दिल्ली विश्वविद्यालय
University of Delhi

परिषद शाखा - II, कमरा नं: 211, नया प्रशासनिक खंड, दिल्ली विश्वविद्यालय, दिल्ली-110007, दूरभाष: 011-27001156/54
Council Branch - II, Room No. 211, New Administrative Block, University of Delhi, Delhi – 110007, Ph: 27001156/54

CNC-II/093/1/AC-1027/26/3
Dated: 27.07.2026

NOTIFICATION

Sub: Amendment to Ordinance V

(AC dated 24.07.2026)

Following addition be made to Annexure-II-A to the Ordinance V (2-A) of the Ordinances of the University;

Add the following:

The following syllabi of the Department of Botany under the Faculty of Science based on Postgraduate Curriculum Framework 2024 are notified herewith for the information of all concerned:

Department	Syllabi	Annexure
Botany	Two-Year M.Sc. Botany (Semester III/IV) and One-Year M.Sc. Botany (Semester I/II).	1

REGISTRAR

Annexure-1

Department of Botany

University of Delhi

Two-Year M.Sc. Botany program

(IInd Year)

Under

POST-GRADUATE CURRICULAR FRAMEWORK IN BOTANY - 2026

(BASED ON NEP 2020)

(Students opting for two-year M.Sc. Botany program will study courses listed in Semesters III & IV)

M.Sc. IInd year syllabus (w.e.f. July 2026)

POST-GRADUATE CURRICULAR FRAMEWORK IN BOTANY - 2026

(BASED ON NEP 2020) - COURSEWORK + RESEARCH

Two Year M.Sc. Botany Programme - IInd Year Courses w.e.f. July 2026

SEMESTER	DSC (4x2=8 credits)	DSE (4x2=8 Credits)	SKILL BASED COURSE/ SPECIALISED LABORATORY (2 Credits)	DISSERTATION	TOTAL CREDITS
III	**DSC-7 Ecology and Environmental Science** **DSC-8 Genetics and Cytogenetics**	**DSE 7** Advanced concepts and methods in Genomics and Proteomics **DSE 8** Advances in Archegoniatae **DSE 9** Molecular interactions of plants with symbionts, pests and pathogens **DSE 10** Recent trends in Plant Systematics **DSE 11** Algae, Environment and Human Welfare **DSE 12** Bioinformatics, Computational Biology and Biostatistics **DSE 13** Functional foods and nutraceuticals **GE 03** Nanobiotechnology	**SBC 3**: Applied Industrial Microbiology	6 credits	22
IV	**DSC-9 Plant Cell Biology** **DSC-10 Plant Biotechnology and Resource Applications**	**DSE 14** Reproductive biology of flowering plants **DSE 15** Concepts and advances in Genetics, Genomics and Molecular Breeding **DSE 16** Agricultural Ecology DSE 17 Molecular Dynamics of the Genome and Developmental Mechanisms Cellular dynamics and Developmental Mechanisms **DSE 18** Recent developments in Plant Physiology and Biochemistry **DSE 19** Morphology and anatomy of angiosperms **DSE 20** Fungal Biology **DSE 21** Bio-based applications and Entrepreneurships **GE 04 –** Nature Based Solutions for sustainable development	**SBC 4:** Bioprospecting of plant resources	6 credits	22

***Students without dissertation will take 2 DSC; 3 DSE and 1SBC (i.e., 22 credits) and the students with dissertation will take 2 DSC; 2 DSE and Dissertation (i.e., 22 credits).**

The following GEs will be offered by the Department for students other than M.Sc. Botany:

GE 03 Nanobiotechnology (To be offered in Semester III)

GE 04 Nature based Solutions for sustainable development (To be offered in Semester IV)

Note: Annual Field studies will be undertaken in different agroclimatic zones of India/ Scientific Organizations/ Industries as part of the curriculum in the Courses of DSC 7, DSC 9, DSC 10, DSE 8, DSE 9, DSE 10, DSE 11, DSE 14, DSE 26, and DSE 20. Field excursions are essential to study plant diversity in real context which is not found in Delhi. Excursions develop crucial skills of plant identification and biodiversity assessment and deepen the understanding on plant-pollinator relationships, soil compositions, and microclimate adaptations, environmental management field collection and herbarium techniques, which indoor laboratories cannot replicate. Collection of samples of plant, fungi, microbes, pathogens and soil for the laboratory experiments for the whole year is another main purpose of the field excursions.

Index of courses being offered in Semester III & IV Two Year M.Sc. Botany Programme

Two Year M.Sc. Botany Programme - IInd Year Syllabus w.e.f. July 2026

Semester III

DISCIPLINE SPECIFIC CORE COURSE- 7:

ECOLOGY AND ENVIRONMENTAL 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		
ECOLOGY AND ENVIRONMENTAL SCIENCE DSC - 7	**4**	**2**	**0**	**2**	**Graduate with Botany as one of the subjects**	**Nil**

Course Objectives:

This course aims to introduce the students to the concepts and principles of ecology, biological diversity, conservation, sustainable development, population, community and ecosystem structure and function, application of these concepts to solve environmental problems.

Course Learning Outcomes:

The students will be learning:

1. Limiting factors controlling distribution and growth of organisms.
2. Characteristics of organisms as population, community and ecosystems.
3. Intra- and inter-specific interactions among organisms.
4. Ecosystem functions.
5. Applications of ecological knowledge for the benefit of anthropogenic society.?

Theory **(15 x 2= 30 hrs.)**

Unit I: **(8 hours)**

Environment – the concept and limits; Law of tolerance and Law of Limiting factors, abiotic factors, biotic interactions, biogeographical distributions – ecological equivalents, Phytogeographical classifications and regions of India, The biosphere, biomes and ecological zones, Bioindicators and biomarkers, Environmental pollution and mitigation strategies.

Unit II: **(8 hours)**

Characteristics of population, population size and exponential growth, limits of population growth, population dynamics, life history pattern, fertility rate and age structure, population growth (density dependent and density independent). Metapopulation dynamics, Competition and coexistence, intra-specific interactions, inter specific interactions, scramble and contest competition model, symbiosis, pre-predator interactions.

Unit III: (7 hours)

Nature of ecosystem, production, food webs, energy flow through ecosystem, biogeochemical cycles, resilience of ecosystem, ecosystem management. Case studies of climax and disturbed ecosystems. Ecological factors and plant adaptation. Concepts of ecosystem restoration and applications. Biodiversity – assessment, conservation and management, Biodiversity acts and conventions.

Unit IV: **(7 hours)**

Sustainable Development, Natural resource management in changing environment, Molecular ecology and applications in conservation biology, Global climatic patterns and variations over time, climate change and global warming, climate change impact on ecosystems, coping with environmental variations. Environmental Impacts assessment.

Practical (15 x 4= 60 hours)

Practical will be based on the theoretical content of the syllabus. A representative list of practical is provided below:

1. To visit natural or polluted water bodies for the collection of water samples, recording the physical properties of water, and studying community composition at the sampling location.
2. Field excursion, biodiversity assessment, sampling techniques, plant and soil sample collection for lab experiments.
3. To test water sample temperature, pH, electrical conductivity, salinity, total dissolved solids, and oxidation reduction potential using specific probes at different depths from the collected water samples.
4. To estimated dissolved oxygen in freshly collected water samples from various sources using Winkler's method (Iodometric titration).
5. To estimation of dissolved oxygen in various water samples containing organic matter using modified Winkler's method (Iodometric titration).
6. To estimate net primary productivity (NPP), gross primary productivity (GPP), and respiration of different water bodies using Winkler's method of dissolved oxygen estimation.
7. To determine acidity and alkalinity of water samples by estimating free CO_2, carbonates, bicarbonates, and hydroxides.
8. To estimate phosphorous as orthophosphates in water samples using ammonium molybdenum blue method.
9. To estimate Sulphate Sulphur in water samples using turbidimetric method.

10. To estimate Magnesium and hardness due to Magnesium in water samples using EDTA complexometric titration method
11. To estimate Calcium and hardness due to Calcium in water samples using EDTA complexometric titration method.
12. To estimate Ammonium Nitrogen in water samples using modified Berthelot's reaction.
13. To estimate Nitrate Nitrogen in water samples using salicylic acid.
14. To study the vegetation and community structure of a nearby natural vegetation (species dominance, species richness, and diversity).
15. To study topographic sheets and find out coordinates of particular location, distance between two points, slope of an area, and area of a watershed or given region.
16. Life table analysis of annual, biannual and perennial species.

Suggested Readings:

1. Odum, E.P. (2011). Fundamental of Ecology. 5th Edition. Saunders. ISBN 9780030584145. 613 pages.
2. Sher, A.A. and Molles, M.C. (2021). Ecology: Concepts and Applications. 9th Edition. McGraw Hill
3. Morin, P.J. (2011). Community ecology. 2nd Edition. Wiley-Blackwell
4. Bowman, W.D. and Hacker, S.D. (2023). Ecology. 6th Edition. Oxford University Press.
5. Stilling, P. (2014) Ecology: Global insights and investigations. McGraw Hill

Additional readings

1. Real, L.A. and Brown, J.H. (Eds.) (1991). Foundations of Ecology: Classic Papers with Commentaries. The University of Chicago Press. ISBN-10 0-226-70594-3. 904 pages.
2. Chapman, J.L. and Reiss, M.J. (2003). Ecology: Principles and Applications. Second Edition. Cambridge University Press, UK. ISBN 0 521 58802 2. 335 pages.
3. Singh, J.S., Singh, S.P. and Gupta, S.R. (2006). Ecology, Environment & Resource Conservation. Anamaya Publishers. ISBN 978 8188342556. 688 pages.
4. Smith, T.M. and Smith, R.L. (2007). Elements of Ecology. 6th Edition. Pearson Education
5. Krebs, C.J. (2009). Ecology. 6th Edition. Pearson.
6. Raven, P.H. Berg, L.R. and Hassenzahl, D.M. (2008). Environment. 6th Edition. Wiley.
7. Cunningham, W.P. and Cunningham, M.A. (2017). Environmental Science: A Global Concern. 14th Edition. McGraw Hill
8. Freeland, J.R., Kirk H. and Petersen, S.D. (2011). Molecular Ecology. Wiley. 449 pages.
9. IPCC. 4th and 6th Assessment reports. https://www.ipcc.ch/reports/
10. UNFCCC. Conference of Parties (COP). https://unfccc.int/

DISCIPLINE SPECIFIC CORE COURSE -8

Genetics and Cytogenetics

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		
Genetics and Cytogenetics DSC-8	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

The paper will deal with Mendelian and non-Mendelian inheritance, quantitative genetics, molecular markers and linkage mapping, prokaryotic and eukaryotic genome-structure, gene function and regulation, epigenetics and cytogenetics.

Course Learning Outcomes:

Students will be provided understanding of

1. Inheritance of qualitative and quantitative traits. - allelic and genotypic frequencies and their partitioning between and among populations. - Factors governing the genetic structure of populations: significance, implications and applications.
2. Mapping genes in bacteria - functional allelism - gene regulation in prokaryotes: the components and the mechanisms.
3. The structure and organization of different components of the eukaryotic genomes. - repetitive elements and transposons: types and their significance. the different levels at which gene regulation occurs in a eukaryotic cell. - the various components and mechanisms involved.
4. The use of linkage and recombination frequencies to map genes. - Molecular markers, types, development and applications.
5. Morphology of chromosomes and its relevance in genetics. - chromosomal aberrations and their role in genome evolution with special reference to crop plants. - evolution of sex chromosomes and their role in sex determination.
6. Use of cytogenetic and molecular tools for genome analysis.
7. The basic concepts of epigenetics, the underlying mechanism and inheritance of the epigenetic modifications. - the tools to study epigenetics.

Theory: **(15 x 2= 30 hours)**

Unit I: Introduction to Genetic concepts **(5 hours)**

Mendelian vs. non-Mendelian inheritance, concept of genetic distance, linkage and crossing over, introduction to genetic mapping; two-point, three-point crosses. Bacterial genetics, fine structure of gene, test for functional allelism. Introduction to quantitative and population genetics.

Unit II: Genome organization **(6 hours)**

Eukaryotic genome, components- repeat elements, transposons, organization and evolution.

Unit III: Gene regulation **(12 hours)**

Prokaryotic and eukaryotic gene regulation- operons (lactose, tryptophan and arabinose) genetic switches, CRISPR-cas, sigma factors, small RNAs. *Cis*- and *trans*- regulation: promoters, transcription factors, post-transcriptional regulation, role of chromatin and its higher order structure. Applications of CRISPR-Cas in genome editing and gene regulation.

Unit IV: Cytogenetics and Epigenetics **(7 hours)**

Chromosome: structure and nomenclature, centromere and telomere; Sex determination mechanisms, sex chromosome, chromosomal aberrations. Molecular cytogenetics: methods and applications. Introduction, methylation, histone modifications, epialleles; their inheritance and role in regulation. Tools to study epigenetics.

Practicals: **(15 X 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Study of mitosis (onion root tip) and meiosis (onion or *Rhoeo* buds)
2. Isolation of genomic DNA from plant samples
3. Qualitative and quantitative analysis of genomic DNA
4. Karyotype analysis
5. Study of chromosome banding and aberrations
6. Handling and culturing of *Drosophila* flies
7. Isolation and preparation of polytene chromosomes from *Drosophila*
8. Identification and analysis of different *Drosophila* mutants
9. Genetics problems based on linkage, deletion mapping, bacterial chromosome mapping
10. Designing of PCR primers for developing gene specific markers

11. Identification of DNA polymorphism using PCR based DNA markers (Intron polymorphism/ SSRs)

12. Designing of sgRNA for CRISPR-based genome editing

Suggested Readings:

1. Russel P. J. (2010). iGenetics-A Molecular Approach, Pearson Education Inc.

2. Gardner E. J., Simmons M. J., Snustad D. P. (1991). Principles of Genetics, John Wiley & Sons.

3. Strickberger M.W. (2008). Genetics, Pearson (Prentice Hall).

4. Acquaah G (2007). Principles of Plant Genetics and Breeding, Blackwell Publishing Ltd. USA.

5. Allard R. W. (1999). Principles of Plant Breeding, John Wiley and Sons.

Additional Readings:

1. Singh R. J. (2002). Plant Cytogenetics, CRC Press.

2. Hartwell L. H., Hood L., Goldberg M. L., Reynolds A. E., Silver L. M., Veres R. C. (2006). Genetics-From Genes to Genomes, McGraw Hill

3. Lewin B. (2008). Genes IX, Jones and Barlett Publishers. 9. Hartl D. L. and Jones E. W. (2007). Genetics-Analysis of Genes and Genomes, Jones and Barlett publishers.

DISCIPLINE SPECIFIC ELECTIVE- 7:

Advanced concepts and methods in Genomics and Proteomics

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		
Advanced concepts and methods in Genomics and Proteomics DSE- 07	**4**	**2**	**0**	**2**	**Graduate with Botany as one of the subjects**	**Nil**

Course Objectives:

This course aims to provide a knowledge to modern *omics* approaches by integrating genome-wide and proteome-wide analysis with functional genomics. It aims to have an understanding of genome sequencing strategies, high-throughput sequencing technologies, sequence alignment, gene annotation, and methods for studying differential gene expression. The course will emphasize forward and reverse genetic approaches, including gene tagging, promoter trapping, and knockout/knockdown mutants, to decipher gene function, along with comparative genomics and dynamic modulation of protein structure. Students will also learn the principles of gene silencing, RNA interference (RNAi), small RNA biogenesis, epigenetic regulation, and chromatin-level control. The course will introduce biophysical and biochemical tools, including UV-visible spectroscopy, fluorescence spectroscopy, circular dichroism, and NMR, as well as mass spectrometry-based protein identification (PMF, tandem MS/LC–MS), 2D-PAGE workflows, and database-based protein analysis. Students will explore gel-free proteomics, comparative proteomics, interactomics, protein chips, proteogenomics, and the applications and future potential of protein engineering and omics technologies in biological research.

Course Learning Outcomes:

Student will be learning:

1. Principles of DNA sequencing, Sequencing technologies from classical Sanger methods to next-generation sequencing, including the significance of genomic variations and their applications.
2. Genome-wide gene expression data and evaluate the utility of different expression profiling approaches.
3. Apply concepts of forward and reverse genetics to understand gene function, and interpret how mutant populations can be used to study genome-wide changes in gene expression.

