | Int. | Ext. | Prac.* | Total |
| **SEMESTER I** | | | | | | | |
| **Compulsory Core** | Principles of Genetics | | 4+1+0 | 40 | 40 | 20 | 100 |
| | Principles of Plant Breeding | | 4+1+0 | 40 | 40 | 20 | 100 |
| | Principles of Cytogenetics | | 4+1+0 | 40 | 40 | 20 | 100 |
| | **Sub-total of credits** | | **15** | | | | |
| **Elective Core** | Statistical Methods for Applied Sciences | | 4+1+0 | 40 | 40 | 20 | 100 |
| | **Sub-total of credits** | | **5** | | | | |
| **Thesis/Project Dissertation** | Component - I | | **8** | | | | |
| | **Total** | | **28** | | | | **400** |
| **SEMESTER II** | | | | | | | |
| **Compulsory Core** | Genetic Enhancement and PGR Utilization | | 4+1+0 | 40 | 40 | 20 | 100 |
| | Molecular Breeding and Bioinformatics | | 4+1+0 | 40 | 40 | 20 | 100 |
| | Molecular Genetics | | 4+1+0 | 40 | 40 | 20 | 100 |
| | **Sub-total of credits** | | **15** | | | | |
| **Elective Core** | Basic Biochemistry and Physiology | | 4+1+0 | 40 | 40 | 20 | 100 |
| | **Sub-total of credits** | | **5** | | | | |
| **Open Elective¥** | General Agriculture | | 4+0+0 | | | | Qualifying |
| **Thesis/Project Dissertation** | Component - II | | **12** | | | | |
| **Value Added§** | Essentials of Laboratory Techniques | | | | | | |
| **Value Added§** | Advance Bioinformatics Techniques | | | | | | |
| | **Total** | | **32** | | | | **400** |
| **SEMESTER III** | | | | | | | |
| **Compulsory Core** | Plant Biotechnology | | 4+1+0 | 40 | 40 | 20 | 100 |
| | Fundamental of Quantitative Genetics | | 4+1+0 | 40 | 40 | 20 | 100 |
| | Breeding for Stress Resistance and Climate Change | | 4+1+0 | 40 | 40 | 20 | 100 |
| | **Sub-total of credits** | | **15** | | | | |
| **Elective Core** | Hybrid Breeding | | 4+1+0 | 40 | 40 | 20 | 100 |
| | **Sub-total of credits** | | **5** | | | | |
| **Open Elective¥** | Global Food and Nutritional Security | | 4+0+0 | | | | Qualifying |
| **Thesis/Project Dissertation** | Component - III | | **12** | | | | |
| **Value Added§** | Techniques in Virology | | | | | | |
| | **Total** | | **32** | | | | **400** |
| **SEMESTER IV** | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Compulsory Core** | Advanced Genetics | | 4+1+0 | 40 | 40 | 20 | 100 |
| | Crop Breeding | | 4+1+0 | 40 | 40 | 20 | 100 |
| | Seed Production and Certification | | 4+1+0 | 40 | 40 | 20 | 100 |
| | **Sub-total of credits** | | **15** | | | | |
| **Elective Core** | Genomics, Transcriptomics and Proteomics | | 4+1+0 | 40 | 40 | 20 | 100 |
| | **Sub-total of credits** | | **5** | | | | |
| **Thesis/Project/ Dissertation** | Component - III | | 8 | | | | |
| **Value Added**[§] | Techniques in Seed Science and Technology | | | | | | |
| **Value Added**[§] | Agricultural Research and Genetic Resources | | | | | | |
| | **Total** | | **28** | | | | **400** |
| **M. Sc. (Ag.) Thesis/Project/ Dissertation** | | | | | | | |
| **M. Sc. (Ag.) Thesis/Project/ Dissertation** | Component-I ($C_1$): Periodic progress and progress reports (15%) | | | | | | |
| | Component-II ($C_2$): Results of work and draft report (15%) | | | | | | |
| | Component-III ($C_3$): Final viva-voce and evaluation (70%)<br>(a) The report evaluation (40%)<br>(b) Viva-voce examination (30%) | | | | | | |
| | **Total credits in M.Sc. Ag. Thesis/Project/ Dissertation** | | **40**[#] | | | | Satisfactory |
| | **Grand Total of credits and maximum marks in whole M.Sc. Ag. program** | | **120** | | | | **1600** |

[*]In each semester, there shall be one joint external practical examination carrying 80 marks based on all the four courses (20+20+20+20 marks) of compulsory and elective core.

[#]Minimum 36 credits are required for M. Sc. (Ag.) Thesis/Project/ Dissertation

¥credit course (qualifying)

[§]Non-credit certificate course

☛Pattern of examination, passing marks, determination of CGPA/division shall be as per rules applicable in the faculty of Agriculture in university campus.

# Semester I

# Principles of Genetics

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **Introduction:** History of genetics, its scope and significance, brief idea of Mendel's laws and physical basis of heredity (chromosome theory of inheritance), forward vs. reverse genetics. Multiple factor hypothesis (a brief introduction); | **4** |
| **2.** | **Modification of $F_2$ ratios:** Epistasis (non-allelic interactions), segregation distortion and selfish genes; penetrance and expressivity; modifiers and suppressors; pleiotropic genes. | **6** |
| **3.** | **Linkage and crossing over:** Coupling and repulsion hypothesis; theories of crossing over; three-point test cross (interference and coincidence; calculation of recombination frequencies from $F_2$ data; brief idea about mapping function; cytological basis of crossing over (experiments of Stern in *Drosophila* and that of McClintock in corn). | **6** |
| **4.** | **Multiple alleles:** Concept of multiple alleles; self-incompatibility alleles in *Nicotiana* and *Brassica;* coat colour in rodents; blood groups in humans, antigen-antibody interaction in inheritance of A, B, AB and O blood groups; H – antigens, MNS system, Rh factor. Epistasis and multiple allelism (e. g. Bombay blood groups). | **6** |
| **5.** | **Population Genetics:** Mendelian population, Random mating population, Frequencies of genes and genotypes, Causes of change: Hardy-Weinberg equilibrium. Changes in gene and genotypic frequencies. | **4** |
| **6.** | **Sex linked inheritance**: Sex linked**,** sex limited and sex influenced traits with suitable examples. | **4** |
| **7.** | **Sex determination and differentiation**: Theories of sex determination -- chromosome theory and genic balance theory of sex determination, sex determination in dioecious plants {*Marchantia, Ceratopteris, Silene (Melandrium), Humulus, Coccinia, Rumex, Papaya*}, mouse and in man; genetic basis of sex differentiation (genes located on sex chromosomes and autosomes), single gene control of sex. Hormonal control of sex, sex reversal and gynandromorphs, human sex anomalies (Klinefelter's syndrome and Turner's syndrome); brief idea of dosage compensation and Lyon's hypothesis. | **6** |
| **8.** | **Extrachromosomal inheritance**: Criteria for extra chromosomal inheritance; plastid inheritance in *Mirabilis*, iojap in corn, Kappa particles in *Paramecium*, coiling in snails, brief idea of mitochondrial (male sterility in plants) and chloroplast genetics, paternal inheritance. | **6** |
| **9.** | **Mutations and mutagenic agents**: Brief history of mutations; types of mutations; rate and frequencies of mutations; physical and chemical mutagens and deletogens; detection of mutations in *Drosophila* (ClB method, Muller–5 method, attached X method), detection of mutations in plants and their practical application in crop improvement. | **8** |
| **10.** | **Biochemical genetics**: Inborn errors of metabolism in man; eye transplantation in *Drosophila;* biochemical mutations in *Neurospora;* biosynthetic pathways and biochemical mutations. | **4** |
| **11.** | **Fine structure of gene**: Classical and modern gene concepts; pseudo-allelism, position effect; intragenic crossing over and complementation (cistron, recon, muton), Benzer's work on $r_{II}$ locus in $T_4$ phage. | **6** |

**COURSE OUTCOMES (COs)**

CO-1: The students will be able to understand the classical and modern concepts of genetics.
CO-2: Students are able to understand the basic principles of inheritance biology.
CO-3: Students will be able to understand the sex-linked inherited characters and diseases.
CO-4: They will get in-depth knowledge about gene interaction, penetrance and expressivity.
CO-5: The student will demonstrate proficiency in understanding the basic structure of atom and interpret the inheritance of characters by using linkage and crossing over.

**Practical**

- Laboratory exercises in probability and chi-square;

- Chromosome mapping using three-point test cross;
- Experiment on monohybrid crosses, dihybrid crosses and trihybrid crosses.
- Study of co-dominance.
- Study of lethal allele
- Study on different gene interaction (Epistasis)
- Numerical exercise on multiple factor hypothesis

**Suggested Readings:**


1. Gupta P K (2009). Genetics, 4/e. Rastogi Publications, Meerut.
2. Gupta P K (2007). Genetics: Classical to modern. Rastogi Publications, Meerut.
3. Griffith et *al* (2008). An introduction to Genetic Analysis. Freeman & Co.
4. Hartl DL and Jones EW (1997). Genetics: Principles and Analysis 4th Ed. Jones & Bartlett Publishers, Inc
5. Hartwell L *et al* (2000). Genetics: From genes to genomics. McGraw Hill, New Delhi.
6. Lewin B. (2007). Genes IX. Wiley Eastern Ltd., New Delhi.
7. Pierce, B. (2005). Genetics: A conceptual Approach 2nd Ed. WH Freeman
8. Snustad D P , Simmons NJ and Jenkins JB (2003). Principles of Genetics. John Wiely & Sons, New York.
9. Strickberger, N.W. (1985). Genetics 3rd Ed. Macmillan Co. New York.

