DISCIPLINE SPECIFIC ELECTIVE COURSE (DSE-15): Advances in Genetics, Genomics and Plant Breeding

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the course			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Advances in Genetics, Genomics and Plant Breeding DSE-15	**4**	**2**	**0**	**2**	Semester VII	Nil

Learning Objectives : This course aims to equip students with advanced knowledge and practical skills in genetics, genomics, and plant breeding to address key challenges in crop improvement.

- Develop a foundational understanding of inheritance, gene interactions, chromosomal behavior, and the application of genomics in identifying gene functions in plants.
- Acquire hands-on knowledge of breeding methods such as hybridization, mutation breeding, marker-assisted and genomic selection for crop improvement.
- Learn to formulate and execute plant breeding programs targeting agricultural challenges like yield enhancement, disease resistance, and abiotic stress tolerance.
- Understand how genetic traits interact with environmental factors to affect plant performance and adapt breeding strategies accordingly.
- Recognize the importance of plant genetic diversity and apply it effectively in breeding programs for sustainable crop development.

Learning Outcomes :

Upon successful completion of the course, students will be able to:

- Understand the core principles of genetics, including inheritance, gene interactions, and chromosomal behaviour.
- Apply genomics to identify genes and analyze their functions in plants.
- Gain hands-on expertise in modern breeding techniques such as hybridization, mutation breeding, marker-assisted selection, and genomic selection.
- Design and implement plant breeding programs aimed at yield enhancement, disease resistance, and abiotic stress tolerance.
- Analyze genotype-environment interactions to optimize plant performance through targeted breeding strategies.

- Appreciate the significance of conserving plant genetic diversity and apply it for sustainable crop improvement.

Theory : 30 Hours

Unit 1: Chromatin Organization and Fine Structure of Gene and Molecular Cytogenetics 06 Hours

Chromatin structure and packaging of DNA: architecture of chromosome in eukaryotes, karyotypes and ideogram. Fine structure of gene (Phage rII locus), cis-trans complementation test.Genome analysis in crops; Utilization of aneuploids (addition, deletion, substitution and nullisomic lines) in gene localization. Evolutionary significance of chromosomal aberrations in crop improvement, molecular cytogenetical tools for identification and structural analysis of genomes, introgression studies and ploidy detection.

Unit 2: Applied Genetics 04 Hours

Applications of molecular cytogenetics: Alien gene transfer studies, gene mapping of agronomic traits and crop improvement in wheat, rice, tomato and cotton. Application of transposons in mutagenesis, genome mapping and evolution. Pedigree analysis and introduction to genetic counselling in humans; ethical, legal and social issues related to genetic analysis.

Unit 3: Current Trends in Genomics, Epigenomics and Metagenomics, Genome Editing Techniques 10 Hours

Gene discovery and deciphering gene function for improvement of crops. Applications of genomics in agriculture, health and environment. Epigenomics: DNA methylation, histone modifications and chromatin remodelling; Epialleles: inheritance and role in genetic regulation. Basic tools for studying epigenomics: Overview of Bisulfite sequencing and ChIP-Seq. Applications in crop improvement and disease management. Introduction to metagenomics; the human microbiome: microbes and health. Environmental metagenomics: role in pollution control and ecosystem management. Introduction to genome editing, CRISPR-Cas9; applications of genome editing in agriculture and medicine. Ethical concerns: Designer babies, GMOs, and genome editing regulations.

Unit 4: Genetic Systems and Breeding Methods and Molecular Breeding 10 Hours

Gene pools (primary, secondary and tertiary), systems of mating, breeding methods for sexually, asexually/clonally propagated crops; self-incompatibility, male sterility and apomixis. Heterosis: types, genetic and molecular basis; Inbreeding. Molecular DNA markers and mapping populations, construction of high-density maps, QTL mapping, Association mapping. Integration of genetic maps with physical maps/chromosomes. Gene tagging, Marker Assisted Selection (MAS), Bulk Segregation Analysis (BSA), Genomic selection and Genome Wide Association Studies (GWAS). Introduction to the statistical tools. Breeding for biotic and abiotic stresses, and

quality traits. Variety development and release of new varieties, Plant breeders and Farmers' rights.

PRACTICALS: 60 hours

1. Preparation of karyotype and ideogram from mitotic metaphase spread and analysis of degree of asymmetry.
2. Study of molecular cytogenetics: identification of progenitor genomes in allopolyploids crops using GISH (wheat, rice, tomato and cotton).
3. Mapping of ribosomal DNA gene using FISH.
4. Localization of Gene introgression using Fiber-FISH/ND-FISH.
5. Pedigree construction and analysis based on inheritance of monogenic traits in humans.
6. Access a plant-specific genome database (e.g., *Oryza sativa* in Gramene or *Arabidopsis thaliana* in TAIR).
7. Search for transcription factors linked to abiotic stress (e.g., drought, salinity). Note down their family (e.g., MYB, WRKY), function, and expression pattern.
8. Study of DNA methylation in plants using methylation sensitive enzymes.
9. Exploration of Single Nucleotide Polymorphisms (SNPs) in plants and their role in trait variation using Bioinformatics databases and tools.
10. Demonstration of basic method of selfing, emasculation, hybridization and crossing techniques in field/potted plants.
11. Comparison of characteristic features of released and notified varieties, hybrid and parental lines.
12. Comparison of quality parameters in improved varieties of cereals, pulses and oilseeds.
13. Genetics/Genomics/Plant breeding in News/Societal issues: presentation on a news article. Articles should have been published within last 2 years.

Suggested reading:

- Phundhan Singh (2014). Plant Breeding: Molecular and New Approaches. Kalyani Publishers
- Phundhan Singh (2015). Essentials of Plant Breeding. Kalyani Publishers
- B.D. Singh (2022). Plant Breeding: Principles and Methods, 12th Edition. MedTech Science Press.
- Arthur M. Lesk (2017), Introduction to Genomics, 3rd Edition, OUP Oxford
- Hartl, D.L. Jones, E.W (2009), Genetics: Analysis of Genes and Genomes, 7th Edition, Jones&BarlettPublishers
- Peter S Harper (2010). Practical Genetic Counselling, 7th Edition, CRC Press
- Genetics A Molecular Approach, Russell PJ, Pearson
- Introduction to Genetic Analysis, Griffith AF et al., W H Freeman & Co

- Concepts of Genetics, Klug WS&Cummings MR, Prentice-Hall, Genetics – a conceptual approach, Pierce BA, W H Freeman & Co
- Principles of Genetics, Sunstad DP & Simmons MJ, John Wiley & sons

- Genetics Analysis of Genes & Genomes, Hartl, D.L. Jones, E.W. Jones & Barlett
- Genetic Analysis, Phillip Meneely, Oxford