4. Comparative genomics datasets and explain how cross-species comparisons contribute to understanding genome organization and evolution.
5. Mechanisms of transcriptional and post-transcriptional regulation, including genome imprinting, small RNA biogenesis, and heterochromatin formation.
6. Demonstrate an understanding of plant proteomics, including its scope, types, methodologies, limitations, and relevance to biological research.
7. Key tools and techniques in proteome analysis, including biophysical, biochemical, and mass spectrometry–based approaches.
8. Design, plan, and execute a basic proteomics experiment, incorporating appropriate analytical workflows and data interpretation.
9. Applications of proteomic technologies in plant sciences and articulate their broader significance in research, biotechnology, and daily life.

THEORY: (15 X 2= 30 hours)

Unit I- Genomics I: Genome Sequencing and Annotation (7 hours)

Genome sequencing strategies and large-scale sequencing programs; New technologies for high-throughput sequencing; Methods for sequence assembly, alignment, and gene annotation.

Unit II- Genomics II: Gene Expression, Functional Genomics, and Epigenomics (8 hours)

Approaches to analyse differential gene expression: ESTs, SAGE, microarrays and their applications; Concepts of forward and reverse genetics for genome-wide functional screening; Gene tagging, promoter trapping, knockout and knock-down mutants; Dynamic modulation of protein structure and function; Introduction to comparative genomics of model plants and crop species; Introduction to RNAi and gene silencing; Genome imprinting; small RNAs and their biogenesis; Role of small RNAs in heterochromatin formation and gene silencing; Genomic tools to study DNA methylation, histone modifications, and chromatin structure

Unit III- Proteomics I: Protein Analysis and Mass Spectrometry (7 hours)

Protein analysis by biophysical and biochemical methods-Circular dichroism (CD), NMR spectroscopy and UV–visible and fluorescence spectroscopy; Introduction to proteomics: scope, need, types, and tools; Mass spectrometry based protein identification- PMF (Protein Mass Fingerprinting) and Tandem MS/LC–MS; Protein identification and analysis using databases (e.g., ExPASy); Gel-based proteome analysis- Protein extraction and lysis, Resolution on 2D–PAGE, Image acquisition, gel matching, master gel creation, and data analysis

Unit IV- Proteomics II: Advanced Proteomics and Applications (8 hours)

Gel-free proteomics: label-based and label-free methods; Comparative proteomics and interactomics; Protein chips and protein arrays; Proteogenomics; Future directions and applications of proteome analysis

Practicals: (15 X 4= 60 hours)

11

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. **Genomic DNA Isolation and Quality Assessment:** Extraction of high-quality genomic DNA from plant tissue and evaluation of purity and integrity using spectrophotometry and agarose gel electrophoresis.
2. **RNA Isolation, cDNA Synthesis and Semiquantitative PCR:** Isolation of total RNA, preparation of first-strand cDNA using reverse transcriptase, and comparison of relative transcript levels using semiquantitative PCR.
3. **Real-Time PCR (qPCR) for Gene Expression Analysis:** Quantitative assessment of gene expression using SYBR Green-based qPCR, including melt curve analysis and basic $\Delta\Delta$Ct calculations.
4. **Primer Design for PCR and qPCR:** In silico design of gene-specific primers for conventional PCR and qPCR using appropriate online tools and evaluation of primer parameters.
5. **Site-Directed Mutagenesis:** Introduction of a defined point mutation or small insertion/deletion into a plasmid by PCR-based mutagenesis and verification by restriction analysis or sequencing (concept/demo if full experiment is not feasible).
6. **Genotyping of Arabidopsis Knockout Mutants (T-DNA Lines):** PCR-based genotyping of *Arabidopsis* T-DNA insertion lines using gene-specific and border primers to distinguish wild-type, heterozygous, and homozygous plants.
7. **Design of CRISPR Guide RNAs (In Silico):** Use of web-based tools (e.g., CHOPCHOP/CRISPR-P) to design guide RNAs for genome editing and evaluation of predicted on-target and off-target sites.
8. **Analysis of Differential Gene Expression (In Silico):** Retrieval and basic analysis of microarray or RNA-seq datasets to identify differentially expressed genes and perform simple functional annotation.
9. **Gateway Cloning:** Recombination-based cloning of a gene of interest into a Gateway destination vector, followed by transformation and screening of recombinant colonies.
10. **Transient Expression in Tobacco (Agroinfiltration):** Introduction of an expression construct into *Nicotiana benthamiana* leaves by Agrobacterium-mediated infiltration and monitoring of transient expression (e.g., visual reporter or documented example).
11. **Protein Extraction and Quantification:** Isolation of soluble protein from plant tissue and estimation of protein concentration using Bradford or BCA assays.
12. **Gel Filtration Chromatography for Desalting:** Use of size-exclusion (gel filtration) chromatography to desalt or perform buffer exchange of a protein sample, followed by assessment of recovery and purity.
13. **Two-Dimensional (2D) Electrophoresis with Differential Staining:** Separation of proteins by IEF followed by SDS–PAGE and visualization using Coomassie, silver, or MS-compatible stains; comparison of staining methods and protein spot patterns.
14. **Western Blotting for Protein Detection:** Resolution of proteins by SDS–PAGE, transfer to membrane, antibody-based detection of a target protein, and interpretation of band intensity and specificity.

12

15. **Mass Spectrometry Data Interpretation:** Interpretation of provided MS or MS/MS spectra for peptide and protein identification using suitable databases (e.g., Mascot/ExPASy) and discussion of confidence scores and coverage.

Suggested Readings:

1. Brown, T.A. (2017). Genomes 4. CRC Press.
2. Armstrong, L. (2013). Epigenetics. CRC Press.
3. Dale, J.W., Schantz, M.V. and Plant, N. (2011). From Genes to Genomes: Concepts and Applications of DNA Technology. Third edition. John Wiley & Sons, UK.
4. Green, M.R. and Sambrook, J. (2012) Molecular Cloning: A Laboratory Manual. Fourth edition. CSHL Press, USA.
5. Leibler, D.C. (2006). Introduction to Proteomics: tools for the new biology, Humana Press.

Additional Readings:

1. Walker, J.M. (2005). The Proteomics Protocols Handbook, Humana Press, Totowa, New Jersey, USA.

13

DISCIPLINE SPECIFIC ELECTIVE- 8:

ADVANCES IN ARCHEGONIATAE

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 Archegoniatae DSE 08	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives

This course aims to provide advanced knowledge about the adaptive strategies during land plant diversification, their physiological and molecular innovations, ecological significance, and bioprospecting potential of archegoniate groups (Bryophytes, Pteridophytes, and Gymnosperms).

Course Learning Outcomes

The students will be learning

1. Plant hormones in bryophytes and their role in regulating growth and development.
2. Water and photosynthate conduction mechanisms and interactions with microorganisms across bryophytes, pteridophytes, and gymnosperms.
3. Molecular mechanisms of desiccation tolerance and identify bryophyte and pteridophyte model systems.
4. Habitat-driven developmental responses of fern gametophytes.
5. Environmental conditions required for conifer seed germination, seedling development, and regeneration.

Theory **(15 X 2= 30 hours)**

Unit I: Bryophytes – Evolutionary diversification and Adaptation strategies **(8 hours)**

Spore germination and protonema differentiation; hormonal regulation of gametophyte development; ecological interactions with microorganisms and animals; responses to climate variability; dispersal and colonization patterns; sexual dimorphism; mineral nutrition and substrate dependence; peatland structure

14

and ecological services; desiccation tolerance mechanisms; biotic stress responses and protective metabolites; organismal and ecological emphasis.

Unit II: Pteridophytes – Morphological and Reproductive innovations (8 hours)

Phenology and habitat specificity; xeric adaptations; life-cycle biology and sex expression in gametophytes; polyploidy, apogamy and vegetative reproduction; ecological and economic significance of ferns; biology and applied importance of *Azolla–Anabaena* symbiosis; conservation biology of threatened taxa; evolutionary perspectives on leaf development, vascular differentiation and reproductive structures; classical and ecological themes.

Unit III: Gymnosperms –Ancient Forests and Ecosystem Dynamics (8 hours)

Pollination biology in Coniferales and Gnetales; seed and seedling ecology, including dormancy and regeneration dynamics; nutrient cycling and litter decomposition rates; conifer plantations as seed traps; ecological impacts of large-scale conifer plantations; acclimatization and adaptive responses of conifers to environmental stresses; fire-adapted traits and post-fire recovery mechanisms; conservation and restoration strategies for gymnosperms; ecological and industrial relevance of secondary metabolites; and the impacts of climate change on gymnosperm diversity and ecosystem functioning.

Unit IV: Molecular Blueprints of Archegoniates – Genomes, Development and Stress Biology (6 hours)

Genome sequencing and molecular evolution; comparative and functional genomics of Bryophytes, Pteridophytes and Gymnosperms; model systems—*Physcomitrium patens, Marchantia polymorpha*, *Ceratopteris*, *Selaginella, Ginkgo biloba*, *Picea abies*; genetic control of developmental cascades and morphogenesis; photoreceptor-mediated photomorphogenesis; molecular and physiological aspects of water conduction and photosynthate transport; habitat-linked developmental responses; molecular mechanisms of desiccation tolerance; drought, cold, salinity and UV-stress adaptation pathways; biotic stress signaling; conservation genetics and population genomics; environmental regulation of germination; micropropagation, somatic embryogenesis, synthetic seed technology and tissue-culture-based conservation tools.

Practical: (15 X 4= 60 hours)

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Comparative morphological analysis of representative taxa of Marchantiophyta.
2. Comparative morphological study of selected moss taxa.
3. Study of adaptation for water conservation in the plant samples
4. Field studies for niche studies, sampling techniques, diversity mapping, collection of plant samples for studies in the lab studies.
5. Determination of water-holding capacity in Bryophytes.

6. Separation and profiling of secondary metabolites in Bryophytes using Thin Layer Chromatography (TLC).
7. Cytological examination of Bryophytes using squash and staining techniques.
8. Taxonomic identification of Bryophyte taxa using diagnostic characters and standard keys.
9. Study and identification of herbarium specimens of Pteridophytes.
10. Microscopic examination of mycorrhizal associations in Pteridophytes.
11. Study of soral arrangement and sporangial patterns in Pteridophytes.
12. Analysis of phytochemical constituents of pteridophytes through Thin Layer Chromatography (TLC).
13. Study of the symbiotic association between *Azolla* and *Anabaena*.
14. Morphological and anatomical examination of sporocarps in aquatic ferns.
15. Anatomical study of stem and leaf tissues in selected Gymnosperm taxa.
16. Observation of pollen types and assessment of pollen germination in Gymnosperms.
17. Study of male and female cones in Gymnosperms, including morphology and developmental stages.

Suggested Readings:

1. Goffinet, B., Shaw, A. J. (Edited) (2008). Bryophyte biology. 2nd ed. – XIV + 565 pp. Cambridge University Press, Cambridge. ISBN 978-0-521-69322-6.

2. Schofield, WB. (1985). Introduction to Bryology. Macmillan. ISBN, 0029496608, 9780029496602.

3. Ranker, T.A. and Haufler, C.H. (2008). Biology and Evolution of Ferns and Lycophytes. Cambridge University Press, Cambridge

4, Bhatnagar, S.P. and Moitra, A. (1996). Gymnosperms. New Age International P Limite. Publishers, New Delhi.

5. Dyer, A.F. (1979). Experimental Biology of Ferns. Academic Press

Additional readings:

Bryophytes

1. Vanderpoorten, A., & Goffinet, B. (2009). *Introduction to Bryophytes.* Cambridge University Press.
2. Oliver, M.J., Velten, J., & Mishler, B.D. (2005). Desiccation tolerance in bryophytes. *Integrative and Comparative Biology*, 45(5), 788–799.
3. Rensing, S.A. (Ed.). (2016). *Genomes and Evolution of Charophytes, Bryophytes, Lycophytes and Ferns.* Advances in Botanical Research, Vol. 78. Academic Press.
4. Cove, D. J., Perroud, P.-F., Charron, A. J., McDaniel, S. F., Khandelwal, A. & Quatrano, R. S. (2009). *The moss Physcomitrella patens: a novel model system for plant development and genomic studies.* **Cold Spring Harbor Protocols**, February 2009 (2009 (2): pdb.emo115). doi:10.1101/pdb.emo115.
5. 3. 4. Dyer, A.F. and Duckett, J.G. (1984). Experimental Biology of Bryophytes. Orlando, Academic Press.

16

Pteridophytes

1. Fernández, H., Kumar, A. and Revilla, M.A. (eds.) (2011). Working with Ferns: Issues and Applications, Springer Science+Business Media, LLC20
2. Mehlereter, K., Walker, L.A. and Sharpe, J.M. (Eds.) (2010). Fern Ecology. Cambridge University Press, Cambridge
3. Ranker, T.A., & Haufler, C.H. (Eds.). (2008). *Biology and Evolution of Ferns and Lycophytes.* Cambridge University Press.
4. Fernández, H., Kumar A., & Revilla, M.A. (Eds.). (2010). *Working with Ferns: Issues and Applications.* Springer.
5. Plackett, A.R.G., Huang, L., Sanders, H.L., & Langdale, J.A. (2014). High-efficiency stable transformation of the model fern *Ceratopteris richardii* via microparticle bombardment. *Plant Physiology*, 165(1), 3–14.
6. Plackett, A.R.G., Di Stilio, V.S., & Langdale, J.A. (2015). Ferns: The missing link in shoot evolution and development. *Frontiers in Plant Science*, 6, 972.
7. Banks, J.A., et al. (2011). The *Selaginella* genome identifies genetic changes associated with the evolution of vascular plants. *Science*, 332(6032), 960–963.

Gymnosperms

1. Nystedt, B., et al. (2013). The Norway spruce genome sequence and conifer genome evolution. *Nature*, 497, 579–584.
2. Leitch, A.R. & Leitch, I.J. (2012). *Ecological and genetic factors linked to contrasting genome dynamics in seed plants.* New Phytologist, 194(3), 629-646. doi:10.1111/j.1469-8137.2012.04105.x.
3. Ahuja, M.R. & Libby, W.J. (eds.) (1993) *Clonal Forestry I: Genetics and Biotechnology*. Springer-Verlag, Berlin & Heidelberg.
4. Singh, H. (1978). Embryology of Gymnosperms. Encyclopedia of Plant Anatomy. Gebruder Bomtraegro, Berlin.

Molecular, Genomic & Evo-Devo Perspectives

1. Bowman, J.L., et al. (2017). Insights into land plant evolution from the *Marchantia polymorpha* genome. *Cell*, 171(2), 287–304.
2. Wickett, N.J., et al. (2014). Phylotranscriptomic analysis of the origin and early diversification of land plants. *PNAS*, 111(45), E4859–E4868.
3. Lüttge, U., Beck, E., & Bartels, D. (Eds.). (2011). *Plant Desiccation Tolerance.* Springer.
4. Harrison, C.J. (2017). Development and genetics in the evolution of land plant body plans. *Philosophical Transactions of the Royal Society B*, 372(1713), 20150490.
5. Rensing, S.A. (2018). Great moments in evolution: Bryophytes. *Current Opinion in Plant Biology*, 42, 88–95.

17

DISCIPLINE SPECIFIC ELECTIVE – 9:

Molecular Interactions of Plants with Symbionts, Pathogens and Pests

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		
Molecular Interactions of Plants with Symbionts, Pathogens and Pests DSE-9	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives: This paper aims to introduce various aspects of biochemical and molecular interactions of plants with symbionts, pathogens and pests at an advanced level.

Course Learning Outcomes:

The students will be learning:

1. Concepts, techniques and applications related to the plant interactions with microbes (symbionts and pathogens)
2. Plant responses to biotic components of their environments

Theory: **(15 X 2= 30 hours)**

Unit I: **(4 hours)**
Introduction to biotic interactions of plants. Evolutionary perspectives on host-microbe co-adaptation

Unit II: **(8 hours)**
Recent advances in plant-pathogen interactions: Stages of pathogenesis, Structural and biochemical host defense mechanisms against pathogens and pests, Basal resistance, Non-host resistance, effector triggered responses and immune suppression by pathogens. Distinction between necrotrophic and biotrophic pathogens.