# Principles of Plant Breeding

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **Historical perspective:** Early Plant Breeding; Accomplishments through plant breeding; Objectives of plant breeding | **2** |
| **2.** | **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. | **4** |
| **3.** | **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. | **6** |
| **4.** | **Breeding methods in self-pollinated crops:** 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. | **10** |
| **5.** | **Breeding methods in cross pollinated crops; Population breeding:** mass selection and ear-to-row methods; S1 and S2 progeny testing, progeny selection schemes, recurrent selection schemes for intra and inter-population improvement and development of synthetics and composites. | **10** |
| **6.** | **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, male sterility and apomixes in crop plants and their commercial exploitation. | **10** |
| **7.** | **Breeding methods in asexually/ clonally propagated crops, clonal selection.** | **4** |
| **8.** | **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. | **8** |
| **9.** | **Cultivar development:** testing, release and notification, maintenance breeding, Participatory Plant Breeding, Plant breeders' rights and regulations for plant variety protection and farmers rights. | **4** |
| **10.** | **Pre-breeding and genetic enhancement**: Wide hybridization and alien gene transfer. | **2** |

## COURSE OUTCOMES (COs)

CO-1: Students will understand the significance of different plant breeding systems.
CO-2: Students will understand the application of conventional breeding approaches and gene technology approaches in plant breeding programs. CO-3: Students will be well versed in practical emasculation and pollination methods of important crops.
CO-4: Students will be able to describe the progression of stages within a modern breeding programme.
CO-5: Students will be able to judge which plant breeding methods are appropriate for specific objectives and situations.
CO-6: Students will be able to carry out specific plant breeding activities, such as selection of parental germplasm, observation and recording of phenotypic variation and selection among progeny.

## 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.

## Suggested Reading


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

# Principles of Cytogenetics

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **Historical perspectives.** | **4** |
| **2.** | **Nucleus and chromosome territories:** A and B chromosomes, NOR, non-random distribution of chromosomes during interphase, Rabl configurations and Bouquet. | **4** |
| **3.** | **Cell division:** Cell cycle (genetics, biochemistry and cell cycle mutants), differences between mitosis and meiosis; mechanism of chromosome movement; reduction division and equational division; double reduction. | **6** |
| **4.** | **Chromosome pairing:** Synaptonemal complex, somatic association, Rabl configurations and its role in pairing, biochemical basis of chromosome pairing. | **4** |
| **5.** | **Chromosome banding techniques for identification of chromosomes:** Q bands, C and N bands, G bands, R bands; Chromatin remodeling. | **2** |
| **6.** | **Structural changes in chromosomes:** Duplications and deficiencies: Classification, methods of production, meiotic pairing, phenotypic effects and breeding behavior. Translocations: Classification, methods of production, identification, meiotic pairing (alternate and adjacent disjunction), crossing over in interstitial region, breeding behavior of translocation heterozygote, role in evolution (balanced lethals- *Oenothera* cytogenetics), A-B translocations. Inversions: Classification (paracentric and pericentric inversions), methods of production, identification, meiotic pairing and crossing over in different regions, anaphase I and anaphase II configurations in paracentric inversions, breeding behavior of inversion heterozygote, role in evolution. | **10** |
| **7.** | **Haploidy**: Classification (monoploids, polyhaploids and aneuhaploids), methods of production (anther culture and chromosome elimination), identification, androgenic and gynogenetic, and parthenogenic haploids, meiotic pairing, utility (hybrid sorting and DH breeding). | **8** |
| **8.** | **Polyploidy**: Classification (autopolyploids, allopolyploids), methods of production, cytological and genetic methods for identification, polyploid genetics (chromosome and chromatid segregation), meiotic pairing (autosyndesis and allosyndesis), diploidizing system (*Ph1* locus) and role in evolution, utility in crop improvement, segmental poluploidy, synthetic polyploids, brief idea of ancient polyploidy. | **8** |
| **9.** | **Numerical changes in chromosomes:** Trisomics and tetrasomics (Hyperploids): Classification (primary, secondary and tertiary trisomics), methods of production, identification, meiotic pairing, breeding behavior of trisomics, trisomic and tetrasomic ratios, utility in chromosome mapping. Monosomics and nullisomics (Hypoploids): Methods of production (particularly in wheat), identification, meiotic behavior; breeding behavior of monosomics, monosomic analysis (monogenic characters only); alien addition/substitution lines. | **8** |
| **10.** | **Physical mapping of genes on chromosomes**: *In situ* hybridization with DNA probes (FISH, McFISH, GISH, fibre fish); deletion mapping | **2** |
| **11.** | **Apomixis**: Cytogenetic basis of apomixis, meiotic behavior in apomicts, autogamy and pseudogamy, agamospermy (apospory and diplospory) and other modes of apomixis. | **4** |

**COURSE OUTCOMES (COs)**

CO-1: Students will understand the basics of chromosome structure and occurrence of cytogenetic abnormalities.
CO-2: Students will able to know the fundamental of cell cycle and Apotosis.
CO-3: Students will able to techniques of fixing and count meiotic and mitotic chromosomes of major crops
CO-4: Students will able to analyse chromosome abnormalities in inter-specific crosses.
CO-5: The student will be able to carry out cytological analysis in breeding populations.

**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
- Study of microtome and its use for anatomical studies.
- Preparation and study of different stages of mitosis in onion root tips.
- Study of different stages of meiosis and translocation ring in anther of *Rhoeo discolour*.
- Micrometry-

a. Distinguish between ocular micrometer and stage micrometer.
b. Calibrate an ocular micrometer with reference to a stage micrometer.
c. Measure the size of the objects using the ocular micrometer.

**Suggested Readings:**


1. Burnham, C.R. (1962). Discussions in Cytogenetics: Burgers, Minneapolis.
2. Fukui K and Nakayama S (eds.) (1996). Plant Chromosomes-Laboratory Methods. CRC Press, London
3. Gupta, P.K. (1999). Cytogenetics. Rastogi & Co., Meerut.
4. Gupta, P.K. and Tsuchiya, T. 1991. Chromosome Engineering in Plants: Parts A & B, Elsevier Publishers, the Netherlands.
5. Gupta PK, Singh SP, Balyan HS, Sharma PC and Ramesh B (1998). Genetics and Biotechnology in Crop Improvement. Rastogi Publications, Meerut
6. Hawes C and Satiat-Jennemaitre (eds.). (2001). Plant Cell Biology 2nd Ed. Oxford University Press, New York
7. Khush GS (1973). Cytogenetics of Aneuploids. Academic Press, New York
8. Singh RJ (2003). Plant Cytogenetics (Second Edition). CRC Press, Taylor & Frances group.
9. Singh RJ and Prem P. Jauhar (Eds.) (2005). Genetic Resources, Chromosome Engineering, and Crop Improvement: Grain Legumes, Volume I. CRC Press, Taylor & Frances group
10. Swaminathan, M.S., Gupta, P.K. and Sinha, U. (1983). Cytogenetics of Crop Plants. Macmillan India, New Delhi.
11. Swanson, C.P., Merz, T. and Young, W.J. (1982). Cytogenetics. Prentice-Hall of India (Pvt.) Ltd., New Delhi.
12. Sybenga, J. (1972). General Cytogenetics. North-Holland publishing Co. Amsterdam.
13. Sybenga, J. (1992). Cytogenetics in Plant Breeding. Springer-verlag, Berlin.

# Statistical Methods for Agriculture Research

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **Presentation of Data**: Frequency distributions; graphical presentation of data by histogram, frequency polygon, frequency curve and cumulative frequency curves. | **6** |
| **2.** | **Measures of Locations and Dispersion**: Mean, median, mode and their simple properties (with-out derivation) and calculation of median by graphs; range, mean deviation, standard deviation, standard error, coefficient of variation. | **8** |
| **3.** | **Probability and Distributions**: Random distributions; events exhaustive, mutually exclusive and equally likely; definition of probability (with simple exercises); definitions of binomial, Poisson and normal distributions; and simple properties of the above distributions (without derivation). | **6** |
| **4.** | **Correlation and Regression**: Bivariate data-simple correlation and regression coefficients and their relation; Spearman rank correlation; limits of correlation coefficient; effect of change of origin and scale on correlation coefficient; linear regression and equations of line of regression; association and independence of attributes | **8** |
| **5.** | **Sampling**: Concept of population and sample; random samples; methods of taking a simple random sample. | **4** |
| **6.** | **Tests of significance**: Sampling distribution of mean and standard error; z and t-test (equality of means; paired and unpaired t-test); t-test for comparison of means when variances of two populations differ; Chi-square test for goodness of fit; independence of attributes, and homogeneity of samples; interrelation between t-test and F-Test | **12** |
| **7.** | **Experimental Designs:** Principles of experimental designs; completely randomized, randomized complete block design (missing plot value in RBD); latin square designs; augmented block design; simple factorial experiments (mathematical derivations not required); analysis of variance (ANOVA) and its use including estimation of LSD (CD) | **12** |
| **8.** | Introduction to R package | **4** |

## COURSE OUTCOMES (COs)

CO-1: Students will acquire independent ability to carry out statistical analysis of data and interpretation of results in breeding programs.
CO-2: Students will be able to statistically analyze the phenotypic data of plant traits. CO-3: The students will recognize and examine the relationships between inputs and outputs in their agricultural field to make effective and profitable decisions.
CO-4: Students will demonstrate an ability to engage in critical thinking by analyzing situations and constructing and selecting viable solutions to solve problems.
CO-5: Student will be able to demonstrate the ability to analyse data and draw appropriate statistical conclusions.
CO-6: Students will be well equipped to handle field level data for analysis and modelling purposes. They will learn how to draw a good sample from a population in order to draw valid inference.
CO-7: Students will be able to develop strategies for experimental designs.

## Practical

- Classification and tabulation of data using provided values to calculate the following:
  - Frequency Distribution
  - Frequency table for exclusion class interval
  - Frequency table for inclusion class interval
  - Cumulative frequency distribution
  - To draw a histogram and frequency polygon.
- Calculation of mean, median and mode from the given data.

