Department of Botany

SEMESTER –VIII

(Under UGCF-2022 based on NEP-2020)

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DISCIPLINE SPECIFIC CORE COURSE (DSC-20): Integrative Plant Biology

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		
Integrative Plant Biology DSC-20	**4**	**2**	**0**	**2**	Semester VII	Nil

Learning Objectives:

- This course would involve study of plants to enhance the understanding of organism/s and/or traits from organismal to molecular levels integrating various core disciplines of plant biology including, but not restricted to, morphology, anatomy, development, taxonomy, inheritance, physiology, biochemistry, molecular and cell biology, genomics, proteomics and bioinformatics studies along with an evolutionary context.
- Additional areas would include interactions of plants with other organisms in an ecosystem, biotic and abiotic challenges and plant responses, transgenic studies (basic and applied) and an ecological or environmental perspective.
- The course would enable development of critical thinking skills among students and enhance their problem-solving abilities. This is an important component of the course since students in the 8th semester would be involved with research at the under-graduate level and would also be eligible to apply for Ph.D. programs after B.Sc. (Hons.) – with Research in Botany.

Learning Outcomes:

- The course would allow students to integrate various sub-disciplines that have been studied over the preceding seven semesters to develop a holistic understanding of plant systems transgressing various subject areas within plant biology. The course would include two main approaches/components:
  - Integrated case studies on selected plants from algae to angiosperms including all aspects of their growth, development and applications as outlined above.
  - Selected trait- or process-based studies of plants to understand the biological, evolutionary and molecular determinants of the traits.

- Both these approaches would involve study of research and review articles that discuss contemporary questions in plant biology by integrating multiple approaches towards understanding a plant system, in addition to textbooks.
- The course design would allow students to study important paradigms in plant sciences, and train them in experimental design, data interpretation and adoption of multi-disciplinary approaches to solve scientific questions.

Theory: 30 hours

Unit 1: Model organisms/ plant systems and trait based studies 7 hours

Introduction, brief timeline development of *Arabidopsis* as a model system, features of model organisms ; vital information for model organisms (Microbial - Bacterial (*E.coli*), viral - TMV(any other); Plant systems : *Chlamydomonas, Neurospora, Marchantia, Physcomitrella, Equisetum, Cycas, Gnetum, Nicotiana sp., Daucus carota*).

Case studies on plants from algae to angiosperms

a. The renaissance and enlightenment of *Marchantia* as a model system
b. *Cuscuta* the Merchant of Proteins
c. The origin of a land flora.
d. Introduction to Systems approach for plants, basic concepts in building networks, computational tools, platforms and pipelines in systems biology ; Pan-omics.
e. Important components of plant evolution – chloroplast acquisition, multicellularity and land colonization.
f. Plant biotic interactions in the Sonoram Desert, current knowledge and future research perspectives.

Unit 2: Plant Developmental processes, environmental stress (biotic & abiotic) and adaptations 10 hours

Water stress; High light stress; Temperature stress; Hypersensitive reaction; Pathogenesis Related (PR) proteins; Reactive oxygen species (ROS) –Production and scavenging mechanisms; Systemic acquired resistance; Mediation of insect and disease resistance by jasmonates. Photosynthesis: a case study, Lighting the way: Compelling open questions in photosynthesis research, Perspectives on improving photosynthesis to increase crop yield, Air plant genomes shed light on photosynthesis innovation , Alternative electron pathways of photosynthesis power green algal CO_2 capture.

Plant Developmental processes and adaptations: Molecular mechanisms underlying leaf development - morphological diversification (and beyond); stomata structure and function, Changes in root: shoot ratio, Aerenchyma development, Cuticle development and function, Genetic control of branching patterns in grass inflorescences, Floral Adaptation in plants, Anther development—The long road to making pollen, Evolution and patterning of the ovule in seed plants, Soil minerals affect taxon-specific bacterial growth.

Unit 3: Genetic and molecular circuitry **05 hours**

a. Molecular motors (Kinesin, dyneins, myosins) and Regulatory RNAs (Attenuators, Riboswitches, siRNAs,miRNAs, lncRNAs, eRNAs), relevant case studies for each.

b. RNA biology in Plants - Beyond transcription: compelling open questions in plant RNA biology

c. Small RNA-mediated DNA methylation during plant reproduction.

d. Genome-editing: Engineering plants using diverse CRISPR-associated proteins and deregulation of genome-edited crops.