18

Unit III: **(10 hours)**

Genetics, genomics and applications: Genetics, genomics and applications: Gene-for-gene concept, Models for perception of effector proteins by plants, Cloning of resistance genes (R genes) and avirulence genes (Avr genes) from plants and pathogens, Genetic engineering for the production of resistance plants to pathogens and pests. Cross talk between SA and JA dependent defence responses.

Unit IV: **(8 hours)**

Recent advances in symbiotic interactions with plant with special references to mycorrhizae and root nodule symbiosis.

Practicals: **(15 X 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Histochemical staining using DAB (3,3'-diaminobenzidine) for hydrogen peroxide or NBT (Nitroblue tetrazolium) for superoxide to visualize oxidative burst (ROS like hydrogen peroxide or superoxide release) by plants upon fungal chitin or effector recognition.
2. Callose deposition assay (Aniline blue staining and Fluorescence microscopy to visualize physical reinforcement of cell walls preventing fungal penetration).
3. Diffusion assay (to detect pectinase/cellulose secreted by fungi to break down fungal cell wall, demonstrating production of virulence factors essential for pathogenesis).
4. Enzyme (Pr1 Protease) assay to study the molecular mechanism by which fungi breach pests.
5. Dual confrontation assay to study mycoparasitism exhibited by pathogenic fungi.
6. Study of mycorrhizal symbiosis/rhizobial-legume symbiosis.
7. Study of necrotrophic and biotrophic pathogens.

Suggested Readings:

1. Strange, R.N. (2003). Introduction to Plant Pathology. John Wiley & Sons, USA.33
2. Dickinson, M. (2003). Molecular Plant Pathology, Bios Scientific Publishers, London.
3. Burchett, S. and Burchett, S. (2018). Plant Pathology. Garland Science, USA
4. Mehrotra, R.S. (2017). Plant Pathology, 3rd Edition, McGraw-Hill Education, New Delhi.
5. Recent and important review articles from scientific journals

19

DISCIPLINE SPECIFIC ELECTIVE-10:

Recent Trends in Plant Systematics

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		
Recent trends in Plant Systematics DSE-10	**4**	**2**	**0**	**2**	**Graduate with Botany as one of the subjects**	**Nil**

Course Objectives:

This course aims to introduce the students to the advanced concepts and principles of taxonomy, evolutionary inference of important morphological characters, biodiversity assessment through field studies in various agroclimatic zones of India, important families of flowering plants, their classification, and role of important characters and application of standard barcode markers in delineating species boundaries.

Course Learning Outcomes:

The students will be learning

1. Principles, historical development, and modern relevance of plant systematics, including species concepts, nomenclature rules, and the role of herbaria and field studies in biodiversity and climate-change research.
2. Morphological characters delineate flowering plants and their classification up to the generic level, and how can this knowledge be applied in biodiversity assessment and conservation.
3. Phylogenetic trees, and how are they used to study evolution, trace traits, and guide conservation efforts?
4. Plant DNA barcoding, and how do standard barcode markers contribute to plant identification, conservation, and the detection of biopiracy or adulteration in herbal drug products.
5. Applications of Next Generation Sequencing in plant systematics?

Theory: **(15 x 2= 30 hours)**

Unit I: Introduction to Advanced Plant Systematics: **(8 hours)**

Major objectives and applications of systematics; Relevance to society and science. Taxonomic History: Natural systems to cladistics. Species concepts and their evolving interpretations; The role of field studies and herbaria in contemporary research and climate-change studies. Application of nomenclature in herbarium curation, phylogenetic revisions, and taxonomic databases. The plant systematics community: Professional organizations; Work environment; Activities.

Unit II: Introduction to the angiosperms: **(8 hours)**

General characteristics; Evolutionary history; Basal angiosperms and Magnoliids; Basal monocots; Petaloid monocots; Commelinids; Basal eudicots and Caryophyllids; Superrosids; Superasterids. Classification: The components of classification; Characters and their states; Sources of characters; Evaluation of characters. Systematic evidence: Morphology, Anatomy, and ultrastructure; Embryology; Palynology; Cytology; Phytochemistry.

Unit III: Molecular Systematics: **(10 hours)**

Plant genomes: nuclear, mitochondrial, chloroplast; Molecular markers; Generating molecular data: restriction site mapping, gene sequencing. Large phylogenies; Introduction to transcriptomic approaches for phylogeny reconstruction and their role in resolving complex plant lineages.

Unit IV: **DNA Barcoding** **(4 hours)**

Barcoding concept; standard barcode markers: nrDNA, cpDNA, and mtDNA; role of DNA barcoding in plant identification, conservation, and detection of biopiracy or adulteration in herbal drug products. Superbarcoding.

Practicals: **(15 x 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. To examine taxonomic literature to understand the rules of nomenclature as per ICNafp.
2. Field studies: Plant collection, herbarium and preservation techniques
3. To study basal angiosperms and magnoliids using morphological characters.
4. To study monocots using morphological characters.
5. To study eudicots using morphological characters.
6. To understand the role of palynology in plant systematics.
7. To understand the role of cytology in plant systematics.
8. To analyze taxonomic data using molecular tools.
9. To interpret large phylogenies using latest tools and software.

10. To interpret transcriptome-based phylogenies using latest tools and software.
11. To understand the role of DNA barcoding using different software.

Suggested Readings:

1. Angiosperm Phylogeny Group (2016). An update of the Angiosperm Phylogeny Group Classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnaean Society 181: 1-20.
2. Pandey, A.K. and Kasana, S. (2021). Plant Systematics. CRC Press / Taylor & Francis, New York, NY.
3. Stuessy, T.F. (2008). Plant Taxonomy: The systematic Evaluation of Comparative Data. Columbia University Press, New York.
4. Pandey, A.K., Choudhary, R.K., Dwivedi, M.D. and Kasana, S. (2024). Plant Molecular Systematics: A Laboratory Manual. Deepika Book Agency, New Delhi.
5. Pandey, A.K., Choudhary, R.K., Dwivedi, M.D. and Kasana, S. (2025). Plant Molecular Systematics. CRC Press / Taylor & Francis, New York, NY.

Additional Readings:

1. Hollingsworth, P.M., Bateman, R.M. and Gornall, R.J. (1999). Molecular Systematics and Plant Evolution. Taylor and Francis, London.
2. Judd. W.S., Campbell, C.S., Kellogg, E.A., Stevens, P.A. and Donoghue, M.J. (2002). Plant Systematics: A Phylogenetic Approach. SinauerAssociaes, Inc., Massachusetts.
3. Patané, J.S.L., Martins, J. and Setubal, J.C. (2018). Phylogenomics. In: Setubal J., Stoye J., Stadler P. (eds) Comparative Genomics. Methods in Molecular Biology, vol 1704. Humana Press, New York, NY.
4. Simpson, M.G. (2006). Plant Systematics. Elsevier, Amsterdam.
5. Cronquist, A. (1981). An Integrated System of Classification of Flowering Plants. Columbia University Press, New York.

DISCIPLINE SPECIFIC ELECTIVE -11:

Algae, Environment and Human Welfare

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		
Algae, Environment and Human Welfare DSE 11	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

The course will deal with the basic and advanced topics in phycology, and phycological research, including the role of algae in the environment and their impact on human welfare, and their potential utilization in biotechnology, bioremediation, and sustainable development.

Course Learning Outcomes:

1. Understand the diversity and ecology of algae
2. Analyze the role of algae in aquatic ecosystems and their impact on environment
3. Evaluate the applications of algae in biotechnology, bioremediation, and human welfare
4. Discuss the challenges and opportunities of algal-based solutions for sustainable development

Theory **(15 X 2= 30 hours)**

Unit I: Introduction to algal world **(6 hours)**

Brief classification on algae, Algal growth in Raceway Ponds and Photobioreactors, Life cycles of important algae from Chlorophyceae, Phaeophyceae and Rhodophyceae, Advances in algal biotechnology.

Unit II: Environment & Energy **(8 hours)**

Phycoremediation of wastewater / heavy metals and pollutants, CO_2 sequestration and climate change mitigation, Algal indicators of water quality and pollution, Ocean afforestation through algae. Biofuels from algae such as Biodiesel, Bioethanol

Unit III: Algae in agriculture, food & nutraceuticals **(7 hours)**

N_2 fixation, assimilation and biofertilization. Seaweed Extracts and Seaweed biostimulants/fertilizers in agriculture. Use of algae as food and food additives. Production of PUFA, various antioxidants & pigments.

Unit IV: Other emerging fields of algae **(9 hours)**

Genetic engineering & mutation of algae. IMTA (Integrated Multi-Trophic Aquaculture), Ecological restoration through artificial reef formation, Algal biopolymer, Algal-concrete, Bioactive compounds from Algae, Advancement in photosynthesis.

Practicals: **(15 X 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Culturing of microalgae using various solid & liquid media
2. Identification of various microalgae from water samples
3. Agar extraction from *Gracilaria*
4. Extraction of algal lipids
5. Carrageenan extraction from *Kappaphycus*
6. Preparation of Seaweed Extract and its application on seed germination
7. Algal isolation & estimation / quantification of various algal pigments
8. Phycoremediation of wastewater through algal culture
9. Herbarium & museum sample specimen preparation
10. To study thallus and reproductive structure of *Gracilaria*
11. To study thallus and reproductive structure of *Kappaphycus*
12. To study thallus and reproductive structure of *Sargassum*
13. To study thallus and reproductive structure of *Ulva* / *Enteromorpha*

Suggested Readings:

1. Sahoo, D. (2000). Farming the ocean: seaweeds cultivation and utilization. 1st edition. Aravali International, New Delhi.
2. Barsanti, L., & Gualtieri, P. (2006). Algae: Anatomy, Biochemistry, and Biotechnology. CRC Press.
3. Borowitzka, M. A., & Moheimani, N. R. (2013). Algae for Biofuels and Energy. Springer.
4. Sahoo, D. and Seckbech, J. (Eds) (2015). The Algae World, 1st edition. Springer, Dordrecht.
5. Lee, R. E. (2018). Phycology. Cambridge University Press.
6. Sahoo, D. (2010). Common seaweeds of India. I.K. International Publishing House Pvt. Ltd. New Delhi.
7. Levine, I.A. & Sahoo, D. (2010). Porphyra: Harvesting gold from the sea. I.K. International Publishing House Pvt. Ltd. New Delhi.

DISCIPLINE SPECIFIC ELECTIVE– 12:

Bioinformatics, Computational Biology and Biostatistics

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		
Bioinformatics, Computational Biology and Biostatistics DSE - 12	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

This course has a strong interdisciplinary component and is designed to equip students with essential skills in bioinformatics (at basic and advanced levels). It will introduce applications of computational biology in diverse areas of biological sciences and provide training in the use of statistics in biological sciences.

Course Learning Outcomes:

The students will learning:

1. Skills in the use of databases and online tools related to biological data.
2. Developing algorithms and write programs for analysis of biological data using PERL.
3. Next Generation Sequencing (NGS) technologies and analysis of NGS data.
4. Principles of *in silico* drug design and molecular modeling using online tools.
5. Statistical concepts and principles relevant to biological data and their applications.

Theory **(15 x 2= 30 hours)**

Unit I **(12 hours)**

Databases and online tools, Fundamentals of computer programming and algorithm development; Programming in PERL for analysis of nucleotide sequences: development of PERL scripts for analysis of sequence length, nucleotide composition, percent GC, generation of complementary and reverse complement sequences, restriction mapping, melting temperature, homology analysis between sequences, translation of mRNA, codon usage analysis.

Unit II **(12 hours)**

Next Generation Sequencing (NGS) technologies and introduction to NGS data analysis.

25

Unit III **(6 hours)**

Introduction to *in silico* drug design and molecular modeling.

Unit IV **(10 hours)**

Biostatistics: Conceptual understanding of Statistic and Statistics. Concepts of populations and samples. Types of Data: attributes and variables, discrete & continuous data. Measures of Central Tendency: Mean, mode, median; measures of dispersion and variability. Normal and standard normal distribution. Calculating areas under the normal distribution, tests of normality; z- scores; one sample and two-sample z-test. Confidence Intervals and Hypothesis testing (critical region, level of significance, P-value, concept and rationale of null hypothesis, One- and Two- tailed hypothesis, type-I and type-II errors). Sampling Distributions: t-distribution. One sample t-test; two- (independent and paired) sample t-tests; Chi-square test and its applications.

Practical **(15 x 4= 60 hours)**

A 4-hour lab exercises per week for hands on practical exercises on the subject.

Suggested Readings:

1. Attwood, T.K. and Parry-Smith, D.J. (2004). Introduction to Bioinformatics, Pearson Education (Singapore) Pvt. Ltd.
2. Edwards, D. (Ed.) (2007). Plant Bioinformatics: Methods and Protocols, Humana Press, New Jersey, USA.
3. Kulas, J.T. (2008). SPSS Essential: Managing and Analyzing Social Science Data. John Wiley & Sons, New York.
4. Pagano, M. and Gauvreau, K. (2007). Principles of Biostatistics. Thomson India Edition, New Delhi.
5. Zar, J.H. (2010). Biostatistical analysis. 5th Edition. Prentice Hall

Additional Readings:

1. Schwartz, R., Phoenix, T. and d Foy, B. (2005). Learning Perl (4th edition), O'Reilly & Associates, ISBN: 0-596-10105-8.
2. Dwyer, R.A. (2004). Genomic Perl: From Bioinformatics Basics to Working Code, Cambridge University Press, 1st South Asian Edition.
3. Rosenkrantz, W.A. (2009). Introduction to Probability and Statistics for Science, Engineering and Finance. CRC Press, Boca Raton.

26

DISCIPLINE SPECIFIC ELECTIVE COURSE – 13:

Functional Foods and Nutraceuticals

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		
Functional Foods and Nutraceuticals DSE 13	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:
This course aims to provide advanced knowledge on production, characterization and application of functional foods and nutraceuticals. Further, the course will provide information of foodomic approaches in functional food development and regulatory aspects related to functional food industry.

Course Learning Outcomes:
The students will be learning:

1. Role of functional foods and nutraceuticals during metabolic disorders.
2. Molecular mechanisms of specific nutraceuticals in relation to its health benefits.
3. Concepts of foodomics approaches applied in plant based functional food production and validation

Theory **(15 x 2= 30 hours)**

Unit I: Functional foods and nutraceuticals **(6 hours)**

Plant based-Functional food, nutraceuticals, and natural health products, Plant based-nutrient-disease relationships - Bioactive ingredients and their metabolic basis, Food derived bioactive metabolites - sources, chemical structure, metabolic aspects and role in prevention of coronary heart diseases, hypertension, diabetes, and obesity. Food Processing techniques for enhancing functionality and bioavailability, Food fortification.

Unit II: Smart Proteins – the next generation alternative **(5 hours)**

Nutritional aspects, Categories (Plant, Fungi and Algae-based, cultivated meat), Importance of smart proteins in modern era, Challenges associated with smart protein production and consumer adoption, Industrial potential of smart proteins (Upscaling, marketing, and entrepreneurial opportunities).

Unit III: Microbial based functional foods - Biotics and fermented functional foods **(8 hours)**

Plant based fermented functional products, Biotransformation of plant based-food bioactives during fermentation, Reduction of antinutritional factors. Health benefits of probiotics, prebiotics, synbiotics, and postbiotics. Diversity of International and Indian Traditional Fermented foods, Interplay between plant-based biomolecules and gut microbiome and its effect on health, Mechanism of action, Functional and Safety aspects, Artificial Gut model for understanding gut microbiome.

Unit IV: Foodomics and computational tools in functional foods and nutraceuticals (7 hours)

Foodomics: Introduction, concepts and scopes, Omics Techniques and computational tools in food research, metagenomics, metabolomics, metatranscriptomics, and peptidomics. Role of computational tools in discovery of novel nutraceuticals and functional food. Challenges and future perspectives. Nutrigenomics: Key concepts, Molecular mechanisms of nutrient-gene interactions.

Unit V: Bioentrepreneurship and Regulatory aspects of functional foods and nutraceuticals (4 hours)

Industrial perspectives and challenges in functional foods, Upscaling, Marketing – Demand and consumer acceptance and readiness, Challenges for marketers at the food-drug interface, Regulatory status and laws governing functional foods and nutraceuticals, Food Safety and Standard Authority of India, European Union - Novel Food Regulations, Japan - Foods of Special Health Use (FOSHU), The Food and Drug Administration (FDA), Bioentrepreneurship.

Practicals (15 x 4= 60 hrs.)