- Calculation of mean deviation and standard deviation from the given data.
- Calculation of arithmetic mean, variance, and standard error of mean from the given data.
- Calculation of correlation coefficient.
- Calculation of regression coefficient and test their significance
- Numerical based on chi square test
- Calculation of z-test
- Calculation of t-test
- Numerical based on Completely Randomized Design
- Numerical Based on Randomized Block Design.
- Numerical Based on Latin Square Design

## Suggested Readings


1. Goulden, C.H. (1952). Methods of Statistical Analysis, 2/e, John Wiley, New York.
2. Hoshmand A. Reza 1988. Statistical Methods for Agricultural Sciences. Timber Press, Portland, Oregan, USA.
3. Kempthorne, O. (1957). An Introduction to Genetic Statistics, John Willey, New York.
4. Kempton RA and Fox PN (1997). Statistical Methods for Plant Variety Evaluation. Chapman and Hall
5. Panse, V.C. and Sukhatme, P.V. (1967). Statistical Methods for Agricultural Workers, I.C.A.R., New Delhi.
6. Snedecor, G.W. and Cochran, W.G. (1980). Statistical Methods, 7/e. Iowa State Univ. Press, Ames, Iowa.
7. Steel, R.G.D. and Torrie , H.H. (1960). Principles and Procedures of Statistics. McGraw- Hill, New York.
8. Gomez, AG and Gomez, AA (1994). Statistical Procedures for Agricultural Research, 2/e. John Wiley & Sons, New York.

# Semester II

# Genetic Enhancement and Plant Genetic Resources Utilization

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **A brief idea of modern system of classification** (angiosperm phylogeny groups). | **2** |
| **2.** | **Biodiversity versus genetic resources:** Definition and explanation, alpha vs. beta biodiversity and methods of their study; present levels of biodiversity and loss of biodiversity; causes for the loss of biodiversity; uses of biodiversity; extent of biodiversity in plants; exploration and germplasm collection, introduction and exchange of PGR. | **10** |
| **3.** | **Direct and indirect uses of plant genetic resources for human welfare**: In plant breeding and agriculture, pharmaceuticals and in maintenance of ecosystem; Red Data books and endangered plant species. | **6** |
| **4.** | **Plant genetic resources**: Different kinds of PGR- basic, derived and molecular; core collections; principles of germplasm characterization, DNA fingerprinting and plant bar codes; germplasm evaluation, maintenance and regeneration; plant quarantine aspects- sanitary and phytosanitary systems (SPS). | **8** |
| **5.** | **Techniques for conservation of plant germplasm**: *In situ* and *Ex-situ* methods of conservation; cryopreservation of genetic materials; gene banks and cryobanks. | **6** |
| **6.** | **CBD and sustainable use of biodiversity**. Gene treaty; Cartagena protocol; harmonization of international and national treaties. | **4** |
| **7.** | **Role of FAO/CGIAR/IPGRI/NBPGR system for access to genetic resources**: ITPGRFA (International treaty on plant genetic resources for food and agriculture) and global system of PGR; FAO's commission on PGR (CPGR); International code of conduct for PGR collection and transfer; multilateral system for access to PGR. | **6** |
| **8.** | **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 | **8** |
| **9.** | **Future harvest centers** (formerly IARCs) - a brief idea. | **2** |
| **10.** | **IPRs in plant breeding:** UPOV, plant breeders rights (PBRs); essentially derived varieties and farmers rights (FRs); protection of plant varieties and farmers rights act (PPV & FRA) 2001; intellectual property rights- patents, copyrights, trademarks; GATT and TRIPs, patents for higher plants; terminator and traitor techniques (v-GURT and t-GURT); biodiversity act 2002; geographical indications act 1999; amendments to patent act 1970 | **8** |

## COURSE OUTCOMES (COs)

CO-1: Students will have knowledge on the conservation of biodiversity.
CO-2: They will acquire knowledge on various organizations involved in conservation and their policies.
CO-3: The students will have knowledge on plant quarantine regulations.
CO-4: The students will be able to promote human capacity to appreciate, maintain, and promote utilization of plant genetic resources.
CO-5: Students will understand different forms of IPRs and legislations related with IPRs. They will be well aware of Farmers' and Plant Breeders' rights.

## Practical

- Recording field data on germplasm evaluation in different agri-horticultural crops,
- 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.
- Study of structure and function of NBPGR and regional stations.

- Phytosanitary test and detection of phytopathogenic fungus *Stenocarpella maydis* in *Zea mays* (maize) seeds.
- Phytosanitary test and detection of *Aschopyta pisi* in pea seeds.
- Study of in-situ and ex-situ conservation.

**Suggested Readings**


1. Engelmann F and Takagi H (eds). (2000). Cryopreservation of tropical germplasm. IPGRI, Rome
2. CGIAR Annual Reports. (http://www.cgir.org)
3. Swaminathan MS (1996). Biodeversity. Konark Publications, New Delhi
4. Swaminathan MS (1996). Agrobiodiversity and Farmers Rights. Konark Pub, New Delhi
5. Maxsted N, Ford-Lloyd BV and Hawkes JJ (eds) (1997). Plant Genetic Conservation. Chapman and Hall, London
6. Indian Framing Vol. 43 (7), October 1993
7. Negi SS (2003). Biodiversity and its Conservation in India, 2/e. Indus Books, New Delhi
8. Anonymous (1995). Encylopedia of Environmental Biology Vol. Academic Press
9. Rao RR (1994). Biodiversity In India. Bishen Singh Mahendra Pal Singh, New Delhi
10. Paroda RS and Arora RK (eds) (1991). Plant Genetic Resources: Conservation and Management. IPPGR, Rome
11. Swaminathan MS and Jana S (eds) (1992). Biodiversity- Implications for Global Food Security. McMillan India, New Delhi
12. Red Data Books Vols. 1 to 4. Botanical Survey of India, Dehradun
13. Benson EE (2003). Plant Conservation Biotechnology. Agrosciences, New Delhi
14. Joshi PC (2004). Biodiversity and Conservation. Agrosciences, New Delhi
15. Gaston KJ (2004). Biodiversity: An Introduction, 2/e.. Agrosciences, New Delhi
16. Zoological Survey of India. Environmental Awareness and Wild Life Conservation. Atlas Books, New Delhi
17. Lewin SA (2000). Encyclopedia of Biodiversity Vols. 1 to 5. Atlas Books, New Delhi
18. Anonymous (2004). Environmental and Pollution Loss: Atlas Books, New Delhi
19. Singh MP and Soma D (2004). Bioresources and Gene Pool Conservations. Biopublications, New Delhi

# Molecular Breeding and Bioinformatics

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **An overview of bioinformatics:** Introduction, objective of bioinformatics, kind of data used in bioinformatics, multiplicity of data and redundancy, major bioinformatics databases, data integration, data analysis | **6** |
| **2.** | **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. | **8** |
| **3.** | **Marker-assisted selection:** 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. | **8** |
| **4.** | **High resolution mapping and cloning of QTL:** strategies for high resolution mapping using BSA and near isogenic lines (NILs); examples of QTL cloning. | **6** |
| **5.** | **Breeding by design:** Mapping of loci involved in all agronomically relevant traits; introgression line libraries; chromosome haplotype; breeding by design | **6** |
| **6.** | **Sequence and structure databases**: Nucleic acid data bases (EMBL, GenBank, DDBJ), protein data bases (SWISS-PROT, TrEMBL PIR-PSD, UNIProt as a single database), URLs (Uniform resource locators) of databases, SWISS-2DPAGE, KEGG, COGS, PROSITE, etc. Sequence cluster database (ProDom, Cluster, SYSTERS, ProtoMap); structure databases (CCDC, DSSP, SCOP, CATH, etc.). | **4** |
| **7.** | **Alignment of sequences:** Introduction to sequence analysis, models for sequence analysis (local, global, end free space alignment and gap penalty), introduction to applications of dot matrices, application of FASTA and BLAST programmes (introduction, BLAST output, significance of BLAST results, recommended steps in BLAST, BLAST programmes), comparison between FASTA and BLAST programmes. | **4** |
| **8.** | **Multiple sequence alignment:** Multiple sequence alignment, structural & evolutionary alignment, Software tools assisting in the analysis of multiple alignments, phylogenetics tree construction. | **4** |
| **9.** | **Assembly of nucleotide sequences**. | **2** |
| **10.** | **Plant Genome databases:** Introductory account of NCBI's GenBank, (dbEST, UniGene), TIGR (TIGR Gene Indices); PlantGDB (TCs, TUGs, GeneSequer); GrainGenes (Gramene, Komugi, MaizeDB; TAIR, CUGI; softwares for genome research (phred/phrap/consed; crossmatch; TIGR's suite of tools; EBI's suit of tools; Staden package). Bibliographic databases | **6** |
| **11.** | **Introduction to Comparative Genomics**; Large scale genome sequencing strategies; Human genome project; Arabidopsis genome project; Rice genome project; Comparative genomics tools; | **6** |

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**COURSE OUTCOMES (COs)**

CO-1: Students will understand the basic principles of genetic markers - MAS, and genomic selection.

CO-2: Students will be able to differentiate between quantitative and Mendelian traits

CO-3: Students will understand computational basis of genetic analysis that use genome data sets in system biology.

CO-4: Students will be able to explain about the methods to characterize and manage the different types of biological data.

CO-5: Student will know about various biological databases that provides information about nucleic acids and protein.

CO-6: Student will understand the basics of sequence alignment and analysis.
CO-7: Students will be able to design and execute the programmes related to structural and functional aspects of genes and proteins.

## Practical

- Number System Conversion Numerical
- Addition of Binary Number
- Multiplication of Binary Number
- Subtraction of Binary Number
- Division of Binary Number
- To prepare document in the MS word
- To insert a table in the MS word documents.
- To make a presentation using MS PowerPoint
- To Perform Calculations using MS Excel
- To find the correlation using MS Excel
- To retrieve the sequence of the protein from UniProt database and to interpret the results.
- To retrieve the sequence of the protein from GenBank database and to interpret the results.
- To retrieve the structure of a protein and viewing it in RASMOL viewer.
- To find the similarity between sequences using BLAST
- To find the similarity between sequences using FASTA
- Multiple sequence alignment and find out the similarity sequences using CLUSTALW etc
- To perform Sequence analysis by using EMBOSS.
- To model a protein sequence using SWISS model.