Unit 4: Emerging areas in plant biology and Applied Botany: **8 hours**

Farming in the Ocean, Drug Discovery, Biomass conversion into valuable products, Cultivation of medicinal plants, Food testing for adulterants, millets, molecular taxonomy.

Learning outcome: The course would enable the development of critical thinking skills among students and enhance their problem-solving abilities. This is an essential component of the course since students to be involved in research. Artificial Intelligence and Machine Learning in plant biology ; Nanotechnology in plant sciences; Introduction to synthetic Biology, metabolic pathway engineering, case studies of *Mycoplasma laboratorium*, Golden Rice

PRACTICALS: **60 hours**

1. Grow a model organism (of choice) in the college (in vitro cultures / garden / greenhouse etc.)

2. Design and conduct an experiment on the model organism (e.g., Antibiotic sensitivity assay in *E.coli,* oxygen evolution in aquatic plants besides *Hydrilla*)

3. Calculate mitotic index and duration of stages in mitosis in temporary preparation of normal and colchicine treated root tips.

4. Adaptations in plants; study cuticle, stomata, aerenchyma development in plants (micrographs/ temporary sections from available material).

5. ROS scavenging experiment (in case not included in Stress Physiology)

6. Study of embryo mutants, homeotic mutants in floral development (ABCDE model) in *Arabidopsis*.

7. Tools for In silico analysis - KEGG, STRING, Cytoscape,

8. Case studies in integrative approaches to understanding plants :

Broad areas of study are listed below, one recent publication from selected field could be provided and students will prepare graphical abstracts, summary and present the same :

a. Environmental physiology

b. Gene regulation circuitry

c. Stress and adaptation

d. Plant cell biology

e. Plant growth and development

f. Photosynthesis and carbohydrate metabolism

g. Nutrient uptake, transport and metabolism

h. Effective resource utilisation (water; assimilates; nutrients)

i. Root – rhizosphere biology

j. Reproduction, seed and fruit biology

k. Defence and protection

l. Building genomic circuits

SUGGESTED READINGS (Books):

- Griffiths, A.J.F., Wessler, S.R., Carroll, S.B., Doebley, J. (2010). Introduction to Genetic Analysis. W. H. Freeman and Co., U.S.A. 10th edition.
- Watson J.D., Baker, T.A., Bell, S.P., Gann, A., Levine, M., Losick, R. (2007). Molecular Biology of the Gene, Pearson Benjamin Cummings, CSHL Press, New York, U.S.A. 6th edition.
- Dickison, W.C. (2000). Integrative Plant Anatomy. Harcourt Academic Press, USA. 4. Taiz, L., Zeiger, E., Møller, I. M., & Murphy, A. (2018). Plant Physiology and Development (6th Ed.). Sinauer Associates.
- Hopkins, W. G., & Hüner, N. P. A. (2009). Introduction to Plant Physiology (4th Ed.). Wiley.
- Buchanan, B. B., Gruissem, W., & Jones, R. L. (2015). Biochemistry & Molecular Biology of Plants (2nd Ed.). Wiley.
- Davies, J.A. (2018) Synthetic Biology: A very short introduction, Oxford University Press
- Raghavan, V. (2000). Developmental Biology of Flowering plants, Springer, Netherlands.
- Ghosh, Z. and Bibekanand, M. (2008). Bioinformatics: Principles and Applications. Oxford University Press. Delhi. 4. Pevsner, J. (2009). Bioinformatics and Functional Genomics. Wiley-Blackwell. U.S.A. 2nd edition.
- Campbell, A.M. and Heyer, L.J. (2007) Discovering Genomics, Proteomics and Bioinformatics. Second edition. Pearson

SUGGESTED READINGS (Selected Papers):

- Bowman., et al (2022). The renaissance and enlightenment of *Marchantia* as a model system. *The Plant Cell*, 34(10), pp.3512–3542. doi:https://doi.org/10.1093/plcell/koac219.
- Paterlini, A., & Helariutta, Y. (2020). *Cuscuta* the Merchant of Proteins. Molecular Plant, 13(4), 533-535. https://doi.org/10.1016/j.molp.2020.01.007.
- Romanov, M. S., Bobrov, A. V. C., Iovlev, P. S., Roslov, M. S., Zdravchev, N. S., Sorokin, A. N., ... & Kandidov, M. V. (2024).Fruit and seed structure in the ANA-grade angiosperms:

Ancestral traits and specializations. *American Journal of Botany*, *111*(1), e16264. DOI: 10.1002/ajb2.16264.