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Assessment of Bile tolerance test of selected lactic acid bacteria.
2. Assessment of acid tolerance test of selected lactic acid bacteria and yeast.
3. Assessment of antioxidant potential of peptides produced on solid state fermentation.
4. Protein extraction and estimation from functional foods.
5. Extraction of functional lipids from microalgae.
6. Production of probiotic and bioactive peptides enriched curd
7. Estimation of flavonoids in green leafy vegetables.
8. Development of functional soybean based functional foods.
9. Extraction and estimation of bioactive compounds from mushroom.
10. Estimation of lactose degradation by this thin layer chromatography.
11. Estimation of free polyphenols in microbially fermented products.

Suggested Readings:

1. Rai AK, Anu A. (2021). Bioactive compounds in Fermented Foods: Health Aspects, CRC Press, USA.ISBN: 9780367136000
2. Li, Y., & Qi, B. (Eds.). (2022). Phytochemicals in soybeans: bioactivity and health benefits. CRC Press.

28

3. Rai, AK, Singh SP. Sacool CS, C Larroche, Pandey P, (2022). Technologies for production of nutraceuticals and functional food products. Elsevier, USA ISBN: 9780128235065.

4. Farnworth, E. R. T. (2008). Handbook of fermented functional foods. CRC press.

5. Rai, AK. Sirhoi R, Vandenberghe L, Parameswaran P, (2022). ‘Microbial enzymes in functional food and health’, CRC Press, USA. ISBN: 9781032317564

Additional Readings:

1. Sun, X., & Udenigwe, C. (Eds.). (2025). Bioavailability of Nutraceuticals and Bioactive Compounds. CRC Press.
2. Sirhoi R, Rai AK, Vandenberghe L, Parameswaran B. (2023). Microbial enzymes and metabolites for health and well-being CRC Press, USA. ISBN: 9781003369295

29

Skill Based Course-03:

Applied Industrial Microbiology

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		
Applied Industrial Microbiology SBC-03	2	1	0	1	Graduate with Botany as one of the subjects	Nil

Course Objectives

- To understand the practical application of microorganisms in products of food and value-added products.
- To evaluate the role of microorganisms in agriculture.
- To evaluate the role of microbes in enzyme production.
- To develop critical thinking on future challenges on biomanufacturing.

Learning outcomes

Students shall be learning:

1. Concepts, scope and significance of microorganisms in industrial applications.
2. Practical applications of microorganisms in food fermentation industry.
3. Utilization of microorganisms in agriculture and production of natural products.
4. Practical skills related to enzyme production for production of nutraceuticals.

Theory

(15 x1= 15 hours)

Unit 1. **4 Hours**

Cultivation, process optimisation, scale up methods for enzyme and metabolites Mechanism and application of phosphate and zinc solubilisation by microorganisms. Applications of carbohydrate active enzymes.

Unit 2. **5 Hours**

Production of value-added compounds from low value byproducts using different group of microorganisms. Biosynthetic pathways in the production of terpenes and their role in plant defence mechanism.

Unit 3: 4 Hours

Recovery and application of bioactive compounds from algae. Metabolic pathway for production of Gibberellic acid and its associated challenges at Industrial level.

Unit 4. 2 Hours

Introduction to bioentrepreneurship using microorganism – opportunities and challenges

Practicals (15 x 2= 30 hours)

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Cultivation and assessment of selected microorganisms for Carbohydrate active enzyme production.
2. Starter culture development for peptide production
3. Cultivation of algae for production of value-added products.
4. Determination of phosphate solubilization potential of microbes
5. Fungal production of Gibberellic acid
6. Determination of Phytic Acid Reduction by Phytase Treatment
7. Effect of precipitation methods on purification of enzymes
8. Determination of antibiosis potential of *Trichoderma* against plant pathogens
9. Visit to biomanufacturing Institute/industry for awareness related to pilot plant.

Suggested readings

1. Nigam, A. (2007). Lab manual in biochemistry, immunology and biotechnology. Tata McGraw-Hill Education.
2. Aneja, K. R. (2018). Experiments in microbiology, plant pathology, tissue culture and microbial biotechnology." 520-528.
3. Baltz, R. H., Demain, A. L., & Davies, J. E. (Eds.). (2010). Manual of industrial microbiology and biotechnology. American Society for Microbiology Press. 2.

Additional readings

1. Rai, AK. Sirhoi R, Vandenberghe L, Parameswaran P, (2022). 'Microbial enzymes in functional food and health', CRC Press, USA. ISBN: 9781032317564.

31

GENERIC ELECTIVE- 03

Nano-Biotechnology

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		
Nano-Biotechnology GE- 03	4	3	1	0	Graduate in any discipline	Nil

Course Objectives

This course aims to introduce the students with the exciting science nano-science and its utilization in life as nanobiotechnology.

Course Learning Outcomes

The students will be learning

1. The properties of nanoparticles and a comparison between bulk and nano.
2. Techniques to analyse different properties of nanoparticles.
3. Types of nano-particles.
4. Synthesis of nano-particles, comparison between green and chemical synthesis.
5. Applications of nano-particles and nano-material in different facets of life.
6. Nnao-toxicity and nano-safety what, why and regulations.

Theory: **(15 X 3= 45 hours)**

Unit I **(4 hours)**

Nanoparticles – Types, Morphology (Shapes), properties of nano-material, comparison with bulk material. Characterization of nano-particles, using techniques-UV-visible spectroscopy, SEM, TEM, DLS Zeta, XRD

Unit II **(4 hours)**

Green and chemical methods for the synthesis of nanoparticles, comparison between the two methods, detailed synthesis of two types of each.

Unit III **(10 hours)**

Nano-machines, biology at the nanoscale with examples like myosin, kinesin and ATPases.

Unit IV **(12 hours)**

Applications of nanomaterials in daily life (water purification, paints, fabric, cosmetics, food) in biomedicine (drug delivery, drug targeting, drugs) and in agriculture (sensors, nano-pesticides, nano-fertilizers, nanopriming). Nano-toxicity and nano-safety.

Suggested Readings:

1. Madhuri Sharon, Maheshwar Sharon, Sunil Pandey and Goldie Oza 2013. Bionanotechnology concepts and applications. Ane books Pvt Ltd , New Delhi .ISBN 978- 93-8116-236-. 389 pages.
2. Tuan vo dinh 2018. Nanotechnology in Biology and medicine : methods, devices and applicationas. CRC press, Taylor and Francis grp, Florida, USA. ISBN 13:978-1-4398-9378-4. 739 Pages.
3. David S. Goodsell 2018 Bio-nanotechnology lessons from nature, Wiley Pvt Ltd, India Edition, ISBN 9788126539362.

Tutorials **(15 X 1= 15 hours)**

Tutorials will provide an opportunity for students to discuss issues raised during the lectures.

33

Semester IV

DISCIPLINE SPECIFIC CORE - 09

Plant Cell 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 Cell Biology DSC-9	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

The objectives of this course are to provide a foundation and understand application-oriented concepts in cellular and acellular entities in plants; architecture of the cell, nucleus and organelles; membranes in prokaryotes and eukaryotes; macromolecules and natural biopolymers; cell division, motility and secretion; advanced techniques in the study of normal and aberrant plant cells

Course Learning Outcomes:

The students will be learning about:

1. Acellular entities including infective particles comprising only protein or RNA, which are parasites of plants and/or animals; the observations/proposals which challenge established dogmas, such as, a cell being the basic unit of life or that higher plants are multicellular rather than supracellular, as well as the current state of knowledge about the plant cell structure and their turn over, starting from cell wall to chromatin, in relation to their functions.
2. What are the components of endo-membrane systems and mechanisms governing intracellular trafficking in plant cells? What are the diverse types and applications of membrane vesicles?
3. What is the role of the plant cytoskeleton and accessory proteins in major cellular processes of plants? What are major constituents of cellular components in plants, their origin, assembly, characteristics and applications?
4. How does cellular organization change in plant tissues that undergo maturation and differentiation under normal and stressed conditions? What are commonly used advanced imaging techniques that can be used to study plant ultrastructure?

Theory (15 x 2= 30 hrs.)

Unit I: Infective Particles, Cell Continuity and Supracellular Organization (6 hours)

Prions and viroids: nature, structure, infectivity, cellular and ultrastructural effects; cell theory and cell body concept, multicellularity and supracellularity in plants and coenocytic systems

Unit II: Cell Wall, Bio-membranes and Cytoplasmic Systems (10 hours)

Cell Wall: temporal and spatial dynamics; structure–function relationships; cell wall biotechnology; Bio-membranes: evolution from PLP model to Dynamically Structured Mosaic Model; membrane domains, lipid rafts, supramolecular lipid–protein assemblies; Cytoplasmic systems: endomembrane organization; organelle architecture; protein sorting; vesicular trafficking networks; ER-Golgi dynamics and stress.

Unit III: Biopolymers and Cytoskeleton (6 hours)

Cytoskeleton: microtubules, microfilaments, intermediate filaments: structure, dynamics, functions; motor proteins and cytoskeletal coordination; cytoskeleton-linked signaling; genomic and proteomic diversity of plant cytoskeletal proteins; applications in agrobiotechnology.

Unit IV: Nuclear Architecture and Cell Cycle (8 hours)

Nuclear architecture: nuclear envelope, nuclear pore complex, nucleocytoplasmic transport; chromosome condensation and packaging; transcription- and replication-linked chromatin states; chromatin remodeling complexes; Cell cycle & cell turnover: mitosis and meiosis; checkpoint control; breakdown of regulation; plant senescence and programmed cell death (PCD).

Practicals (15 x 4= 60 hours)

Practicals will be based on the theoretical content of the syllabus. A representative list of type of practical exercises is provided below:

1. To isolate chloroplast from plant leaves and to measure chlorophyll content as an indicator of photosynthetic activity.

2. To determine the succinate dehydrogenase activity in isolated mitochondria of the given plant material and to check the effect of competitive inhibitor on the enzymatic activity.

3. To separate and compare chlorophylls and carotenoids from control and stress–treated leaves using TLC and relate pigment changes to chloroplast function under stress.

4. To extract total lipids from control and salt-stressed seedlings, separate neutral lipids and phospholipids by TLC, and compare lipid profiles as an indicator of membrane re-modelling under stress.

5. To study structure- function relationships of genes encoding components of the plant cytoskeletons using PCR amplifications and/or histochemical staining with GUS-cytoskeleton (actin) gene fusion constructs

6. Ultra-structures of cell types and organelles in tissues of normal- and diseased plant types

35

Suggested Readings:

1. Alberts, B., Johnson, A.D., Lewis, J., Morgan, D., Raff, M. and Roberts, K. (2014). Molecular Biology of the Cell. CRC Press, Taylor & Francis Group, USA.; 1464 pages

2. Karp, J.G. (2007) Cell and Molecular Biology. John Wiley & Sons, USA.

3. Brown, T. A. (2017). Genomes 4. CRC Press, Taylor & Francis Group, USA. 524 pages

4. Berk, A., Kaiser, C.A., Lodish, H., Amon, A., Ploegh, H, Bretscher (Author), Monty Krieger, A., Martin, K.C. (Eds). (2016) Molecular Cell Biology. Freeman & Co., USA.

5. Buchanan, B.B., Gruissem, W. and Jones, R.L (2015). Biochemistry and molecular biology of plants. Wiley Publisher; pages: 1264p

36

DISCIPLINE SPECIFIC CORE COURSE -10:

Plant Biotechnology and Resource Applications

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 Biotechnology and Resource Applications DSC-10	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

This course would provide students with an understanding of principles and techniques of plant tissue culture, concepts and methods associated with development and analysis of transgenic plants, and their applications in basic and applied research. In addition, students would be exposed to the economic importance and current research paradigms in various categories of commercially cultivated plants.

Course Learning Outcomes:

The students will learning: -

1. Concepts, tools and techniques related to *in vitro* propagation of plants.
2. Methods used for genetic transformation of plants, use of *Agrobacterium* as a vector for plant transformation, components of a binary vector system.
3. Case studies related to basic and applied research in plant sciences using transgenic technology.
4. Principles and methods used for phenotypic, genetic and molecular analysis of transgenic plants
5. Uses and current research paradigms in various plants of economic value.

Theory: (15 X 2= 30 hours)

Unit I (6 hours)

Plant tissue culture – history; concepts of cell differentiation and totipotency; pathways for *in vitro* regeneration: organogenesis, somatic and gametic embryogenesis; protoplast isolation, culture and regeneration; somatic hybridization; Applications: micro-propagation, meristem culture, embryo rescue, synseed production, somaclonal and androclonal variations, cryopreservation and germplasm storage.

Unit II. **(5 hours)**

Principles and methods of genetic transformation – Introduction; direct gene transfer methods: particle bombardment, electroporation, PEG-mediated and floral-dip; marker and reporter genes; *Agrobacterium* biology and biotechnology; plant – *Agrobacterium* interactions; chloroplast transformation.

Unit III **(15 hours)**

Applications of genetic transformation – case studies on use of transgenic technology for basic studies and crop/plant improvement; phenotypic, genetic and molecular analysis of transgenic plants; factors influencing transgene expression levels; transgene silencing; marker-free transgenics; genome editing for crop improvement; environmental, social and legal issues.

Unit IV **(4 hours)**

Plant resource utilization – centres of primary diversity and secondary centres of cultivated plants; crop domestication genes; introduction to current research paradigms in major cereals, oilseeds, legumes, medicinal plants, forest trees, non-alcoholic beverages.

Practicals: **(15 X 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Preparation of different types of plant tissue culture media.
2. Surface sterilization of seeds and their inoculation.
3. Preparation of hypocotyl explants and study of their regeneration response on appropriate media.
4. Tissue culture and propagation of shoot apices and nodal explants.
5. Recursive PCR for construction of a synthetic DNA sequence.
6. SOE-ing PCR for assembly of a gene expression cassette.
7. Inoculation of Agrobacterium cultures.
8. Comparison of morphological features of economically important plants and their common adulterants.
9. Study of economically important plants and their uses.
10. Identification of important forest tree species and assessment of their threat status.
11. Extraction of natural plant dyes.
12. Fibre extraction from commonly available plants.
13. Documentation of plant resources of botanical garden/museum/herbarium.

Suggested Readings:

1. 1 Adrian, S., Nigel, W.S. and Mark, R.F. (2008). Plant Biotechnology: The genetic manipulation of Plants, Oxford University Press.
2. Buchanan, B.B., Gruissem, W. and Jones, R.L. (2015). Biochemistry and Molecular Biology of Plants, John Wiley and Sons Ltd., UK.
3. Butenko, R.G. (2000). Plant Cell Culture, University Press of Pacific.
4. Davies, P.J. (2010). Plant Hormones, Kluwer Academic Publishers, Netherlands.
5. Halford, N. (2006). Plant Biotechnology - Current and future applications of genetically modified crops, John Wiley and Sons, England.

Additional Readings:

1. Kirakosyan, A. and Kaufman, P.B. (2016). Recent Advances in Plant Biotechnology, Springer, UK.
2. Kochhar, S.L. (2016). Economic Botany: A comprehensive study, Fifth edition, Cambridge University Press, NY.
3. Primrose, S.B. and Twyman, R.M. (2016). Principles of Gene Manipulation, 8th edition, John Wiley and Sons Ltd., Chicester, UK.
4. Ricroch, A., Chopra, S. and Fleischer, S.J. (2014). Plant Biotechnology: Experiences and future prospects, Springer International Publishing AG, Springer, Switzerland.
5. Wickens, G.E. (2004). Economic Botany: Principles and Practices, Springer, ISBN 978-0-7923-6781-9.

Research articles and review articles related to the course contents provided by faculty during the course.

39

DISCIPLINE SPECIFIC ELECTIVE-14:

Reproductive Biology of Flowering Plants

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		
Reproductive Biology of flowering plants DSE-14	**4**	**2**	**0**	**2**	**Graduate with Botany as one of the subjects**	**Nil**

Course Objectives:

Reproductive success among the angiosperms is significantly dependent on the innate biology and immediate ecological conditions of plants. The outcome of reproductive effort may vary among different ecological conditions in the same species. This course is meant to answer how the fitness attributes of plants are influenced by a variety of developmental and ecological constraints.