**Suggested Readings**


1. Gear CW (1980). Computer Organization and Programming. McGraw-Hill Inc., New York
2. Gotefried BS (1986). Theories and Problems of Programming with BASIC. Schaum's Outline Series, McGraw-Hill Book Company, Singapore
3. Lipschutz MM, Lipschutz S (1981). Theories and Problems of Data Processing. Schaum's Outline Series, McGraw-Hill Book Company, Singapore
4. Subramanian N (1986). Introduction to Computer. Fundamentals of Computer Science. Tata McGraw-Hill Publishing Company Ltd., New Delhi
5. Rajaraman V Fundamentals of Computers. Prentice-Hall of India (Pvt.) ltd., New Delhi.
6. Sansom CE, Horton RM Eds. (2004). Internet for Molecular Biology. Oxford Univ. Press
7. Grant CAR, Helmer-Citterich M Eds. (2004). The Internet for Cell and Molecular Biologists, 2/e. Horizon Bioscience
8. Mount DW (2004**).** Bioinformatics: Sequence and Genome Analysis, 2/e. Cold Spring Harbor laboratory Press, USA
9. Brown SM (2000). Bioinformatics: A Biologist's Guide to Biocomputing and the Internet. Eaton Publishing
10. Rastogi SC, Mendiratta N, Rastogi P (2003). Bioinformatics: Concepts, Skills and Applications. CBS Publishers, New Delhi
11. Baxevanis AD, Ouellette BFF Eds. (2001). Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins (2nd Edition). John Wiley & Sons
12. Sharma TR (2009). Genome Analysis and Bioinformatics: A Practical Approach. IK International, New Delhi

# Molecular Genetics

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **Genetic material:** DNA and RNA as genetic material (experimental evidences; Griffith, Harshey and Chase, and TMV); structure of DNA (including Z-DNA, and Shasisekharan's RL model); supercoiling of DNA; different types of RNAs and their roles; differences between DNA and RNA. | **6** |
| **2.** | **DNA replication (in prokaryotes and eukaryotes):** Unwinding proteins; role of RNA polymerases for synthesis of RNA primers, DNA polymerases in prokaryotic and eukaryotic DNA replication; semi- conservative, discontinuous and bi-directional replication; RNA primers; role of a number of proteins in prokaryotic and eukaryotic DNA replication; models of replication. | **6** |
| **3.** | **Organization of genetic material:** Chromosome ultra-structure and nucleosome concept; packaging of DNA as nucleosomes in eukaryotes; techniques used for discovery of nucleosome; structure and assembly of nucleosomes, solenoid; phasing of nucleosomes; DNA content and C- value paradox, repetitive and unique sequences; overlapping, pseudo, cryptic and split genes; satellite DNA's; selfish DNA (including transposons and retroposons); Centromere and telomere. | **10** |
| **4.** | **Genetic code (including mitochondria genetic code):** Deciphering of code *in vitro* and *in vivo* (use of mutations -base replacement, frame shift and suppressor mutations. | **6** |
| **5.** | **Primary, secondary, tertiary and quaternary structures of proteins:** Protein folding problem and second half of the genetic code; elementary idea of prions. | **6** |
| **6.** | **Protein synthesis apparatus:** Transfer RNA and ribosomes (including Rosen Kornberg's work); transfer RNA synthetases and second genetic code. | **2** |
| **7.** | **Transcription of message:** Central dogma (including reverse transcription), prokaryotic RNA polymerases and eukaryotic RNA polymerases (I to V); promoters for transcription initiation (pribnow box, TATA box, CAAT box, GC box, etc.); enhancers and silencers; transcription initiation complex (including scaffold complex); different transcription factors for different RNA polymerases in eukaryotes (including mediators); DNA binding and activation domains in transcription factors; elongation of RNA transcript; termination of transcription. | **8** |
| **8.** | **Processing of RNA transcript:** Different mechanisms of RNA splicing; spliceosomes; alternative splicing (exosomes); ribozymes; snRNAs; RNA editing (editosomes) | **4** |
| **9.** | **Translation of message:** Initiation in prokaryotes and eukaryotes; Kozak's hypothesis; role of initiation factors; initiation complex; elongation of polypeptide (EF – Tu, EF –Ts & EF-G; eEF1 and eEF2); termination of polypeptide. | **4** |
| **10.** | **Regulation of gene expression in prokaryotes:** The operon concept and its recent modifications, positive and negative controls; leader sequence and attenuation; feedback inhibition. | **4** |
| **11.** | **Regulation of gene expression in eukaryotes:** Regulation of transcription, Britten–Davidson model, histone and non-histone proteins in regulation, signal transduction pathways, transcription factors (DNA-binding and activation domains) | **4** |

**COURSE OUTCOMES (COs)**

CO-1: This course will contribute towards learning and understanding the concepts of central dogma of molecular biology.

CO-2: Students will be able to explain the concept of DNA and RNA as genetic material through experimental techniques.

CO-3: Students will be able to discuss the mechanism of DNA replication in prokaryotes and eukaryotes.

CO-4: Students will be able to explain the protein synthesis machinery in prokaryotes and eukaryotes.
CO-5: Students will have knowledge of microbial genetics.
CO-6: Students will understand the regulatory mechanism of gene expression.

## Practical

- Genaeral laboratory procedure and safety rules of cell and molecular biology laboratory.
- Preparation of stock and working solution.
- DNA isolation from plants using CTAB method.
- DNA purification and quantification test.
- Agarose Gel electrophoresis.
- Polyacrylamide Gel electrophoresis.
- Study of genotyping using Polymerase Chain reaction (PCR).
- PCR-based DNA markers, gel scoring and data analysis for tagging and phylogenetic relationship.

## Suggested Readings


1. Albert B, Jhonson A, Lewis J, Raff M, Roberts K and Walter P (2002). Molecular Biology of the Cell, 4/e. Graland Science, New York
2. Freifelder D and Malacinski GM (1993). Essentials of Molecular Biology 2nd Ed. Johns and Bartlett Publishers, Boston
3. Gupta PK (2003). Cell and Molecular Biology, 2/e. Rastogi Publications, Meerut
4. Kahl G (2001). Dictionary of Gene Technology (2 Vols). Wiley-VCH Verlag GmBH & Co. KGaA, Weinheim
5. Lewin B (2007). Gene IX. Oxford Univ. Press, New York.
6. Primrose SB, and Twyman RM (2006). Principles of Gene Manipulation, 7/e.. Blackwell Science
8. Rapley R and Harbon S (Eds.) (2004). Molecular Analysis and Genome Discovery. Wiley
9. Watson JD et al. (2004). Molecular Biology of Gene.
10. Wilson J and Hunt T (1994). Molecular biology of the Cell: the Problems Book. Garland Publishing Inc., New York

# Basic Biochemistry and Physiology

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **Water:** Structure of water, ionization of water, acid base concept, pH and buffers, significance of structure-function relationship. | **6** |
| **2.** | **Biomolecules:** Structure, classification, properties and function of carbohydrates, amino acids, proteins, lipids and nucleic acids. | **6** |
| **3.** | **Molecules aiding metabolism:** Structure and biological functions of vitamins and coenzymes, enzymes: classification and mechanism of action; regulation, factors affecting enzyme action | **6** |
| **4.** | **Water uptake and transport mechanism:** water and its role in plants, water potential of plant cells, mechanism of water uptake by roots, transport in roots, aquaporins, movement of water in plants. | **6** |
| **5.** | **Mechanism of transpiration:** Stomata structure and function – mechanism of stomatal movement, factors influencing transpiration rate. | **6** |
| **6.** | **Role of mineral nutrients in plant metabolism:** Essential elements and their resources, classification based on function of elements in plants, mechanisms of uptake and translocation of minerals in plants, physiological and metabolic functions of mineral elements. | **6** |
| **7.** | **Mechanism of photosynthesis:** Photosynthesis and its importance in bio productivity. Photochemical process, photochemical reactions, $CO_2$ reduction in Calvin cycle, supplementary pathway of C fixation in $C_4$ and CAM plants and its significance, differences among $C_3$, $C_4$ and CAM plants, translocation of photosynthates and its importance in sink growth, source-sink relationship. | **8** |
| **8.** | **Plant respiration and lipid metabolism:** Mechanism of respiration, glycolysis, Kreb's cycle, electron transport system. | **8** |
| **9.** | **Plant growth regulators:** Hormonal regulation of growth and differentiation, plant growth hormones and their physiological role. | **4** |
| **10.** | **Photo morphogenesis:** Physiology of flowering: Photoperiodism and vernalization. | **4** |

## COURSE OUTCOMES (COs)

CO-1: Students will understand importance of various biomolecules for life.
CO-2: Students will be able to learn structure of carbohydrates, amino acids, nucleic acids.
CO-3: Students will be able to discuss the mechanism of photosynthesis.
CO-4: Students will be able to learn role of different plant growth regulators.
CO-5: Students will get information about various plant harmones and their functioning.

## Practicals

- Preparation of standard and buffer solutions
- Extraction and estimation of sugars
- Extraction and estimation of proteins
- Estimation of DNA and RNA by spectroscopic methods
- Separation of biomolecules by Paper chromatography
- Deficiency and toxicity symptoms of nutrients
- Effect of water stress on plant growth and development
- Study different sterilization techniques, prepare media stocks and plant hormones.