- Bowman, J.L. (2022). The origin of a land flora. *Nature Plants*, 8(12), pp.1352–1369. doi:https://doi.org/10.1038/s41477-022-01283-y.
- Eckardt et al. (2024) Lighting the way: Compelling open questions in photosynthesis research. *The Plant Cell*, Volume 36, Issue 10, October , Pages 3914–3943, https://doi.org/10.1093/plcell/koae203
- Croce et al. (2024) Perspectives on improving photosynthesis to increase crop yield. *The Plant Cell*, Volume 36, Issue 10, October , Pages 3944–3973, https://doi.org/10.1093/plcell/koae132.
- Willoughby, A.C. (2024) Air plant genomes shed light on photosynthesis innovation. *The Plant Cell*, Volume 36, Issue 10, October , Pages 3897–3898, https://doi.org/10.1093/plcell/koae213.
- Gilles Peltier et al. (2024) Alternative electron pathways of photosynthesis power green algal CO_2 capture. *The Plant Cell*, Volume 36, Issue 10, October, Pages 4132–4142, https://doi.org/10.1093/plcell/koae143.
- Manavella et al. (2-23) Beyond transcription: compelling open questions in plant RNA biology. *The Plant Cell*, Volume 35, Issue 6, June 2023, Pages 1626–1653, https://doi.org/10.1093/plcell/koac346.
- Hiu Tung Chow, Rebecca A Mosher (2023) Small RNA-mediated DNA methylation during plant reproduction. *The Plant Cell*, Volume 35, Issue 6, June 2023, Pages 1787–1800, https://doi.org/10.1093/plcell/koad010.
- Nakayama et al. (2022) Molecular mechanisms underlying leaf development, morphological diversification, and beyond. *The Plant Cell*, Volume 34, Issue 7, July 2022, Pages 2534–254. https://doi.org/10.1093/plcell/koac118.
- Elizabeth A Kellogg. (2022) Genetic control of branching patterns in grass inflorescences. *The Plant Cell*, Volume 34, Issue 7, July 2022, Pages 2518–2533, https://doi.org/10.1093/plcell/koac080.
- D Blaine Marchant, Virginia Walbot (2022) Anther development—The long road to making pollen. *The Plant Cell*, Volume 34, Issue 12, December 2022, Pages 4677–4695, https://doi.org/10.1093/plcell/koac287
- Rudall, P. J. (2021) Evolution and patterning of the ovule in seed plants. *Biological Reviews*, *96*(3), 2021, 943-960. doi: 10.1111/brv.12684.
- Finley, B. K., Mau, R. L., Hayer, M., Stone, B. W., Morrissey, E. M., Koch, B. J., ... & Hungate, B. A. (2022) Soil minerals affect taxon-specific bacterial growth. *The ISME journal*, *16*(5), 1318-1326.
- Franklin, K. A., Sommers, P. N., Aslan, C. E., López, B. R., Bronstein, J. L., Bustamante, E., ... & Marazzi, B. (2016) Plant biotic interactions in the Sonoran Desert: current knowledge and future research perspectives. *International Journal of Plant Sciences*, Volume *177, Issue* 3, 2016. Pages 217-234, https://www.journals.uchicago.edu/doi/pdf/10.1086/684261.
- Qamar U. Zaman (2024) Genome-editing: Engineering plants using diverse CRISPR-associated proteins and deregulation of genome-edited crops. Trends in Biotechnology, Volume 42, Issue 5; P560-574 May 2024.