Course Learning Outcomes

The students will be learning:

1. Proximate causes and consequences of transition in the reproductive attributes of flowering plants
2. Theoretical assumptions, and evidences in the evolution of gender in flowering plants?
3. Accomplishment of male sterility in plants is naturally or artificially, and the use of mechanism in yield improvement.
4. Stages of concealment of ovules in angiosperms
5. Breakdown in self-incompatibility to self-compatibility.
6. Dynamics of plant-pollinator interaction.
7. Breeding system analysis in a plant and relative contribution of selfing and outcrossing
8. Interdependency of development of embryo and endosperm, and their exceptions to this interdependence?
9. Ratio of flowers to fruit and that of ovule to seed .
10. Differentiation of aposporous and sexual modes of reproduction?

Theory: **(15 x 2= 30 hours)**

40

Unit I: **(8 hours)**

Mechanistic diversity in the reproductive modes of flowering plants; Floral contrivances and outbreeding devices; Molecular regulation of pistil and ovule development; Signal transduction during pollen-pistil interaction and double fertilization; Embryogenesis and embryonic pattern formation.

Unit II: **(7 hours)**

Pollination Ecology: Floral display, attractants and rewards; pollen presentation; foraging behavior of pollinators, applied pollination ecology; Diversity and quantitative estimation of breeding and mating systems; Resource allocation patterns

Unit III: **(8 hours)**

Evolutionary transitions in reproductive attributes: Flower (architecture, colour), Pollination modes; Mating patterns (Self-incompatibility, Self-fertilization); Sexual systems (Dioecy, sex determination mechanisms); Sexual selection and gene-flow patterns; Diaspore dispersal and natural recruitment patterns.

Unit IV: **(7 hours)**

Endosperm Development and Imprinting; Seed development: pattern, regulation of gene expression; Agamospermy and parthenocarpy; Embryo and endosperm culture; Male sterility and its applications for crop improvement.

Practicals: **(15 x 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Screening of ovaries showing apomictic and sexual modes of reproduction in *Cenchrus ciliaris*, using methyl salicylate clearing, DIC and Confocal microscopy.
2. Determination of mating systems using MLTR software.
3. Performing cross-hybridization studies.
4. Demonstration of RNA in situ hybridization technique using slides, micrographs and published papers.
5. Estimation of the stigma receptivity by localizing enzymes and pollen viability
6. Estimation of floral rewards by rapid test methods.
7. Establishing the breeding system by semi-vivo pollination studies, bagging experiments, and computing the pollen:ovule ratio
8. Determining the visual spectrum of flower colour in relation to possible flower visitors.
9. Plant-pollinator network analysis by employing suitable software packages.
10. Anther and ovary culture to demonstrate non-zygotic embryo formation.

41

Suggested Readings:

1. Barrett, S.C.H. (2008). Major Evolutionary Transitions in Flowering Plant Reproduction. Univ. of Chicago Press.
2. Faegri, K. and van der Pijl, L. (1979). The Principles of Pollination Ecology. Pergamon Press, Oxford. 291 pp.
3. Harder, L.D. and Barrett, S.C.H. (2006). Ecology and Evolution of Flowers, Oxford Univ. Press.
4. O'Neill, S.D. and Roberts, J.A. (2002). Plant Reproduction, Sheffield Academic Press.
5. Raghavan, V. (1997). Molecular Embryology of Flowering Plants, Cambridge Univ. Press.

Additional Readings:

1. Raghavan, V. (2000). Developmental Biology of Flowering Plants, Springer Verlag, New York.
2. Richards, A.J. (1986). Plant Breeding System, George Allen and Unwin, UK.
3. Scott, R.J. and Stead, A.D. (2008). Molecular and Cellular Aspects of Plant Reproduction. Society for Experimental Biology, Seminar Series 55.
4. Shivanna, K.R. (2003). Pollen Biology and Biotechnology. Enfield, New Hampshire, U.S.A.: Science Publishers.
5. Shivanna, K.R. and Johri, B.M. (1985). The Angiosperm Pollen: Structure and Function. New Delhi, India: Wiley-Eastern.
6. Shivanna, K.R. and Rangaswamy, N.S. (1992). Pollen Biology: A Laboratory Manual, Springer Verlag, Berlin
7. Shivanna, K.R. and Tandon, R. (2014). Reproductive Ecology of Flowering Plants: A Manual, Springer

42

DISCIPLINE SPECIFIC ELECTIVE-15

Concepts and advances in Genetics, Genomics and Molecular 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		
Concepts and advances in Genetics, Genomics and Molecular Breeding DSE-15	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

The paper aims to develop an understanding of the relationship between genetics and genomics. It will also help in comprehending how genomic information is related to chromosomes and its usage in developing tools for genetics and molecular breeding.

Course Learning Outcomes:

The students will be learning:

1) Genetic and molecular basis of domestication in selected taxa. - conservation and effective utilization of existing diversity for crop improvement.
2) Breeding methods employed for different type of crops.
3) Basis of developing different molecular markers systems, and advancements made in post-genomic era.
4) The key concepts and methodologies for construction of linkage maps, mapping of quantitative traits and association mapping.
5) Integrating molecular methods with conventional improvement strategies to accelerate plant breeding.

Theory: (15 x 2= 30 hours)

Unit I: Genetics and genomics of crop domestication (8 hours)

Molecular basis of domestication, domestication syndrome, archaeological and molecular evidence, consequences of domestication, genetic erosion. Case studies: Maize, Coffee, Safflower etc.

Unit II: **Genetic systems and breeding methods** **(5 hours)**

Selection and breeding strategies. Self-incompatibility, male sterility. Genetics and molecular basis of heterosis; Types of heterosis, genetic and molecular basis of inbreeding and heterosis, utilization in crop improvement.

Unit III: **Molecular markers and Genetic maps** **(8 hours)**

Development of molecular markers: trends and progress, NGS-based markers. Applications of molecular markers. Construction of linkage maps, principles and methods, development of mapping populations, high density genetic maps, integration of genetic maps with physical maps.

Unit IV: Molecular breeding and identification of trait loci **(9 hours)**

QTL mapping: principles, methods, estimation of gene effects, fine mapping of QTL. identification of candidate gene/s. Linkage disequilibrium; factors, parameters of estimation. Association mapping; principles, GWAS, genomics selection, Gene tagging, Marker Assisted Selection (MAS), Bulk Segregation Analysis (BSA)**.**

Practicals: **(15 x 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Basics of Linux
2. Quality assessment of short read NGS data using FastQC
3. Genome assembly using MASURCA
4. Isolation of microsatellites using MISA
5. De-novo Transcriptome assembly using TRINITY
6. SNP analysis using GATK pipeline.
7. Genotyping with microsatellite and intron polymorphism markers
8. Linkage analysis with DNA markers
9. Construction of linkage map using program JoinMap4
10. Mapping of trait locus using linkage map
11. Assessment of Genetic diversity
12. Estimating population structure using the software STRUCTURE
13. To study and analyse domestication traits in crop plants
14. To study self-compatibility / incompatibility through manual- / reciprocal crosses
15. To study linkage of molecular markers associated with a trait using bulked-segregant analysis

Suggested Readings:

1. Recent reviews and relevant reading material will be provided to the students for the topics covered in theory as well as in laboratory exercises.

2. Acquaah G (2012). Principles of Plant Genetics and Breeding, Blackwell Publishing Ltd. USA. Print ISBN:9780470664766 |Online ISBN:9781118313718
3. Allard RW (1999). Principles of Plant Breeding (2nd Edition), John Wiley and Sons, ISBN 0471023094, 9780471023098.
4. Hartl and Cochrane (2019). Genetics – Analysis of Genes and Genomes, 9th edition, Jones and Barlett publishers.
5. Jocelyn E. Krebs, Benjamin Lewin, Elliott S. Goldstein, Stephen T. Kilpatrick Jones and Barlett (2014). Lewin's Genes XI. Jones and Barlett Publishers, ISBN. 1449659055, 9781449659059.

45

DISCIPLINE SPECIFIC ELECTIVE COURSE – 16

Agricultural Ecology

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		
Agricultural Ecology DSE - 16	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

This course aims to introduce the students to the application of concepts and principles of ecology to human managed ecosystems.

Course Learning Outcomes:

The students will be learning

1. The meaning of terms agriculture, domestication and selection.
2. What are the ecological principles that are applicable in managed ecosystems such as agriculture systems?
3. The relationship of domesticated biodiversity with its wild biodiversity?
4. How ecological problems influence the agriculture and human food security?

Theory **(15 x 2= 30 hours)**

Unit I: **(7 hours)**

Agroecology – definitions of terms, scope of the discipline, approaches and viewpoints, domestication, selection and protection of crop plants and farm animals, wild relatives of the crops, ecological experimentation in agriculture.

Unit II: **(8 hours)**

Ecosystem functioning of farming systems – energy and material flows, trophic relations, spatial scales and ecological footprints, organic farming, earth overshoot day, conservative and conventional agriculture, genetically modified organisms and their implications, climate change – agriculture and adaptation mechanisms.

Unit III: **(7 hours)**

Ecological problems of crop cultivation and solutions – pollution, leakage and erosion, land development, diseases, weeds and pests, chemical, biological and ecological control.

Unit IV: **(8 hours)**

Interactions between farming systems and biodiversity – biodiversity in farming systems, landscape fragmentation, relationships and interdependencies of biodiversity within farming systems with outside farming systems. Case studies of farming systems of India.

Practical **(15 x 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Field visits to agricultural fields in Delhi and adjoining areas. Study of agrobiodiversity, microclimatic variables, interaction with farmers about farming practices (preparation of field, irrigation, fertilizers, harvest, storage etc), soil sampling for nutrient analysis from different agricultural systems,
2. Processing of soil samples, homogenization and drying.
3. Field preparation for garden experiment: Plantation of seeds in the prepared seed beds for understanding land equivalent ratio (Monocropping and intercropping), effect of weeding, density and light intensity on economic and biological yield.
4. Seed viability test, germination experiment and determination of Mean germination time (MGT) for different crop species.
5. Determination of mean seed weight, seed viability, and mean germination rate and time for seasonal crop species.
6. Sieving of soil collecting from different agroecosystems and determination of soil moisture, soil pH, electrical conductivity, and salinity using specific probes.
7. To estimate soil organic carbon in different agroecological soil samples using Walkley Black Titration method.
8. To estimate Phosphorous as orthophosphates in different agroecological soil samples using ammonium molybdenum blue method.
9. To estimate Sulphur as Sulphates in different agroecological soil samples using turbidimetric method
10. To estimate extractable Magnesium in different agroecological soil samples using EDTA complexometric titration method
11. To estimate extractable Calcium in different agroecological soil samples using EDTA complexometric titration method.
12. To estimate Ammonium Nitrogen in different agroecological soil samples using modified Berthelot’s reaction.

13. Harvest of crops from garden experiment and determining the land equivalent ratio (Monocropping and intercropping), effect of weeding, density and light intensity on economic and biological yield.
14. To estimate Nitrate Nitrogen in different agroecological soil samples using salicylic acid.
15. To study the impact of light and shade environment on plant pigments (chlorophylls and carotenoids).

Suggested Readings:

1. Connor, D.J. Loomis, R.S. and Cassman, K.G. (2011). Crop ecology: Productivity and management in agricultural systems. 2^{nd} Edition. Cambridge University press.
2. Gliessman, S.R. (2015). Agroecology: The Ecology of Sustainable Food Systems. CRC Press. ISBN 978 14398956 10; 978 1439895764, 371pp.
3. Vandermeer, J.H. (2011). The ecology of agroecological systems. Jones and Barlett publishers.
4. Altieri, M.A. (2018). Agroecology: The Science of Sustainable Agriculture. Second Edition. CRC press. ISBN 0429975090, 400pp.
5. Gliessman, S.R. (2014). Field and Laboratory Investigations in Agroecology. Third Edition. CRC Press. ISBN 1498728499. 241pp.

Additional Readings:

1. Wojtkowski, P.A. (2006). Introduction to Agroecology: Principles and Practices. Food Products Press. ISBN-10 1-56022-317-0. 407pp.
2. Alagh, Y.K. (2013). The Future of Indian Agriculture. ISBN 8123767366, ISBN 9788123767369. 220pp.
3. Mazoyer, M. and Roudart, L. (Translated by Membrez, J.H.). (2014). A History of World Agriculture: From the Neolithic Age to the Current Crisis. Monthly Review Press, New York. ISBN 1-58367-121-8. 527pp.

48

DISCIPLINE SPECIFIC ELECTIVE-17

Molecular Dynamics of the Genome and Developmental Mechanisms

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		
Molecular Dynamics of the Genome and Developmental Mechanisms DSE 17	**4**	**2**	**0**	**2**	**Graduate with Botany as one of the subjects**	**Nil**

Course Objectives:

The module introduces a unified view of genome structure and regulatory mechanisms shaping development and adaptation, with emphasis on plants. It covers cellular and molecular processes governing developmental pathways, including epigenetic regulation during vegetative and reproductive phases, and adaptive responses. Relevant insights from non-plant systems will be included when helpful. The course also provides an overview of essential strategies and methods used to study these processes.

Course Learning Outcomes:

The students will be learning:

1. Eukaryotic nuclear and organellar genome, principal mechanisms of genome replication, maintenance, transcriptional regulation of gene expression; fidelity of translational process, and,
2. Role of regulatory RNAs and epigenetics in eukaryotic gene regulation
3. Various factors such as genetic, environmental, and hormones that govern developmental events
4. Cellular processes such as inter-cellular and intra-cellular signal transduction and cross-talks regulating development
5. Cell cycle regulation, including PCD and senescence
6. Molecular and cellular events/processes that regulate meristem development and maintenance; vegetative and reproductive organ development
7. Genetic and molecular elements of epigenetic/chromatin and how chromatin remodeling/epigenetics regulates development and adaptation

49

Theory: **(15 x 2= 30 hours)**

Unit I: Molecular Biology **(7 hours)**

Eukaryotic nuclear and organellar genome structure and variation; gene promoter architecture-diversity and structure; Replicative machinery of eukaryotic genome-initiation, fidelity, end-replication, Polymerase-structure function relationship; Transcriptional, co-transcriptional, and post-transcriptional machinery and processes; Translational processes and fidelity; RNA surveillance mechanism and Pioneering round of translation; Alternative reading frames and Peptide diversity; small ORFs (sORFs) and Micropeptides (mPIPs)

Unit II. Regulation of development **(8 hours)**

Positional information and Cell fate; morphogenetic gradient; polarity determination; commitment, differentiation; Genetic (molecular), environmental (light, temperature, gravity, etc.), and hormonal regulation and cross-talk during basic development processes

Cell cycle regulation; Cancer v/s plant tumors; Programmed cell death and senescence; Cytoskeleton and signal transduction.

Unit III. Vegetative and reproductive development **(8 hours)**

Comparative account of the organization of shoot and root apical meristems; Regulation of meristem size and maintenance; Tools and strategies to understand development; Organ initiation from root and shoot meristems (root and leaf development).

Transition from vegetative to reproductive phase; Molecular basis of flower development and its regulation; Molecular and hormonal control of fruit and seed development.

Unit IV. Chromatin organization, remodeling, and development **(7 hours)**

Gene regulation via regulatory RNA, and epigenetics; Small RNA as regulatory molecule; Epigenetics-Role of histones and small RNA in chromatin organization; RdDM; paramutations, genomic imprinting; gene dosage; Chromatin remodelling-factors, models and processes; Chromatin state during replication and transcription, and inheritance of epigenetics; Epigenetic regulation of developmental processes (vegetative and reproductive processes; stress responses).