## Suggested Readings


1. Buchannan BB, Gruissem W and Jones R.L. (eds.). 2000. Biochemistry and Molecular Biology of Plants. 2nd edition. WILEY Blackwell
2. Heldt, H-W. 2010. Plant Biochemistry and Molecular Biology. 4th ed. Oxford University Plant Physiology Book by Eduardo Zeiger and Lincoln Taiz.
3. Plant Physiology Book by Frank B. Salisbury, Cleon W. Ross Salisbury, Frank B

4. Nelson DL and Cox MM. 2017. *Lehninger, Principles of Biochemistry,* 4th Edition, W.H.Freeman & Company, 2004. (T1)
5. Taiz T, Zeiger E and Max Mller IM, 2018, *Fundamentals of Plant Physiology*
6. Taiz L and Zeiger E. 2015. *Plant Physiology and development*.6th Ed
7. Salisbury FB and Ross C. 1992 (4th Ed.) *Plant Physiology*
8. Epstein E and Bloom AJ. 2004. *Mineral nutrition of plants: principles and perspectives*.2nd Ed
9. Hopkins WG and Huner NPA. 2004. *Introduction to Plant Physiology*
10. Kramer, P. J., *Water relations of plants*
11. Hopkins WG, 2008, *Introduction to Plant Physiology*

# Semester III

# Plant Biotechnology

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **Crop biotechnology and its scope:** An introduction | **4** |
| **2.** | **Plant organ, tissue and cell culture**: Totipotency; micro-propagation and its uses; somaclonal variation and its use in crop improvement; embryo culture; anther culture; somatic embryo; artificial seeds; techniques of protoplast culture, regeneration and somatic cell hybridization, achievements and limitations, utility in improvement of crop plants; application in production of secondary metabolites and transformations. | **8** |
| **3.** | **Elementary idea of theory and application of molecular techniques:** Centrifugation; spectrophotometry, MALDI-TOF; autoradiography, electrophoresis including pulse field and other tracer techniques; micro arrays; biosensors for agriculture. | **6** |
| **4.** | **Post-transcriptional gene silencing (PTGS):** VIGS and RNAi and their use in functional genomics and crop improvement. | **6** |
| **5.** | **Restriction enzymes:** Type I, II, and III enzymes; frequent and rare cutters; isoschizomers. | **6** |
| **6.** | **Vectors and gene cloning:** Plasmid, phage, cosmid, phagemid vectors, BAC, PAC and YAC vectors; expression vectors; binary and shuttle vectors | **4** |
| **7.** | **Libraries and molecular probes:** Construction and screening of genomic and cDNA libraries; BAC libraries and assembly of BACs into contigs, molecular probes and their preparation, labeling and applications; chromosome walking and chromosome jumping. | **6** |
| **8.** | **Polymerase chain reaction (PCR):** Basic PCR, designing of primers (including available softwares), different schemes of PCR (including RT-PCR); application of PCR; electronic-PCR (e-PCR) | **4** |
| **9.** | **Methods of gene transfer in plants:** *Agrobacterium* mediated gene transfer (dicots and monocots), directDNA delivery methods (microinjection, particle gun method electroporation); gene targeting (including zinc finger nucleases). | **6** |
| **10.** | **Transgenic plants in dicots and monocots:** Utility of transgenics in basic studies and in crop improvement (resistance for biotic and abiotic stresses; barnase and barstar for hybrid seed production); molecular farming for production of foreign proteins and edible vaccines; biosaftey issues including risks associated with transgenic crops; biosafety regulations (role of IBC, RCGM and GEAC or NBRA). | **6** |
| **11.** | **Genome Editing for Crop Improvement:** Recent transgene free genome editing tools such as CRISPR-Cas9 system, TALENS and ZFNs. | **4** |

**COURSE OUTCOMES (COs)**

CO-1: Students will be able to recall the basic concepts of Biotechnology and explain fundamental cellular events during the process of plant cell culture development.

CO-2: Students will develop skills on usage of the acquired knowledge on practical biotechnology tools to augment plant breeding research.

CO-3: Students will acquire knowledge required to execute, analyze and apply molecular marker systems for crop improvement.

CO-4: Students will be able to define the principles behind DNA fingerprinting methodologies using molecular markers RFLP, RAPD, STR, and SNP's.

**Practical**

- Preparation of solution used in plant biotechnology.
- Extraction of genomic DNA from crop plant.
- Gel electrophoresis techniques
- Polymerase Chain Reaction
- Application of restriction endonuclease digestion.
- Primer designing- Primer 3/ Primer BLAST.
- Bacterial transformation through plasmid vector

**Suggested Readings**


1. Ammirato, P. V., Evans, P. V., Evans, D. A., Sharp, W. R. and Yamada, Y. (Eds.) (1984). Handbook of Plant Cell Culture. Vols. 1, 2 & 3. MacMillan Publishing Co, New York.
2. Dodds, J. H. and Roberts, L. W. (1985). Experiments in Plant Tissue Culture. Cambridge University Press, Cambridge.
4. Mantell, S. H. and Smith, H. (Eds.) (1983). Plant Biotechnology. Cambridge University Press, Cambridge.
5. Swaminathan, M. S. (1991). Biotechnology in Agriculture – A dialogue. MacMillan India, New Delhi.
6. Kung, S. and Arntzen, C. J. (Eds.). (1989). Plant Biotechnology. Butterworth, Boston.
8. Grierson D (Ed.). (1991). Plant Genetic Engineering: Plant Biotechnology Series, Volume I. Blockie, Glasgow, London.
9. Charles, S. G. and Robert, T. F. (1992). Transgenic Crops. Sci. Am. June 1992, pp. 62 – 69.
10. Bengochea, T. and Dodds, J. H. (1986). Plant Protoplasts: A Biotechnological Tool for Plant Improvement. Chapman & Hall, New York.
11. Joshi, P. (2002). Genetic Engineering and Its Applications. Agrobios (India), Jodhpur
12. Trivedi, P. C. (2000). Plant Biotechnology: Recent Advances. Panima Publishing Corporation, New Delhi
13. Chawla, H. S. (2000). Introduction to Plant Biotechnology. Oxford & IBH Publishing CO. Ltd., New Delhi
14. Lorz, H. and Wenzel, G. (2004). Biotechnology in Agriculture and Forestry. Springer-Verlag
15. Henry, R. J. (2001). Plant Genotyping: The DNA Fingerprinting of Plants. CABI Publishing, Oxon, UK
16. Singh, B. D. (1998). Biotechnology. Kalyani Publishers, Ludhiana
17. Miesfeld, R. L. (1999). Applied Molecular Genetics. John Wiley & Sons
18. Primrose, S. B., Twyman, R. M. and Old, R. W. (2001). Principles of Gene Manipulation, 6/e. Blackwell Science
19. Kahl, G. (2001). Dictionary of Gene Technology (2 Vols). Wiley-VCH Verlag GmBH & Co. KGaA, Weinheim
20. Rapley, R. and Harbon, S. (Eds.) (2004). Molecular Analysis and Genome Discovery. Wiley VCH.

# Fundamental of Quantitative Genetics

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **Introduction and historical background of quantitative genetics:** Multiple factor hypothesis, Qualitative and quantitative characters, 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. | **8** |
| **2.** | **Designs for plant breeding experiments:** principles and applications; Variability parameters, concept of selection, simultaneous selection modes and selection of parents, MANOVA. | **6** |
| **3.** | **Association analysis:** Genotypic and phenotypic correlation, Path analysis Discriminate function and principal component analysis, Genetic divergence analysis- Metroglyph and D2, Generation mean analysis, Parent progeny regression analysis | **8** |
| **4.** | **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. | **8** |
| **5.** | **Statistics for QTL mapping:** Likelihood function, maximum likelihood estimates, likelihood ratio tests; the LOD score approach; expectation maximization (EM) algorithm (compare with least square method); use of EM in developing software for QTL interval mapping. | **10** |
| **6.** | **QTL mapping:** Quantitative genetic models (single QTL model, multiple locus model), mixture model. *single marker QTL analysis (SMA)*: bulk segregation analysis, linear regression and t-test, analysis of variance. *Interval mapping*: simple interval mapping (SIM) and composite interval mapping (CIM), multiple trait mapping (multiple trait simple interval mapping and multiple trait composite interval mapping), advantages of CIM over SMA and SIM. software's for QTL mapping | **10** |
| **7.** | **Epistatic QTLs and QTL × environment interaction:** Epistatic QTL with and without main effects, QTL × environment interaction. | **4** |
| **8.** | **Linkage disequilibrium (LD):** Introduction, measures of LD, factors affecting LD, LD and association mapping in plants. | **6** |

## COURSE OUTCOMES (COs)

CO-1: Students will understand the importance of quantitative genetics in plant breeding practices.
CO-2: Students will know about genetic markers and QTL - QTL mapping.
CO-3: Students will understand the basic principles of genetic markers - MAS, and genomic selection.
CO-4: Students will be able to differentiate between quantitative and Mendelian traits

**Practical**

- L × T analysis and interpretation
- Diallel analysis;
- G × E interaction and stability analysis.
- Construction of linkage map using suitable computer software packages.
- Single marker analysis for QTL identification
- QTL interval mapping using suitable computer software packages.
- Genome-wide association analysis using suitable computer software packages.
- Principal component analysis using suitable computer software packages.
- Clustering and interpretation of D2 analysis;

**Suggested Readings:**

1. Liu, B. H. (1998). Statistical Genomics: Linkage, Mapping, and QTL Analysis. CRC Press, Boca Raton, New York, USA
2. Phillips, R. L. and Vasil, I. K. (eds.) (1994). DNA Based Markers in Plants. Kluwer Academic Publishers, Dordrecht

3. Chahal, G. S. and Gosal, S. S. (2003). Principles and Procedures of Plant Breeding: Biotechnological and Conventional Approaches. Narosa Publishing House, New Delhi
4. Gupta, P. K. and Varshney, R. K. (eds.) (2004) Cereal Genomics. Kluwer Academic Publishers, Dordrecht
5. Paterson, A. H. (ed.) (1998) Molecular Dissection of Complex Traits. CRC Press, Boca Raton, New York, USA
6. Lee, P. (2004). Bayesian Statistics: An Introduction, 3/e. Hodder & Stoughton Publishers, Oxon, UK
7. Shoemaker, J. S., Painter, I. S., Weir, B. S. (1999). Bayesian statistics in genetics: A guide for the uninitiated. Trends Genet 15:354-358
8. Flint-Garcia, S. A., Thornsberry J. M. and Buckler, E. S. (2003) Structure of linkage disequilibrium in plants. Ann Rev Plant Biol 54:357-374
9. Rafalski, A. and Morgante, M. (2004). Corn and humans: recombination and linkage disequilibrium in two genomes of similar size. Trends Genet 20: 103-111
10. www.iasri.icar.gov.in
11. www.hau.ac.in/OPstat