DISCIPLINE SPECIFIC ELECTIVE COURSE (DSE-13): Plant Stress Biology

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		
Plant Stress Biology DSE-13	**4**	**2**	**0**	**2**	Semester VII	Nil

Learning Objectives:

This course explores the physiological, biochemical, and molecular mechanisms by which plants respond to environmental stresses. It covers abiotic and biotic stress factors, their impact on plant growth and development, and adaptive mechanisms to mitigate stress effects. The course also introduces strategies for improving stress tolerance in crops. The following are the specific objectives of this course:

- Identify key abiotic and biotic stress factors affecting plants and explain the associated physiological, biochemical, and molecular responses.
- Examine plant signaling pathways and adaptive strategies such as avoidance, acclimation, and resistance under stress conditions.
- Gain hands-on experience in plant identification, vegetation assessment, and classification techniques, with emphasis on ecological and agricultural relevance.
- Apply principles from plant physiology, molecular biology, and biochemistry to analyze plant-environment interactions and stress resilience.
- Critically assess transgenic and biotechnological approaches to enhance plant tolerance to climate stress and improve crop productivity.

Learning Outcomes:

At the end of this course students will be able to:

- Identify different types of plant stresses and their effects on plant physiology.
- Understand the molecular and biochemical responses of plants to stress.
- Analyze plant adaptation and tolerance mechanisms under stress conditions.
- Explore strategies to enhance plant resilience against environmental challenges.
- Apply knowledge of plant stress biology in agricultural and environmental contexts.

Theory : 30 hours

Unit 1: Introduction to Plant Stress Biology, Abiotic and Biotic Stresses 15 hours

Types (abiotic and biotic), Perception, Acclimation vs Adaptation, Phenotypic plasticity.

- Drought stress- Physiological and Biochemical responses, Resistance or Tolerance mechanisms
- Salinity- Osmotic and Cytotoxic effects, Ion homeostasis, Salt-tolerant mechanisms: Developmental and Physiological protective mechanisms-exclusion vs tolerance, Osmoprotectants, Ion transporters, Compatible solutes- glycine betaine, proline
- Temperature - Cold and heat stress (in brief)
- Stress caused by Pathogens, Herbivores, Parasitic plants, Susceptibility and Resistance, PR proteins, Pattern-triggered immunity and Effector triggered immunity (in brief).

Unit 2: Stress Sensing and Signaling Mechanisms 7 hours

Hormonal regulation (Abscisic acid, Jasmonic acid, Salicylic acid), Reactive Oxygen Species and Nitrous Oxide, Salt Overly Sensitive pathway, Late embryogenesis abundant proteins (LEA), Calcium signaling and binding proteins.

Unit 3: Stress Tolerance Mechanisms 6 hours

Antioxidant enzymes (Superoxide dismutase, Catalase, Peroxidase), Osmolytes, Secondary metabolites (Alkaloids, Phenolics and Terpenoids), Chaperones (Heat Shock Proteins).

Unit 4: Crop Improvement Strategies 2 hours

Traditional plant breeding (Mutation breeding, Protected cultivation) and Biotechnological approaches (brief account of stress tolerant genetically engineered plants).

PRACTICALS: 60 hours

1. To study the effect of salt stress on seed germination percentage.
2. To study the effect of salt stress on plant shoot and root length.
3. To study the effect of stress (any one) on chlorophyll content.
4. To determine electrolyte leakage in stressed plants.
5. To determine SOD or peroxidase enzyme activity in control and stress plants.

Experiments through demonstration (through photographs)

6. To study the plant responses under environmental stress (Stomatal closure, Leaf curling, Root alteration, Stunted plant growth, Wilting).
7. To demonstrate the effect of stress on total protein through 2-D gel electrophoresis profile.
8. To study the effect of stress on plant cell wall and membrane.

9. To study the effect of biotic stress on plants through photographs (necrosis, rotting, nematode attack, SAR).

Suggested Readings:

1. Taiz, L., Zeiger, E., Moller, I. M., Murphy, A. (2018). Plant Physiology and Development, 6th edition. New York, NY: Oxford University Press, Sinauer Associates.
2. Bhatla, S.C., Lal, M.A. (2018). Plant Physiology, Development and Metabolism. Singapore: Springer Nature, Singapore Pvt. Ltd.
3. Giri, B., & Sharma, M. P. (Eds.) (2021). Plant Stress Biology: Strategies and Trends. Springer Nature.
4. Buchanan, B. B., Gruissem, W., & Jones, R. L. (Eds.) (2015). Biochemistry and molecular biology of plants. John wiley & sons.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE (DSE-14): Immunological Concepts and Applications in Plant Science