Practicals **(15 x 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. To study gene structure and detect presence of exons-introns
2. To study replication, transcription and translational control using inhibitors on growth of *Saccharomyces cerevisiae* (budding yeast)
3. To study the application of organellar genome as molecular marker through PCR-RFLP
4. To study distribution patterns of biomolecules using histochemical and fluorescent dyes

during development and stress
5. To study transcriptional regulation associated with developmental events and stress responses
6. To study hormonal regulation of transcriptional processes and developmental events
7. To study natural variation of developmental traits and analyse patterns of growth through morphometry
8. To generate gene silencing constructs using RNAi / artificial miRNA, and analyse developmental mutants
9. To isolate protoplasts from Arabidopsis leaves and demonstrate protoplast viability via vital staining using fluorescein-diacetate and propidium iodide.
10. To prepare permanent leaf impressions of Arabidopsis wild type and mutant leaves to study the effect of a mutation on stomata density and index.
11. To study the ploidy level of different plant tissues using flow cytometry
12. To study transient gene expression using Agrobacterium infiltration into tobacco leaves.
13. To study the effect of expression of a gene on the expression pattern/localization of another interacting gene/protein through GUS staining in Arabidopsis.
14. To test the effect of a gene's mutation (Arabidopsis mutant) on seed viability using the 2,3,5-triphenyltetrazolium chloride /TTC seed staining method
15. To study vegetative and reproductive organ developmental events (eg. leaf, ovule, anther)
16. To study various cellular changes during fruit development
17. To study root and shoot apical meristems, including the development of leaf primordia
18. To demonstrate apical dominance and the inhibitory effect of the shoot apex on lateral bud outgrowth

Suggested Readings:

1. Beck, C. (2010). An Introduction to Plant Structure and Development. Cambridge University Press, 465pp.
2. Steeves, T.A. and Sussex, I.M. (1989). Patterns in plant development. Cambridge University Press, 405pp.
3. Inz´e, D. (Ed.) (2007). Cell Cycle Control and Plant Development, Blackwell Publishing Ltd. 394pp.
4. Whitelam, G.C. and Halliday, K.J. (2007). Light and Plant Development. Blackwell Publishing Ltd, 350pp.
5. Meyer, P. (Ed.) (2005). Plant Epigenetic. Blackwell Publishing Ltd. 281pp.

Additional Readings:

1. Gerald Karp, Janet Iwasa, Wallace Marshall (2020) Karp's Cell and Molecular Biology, 9th Edition. John Wiley & Sons, USA.
2. Harvey Lodish, Arnold Berk, Chris A. Kaiser, Monty Krieger, Anthony Bretscher, Hidde Ploegh, Angelika Amon, Matthew P. Scott (2021) Molecular Cell Biology. W.H. Freeman & Company.

51

3. Leyser, O. and Day, S. (2003). Mechanism in Plant Development. Blackwell Publishing Ltd. 241pp.
4. Timmermans, M. (2010). Plant Development. Academic Press, 480pp.
5. Howell, S.J. (1998). Molecular Genetics of Plant Development. Cambridge University Press, 365pp.
6. Davies, P.J. (ed.) (2010). Plant Hormones: Biosynthesis, Signal Transduction, Action. Springer, Netherlands, 802pp.
7. Karp, J.G. (2007). Cell and Molecular Biology. John Wiley & Sons, USA.
8. Buchanan, B.B., Gruissem, W. and Jones, R.L. (2015). Biochemistry and Molecular Biology of Plants. Wiley Publisher, 1264pp.
9. Research and review articles on relevant topics

52

DISCIPLINE SPECIFIC ELECTIVE-18

Recent Developments in Plant Physiology and Biochemistry

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		
Recent Developments in Plant Physiology and Biochemistry DSE - 18	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

The course will deal with advanced topics on stress physiology, physiology of programmed cell death, seed dormancy, fruit development and ripening.

Course Learning Outcomes:

The students will be learning

1. Abiotic stress signaling, stress tolerance/adaptive physiological and biochemical changes focusing on mechanism (s). They should be in a position to extrapolate this knowledge for creating stress tolerance crops.
2. Redox changes in normal growth and development as well as during stress are important. These redox changes decide the fate of plant. Reactive oxygen species (ROS) and Reactive nitrogen species (RNS) are the main players. Students would be able to understand the biosynthesis of these redox species in biological systems as well as the antioxidative defense and significance of these in various physiological functions.
3. Physiological, molecular and biochemical basis of seed dormancy, fruit development and ripening is an important aspect of plant development, understanding of this process can help in preventing post harvest losses. Student would acquire a detailed understanding of major regulatory (biochemical/molecular) framework for the process.
4. Physiology of plant programmed cell death and senescence, molecular mechanism and physiological changes that a cell undergoes during these processes.

Theory **(15 X 2= 30 hours)**

Unit I: Stress Physiology **(4 hours)**

53

Freezing, heat, salinity, and heavy metals stresses in plants; plant responses to abiotic stresses, molecular mechanisms of stress tolerance in plants.

Unit II: Oxidative and nitrosative stress and antioxidative strategies (7 hours)

Nitrosative and oxidative stress - causes and effects, nitric oxide biosynthesis and metabolism, NO mediated signaling, markers of nitrosative stress, cross talk between ROS and RNS in plants; antioxidants defense mechanism(s) in plants.

Unit III: Programmed cell death (PCD) (10 hours)

Concept of PCD and its types in plants during various plant development stages. stress-induced PCD. Senescence as programmed cell death and it characteristics. Leaf and flower senescence. Altered metabolism during senescence and its regulation. The oxidative stress and the anti-oxidative strategies. Hormonal. Environmental, genetic and molecular regulation during cell death processes.

Unit IV: Physiology of seed, fruit development, and ripening (9 hours)

Regulation of seed development and maturation, mobilization of food reserves during seed germination, dormancy, stages of fruit development and their regulation, biochemical and related events during fruit ripening in climacteric and non-climacteric fruits, physiology and biochemistry of fruit abscission, post-harvest changes, production of transgenic fruits.

Practical (15 X 4= 60 hours)

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Estimation of Chlorophyl a, Chlorophyll b and carotenoids in leaves undergoing various stages of senescence
2. Estimation of protease activity in leaves undergoing various stages of senescence.
3. Estimation of superoxide production during PCD/senescence using NBT (nitrobluetetrazolium)
4. Visualization of DNA fragmentation during cell death processes.
5. CAT activity in the leaf samples of plant and determine the stressed and control samples based on the CAT activity comparison
6. Ascorbate peroxidase (APX) activity determination for ROS scavenging potential of plant
7. Quantification of reduced glutathione (GSH) a central antioxidative molecule in leaf samples of plant
8. Demonstration of heavy metals analysis in plant tissue and soil samples
9. Experiment on Seed dormancy, climacteric and non-climacteric fruit determination
10. Measuring electrical conductivity under temperature (high and low) stress and control plants.
11. To measure hydrogen peroxide content in salinity stress.

Suggested Readings:

1. Buchanan, B., Gruissem, G. and Jones, R. (2015). Biochemistry and Molecular Biology of Plants. 2nd Edition, American Society of Plant Physiologists, USA.

2. Davies P J. (2010). Plant Hormones: Biosynthesis, Signal Transduction, Action. 3rd Edition, Kluwer Academic Publisher, Dordrecht, The Netherlands.

3. Jordan, B.R. (2006). The Molecular Biology and Biotechnology of Flowering, 2nd Edition, CAB International, U.K.
4. Nelson, D.L., and Cox, M.M. (2021). *Lehninger Principles of Biochemistry* (8^{th} edition). W.H. Freeman & Co., New York.
5. Taiz, L. and Zeiger, E., Møller, I.M., Murphy, A. (2023) Plant Physiology and Development.. 7^{th} Edition. Sinauer Associates, USA.

Additional Readings:

1. Heldt, H-W. and Piechulla, B. (2024). Plant Biochemistry, 6^{th} Edition. Academic Press, NY.
2. Bhatla, S.C., Lal, M.A. (2024). Plant Physiology, Development and Metabolism. 7th Edition. Springer Nature, Singapore.

55

DISCIPLINE SPECIFIC ELECTIVE-19

Morphology and Anatomy of Angiosperms

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		
Morphology and Anatomy of Angiosperms DSE-19	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives

This course is designed to equip students with skills and mechanisms being discovered in the progressive field of Angiosperm structural biology. Students will gain exposure of important and unique plant structures/their development linked with diverse adaptations, along with biochemical, molecular principles governing them. Emphasis on structures cum developmental mechanism of economically importance plant parts, and specific organs/tissues in plants inhabiting different environments is the course highlight that will bring forth the aspects which are being and can be addressed for crop improvement.

Course Learning Outcomes:

Students will be learning:

1. Diversity in structure and development of cell wall and ergastic substances found in plant cell.
2. Structures involved in physical defense (secretory and non-secretory), mutualistic associations and their developmental mechanisms.
3. Structures and developmental mechanisms that play vital role in angiosperms, including plants like carnivorous plants.
4. Structures associated developmental pathways/mechanisms that allow plants to thrive in different environments.
5. Morphological feature updates and developmental mechanisms associated with structures of economic importance in plants?

Theory: **(15 X 2= 30 hours)**

Unit I: Cellular anatomy **(3 hours)**

56

Structural diversity and mechanisms behind formation of ergastic substances, cell wall components of plant in different tissues.

Unit II: Unique structures in Angiosperms **(4 hours)**

Morphological variations, developmental mechanism of structures-secretory cum non-secretory structures at macro/micromorphological level in angiosperms (for protection; including wounds), in plants of special categories *viz*. carnivorous plants etc, including structures due to mutualistic associations viz. insects/microbes.

Unit III: Ecological anatomy **(8 hours)**

Case studies on structural adaptations – specific developmental pathways/mechanisms found in plants of different habitat *viz*. hydrophytes, xerophytes (spines etc.), halophytes (salt glands, pnuematophores), epiphytes (surface hairs, aerial roots), climbers/lianas (tendrils, stem secondary growth etc.), tropical plants vs temperate etc. (leaf coloration etc.); general account on structural modifications due to abiotic stress in crop plants.

Unit IV: Economically important plant structures **(15 hours)**

Case studies about structural features, associated molecular and biochemical pathways of development, localization of metabolites in the plant parts of economic importance (such as stem, bark, leaf, root, flowers, fruits, seeds etc.) addressing plants which are starch-sugar yielding (tubers/roots/stem/pulp), oil yielding (seeds/fruits etc.), pulses (legumes seeds etc.), fiber-yielding (surface cum bast fibers etc.), latex yielding (laticifers), timber cum cork yielding (wood, bark), essential oil yielding and spices (ducts, glands etc.), pigment yielding (flower, fruit, leaf), of fumicatory importance (leaves, fruit), horticultural importance: vegetables (fruit shapes etc.), ornamentals (leaf variegation, plant architecture/branching patterns etc.).

Practicals: **(15 x 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Structural features in model plants (a dicot and a monocot)
2. Field studies, to observe the habitat and plant adaptations
3. Histochemistry Part 1: visible dyes and plant cell component analysis, resin ducts/laticifers content
4. Histochemistry Part 2: Autofluorescent tissues; fluorescent staining of plant tissues
5. Ergastic substances diversity analysis: sectioning, whole mounts
6. Anomalous secondary growth in detail: lianas etc. by sectioning
7. Study of bark types in plants
8. Study of wood types and lignin assay
9. Tissue processing for Anatomy Part 1: embedding/Wax block preparation, leaf clearing
10. Tissue processing for Anatomy Part 2: Permanent slide preparation, double-staining

57

11. Leaf surface analysis method, SEM basics
12. Pigment characterization/localization from petals of different flowers
13. Study of root/shoot development in seedlings

Suggested Readings:

1. Beck C.B. (2020) An Introduction to Plant Structure and Development: Plant Anatomy for the Twenty-First Century, 2nd Ed. Cambridge University Press.
2. Evert R.F. and Eicchorn S.E. (2005) Esau's Plant Anatomy: meristems, cells, and tissues of the plant body: their structure, function, and development. 3rd Ed. Wiley.
3. Hodson M.J., Bryant J.A. (2012) Functional Biology of Plants. 1st ed. Wiley-Blackwell.
4. Luke (2020) Plant anatomy and morphology: Structure function and development / Fitzgerald. 1st Ed., Callisto, New York.
5. Ottoline Leyser O. and Day S. (2002) Mechanisms in Plant Development. 1st Ed. Wiley-Blackwell.

Additional Readings:

1. Rudall P.J. (2020) Anatomy of Flowering Plants: An Introduction to Structure and Development, 4th Ed. Cambridge University Press.
2. Bowes B.B. and Mauseth J.D. (2008) Plant Structure: A Colour Guide, by, Jones and Bartlett Publishers London: Manson Publishing Ltd.
3. Crang R., Lyons-Sobaski S. and Wise R. (2018) Plant Anatomy: A Concept-Based Approach to the Structure of Seed Plants, 1st ed. Springer

58

DISCIPLINE SPECIFIC ELECTIVE - 20

Fungal 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		
Fungal Biology DSE 20	2	2	0	2	Graduate in any discipline	Nil

Course Objectives

- To provide an in-depth understanding of fungal biology, ecology and applications.
- To understand the ecological, industrial and sustainable utilization of fungi.
- To study the role of fungi in carbon sequestration and environmental sustainability.
- To explore molecular techniques in fungal identification and phylogeny.
- To understand the use of fungi in biofabrication.
- To understand the role of fungi in bioremediation.
- To develop research skills in mycology through practical and project-based learning.

Course Learning Outcomes:

Students will be learning;

1. Phases of fungal growth and the mechanisms of hyphal extension and branching.
2. Genetic implications of heterokaryosis.
3. Role of specific sex hormones in mediating sexual reproduction in fungi.
4. Potential of emerging antifungal compounds in addressing drug resistance.
5. Health and economic impact of major mycotoxins and propose integrated management strategies for their control.
6. Critical role of fungi in industrial processes.
7. Application of fungi in biofertilizers and biofuel production, bioremediation of pollutants and bio-fabrication of materials.
8. Process of fungal-mediated nanoparticle synthesis.
9. Potential of fungi in carbon sequestration.
10. Ccritical role of fungi in the carbon and nitrogen cycles and the potential impacts of climate change on fungal distribution and ecosystem functioning.

Theory: **(15 X 2= 30 hours)**

Unit 1: Introduction to Fungal Biology **(6 hours)**

Historical development of mycology, Overview of kingdom fungi: Evolution and Phylogeny, Advanced classification systems, Fungal cell structure and ultrastructure, Fungal growth, development, and reproduction, Heterokaryosis and parasexual cycle, Sex hormones in fungi.

59

Unit 2: Medical and Industrial Mycology **(10 hours)**

Opportunistic and systemic fungal infections, Invasive mycoses: candidiasis, aspergillosis, mucormycosis, Antifungal agents and emerging compounds, Mycotoxin problems and their management. Fungi in the food industry: Fermentation and enzyme production, Fungi in biofuels, biofertilizers, and bioremediation, Fungi-mediated synthesis of nanoparticles.

Unit 3: Fungal Ecology and Interactions **(5 hours)**

Fungi in soil and other Ecosystems, Symbiotic associations: Mycorrhizal fungi, Lichens, Endophytes and environmental applications, Role of fungi in biogeochemical cycles, climate change and fungal ecology.

Unit 4: Advanced Techniques and Applications **(9 hours)**

Microscopy and imaging techniques for fungi, Culture methods of fungal strains, Fungal secondary metabolites, Role of fungi in climate change, carbon sequestration, and in agriculture, Mushrooms cultivation **(**types, diversity, methods of reproduction, nutritional and medicinal properties of wild and edible mushrooms, products from mushrooms), current research frontiers in mycology.

Practicals **(4 X 15= 60 hrs.)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Isolation and identification of fungal species from specific habitats.
2. Polygenic molecular identification of fungi.
3. Screening of fungal species for the enzymes of industrial importance.
4. Biochemical characterization of enzymes from selected fungal isolates.
5. Preparation of spawn and cultivation of various mushrooms.
6. Biochemical characterization to determine the nutritional values of mushrooms.
7. Use of fungal isolates for the biosynthesis of economically important nanoparticles.

Suggested Readings:

- Introduction to Fungi by Webster & Weber Cambridge University Press in 2007
- The Fungal Kingdom (Joseph Heitman et al. 2017)
- Introductory Mycology (C.J. Alexopoulos, C.W. Mims, and M. Blackwell 2017), Wiley.
- Fungal Biology (J.W. Deacon 2006), Blackwell Publishing Oxford UK.
- Textbook of Fungi and Their Allies (Inderjeet Kaur Sethi and Surinder Kaur Walia 2018), Medtech Scientific International.

Additional Readings:

1. Recent research articles from journals like Fungal diversity, Mycologia, Mycology, Mycological Research, Fungal Genetics and Biology, and Studies in Mycology, The Fungi etc.

60

DISCIPLINE SPECIFIC ELECTIVE – 21:

Biobased Applications and Entrepreneurships

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		
Biobased Applications and Entrepreneurships DSE-21	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives

1. To understand the Carbon Emissions reduction
2. To lean the methods to control plastic pollution by utilizing biodegradable polymers minimizing the accumulation of non-biodegradable plastics
3. To learn the production of biofuel and decrease fossil dependency
4. To have an understanding of converting of organic urban waste into valuable everyday products like textiles, packaging, and fertilizers.
5. Stimulating economic growth and generating skilled employment opportunities, particularly in rural areas.
6. To learn to make natural polymers which offer characteristics such as antimicrobial activity, biocompatibility, and controlled drug delivery.
7. Learning to supply durable, and moisture-resistant materials for sustainable agriculture.