# Breeding for Stress Resistance and Climate Change

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **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. | **6** |
| **2.** | **Introduction to Phenomics** | **8** |
| **3.** | **Concepts of resistance to insect and pathogen:** 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; Effector proteins; Concept of signal transduction and other host-defence mechanisms. | **10** |
| **4.** | **Types and genetic mechanisms of resistance to biotic stresses:** Horizontal andvertical resistance in crop plants; Quantitative resistance/ adult plant resistance and slow rusting resistance; Classical and molecular breeding methods – Measuring plant resistance using plant fitness. | **10** |
| **5.** | **Phenotypic screening methods for major pests and diseases:** Recording of observations; Correlating the observations using marker data – Gene pyramiding methods and their implications. | **6** |
| **6.** | **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. | **4** |
| **7.** | **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 crop plants. | **4** |
| **8.** | **Breeding for resistance to stresses caused by toxicity, deficiency and pollutants/ contaminants in soil, water and environment.** | **4** |
| **9.** | **Transgenics in management of biotic and abiotic stresses:** use of toxins, protease inhibitors, lectins, chitinases and Bt for diseases and insect pest management. | **4** |
| **10.** | **Use of crop wild relatives as a source of resistance to biotic and abiotic factors in major field crops** | **4** |

## COURSE OUTCOMES (COs)

CO-1: Students will understand the molecular basis of susceptibility and resilience in crop plants against abiotic and biotic stress factors.
CO-2: Students will understand the approaches to select abiotic and biotic resistant lines from a breeding population.
CO-3: Students will understand various abiotic and biotic stress factors and their impact on the crop plants.
CO-4: Students will be able to discuss various abiotic and biotic resistant crop varieties.
CO-5: Students will gain knowledge about breeding approaches to incorporate abiotic and biotic stress resilience in crop plants.

## Practical

- Study of Koch Postulates
- Preparation of culture media for fungi and bacteria
- Isolation of bacteria through streak plate and spread plate method
- Identification and isolation of fungus from infected plant
- Study of important disesesin wheat and rice
- Study of cereal cyst nematode
- 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

## Suggested Readings


1. Tarr, S.A.J. (1972). The Principles of Plant Pathology. Macmillan Press, London.
2. Agrios, G.N. (1998). Plant Pathology. Acad. Press, New York.
3. Russel GE. (1978) Plant Breeding Pest and Disease Resistance. Butterworths.
4. Campbell, R. (1989). Biological Control of Microbial Plant Pathogens. Cambridge Univ. Press.
5. Fenemore. P.G. (1984). Plant Pests and Their Control. Butterworths, London.
6. Mundkur, B.B. (1949). Fungi and Plant Diseases. Macmillan & Co, London.
7. Rangaswami, G. (2002). Diseases of Crop Plants in India. Prentice Hall of India, New Delhi.
8. Singh, R.S. (2002). Introduction to Principles of Plant Pathology. Oxford & IBH Publishing Co. New Delhi.
9. Walker, J.C. (1969). Plant Pathology. McGraw Hill Book Co., New York.
10. Roger Hull (2013) Plant virology, 5th Edition. Academic Press.

# Hybrid Breeding

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | 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 | **6** |
| **2.** | 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. | **6** |
| **3.** | Prediction of heterosis from various crosses, inbreeding depression, coefficient ofinbreeding and its estimation, residual heterosis in F2 and segregating populations, importance of inbreeding in exploitation of heterosis – case studies. | **8** |
| **4.** | 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. | **8** |
| **5.** | 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. | **12** |
| **6.** | 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; | **6** |
| **7.** | 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. | **4** |
| **8.** | Hybrid breeding in wheat, rice, cotton, maize, pearl millet, sorghum and rapeseed mustard, sunflower, safflower and castor oilseed crops and pigeonpea. | **4** |
| **9.** | **Biotechnological applications in heterosis breeding:** (a) *Barnase* and *barstar* genes in hybrid seed production; (b) marker-assisted heterosis breeding in maize, pearl millet and rice; (c) possible use of molecular markers in selection of diverse parents for hybrid breeding. | **4** |
| **10.** | **Hybrid seed production:** Role of the hybrids in enhancing crop productivity in India | **2** |

## COURSE OUTCOMES (COs)

CO-1: Student will acquire knowledge on conventional and molecular breeding methods to obtain yield improved crop varieties.
CO-2: Students will be able to discuss the examples of crop varieties developed with heterosis breeding.
CO-3: Students will cultivate skill in emasculation and pollination of various crop plants.
CO-4: Students will understand the practices that hinder the development of improved traits in offspring.
CO-5: Students will learn to use the descriptors in various crops for selection of superior genotypes.

## Practical

- Study of hybridizing tools which used in hybrid seed production.
- Study of the steps & procedure of hybrid seed production.
- Study of one-line, two-line and three-line system of hybrid seed production.
- Study of Barnase/Barstar system of male sterility in hybrid seed production.
- Calculation of heterosis over mid parent value on given experimental data.
- Calculation of heterosis over better parent value on given experimental data.
- Calculation of heterosis over check cultivar on given experimental data.
- Calculation of inbreeding depression on given experimental data.
- Heterosis & hybrid seed production of maize crop.
- Heterosis & hybrid seed production of rice crop.
- Heterosis & hybrid seed production of rapeseed & mustard crop.
- Heterosis & hybrid seed production of pearl-millet crop.

**Suggested Readings**


1. Singh, B. D. (2003). Plant Breeding. Kalyani Publishers, New Delhi
2. Chahal, G. S. and Gosal, S. S. (2003). Principles and Procedures of Plant Breeding: Biotechnological and Conventional Approaches. Narosa Publishing House, New Delhi
3. Poehlman, J. M. and Sleper, D. A. (1995) Breeding Field Crops, 4th. edition. Iowa State Univ. Press, Ames, Iowa
5. Gupta, P. K. (2003). Biotechnology and Genomics. Rastogi Publications, Meerut.
6. Chopra, V. L. (ed.) (2000). Plant Breeding: Theory and Practice, 2/e. Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi
7. Smith, R. H. (1992). Plant Tissue Culture Academic Press Inc., San Diego
8. Simmonds, N.W. and Smart, J. (2000). Principles of Crop Improvement. 2nd Edition. Blackwell Science, Malden, MA
9. Fehr, W. R. (1987) Principles of Cultivar Development. Vol. 1. Theory and Technique. Macmillan Pub. Co., New York
10. Fehr, W. R. (1987). Principles of Cultivar Development. Vol. 2. Crop Species. Macmillan Pub. Co., New York
11. Fehr, W. R. and Hadley, H. H. (1980) Hybridization of Crop Plants. American Society of Agronomy, Madison, WI
12. Banga, S. S. and Labana, K. S. (1983). Production of $F_1$ hybrids using ethrel induced male sterility in Indian mustard. J. Agric. Sci. Camb. 101:453-455
13. Kalloo, G. (1995). Heterosis breeding in vegetable crops: present status and future prospects. In: Hybrid Research and Development (Rai M and Mauria S, eds.). Indian Society of Seed Technology, New Delhi, pp 165-174.
14. Paroda, R. S. (1995). Hybrid technology for improving productivity of cereals in Asia: Issues and strategies. In: Hybrid Research and Development (Rai M and Mauria S, eds.). Indian Society of Seed Technology, New Delhi, pp 7-18.

15 Rai, M. and Mauria, S. (eds.) (1995). Hybrid Research and Development. Indian Society of Seed Technology, New Delhi.

16. Rai, B. (1979). Heterosis Breeding. Agro Biological Pub., Delhi.
17. Mukherjee, B .K. Heterosis Phenomenon.
18. Coor and Pandey, S. (eds.) (1999). Genetics and Exploitation of Heterosis.

# Semester IV

# Advanced Genetics

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **Genetics and biochemistry of cell cycle (role of reversible phosphorylation):** Genetic vs. biochemical approaches; mitotic cell division in yeast; variation in mitotic cell cycle; central cell cycle control system; cell cycle check points cyclin dependent kinases (Cdks) and cyclins; meiotic cell division; dynamics of chromosome movements during cell division; role of degradation of proteins (proteolysis) in cell cycle. | **10** |
| **2.** | **Mechanism of gene mutation:** Target theory, peroxide formation, UV and thymine dimers, incorporation of base analogues and chemical alteration in nucleic acids; radiation damage and repair of DNA (photo–repair, excision repair; recombination repair, adaptive response); site specific mutagenesis; insertion mutagenesis, TILLING. | **10** |
| **3.** | **Molecular mechanism of homologous recombination:** Crossing over, gene conversion (chiasma type or precocity, Billing's theory, hybrid DNA models of Whitehouse and Holliday); recombinases, and resolvases in prokaryotes and eukaryotes. | **6** |
| **4.** | **Molecular mechanism of site-specific recombination:** Invertases/resolvase system; integrase system; integrons and mobile gene cassettes. | **4** |
| **5.** | **Organellar genetics:** DNA in mitochondria and chloroplasts; molecular mechanism of cell division of mitochondria and chloroplast; techniques to locate genes on organellar DNA; petite character in yeast; male sterility; resistance to antibiotics in *Clamydomonas;* circular genetic maps of chloroplasts and mitochondria. 6 | **8** |
| **6.** | **Gene mapping in bacteria, viruses, algae and fungi (including parasexual cycles):** Methods of transfer of genetic material in bacteria (transformation, conjugation and transduction); linkage maps in bacteria; replication and recombination in viruses; tetrad analysis, mitotic recombination and chromosome mapping and gene conversion in fungi and algae; somatic crossing over in *Drosophila*, mitotic recombination and parasexual cycle in *Aspergillus.* | **10** |
| **7.** | **Plasmids, transposons and retroelements:** Plasmids, IS sequences or IS elements, transposons and controlling elements, retroelements, mechanism of transposition; uses of transposons. | **4** |
| **8.** | **Developmental genetics:** Genetics of development (homeotic genes in initiation, development and for gene transfer with examples of embryo development in Drosophila and for flower development in *Arabidopsis*-ABCDE model). | **4** |
| **9.** | **Epigenetics**: An Introduction to paramutation; DNA methylation and histone modification; genome imprinting ($IGF_2$ in mammals) 'Solid gold' or Callipyge in sheep; epigenetics in *Arabidopsis* and *Linaria*; histone code. | **4** |

## COURSE OUTCOMES (COs)

CO-1: Students will understand different methods of gene-mapping.
CO-2: Students will be well versed with the concept of Epigenetics and epigenetic mutations.
CO-3: Students will understand the different types of mutations in genetic material.
CO-4: Students will understand the basic concepts of immunology, antigen -antibody reaction methods.
CO-5: Students will understand the basic concepts crossing over and recombination.