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		
Immunological Concepts and Applications in Plant Science DSE-14	**4**	**2**	**0**	**2**	Semester VII	Nil

Learning Objectives:

- Comprehend innate and induced plant immune responses. Recognize major plant pathogens—fungi, bacteria, viruses, and nematodes—and study their interactions with host defense systems.
- Examine the molecular and physiological basis of plant-microbe interactions and the dynamic strategies used by both.
- Utilize immunological tools and diagnostics for plant disease management, including detection and characterization of plant pathogens.
- Apply knowledge of plant immunology to develop eco-friendly, sustainable control strategies using beneficial microbes and natural compounds.
- Understand and apply plant immune principles for breeding disease-resistant crops and enhancing plant health.
- Design and conduct laboratory experiments to investigate plant immune responses and assess disease control strategies.

Learning Outcomes:

At the end of this course students will be able to:

- Describe the fundamental principles of plant immunity, including innate and induced defense mechanisms.
- Analyze interactions between plants and pathogens at the molecular and cellular levels.
- Apply immunological methods for diagnosing and managing plant diseases effectively.
- Identify major types of plant pathogens—fungi, bacteria, viruses, and nematodes—and their disease strategies.

- Explain the concept of ISR and its role in enhancing plant defense against diverse pathogens.
- Outline key signaling pathways involved in plant defense, such as MAPK cascades and calcium signaling.
- Integrate knowledge of plant immunity to design eco-friendly and sustainable disease control measures.
- Evaluate the use of plant immunity in breeding disease-resistant crops and applying beneficial microbes or natural products.

Unit 1: (i) Introduction to Immunological Concepts: 10 hours

Basic concepts of immunology, Innate and Acquired (Adaptive) immunity, Human Immune system, Humoral (antibody-mediated) and cellular (cell-mediated) Immunity, Concepts of antigen, epitope, hapten, valence, antibodies (immunoglobulins)- structure, types (IgG, IgM, IgA, IgD, and IgE) and functions, antigen-antibody reaction, antisera and vaccines. Immune system in plants, Comparison between the plant and animal immune system.

(ii) Plant Immunity:

Plant pathogens and pests (viruses, bacteria, fungi, insects, mites and nematodes), Plant-pathogen interactions; Compatible interactions (parasite virulence and host plant susceptibility), Incompatible interactions (parasite avirulence and host plant resistance), non-host and host - resistance, Horizontal and vertical resistance, concept of host range, coevolution of plant defence and pathogen attack mechanisms: the Zigzag Model.

Unit 2: Components of Plant Immunity: 10 hours

(i) Innate Immunity/ Resistance

- **Non-specific or Basal Resistance: Passive (Constitutive defenses**) including pre-existing mechanical defences (cuticle, waxes, lignified cell wall, bark, trichomes, thorns); pre-existing biochemical defences (alkaloids, phenolic compounds, terpenoids, nutrient deprivation, phytoanticipins); **Active (Inducible Defences):** Pathogen-associated molecular patterns (PAMPs), pattern-recognition receptors (PRRs), PAMP-triggered Immunity (PTI). Popular Models of PTI in plants- Flagellin-induced Resistance, Elongation Factor (Ef-tu)-induced Basal Resistance.
- **Pathogen Race-specific resistance:** Molecular Models of specific Host-pathogen Recognition, gene-for-gene or receptor-ligand model (Flor's Model), Pathogen effectors, Intracellular nucleotide-binding leucine-rich repeat receptors (NLRs), Plant Resistance (R) genes, Avirulence (Avr) proteins/ Effectors, Effector-triggered susceptibility (ETS), Effector-triggered immunity (ETI), Hypersensitive response.

(ii) Acquired Resistance : Systemic Acquired Resistance (SAR), Induced Systemic Resistance (ISR)

Unit 3: Signal Transduction Pathways activated during Plant resistance: 5 hours

- Phytohormone signaling: salicylic acid, jasmonic acid, ethylene
- Calcium signaling: Calmodulin (CaM), Calcineurin B-like proteins (CBLs) in *Arabidopsis*
- Mitogen-activated protein kinase (MAPK) Cascades
- The Oxidative burst (ROS)
- Major transcription factor families in plant immunity (WRKY, NAC, MYB, bZIP)

Unit 4: Applications of immunology in Plant Science: 5 hours

Development of disease-resistant crops, enhanced nutrient uptake, engineering enhanced resistance in crops via gene editing (e.g., CRISPR-Cas9), developing novel biopesticides/ biocontrol agents based on induced systemic resistance (ISR), genetic engineering strategies for broad-spectrum resistance by Pseudo-Response Regulator (PRR) and chimeric PRR transgenes. RNAi based antiviral resistance (siRNA).