Learning Outcome:

Students shall be learning:

1. Sustainable biomass sourcing, and production systems, with focus on high-value applications and uses and overall resource efficiency
2. Prospecting and sustainably using biological resources
3. Bio-based value chains, materials, including bio-inspired materials, products, services and processes with novel qualities, functionalities and improved sustainability.

61

4. biotechnology for application in competitive, sustainable and novel industrial processes, environmental services and consumer products;
5. participating in the creation of value, maximising societal impact and public engagement.
6. Increased understanding of the ecological boundaries, metrics and indicators of the environmental sustainability of the bio-based industry, and its synergies and trade-offs with a healthy environment, and with the other sectors of the bioeconomy

Theory **(15 x 2= 30 hours)**

Unit I : Biobased material in Packaging and Textiles: **8 Hours**

Carbohydrate based materials: Chitosan-a biopolymers in food coating and packaging. Amylose and amylopectin in the production of biodegradable bio-plastics. Chitin and cellulose as sources of nanosized reinforcements. Nanocellulosic materials for improving the mechanical, thermal, antimicrobial properties. Nanocrystals and cyclodextrin, alginate, carrageenan, and agar; Protein-Based Materials: protein-based packaging. Gelatin- for the fabrication of biodegradable packaging. Protein-based films, Protein-based bio-nanocomposites suitable for food packaging, gelatin proteins, corn zein, and wheat gluten proteins. Lipid-Based Materials: Lipids for edible films and coatings for food applications, waxes (paraffin, carnauba, beeswax, candelilla, and jojoba), natural resins (chicle, guarana, and olibanum), and emulsifiers and surface-active agents (fatty alcohols, lecithin, and fatty acids), Combination with hydrophilic materials or lamination with a hydrocolloid film lipid layer for improving mechanical properties.

Antibacterial Agents: bacteriocins, ε-polylysine, tea polyphenols,), inorganic antibacterial agents (oxidized nanoparticles and metals), and organic synthetic antibacterial agents. Natural antimicrobial peptides-nisin, natamycin, leucocin, enterocin, and pediocin as bio-preservatives. Essential oils with alkaloids, flavonoids, isoflavones, monoterpenes, phenolic acids, carotenoids, and aldehydes. Inorganic antibacterial agents. ZnO, magnesium oxide (MgO), TiO_2, and metal oxide nanoparticles (ZnO-NPs, CuO-NPs, TiO_2-NPs, SiO_2-NPs, Al_2O_3-NPs, and Ag-NPs), ZnO-NPs for antibacterial process. CuO-NPs as packaging. TiO_2 in food packaging materials, cosmetics, and healthcare. SiO_2-NPs as a contact surface for food packaging and for generating nonstick coatings for bags, bottles, and jars. Aluminum oxide (Al_2O_3) coatings for food packaging. Ag-NPs against different pathogenic microorganisms such as viruses, bacteria, and fungi.

Unit II: Organic synthetic polymers **7 Hours**

Organic synthetic polymers- in food packaging, including fermentation-based biopolymers (such as polylactic acid (PLA), polyhydroxyalkanoates (PHA), polyhydroxyvalerate (PHV), poly-b-hydroxyl butyrate (PHB), poly-3-hydroxybutyrate-co-3-hydroxyvalerate (PHBV) and exopolysaccharides (EPS), etc.), and bio-based biopolymers (such as bio-polyethylene (Bio-PE), bio-polyethylene terephthalate (Bio-PET), bio-polypropylene (Bio-PP), etc. Antimicrobial Bio-Nanocomposites. Montmorillonite (MMT), Ag/AgO, ZnO/ZnO_2, TiO_2, and SiO_2 and biodegradable polymers including PLA, polyhydroxylbutyrate (PHB), polybutylene succinate (PBS), polyvinyl alcohol (PVA), and poly-caprolactone (PCL), Clay and silicate-based bio-nanocomposites, biopolymer-based bio-nanocomposites, metallic-based bio-nanocomposites, nano cellulose-based bio-nanocomposites, and layered double hydroxide-based bio-nanocomposites. Natural bio-polymers, fungal mycelium, and agricultural byproducts are engineered into sustainable insulation panels and structural elements. Fungal mycelium, and agricultural byproducts as sustainable insulation panels and structural elements

Unit III: Plant based value added products 7 Hours

Hydroponics farming- Importance and relevance of Hydroponics in urban farming: Advantages of hydroponic farming System: Types of Hydroponic Systems: AI-Driven Hydroponics: Factors affecting plant growth and development in hydroponics system: Effect of Nutrients in Hydroponics and its Importance: Advantages of hydroponic smart farming: A sustainable hydroponics approach to the circular economy: Domotics for indoor cultivation- control tools: Data Acquisition for Cultivation: Remote cultivation: Integration of IoT in Vertical Farming: Aeroponics Technology: Aquaponics: Microgreens, Nutritional Value, methods of growing Rooftop Gardens: Nature based purifiers. Bioink, biodetergent and biocontrol agents. Extraction of Carotenoids from Pumpkin Peel and Pulp. Plant based value added nutritional, edible and medicinal products

Unit IV: Chemicals & Cleaning and construction material 8 Hours

Biowaste Valorization: Transforming agricultural, industrial, and municipal waste into high-value biochemicals, biomaterials, Scaling sustainable technologies for biofuel production (such as biodiesel, bioethanol, and biogas), biorefinery processes. Environmental footprints of bio-based processes. Incorporating artificial intelligence, machine learning, and synthetic biology to optimize bioprocesses and accelerate climate action. Organic waste to carbon-rich biochar for water filtration, soil improvement, and concrete additives. Anaerobic digestion converts organic waste and wastewater into biogas and green electricity. Learning: Intelligent algorithms are deployed to predict biomass yields, monitor resource management, and optimize bioprocesses. Biofertilizers, Cultivation systems and photogranules for wastewater treatment, carbon capture, and production of advanced biofuels. Bioelectrochemical Systems: Processes like microbial electrosynthesis turn light-driven bioprocesses into functional energy and materials. Natural fibers (hemp, flax, bamboo) and bio-based adhesives for manufacture eco-efficient insulation boards, low-carbon building materials. biolubricants and plant-based industrial enzymes that allow detergents to work at lower temperatures.

Practicals (15 x 4= 60 hrs.)

1. Extracting starches from potatoes or corn and combining them with plasticizers (like glycerol) and crosslinkers to cast flexible, biodegradable packaging films
2. Cultivating bacteria (such as *Cupriavidus necator*) to synthesize Polyhydroxyalkanoates (PHAs) as an energy storage, followed by extracting and purifying the polymer using solvents like chloroform.
3. Crosslinking sodium alginate with calcium chloride to form beads or scaffolds used in drug delivery or agricultural water retention.

4. Testing the tensile strength, elongation at break, and Young's modulus of biobased films using a texture analyzer to see how they compare to traditional plastics
5. Submerging biopolymer films in enzyme solutions (e.g., amylase for starch, cellulase for cellulose) to track the breakdown of the polymer matrix over time.
6. Extracting essential oils from plant materials or pigments (like anthocyanins) from food waste, and incorporating them into biobased films to give them antimicrobial or antioxidant properties
7. Testing biomass for moisture content, volatile matter, fixed carbon, and ash.
8. Using a bomb calorimeter to measure the higher heating value (calorific value) of solid bio-wastes.
9. Thermally converting biomass into bio-oil and bio-char in a reactor at high temperatures
10. Assaying enzymes like amylase or cellulase to determine optimum pH and temperature for breaking down plant matter.
11. Constructing lab-scale MFCs to extract biochemical energy directly from biomass into electricity.
12. Cultivating specific fungi or bacteria to produce bioethanol or platform chemicals
13. Testing water samples for Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), and heavy metals
14. Designing or simulating bio-aided filtration systems to clean up contaminated water using algae or plant-based wetlands.
15. Using Gas Chromatography (GC) or High-Performance Liquid Chromatography (HPLC) to analyze and quantify bio-oil compositions or sugar concentrations.

Suggested Readings

1. Gronau N., Mϋller C., Uslar M., 2004. The KMDL Knowledge Management Approach: Integrating knowledge conversions and business process modeling in practical aspects of knowledge management. In: Karagiannis, D., Reimer, U. (Eds.), Proceedings of the 5th International Conference on Practical Aspects of Knowledge Management (PAKM), Vienna Austria, December 2004. Springer.
2. Innovating for Sustainable Growth, 2012: Bioeconomy for Europe Publication Office of the European Office, Luxembourg.
3. Zhao L 2025. Research and Applications of Bio-based Degradable Materials. Springer Singapore .
4. Jingjun G. 2007. Study on the properties and fiber preparation of biodegradable polyester polybutylene succinate (PBS) and polyterephthalate-co-butylene succinate (PBST). Donghua University, Shanghai
5. El-Halwagi MM. 2013. Conserving Material Resources through Process Integration: Material Conservation Networks Woodhead Publishing Limited

Additional Reading

64

1. China Chemical Fiber Industry Association (2018) Analysis and forecast of China's chemical fiber economic situation in 2018. China Textile University Press, Beijing

2. Guoqiang C, Daixu W (2014) Microbial polyhydroxyalkanoates. Chemical Industry Press, Beijing

3. Perego G, Cella GD (2010) Poly(lactic acid): synthesis, structures, properties, processing, and applications. Poly(Lactic Acid)

4. Bastiaens, L , Van Roy S, Thomassen,G Elst K. 2017. Biorefinery of Algae Elsevier Ltd.

5. Birner R 2018. Bioeconomy Concepts Springer, Berlin Heidelberg , pp. 17-38

6. Corrado, S., . Sala S, 2018. Designing Sustainable Technologies, Products and Policies Springer International Publishing

7. Raman,JK. Gnansounou E. 2017. Life Cycle Assessment of Vetiver-Based Biorefinery With Production of Bioethanol and Furfural Elsevier B.V (2017)

8. Vaskan, P., Pachón, E.R., Gnansounou, E. 2017. Life Cycle Assessment of Sugar Crops and Starch-Based Integrated Biorefineries.

9. Venkata Mohan S. 2014. Reorienting Waste Remediation Towards Harnessing Bioenergy: A Paradigm Shift Elsevier Ltd

10. Auras R, Lim LT, Selke S et al (2011) Poly (lactic acid): synthesis, structures, properties, processing, and applications. Wiley

11. Goosen MFA (1997) Applications of chitin and chitosans. Lancaster, p 297

12. Ahmed S and Annu 2023. Advanced Applications of Biobased Materials. Food, Biomedical, and Environmental Applications. 978-0-323-91677-6. **DOI:** 10.1016/C2021-0-00411-9

65

SKILL-BASED COURSE-04

Bioprospection of Natural Resources

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		
Bioprospection of Natural Resources SBC-04	2	1	0	1	Graduate with Botany as one of the subjects	Nil

Course Objectives

- To understand the importance of plants and microorganisms to discover beneficial products.
- To explore sustainable strategies for plant resource management.
- To evaluate plant-based innovations contributing to a green economy.
- To develop critical thinking on future challenges.

Learning outcomes

Students will be learning:

1. Concepts, scope and significance of plant bioprospecting and microbial based natural products.
2. Utilization and sustainable management of plant resources to discover useful natural products.
3. Role of natural resources in food and feed security and ecosystem sustainability.
4. Knowledge and practical skills related to plant-based solutions for a sustainable future.

Theory **(15 X 1= 15 hours)**

Unit I **4 Hours**

Resources and the collection of resources (plants, animals and all living organisms, including bacteria and fungi) for commercialization. Collection of traditional knowledge relating to the use of resources. Keeping, breeding, cultivation, trading and use for the purpose of development and production of drugs, food flavours, fragrances, cosmetics, colours, extracts, other biochemical compounds. timber and fibre from trees, lac from lac-producing insects, starch and other polysaccharides from the plants are available from the forest.

66

Unit II 4 hours

Endophytic microbial products, Anticancer agents, Antioxidants, Immunosuppressive, antidiabetic, antiviral and insecticidal agents, Drugs of plant origin, Plants with promising anti-infective activity, Plant/ plant products for pest management,

Unit III **4 hours**

Nutritional, socio-economic and ecological values of entomophagy, Need for linking entomophagy with food security system and conservation, Exploiting variation in marine organisms, Marine biofouling, Ecology, biomimetics and bio-inspired design, Wood, Adhesives, Photonics, Cryoprotectants, Biomineralization, Microorganisms (extremophiles), to yield resilient enzymes, detergents.

Unit IV **3 hours**

Ethical & Legal Frameworks**:** Convention on Biological Diversity (CBD) to prevent **biopiracy**—the unauthorized use of indigenous knowledge and resources for corporate profit, Regulating wild harvests, Economic awareness: ecosystem products and services, natural resistance genes and botanical compounds to develop sustainable, eco-friendly biopesticides

Practicals **(15 X 2= 30 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Study of economically valuable seaweeds/macrophytes.
2. Selection of seaweeds/macrophytes suitable for food and feed development.
3. Cultivation of selected macrophytes/seaweed species.
4. Qualitative proximate analysis of nutritional components of macrophytes/seaweeds.
5. Evaluation of plant extracts for the presence of biologically active secondary metabolites.
6. Extraction of essential oil using the Clevenger Apparatus.
7. Cultivation and assessment of selected microorganisms for enzyme production.
8. Cultivation of microorganisms for the production of bioactive peptides.
9. Determination of nutritional properties of mushrooms.
10. Separation and identification of bioactive compounds by TLC.
11. Biosynthesis of nanoparticles.
12. Biofertilizers
13. Visit to a bioprospecting laboratory, research institution, or related industry

Suggested readings

1. Raven Capello (2024). Macrophytes: Biodiversity, Role in Aquatic Ecosystems and Management Strategies. Nova Science Pub Inc.
2. Kumar S, Bauddh K, Singh R, Kumar N, Kumar R (2023). Aquatic Macrophytes: Ecology, Functions and Services. Springer Singapore.

67

3. Dinabandhu Sahoo (2000). Farming the Ocean: Seaweeds Cultivation and Utilization. Aravali Books International (P) Ltd. New Delhi.
4. Fatih Ozogul, Monica Trif and Alexandru Rusu (2024). Seaweeds and Seaweed-Derived Compounds: Meeting the Growing Need for Healthy Biologically Active Compounds. Springer.
5. Upadhyay, Santosh Kumar, and Sudhir Pratap Singh, eds. (2021) Bioprospecting of plant biodiversity for industrial molecules. John Wiley & Sons.

Additional readings

1. Angelo Troia (2023). Macrophytes in Inland Water: From Knowledge to Management. MPDI Publications
2. Sharangi, Amit Baran, and K. V. Peter, (eds.) (2022) Medicinal plants: Bioprospecting and pharmacognosy. CRC Press.
3. Semih Otles (2012) Methods of Analysis of Food Components, CRC Press.
4. Ambati Ranga Rao, Gokare A. Ravishankar (2022). Sustainable Global Resources of Seaweeds Volume 1: Bioresources, cultivation, trade and multifarious applications. Springer.
5. Tatiana Lobato-de Magalhas, Kevin Murphy, Marinus L. Otte, Eugenio Molina-Navarro (2024). World Atlas of Fresh Water Macrophytes. Springer Chem.
6. Anuradha Kumari (2021). Aquatic macrophytes of North Bihar. Rajesh Publications.

68

GENERIC ELECTIVE - 04

Nature Based Solutions for Sustainable Development

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		
Nature Based Solutions for Sustainable Development GE- 04	**4**	**3**	**1**	**0**	**Graduate in any discipline**	**Nil**

Course Objectives

To understand the impact of urbanization on urban greenery and to learn suitable ways for enhancing urban greens.

Course Learning Outcomes

Students will be learning

1. Importance of nature-based solutions in addressing modern urban planning challenges and enhancing urban well-being.
2. Evaluate major nature-based solutions categories, their benefits, and their suitability across different urban contexts.
3. Ecological design principles to create effective site-level green infrastructure concepts.
4. Navigate policy, regulatory, and governance frameworks that shape nature-based solutions implementation.
5. Engage communities and stakeholders through inclusive strategies that support successful nature-based solutions projects.
6. Assess, measure, and compare nature-based solutions performance using real-world examples to produce a comprehensive, integrated nature-based solution plan.