## Practical

- Preparation of slides for mitotic cell division using suitable tissue samples
- Isolation of plasmid DNA and visualization in gel
- Bacterial transformation using heat shock method
- Procedure of conducting Targeted Induced Local Lesion IN Genome (TILLING)
- Isolation of plasmid DNA using kit
- ABC model in Arabidopsis.

## Suggested Readings


1. Auerbach, C. (1976). Mutation Research: Problems, Results, and Perspectives. Chapman and Hall. London.
2. Bacq, Z.M. and Alexander, P. (1966). Fundamentals of Radiobiology. Pergamon Press.
3. Beale, G. and Knowles, J. (1978). Extranuclear genetics. Edward Arnold, London.
4. Fincham, J.R.S. (1983). Genetics. John Wright and Sons Ltd. Bristol.
5. Freese, E. (1963). Molecular mechanism of mutation. Molecular Genetics Part I. (Ed. J.H. Taylor). Acad. Press.
6. Gaul, H. (1964). Mutations in Plant Breeding. Radiation Botany 4: 155 – 232.
7. Howard – Flanders, P. (1981). Inducible repair of DNA. Sci. Am. 245 (5): 56.
8. Strickberger, M. W. (1988). Genetics 3/e Macmillan Publishing Co. Inc., New York.
9. Griffith et al. (2004). An Introduction to Genetic Analysis 8th Ed. W.H. Freeman & Co., New York.
10. Gupta, P. K. (2004). Cell and Molecular Biology. Rastogi Publications, Meerut
11. Gupta, P. K. (2003). Genetics 3rd Ed. Rastogi Publications, Meerut
12. Snustad, D. P., Simmons, N. J., and Jenkins, J. B. (2003). Principles of Genetics. John Wiley and Sons, New York
13. Hartwell, L. H. et al. (2000). Genetics: From Genes to Genomes. McGraw Hill, New Delhi
14. Pierce, B. (2005). Genetics: A conceptual Approach 2nd Ed. WH Freeman & Co
15. Knowles. Solving Problems in Genetics.
16. Hartl, D. L. and Jones, E. W. (1997). Genetics: Principles and Analysis. Jones & Bartlett Publisher Inc.
17. Primrose, S. B., Twyman, R. M. and Old, R. W. (2001). Principles of Gene Manipulation, 6/e. Blackwell Science
18. Kahl, G. (2001). Dictionary of Gene Technology (2 Vols). Wiley-VCH Verlag GmBH & Co. KGaA, Weinheim
19. Rapley, R. (Ed.) and Harbon S (2004). Molecular Analysis and Genome Discovery. Wiley

# Crop Breeding

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **Plant ideotype:** Ideotype concept, ideotypes of wheat, rice, maize, *Brassica* species, cotton, pigeon pea, mung bean and chickpea, super plant types. | **8** |
| **2.** | **Breeding for nutritional quality traits (protein, oil, vitamins and iron):** Breeding for improved protein content and quality in cereals and legumes, sources of quality traits, breeding approaches, achievements; breeding for improved oil content and quality, breeding approaches and achievements; biofortification {including Fe (rice) and Zn, vitamins (golden rice and maize); quality protein maize (QPM); Nutritional genomics | **8** |
| **3.** | **Mutation Breeding:** 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; | **8** |
| **4.** | **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 M3 generation; Comparative evaluation of physical and chemical mutagens for creation of variability in the some species- Case studies. | **8** |
| **5.** | **Breeding for cereal crops: (Rice; Maize; Wheat; barley pearl millet, sorghum):** mode of reproduction**;** chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; | **8** |
| **6.** | **Breeding for pulse crops: (Chickpea; pigeon pea; urdbean; mungbean; lentil):** mode of reproduction; chromosome number; Genetics –cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; | **8** |
| **7.** | **Breeding for oilseed crops (Rapeseed mustard, soyabean, Groundnut; Sunflower):** mode of reproduction, chromosome number; Genetics – cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc.; | **6** |
| **8.** | **Breeding for other crops (potato; sugarcane; cotton; pea):** mode of reproduction; chromosome number; Genetics –cytogenetics and genome relationship; Breeding objectives: yield, quality characters, biotic and abiotic stress resistance, etc. | **6** |

## COURSE OUTCOMES (COs)

CO-1: Students will understand the importance of various quality traits.
CO-2: Student will acquire knowledge about polyploidy and cytogenetic aspects of crop evolution.
CO-3: Students will understand recent advances in improvement of kharif cereals, legumes, oilseeds, fibre, sugarcane and vegetative propagated crops.
CO-4: Students will understand application of mmutation breeding for crop improvement.
CO-5: Students will understand application of conventional and modern biotechnological approaches in crop breeding.

## Practical

- Quality parameters evaluation in wheat, rice, pulses and oilseeds
- Pollen viability and fertility studies (1);
- Hands on practices in hybridization
- Floral biology, emasculation, pollination techniques in wheat, rice maize etc. ,
- Study of range of variation for yield and yield components

## Suggested Readings


1. Agarwal RL. 1996. *Identifying Characteristics of Crop Varieties*. Oxford & IBH.
2. Bahl PN and Salimath PM. 1996. *Genetics, Cytogenetics and Breeding of Crop Plants*. Vol. I. *Pulses and Oilseeds*. Oxford & IBH.
3. Chandraratna MF. 1964. *Genetics and Breeding of Rice*. Longmans.
4. Chopra VL and Prakash S. 2002. *Evolution and Adaptation of Cereal Crops*. Oxford & IBH.
5. Gill KS. 1991. *Pearl Millet and its Improvement*. ICAR.
6. IRRI. 2000. *Rice Genetics IV*. Proc. International Rice Genetics Symposium. IRRI, Los Banos, Manila, Philippines.
7. Jennings PR, Coffman WR and Kauffman HE. 1979. *Rice Improvement*. IRRI, Los Banos, Manila, Philippines.
8. Gupta SK. 2012. *Technological Innovations in Major World Oil crops*. Vol. II. Springer, USA.
9. Gupta SK. 2016. *Breeding of Oilseed Crops for Sustainable Production*. Academic Press, USA.
10. Kannaiyan S, Uthamasamy S, Theodore RK and Palaniswamy S. 2002. *New Dimensions and Approaches for Sustainable Agriculture*. Directorate of Extension Education, TNAU, Coimbatore.
11. Parthasarathy VA. 2017. *Spices and Plantation Crops* Vol.1 (Part A) *Breeding of Breeding and Genetics*. John Wiley & Sons.
12. Allard RW. 1999. *Principles of Plant Breeding*. John Wiley & Sons.
13. Fageria MS, Arya PS and Choudhary AK. 2000. *Vegetable Crops: Breeding and Seed Production*. Vol. I. Kalyani Publishers, New Delhi.
14. Kalloo G. 1988. *Vegetable Breeding*. Vols. I-III. CRC Press.

# Seed Production and Certification

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **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. | **8** |
| **2.** | M**aintenance breeding:** general principles of nucleus, breeder, foundation and certified seed production | **6** |
| **3.** | **Principles of seed production in field crops:** Floral structure, pollination mechanism and seed production techniques in self- and cross-pollinated cereals and millets. | **6** |
| **4.** | **Seed production of GM crops**: Isolation distances; refugia; regulatory measures. | **6** |
| **5.** | **Floral structure, pollination mechanism and methods and techniques of seed Production:** major pulses and oilseed crops; Varietal and hybrid seed production techniques in rice, maize, pearl millet, pigeon pea, sunflower, tomato, brassica, cotton. | **8** |
| **6.** | **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 | **8** |
| **7.** | **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. | **6** |
| **8.** | **Seed testing**: Importance, history and development; seed testing laboratory; sampling and its methods; purity analysis, germination tests and seedling evaluation; moisture test; viability tests; reporting of results; seed priming; synthetic seeds; taped seeds. | **6** |
| **9.** | **Seed processing and packaging:** Principles and practices; seed drying and conditioning; seed cleaning and grading; methods of seed packing and storage; factors affecting seed storage | **6** |

## COURSE OUTCOMES (COs)

CO-1: Students will be able to grasp the significance of basic principles of seed production in crop plants.
CO-2: Students will understand the importance of good seed and enforcement of seed laws and legislations in the country.
CO3: Students will learn different seed testing techniques.
CO-4: Students will understand the methodology of seed production of GM crops.
CO-5: To understand the importance of field standards and seed standards in seed production and certification.

## Practical

- Establishment of Seed Testing laboratory.
- The physical purity analysis is to determine whether the submitted sample conforms to the prescribed physical quality standards with regard to physical components.
- To determine the Seed Germination by between paper (BP) method.
- To determine the moisture content of seeds by Air oven method.
- To estimation of Seed viability test using Tetrazolium test (TZ).
- Numerical on Seed blinding.