PRACTICALS 60 hours

1. To study the structure of antibody (diagrammatic and crystal structure) digitally.

2. Study of diseased plants and identification of its causal pathogen based on visually observed symptoms (Viral, bacterial, Fungal - one disease each)

3. Analysis and interpretation of digitally represented zig-zag model

4. Analysis and Interpretation of Western blots

5.Understanding the concept of immunoprecipitation by performing immunodiffusion.

6. To study the antigen-antibody reaction by ABO blood group system and Rh factor

7. Study and applications of immunological techniques: ELISA, Immunodiffusion, Radioimmunoassay.

Suggested Readings:

- Dhia Bouktila and Yosra Habachi (2021) *An Introduction to Plant Immunity*: Bentham Science Publishers, Sharjah, UAE.
- Iakovidis, M., Chung, E. H., Saile, S. C., Sauberzweig, E., & El Kasmi, F. (2023). *The emerging frontier of plant immunity's core hubs. The FEBS journal, 290(13), 3311–3335. https://doi.org/10.1111/febs.16549*
- Prescott, L.M., Harley J.P., Klein D. A. (2005). *Microbiology*, 6th edition: McGraw Hill, New Delhi.

Additional Reading:

Agrios, G.S. (2005) Plant Pathology 5th Edition: Elsewhere Academic Press, Amsterdam.

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 & Bartlett Publishers.
- Peter S Harper (2010). Practical Genetic Counselling, 7th Edition. CRC Press.
- Russell, P. J. (2013). iGenetics: A Molecular Approach: Pearson New International Edition. Pearson Higher Ed.
- Griffith et al. (2015). Introduction to Genetic Analysis. W H Freeman & Co.
- Klug, W.S., & Cummings, M.R. (2003). Concepts of Genetics, 7th Edition. Prentice-Hall.
- Pierce, B.A. (2016). Genetics – A conceptual approach, 7th Edition. W H Freeman & Co.
- Snustad D.P. & Simmons, M.J. (2015). Principles of Genetics. John Wiley & sons.
- Hartl, D.L., Jones, E.W. (2009). Genetics Analysis of Genes & Genomes. Jones & Barlett Pub.
- Phillip Meneely (2020). Genetic Analysis: Gene, Genomes, and Networks in Eukaryotes. Oxford University Press.

DISCIPLINE SPECIFIC ELECTIVE COURSE (DSE-16): Genomics, Proteomics and Bioinformatics

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		
Genomics, Proteomics and Bioinformatics DSE-16	**4**	**2**	**0**	**2**	Semester VII	Nil

Learning Objectives:

- Introduce students to fundamental and emerging concepts in genomics, proteomics, and bioinformatics.
- Familiarize students with analytical tools and real-world applications of omics technologies across agriculture, health, and environmental sectors.
- Explore interdisciplinary fields such as metagenomics, epigenomics, and single-cell genomics and their significance in global problem-solving.
- Develop basic computational skills to utilize bioinformatics databases and tools for data interpretation in genomics and proteomics.

Learning Outcomes:

By the end of the course, students will be able to:

- Explain the principles and applications of genomics in agriculture, human health, and environmental science.
- Understand the concepts of epigenetics and demonstrate familiarity with tools used to study epigenetic modifications.
- Describe metagenomics and single-cell genomics, and their relevance in microbiome analysis and environmental monitoring.
- Understand core techniques and tools in proteomics, including post-MS data analysis, and their translational value.

- Demonstrate knowledge of bioinformatics concepts, databases, and software tools for sequence, structure, and functional analysis of biological data.

Theory : **30 Hours**

Unit 1: Genomics and Epigenetics **10 Hours**

Genomic concepts: genomes, genes, and non-coding regions, Structure of complexity of eukaryotic genome, Applications in agriculture, health, and the environment, CRISPR-Cas9: A beginner-friendly introduction to genome editing, Genomics ethics: privacy, data sharing, and equity. Epigenomics. DNA methylation and histone modifications, Overview of Bisulfite sequencing and ChIP-Seq, Role of epigenetics in stress adaptation in plants.

Unit 2: Metagenomics and Single-Cell Genomics **5 Hours**

Metagenomics: concept and applications, Human Microbiome Project (HMP), Environmental metagenomics: Role in pollution control and ecosystem management. Single-cell genomics: its concept and importance.

Unit 3: Proteomics **7 hours**

Overview of Proteomics, Complexity of protein structure (primary, secondary and tertiary), Post translational modifications (phosphorylation, glycosylation), Proteome analysis by 2-D gel electrophoresis, Edman sequencing (Methodology and limitations in protein sequencing) and MALDI-ToF (Matrix-Assisted Laser Desorption/Ionization – Time of Flight), nLC-MS/MS (nano-Liquid Chromatography coupled with Tandem Mass Spectrometry), X-ray crystallography.

Unit 4. Bioinformatics **8 hours**

Introduction to bioinformatics: definition and scope, Nucleotide and Protein databases (GenBank, UniProt, PDB), metabolic pathway database (KEGG), Search engines for databases (Entrez and PubMed), File format (FASTA), BLAST, Concept of sequence alignment, molecular phylogeny

PRACTICALS : **60 Hours**

1. Virtual Exploration of Plant Genomes:

    1a. Access a plant-specific genome database (e.g., *Oryza sativa* in Gramene or *Arabidopsis thaliana* in TAIR).

    1b. Search for a gene of interest (e.g., drought resistance or photosynthesis-related genes).

    1c. Record details such as gene location, sequence, function, and related pathways.

1d. Compare homologous genes between two plant species using BLAST.

2. Study of GenBank and UniProt for the retrieval of nucleic acid and amino acid sequences

3. Sequence homology and gene annotation through BLAST tool.

4. Illumina sequencing through photographs.

5. Explore single nucleotide polymorphisms (SNPs) in plants and their role in trait variation.
6. Predict the structure of protein from its amino acid sequence. (Phyre 2/ Modweb/ CPH model/ Swiss Model).

7. Analysis of protein (s) on 2-D Gels, X-ray crystallography and protein microarray through photographs.

8. *In silico* analysis for PTM, Localization, and functions using the above-mentioned software.

9. Basic handling of data, transcriptome assembly, batch blast, batch primer design, setting up a local blast, basic of genome assembly, and isolation of microsatellites using MISA.

Suggested Readings (Books and Articles):

- Brown, T.A. (2017). *Genomes 4*. Garland Science. *A student-friendly introduction to genomics with clear explanations and examples.*
- Dale, J.W., & Park, S.F. (2010). *Molecular Genetics of Bacteria*. Wiley-Blackwell. *Covers foundational concepts in bacterial genomics and applications.*
- Allis, C.D., Caparros, M.-L., Jenuwein, T., & Reinberg, D. (2015). *Epigenetics*. Cold Spring Harbor Laboratory Press. *(Focus on the introductory sections for basics of DNA methylation and histone modifications.)*
- Pevsner, J. (2015). *Bioinformatics and Functional Genomics*. Wiley-Blackwell. *(Chapters on metagenomics provide a straightforward introduction with practical applications.)*
- Handelsman, J. (2004). *Metagenomics: Application in Microbial Ecology.* ASM Press. *(Focuses on simple and engaging content about microbial diversity studies.)*
- Doudna, J.A., & Sternberg, S.H. (2017). *A Crack in Creation: Gene Editing and the Unthinkable Power to Control Evolution.* Houghton Mifflin Harcourt. *(Written for a general audience, this book explains CRISPR in simple terms.)*
- Regev, A. et al. (2017). "The Human Cell Atlas." *eLife. (Overview of single-cell genomics and its goals in mapping human cells.)*
- Varshney, R.K., Roorkiwal, M., & Sorrells, M.E. (2017). *Genomic Selection for Crop Improvement.* Springer. *(Readable sections on GWAS and genomic applications in crop breeding.)*
- Sandel, M.J. (2009). *The Case Against Perfection: Ethics in the Age of Genetic Engineering.* Harvard University Press. *(Simplifies the ethical dilemmas posed by genomics and genome editing.)*