- Flow chart of seed processing.
- 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

**Suggested Readings**


1. Anonymous (2004). International rules for seed testing. ISTA, Switzerland.
2. Douglas, J.E. (1967). Seed certification manual. NSC and Rockefeller Foundation, New Delhi.
3. Agarwal, R.L. (2003). Seed Technology. Oxford & I.B.H. Delhi.
4. Feistritzer,W.P (1975). Cereal Seed Technology, F.A.O. Agricultural Development Paper No. 98.
5. Indian Minimum Seed Certification Standards. The Central Seed Certification Board, New Delhi, 1988.
6. Chalam, G.V., Singh, A. and Douglas, J. E. (1967). Seed Testing Manual. ICAR & USDA Publication, New Delhi.
7. Nema, N. P. (1987). Principles of Seed certification and Testing.
8. McDonald, M.B. and Copeland, L. O. (1995). Principles and practices of seed Production. Chapman & Hall, London.
9. Kelly, A.F. and George, R.A.T.(eds,). (1998). Encyclopedia of Seed production of world crops. John Wiley & Sons, England.
10. Desai, B.B., Kotecha, P.M. and Salunkhe, D.K. (1995). Principles and practices of seed production. Chapman & Hall, New York.
11. Agrawal, P.K. (2002). Principles of Seed Technology. ICAR, New Delhi.
12. ISTA Handbook on Seedling Evaluation, 3/e. ISTA, Basserdorf, CH- Switzerland
13. Singh, NP, Bhardwaj, AK, Kumar, banish and Singh KM ((2004). Modern Technology on Vegetable Production. International Book Co., Lucknow
14. Singh, S. P. (2001). Seed Production of Commercial Vegetables. Agrotech Publishing Academy, Udaipur
15. Singhal, N. C. (2003). Hybrid Seed Production in Field Crops. Kalyani Publishers, New Delhi
14. Khare, D. and Bhale, M. S. (2000). Seed Technology. Scientific Publishers (India), Jodhpur

# Genomics, Transcriptomics and Proteomics

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **Molecular maps and comparative genomics:** Genetic maps, physical maps, EST and transcript maps/contig map, functional maps; comparative mapping, genomics and collinearity/synteny in maps. | **6** |
| **2.** | **Isolation, sequencing and synthesis of genes and genomes:** Methods of gene isolation (use of antibody; transposon tagging); chemical (Maxam and Gilbert's degradation method) and enzymatic (Sanger's dideoxy synthetic method) methods of DNA sequencing, gene synthesis machines, PCR methods of gene synthesis, synthesis of genomes. | **8** |
| **3.** | **Whole genome sequencing:** Whole genome shotgun sequencing; clone-by-clone or 'hierarchical shotgun' sequencing; pan genomes and metagenome. | **8** |
| **4.** | **Next generation sequencing technologies:** DNA sequencing technologies e.g., 454, Illumina, ABI SOliD, single molecule and nanopore sequencing; microbial genomes (including yeast); plant genomes (Arabidopsis, rice and wheat); | **8** |
| **5.** | **Annotation of whole genome sequence and functional genomics:** *In silico* methods, insertion mutagenesis (T-DNA and transport insertion), VIGs, RNAi, TILLING, Eco-TILLING, use of DNA chips and microarrays. | **8** |
| **6.** | **Significance of transcriptomics:** Differential expression of genes in different tissues/ organs and in response to biotic and abiotic stresses. | **2** |
| **7.** | **Methods of transcriptome analysis:** (a) Sequence-based technologies (ESTs, SAGE, MPSS), (b) array-based technologies, (c) computational-based technologies (d) RNA sequencing. | **6** |
| **8.** | **Significance of proteomics**: Proteomes in different tissues/organs and in response to biotic and abiotic stresses; nuclear and organellar proteomics | **4** |
| **9.** | **Post-translational modification of proteins**: Phosphorylation, glycosylation and sulphation | **4** |
| **10.** | **Methods for proteomics analysis**: SDS- PAGE, 2D-PAGE, X- ray crystallography NMR spectroscopy, isoelectric focusing (IEF), mass spectroscopy (MS), MALDI-TOF, differential display (DD), protein chips and antibody microarrays, functional protein microarrays; resolution and identification of proteins, analysis of post-translational modifications of proteins. | **6** |

## COURSE OUTCOMES (COs)

CO-1: Students will understand commonly used in genome sequencing, genome assembly and annotation.
CO-2: Students will be able to develop basic skills and techniques involved in isolation and quantification of DNA and plasmids.
CO-3: Students will be able to understand and build skills for separation and amplification of DNA.
CO-4: Students will be able to understand and demonstrate the extraction and quantification of proteins.
CO-5: Students will be able to use different methodologies used in proteomics.

## Practical

- Conduct pairwise alignment of nucleotide protein sequencing using different programs of BLAST family and analyses the result.
- Mining microsatellite or SSRs from given DNA sequence using SSRIT software and characterize these SSRs.
- Isolation and purification of mRNA from leaf tissue at anthesis stage.
- Development of 3D structure of protein using sequence from a given gene ID.
- Construction of phylogenetic tree among grass species for a particular gene.
- Designing PCR primers using Primer3 software and calculate the annealing temperature (Ta) of both (forward and Reverse) the primers.

## Suggested Readings


1. Gupta, P. K. (2004). Biotechnology and Genomics. Rastogi Publication, Meerut.
2. Cullis, C. A. ( 2004). Plant Genomics and Proteomics. Agrosciences, New Delhi.
3. Reece, R. J. (2004). Analysis of Genes and Genomes. Agrosciences, New Delhi.
4. Brown, T. A. (2007). Genomes, 3/e. Garland Science, New York..
5. Stein (2003). Fundamentals of Protein Biotechnology. Atlas Books, New Delhi.

# General Agriculture
# (Open Elective)

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | Brief Idea of different branches of agricultural Sciences and their scope. | **4** |
| **2.** | Classification of Crops on the basis of climate. Agroclimatic zones. | **6** |
| **3.** | General principles of Crop production: mixed and inter-cropping; Nutritional management of crops including application of manures, fertilizers and bio-fertilizers, Sustainable agriculture. | **8** |
| **4.** | Classifications of soil and soil texture. | **4** |
| **5.** | Importance of water in crop production; Soil Moisture content, Drought and Flood. | **4** |
| **6.** | Definition and scope of farm economics and management, Agricultural Economics and industrial Economics. | **4** |
| **7.** | Extension Teaching and Learning: Community Development. | **4** |
| **8.** | Role of extension agent in programme planning. | **4** |
| **9.** | Disease, insect and pest: Brief idea about economically important pathogens, insects and pests/storage pest. | **4** |
| **10.** | Plant Breeding - history, objectives and scope, mode of reproduction in crop plants in relation to breeding techniques. | **6** |
| **11.** | Livestock production and management. Brief idea about common breeds and poultry. Dairy science and products | **4** |
| **12.** | Irrigation and drainage system. | **4** |
| **13.** | Common agriculture equipment. | **4** |

# Global Food and Nutritional Security
# (Open Elective)

**Credits: 4+1+0**

| Unit | Course content | Teaching hours: 60 |
|---|---|---|
| **1.** | **Introduction**: Major sources of human foods in India and other countries and their relative contribution to food basket; food production and productivity; food production during 20$^{th}$ and 21$^{st}$ century; food security (supply and demand) in: (i) Asia, (ii) Africa, (iii) Other countries; yield potential and yield gaps. | **8** |
| **2.** | **Sustainable intensification of food production system:** Major crops (wheat, rice, maize, mustard, chickpea, pigeonpea, groundnut) for food security and their contribution to world food requirement; Crop Varieties and Cropping Systems. | **10** |
| **3.** | **Reducing risks to food production and distribution system:** Factors affecting food and nutritional security; brief idea about (i) human health including diseases; (ii) climate change and green-house effect/global warming; (iii) socio-economic factors; (iv) yield losses due to biotic and abiotic stresses; (v) Food losses during storage; (vi) Agriculture food distribution system. | **16** |
| **4.** | **Food Policy and Food Security**: **Efforts/suggestions for possible future solutions**: Definitions and meaning; concept of zero hunger by 2030, brief idea about world food crisis, role of UNO, FAO, NARS, National food security bill and act 2013 | **10** |
| **5.** | **Nutritional security and measures for achieving nutritional security:** Current nutritional status in India and other major countries. Causes of malnutrition; Role HarvestPlus; Fortified foods; Hidden hunger and Biofortification of food crops to reduce malnutrition; nutrients use efficiency in food crops; Nutritional self-reliance; Emergency nutrition (Ensuring good nutrition in emergency aid). | **12** |
| **6.** | **National and Global policies for nutritional security:** Assessing, analyzing and monitoring nutrition situations; World declaration and plan of action for nutrition; The National Nutrition Monitoring Bureau (NNMB). | **4** |

# Value-added Courses

## Essentials of Laboratory Techniques

**Teaching hours: 30**

Safety measures while in Lab; Handling of chemical substances; Use of burettes, pipettes, measuring cylinders, flasks, separatory funnel, condensers, micropipettes; Washing, drying and sterilization of glassware; Drying of solvents/ chemicals; Weighing and preparation of solutions of different strengths and their dilution; Handling techniques of solutions; Preparation of different agro-chemical doses in field and pot applications; Preparation of solutions of acids; Neutralisation of acid and bases; Preparation of buffers of different strengths and pH values; Use and handling of microscope, laminar flow, vacuum pumps, viscometer, thermometer, magnetic stirrer, micro-ovens, incubators, sandbath, waterbath,

## Advance Bioinformatics Techniques

**Teaching hours: 30**

Sequence Database, Sequence alignment, Molecular phylogeny, genome assembly, genome annotation, SSR and SNP mining from whole genome data, population structure and GWAS analysis in crops, Useful packages for genomic selection, Protein structure prediction, Proteomics data analysis in Agriculture, programming in PERL and BioPERL, Basics in R and R-studio.

## Techniques in Virology

**Teaching hours: 30**

Introduction to Viruses, Introduction to vectors that transmit viruses. Introduction to PCR based diagnosis for viruses, Bioinformatics analysis for the viral sequences

## Techniques in Seed Science and Technology

**Teaching hours: 30**

Introduction and Scope of Seed Science and Technology and Seed quality; Introduction of Science of Seed Testing (Brief history, ISTA, Seed sampling, Purity analysis; Germination test, TZ viability test, seed Moisture test); Introduction to Seed processing and Drying; Hybrid seed production technology for Rice wheat, maize, Bajra and Cotton

## Agricultural Research and Genetic Resources

**Teaching hours: 30**

National Agricultural Research System (NARS) including ICAR institutes and State Agricultural Universities (SAUs). Consultative Group on International Agricultural Research (CGIAR): International Agricultural Research Centres (IARC), Genetic resources and their conservation, Biodiversity conservation, Nutritional deficiency; Malnutrition; Fortified foods; Hidden hunger and crop Bofortification