Theory: (15 X 3= 45 hours)

Unit I: Urban Planning (10 hours)

Uniqueness and significance of urban ecosystem; Concept and scope of urban planning; Benefits (Ecological, Social, Physical; Economic); Types of Urban greens; Government norms and frameworks; Indian and Global Scenario; Urban heat island; Urban sustainability; Climate resilience through green infrastructure and ecosystem services of green planning.

UNIT II: Avenue Trees and Indoor Plants (10 hours)

69

Properties of avenue trees and Indoor plants; their requirement and maintenance; functional benefits in creating green spaces; examples of species suitable for Delhi. Case studies from metro cities.

UNIT III: Plantation site selection in an urban layout **(10 hours)**

Factors influencing site selection; layout planning; role of different government agencies. Examples from metro cities.

UNIT IV: Green solutions for limited spaces **(15 hours)**

Carbon Garden, Urban ecosystem, Mini-Biodiversity Park, Miyawaki forest, vertical gardens, Roof-top gardens: their requirements; maintenance; role in creating green spaces; examples of species suitable for Delhi. Plants for sustainable future.

Tutorials **(15 X 1= 15 hours)**

Tutorials will provide an opportunity for students to discuss issues raised during the lectures.

Suggested readings

1. Urban Greening Guidelines. Town and Country Planning Organization, Government of India, Ministry of Urban Development, 2014.
2. National Mission for a Green India, Draft submitted to Prime Minister's Council on Climate Change, Ministry of Environment and Forests, Government of India, 2010.
3. Guidelines for Greening of Urban Areas and Landscaping, Ministry of Urban Affairs and Poverty Alleviation, Government of India, 2000.
4. Green City Guidelines, Advice for the protection and enhancement of biodiversity in medium to high-density urban developments, UCD Urban Institute. Ireland, 2008.
5. Proceedings of Session Challenges of Urban Green Development, Workshop on Climate Change Mitigation and Energy Use Optimization, International Congress on Urban Green Spaces. New Delhi, 2012.

Additional readings

1. Giudice, B., Novarina, G. and Voghera, A. (2023). Green Infrastructure: Planning Strategies and Environmental Design (The Urban Book Series). Springer.
2. Mell, I. (2019). Green Infrastructure Planning: Reintegrating Landscape in Urban Planning. Lund Humphries Publishers Ltd.
3. Good Practices for Urban Greening, Environment Division of the Social Programs and Sustainable Development Department of the Inter-American Development Bank. Washington, 1997.
4. Guide on Plant Materials for Landscaping in India, Town and Country Planning Organization, Ministry of Works and Housing, 1980.
5. Manual on norms and standards for environment clearance of large construction projects, Ministry of Environment and Forests, Government of India, 2005.

Department of Botany

University of Delhi

M.Sc. One Year Programme

Under

POST-GRADUATE CURRICULAR FRAMEWORK IN BOTANY - 2026

(BASED ON NEP 2020)

(Students opting for one-year M.Sc. Botany program will study courses listed in Semesters I & II)

M.Sc. One year syllabus (w.e.f. July 2026)

STRUCTURE – 2

(PG Curricular Structure with Course work + Research)

POST-GRADUATE CURRICULAR FRAMEWORK IN BOTANY – 2026 (BASED ON NEP 2020) – COURSEWORK + RESEARCH

M.Sc. Botany One Year Programme -Courses structure w.e.f. July 2026

SEMESTER	DSC (4x2=8 credits)	DSE (4x2=8 Credits)	SKILL BASED COURSE/ SPECIALISED LABORATORY (2 Credits)	DISSERTATION	TOTAL CREDITS
I	**DSC-7 Ecology and Environmental Science** **DSC-8 Genetics and Cytogenetics**	**DSE 7** Advanced concepts and methods in Genomics and Proteomics **DSE 8** Advances in Archegoniatae **DSE 9** Molecular interactions of plants with symbionts, pests and pathogens **DSE 10** Recent trends in Plant Systematics **DSE 11** Algae, Environment and Human Welfare **DSE 12** Bioinformatics, Computational Biology and Biostatistics **DSE 13** Functional foods and nutraceuticals **GE 03** Nanobiotechnology	**Nil**	6 credits	22
II	**DSC-9 Plant Cell Biology** **DSC-10 Plant Biotechnology and Resource Applications**	**DSE 14** Reproductive biology of flowering plants **DSE 15** Concepts and advances in Genetics, Genomics and Molecular Breeding **DSE 16** Agricultural Ecology **DSE 17** Molecular Dynamics of the Genome and Developmental Mechanisms **DSE 18** Recent developments in Plant Physiology and Biochemistry **DSE 19** Morphology and anatomy of angiosperms **DSE 20** Fungal Biology **DSE-21** Bio-based applications and Entrepreneurships **GE 04 –** Nature Based Solutions for sustainable development	**Nil**	6 credits	22

Students without dissertation will take 2 DSC; 3 DSE and 1SBC (i.e., 22 credits) and the students with dissertation will take 2 DSC; 2 DSE and Dissertation (i.e., 22 credits).

The following GEs will be offered by the Department for students other than M.Sc. Botany:

GE 03 Nanobiotechnology (To be offered in Semester I)

GE 04 Nature based Solutions for sustainable development (To be offered in Semester II)

Note: Annual Field studies will be undertaken in different agroclimatic zones of India/ Scientific Organizations/ Industries as part of the curriculum in the Courses of DSC 7, DSC 9, DSC 10, DSE 8, DSE 9, DSE 10, DSE 11, DSE 14, DSE 26, and DSE 20. Field excursions are essential to study plant diversity in real context which is not found in Delhi. Excursions develop crucial skills of plant identification and biodiversity assessment and deepen the understanding on plant-pollinator relationships, soil compositions, and microclimate adaptations, environmental management field collection and herbarium techniques, which indoor laboratories cannot replicate. Collection of samples of plant, fungi, microbes, pathogens and soil for the laboratory experiments for the whole year is another main purpose of the field excursions.

Index of courses being offered in ONE YEAR M.Sc. BOTANY PROGRAMME- Semester I & II

One Year M.Sc. Botany Programme - Syllabus w.e.f. July 2026

Semester I

DISCIPLINE SPECIFIC CORE COURSE- 7:

ECOLOGY AND ENVIRONMENTAL 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		
ECOLOGY AND ENVIRONMENTAL SCIENCE DSC - 7	**4**	**2**	**0**	**2**	**Graduate with Botany as one of the subjects**	**Nil**

Course Objectives:

This course aims to introduce the students to the concepts and principles of ecology, biological diversity, conservation, sustainable development, population, community and ecosystem structure and function, application of these concepts to solve environmental problems.

Course Learning Outcomes:

The students will be learning:

1. Limiting factors controlling distribution and growth of organisms.
2. Characteristics of organisms as population, community and ecosystems.
3. Intra- and inter-specific interactions among organisms.
4. Ecosystem functions.
5. Applications of ecological knowledge for the benefit of anthropogenic society.?

Theory **(15 x 2= 30 hrs.)**

Unit I: **(8 hours)**

Environment – the concept and limits; Law of tolerance and Law of Limiting factors, abiotic factors, biotic interactions, biogeographical distributions – ecological equivalents, Phytogeographical classifications and regions of India, The biosphere, biomes and ecological zones, Bioindicators and biomarkers, Environmental pollution and mitigation strategies.

Unit II: **(8 hours)**

Characteristics of population, population size and exponential growth, limits of population growth, population dynamics, life history pattern, fertility rate and age structure, population growth (density dependent and density independent). Metapopulation dynamics, Competition and coexistence, intra-specific interactions, inter specific interactions, scramble and contest competition model, symbiosis, pre-predator interactions.

Unit III: **(7 hours)**

Nature of ecosystem, production, food webs, energy flow through ecosystem, biogeochemical cycles, resilience of ecosystem, ecosystem management. Case studies of climax and disturbed ecosystems. Ecological factors and plant adaptation. Concepts of ecosystem restoration and applications. Biodiversity – assessment, conservation and management, Biodiversity acts and conventions.

Unit IV: **(7 hours)**

Sustainable Development, Natural resource management in changing environment, Molecular ecology and applications in conservation biology, Global climatic patterns and variations over time, climate change and global warming, climate change impact on ecosystems, coping with environmental variations. Environmental Impacts assessment.

Practical **(15 x 4= 60 hours)**

Practical will be based on the theoretical content of the syllabus. A representative list of practical is provided below:

1. To visit natural or polluted water bodies for the collection of water samples, recording the physical properties of water, and studying community composition at the sampling location.
2. Field excursion, biodiversity assessment, sampling techniques, plant and soil sample collection for lab experiments.
3. To test water sample temperature, pH, electrical conductivity, salinity, total dissolved solids, and oxidation reduction potential using specific probes at different depths from the collected water samples.
4. To estimated dissolved oxygen in freshly collected water samples from various sources using Winkler's method (Iodometric titration).
5. To estimation of dissolved oxygen in various water samples containing organic matter using modified Winkler's method (Iodometric titration).
6. To estimate net primary productivity (NPP), gross primary productivity (GPP), and respiration of different water bodies using Winkler's method of dissolved oxygen estimation.
7. To determine acidity and alkalinity of water samples by estimating free CO_2, carbonates, bicarbonates, and hydroxides.

8. To estimate phosphorous as orthophosphates in water samples using ammonium molybdenum blue method.
9. To estimate Sulphate Sulphur in water samples using turbidimetric method.
10. To estimate Magnesium and hardness due to Magnesium in water samples using EDTA complexometric titration method
11. To estimate Calcium and hardness due to Calcium in water samples using EDTA complexometric titration method.
12. To estimate Ammonium Nitrogen in water samples using modified Berthelot's reaction.
13. To estimate Nitrate Nitrogen in water samples using salicylic acid.
14. To study the vegetation and community structure of a nearby natural vegetation (species dominance, species richness, and diversity).
15. To study topographic sheets and find out coordinates of particular location, distance between two points, slope of an area, and area of a watershed or given region.
16. Life table analysis of annual, biannual and perennial species.

Suggested Readings:

1. Odum, E.P. (2011). Fundamental of Ecology. 5th Edition. Saunders. ISBN 9780030584145. 613 pages.
2. Sher, A.A. and Molles, M.C. (2021). Ecology: Concepts and Applications. 9th Edition. McGraw Hill
3. Morin, P.J. (2011). Community ecology. 2nd Edition. Wiley-Blackwell
4. Bowman, W.D. and Hacker, S.D. (2023). Ecology. 6th Edition. Oxford University Press.
5. Stilling, P. (2014) Ecology: Global insights and investigations. McGraw Hill

Additional readings

1. Real, L.A. and Brown, J.H. (Eds.) (1991). Foundations of Ecology: Classic Papers with Commentaries. The University of Chicago Press. ISBN-10 0-226-70594-3. 904 pages.
2. Chapman, J.L. and Reiss, M.J. (2003). Ecology: Principles and Applications. Second Edition. Cambridge University Press, UK. ISBN 0 521 58802 2. 335 pages.
3. Singh, J.S., Singh, S.P. and Gupta, S.R. (2006). Ecology, Environment & Resource Conservation. Anamaya Publishers. ISBN 978 8188342556. 688 pages.
4. Smith, T.M. and Smith, R.L. (2007). Elements of Ecology. 6th Edition. Pearson Education
5. Krebs, C.J. (2009). Ecology. 6th Edition. Pearson.
6. Raven, P.H. Berg, L.R. and Hassenzahl, D.M. (2008). Environment. 6th Edition. Wiley.
7. Cunningham, W.P. and Cunningham, M.A. (2017). Environmental Science: A Global Concern. 14th Edition. McGraw Hill
8. Freeland, J.R., Kirk H. and Petersen, S.D. (2011). Molecular Ecology. Wiley. 449 pages.
9. IPCC. 4th and 6th Assessment reports. https://www.ipcc.ch/reports/
10. UNFCCC. Conference of Parties (COP). https://unfccc.int/

DISCIPLINE SPECIFIC CORE COURSE -8

Genetics and Cytogenetics

CREDIT DISTRIBUTION, ELIGIBILITY AND PRE-REQUISITES OF THE COURSE

Course title & Code	Credits	Credit distribution of the co urse			Eligibility criteria	Pre-requisite of the course (if any)
		Lecture	Tutorial	Practical/ Practice		
Genetics and Cytogenetics DSC-8	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

The paper will deal with Mendelian and non-Mendelian inheritance, quantitative genetics, molecular markers and linkage mapping, prokaryotic and eukaryotic genome-structure, gene function and regulation, epigenetics and cytogenetics.

Course Learning Outcomes:

Students will be provided understanding of

1. Inheritance of qualitative and quantitative traits. - allelic and genotypic frequencies and their partitioning between and among populations. - Factors governing the genetic structure of populations: significance, implications and applications.
2. Mapping genes in bacteria - functional allelism - gene regulation in prokaryotes: the components and the mechanisms.
3. The structure and organization of different components of the eukaryotic genomes. - repetitive elements and transposons: types and their significance. the different levels at which gene regulation occurs in a eukaryotic cell. - the various components and mechanisms involved.
4. The use of linkage and recombination frequencies to map genes. - Molecular markers, types, development and applications.
5. Morphology of chromosomes and its relevance in genetics. - chromosomal aberrations and their role in genome evolution with special reference to crop plants. - evolution of sex chromosomes and their role in sex determination.
6. Use of cytogenetic and molecular tools for genome analysis.

7. The basic concepts of epigenetics, the underlying mechanism and inheritance of the epigenetic modifications. - the tools to study epigenetics.

Theory: **(15 x 2= 30 hours)**

Unit I: Introduction to Genetic concepts **(5 hours)**

Mendelian vs. non-Mendelian inheritance, concept of genetic distance, linkage and crossing over, introduction to genetic mapping; two-point, three-point crosses. Bacterial genetics, fine structure of gene, test for functional allelism. Introduction to quantitative and population genetics.

Unit II: Genome organization **(6 hours)**

Eukaryotic genome, components- repeat elements, transposons, organization and evolution.

Unit III: Gene regulation **(12 hours)**

Prokaryotic and eukaryotic gene regulation- operons (lactose, tryptophan and arabinose) genetic switches, CRISPR-cas, sigma factors, small RNAs. *Cis*- and *trans*- regulation: promoters, transcription factors, post-transcriptional regulation, role of chromatin and its higher order structure. Applications of CRISPR-Cas in genome editing and gene regulation.

Unit IV: Cytogenetics and Epigenetics **(7 hours)**

Chromosome: structure and nomenclature, centromere and telomere; Sex determination mechanisms, sex chromosome, chromosomal aberrations. Molecular cytogenetics: methods and applications. Introduction, methylation, histone modifications, epialleles; their inheritance and role in regulation. Tools to study epigenetics.

Practicals: **(15 X 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Study of mitosis (onion root tip) and meiosis (onion or *Rhoeo* buds)
2. Isolation of genomic DNA from plant samples
3. Qualitative and quantitative analysis of genomic DNA
4. Karyotype analysis
5. Study of chromosome banding and aberrations
6. Handling and culturing of *Drosophila* flies
7. Isolation and preparation of polytene chromosomes from *Drosophila*
8. Identification and analysis of different *Drosophila* mutants

9. Genetics problems based on linkage, deletion mapping, bacterial chromosome mapping
10. Designing of PCR primers for developing gene specific markers
11. Identification of DNA polymorphism using PCR based DNA markers (Intron polymorphism/ SSRs)
12. Designing of sgRNA for CRISPR-based genome editing

Suggested Readings:

1. Russel P. J. (2010). iGenetics-A Molecular Approach, Pearson Education Inc.

2. Gardner E. J., Simmons M. J., Snustad D. P. (1991). Principles of Genetics, John Wiley & Sons.

3. Strickberger M.W. (2008). Genetics, Pearson (Prentice Hall).

4. Acquaah G (2007). Principles of Plant Genetics and Breeding, Blackwell Publishing Ltd. USA.

5. Allard R. W. (1999). Principles of Plant Breeding, John Wiley and Sons.

Additional Readings:

1. Singh R. J. (2002). Plant Cytogenetics, CRC Press.
2. Hartwell L. H., Hood L., Goldberg M. L., Reynolds A. E., Silver L. M., Veres R. C. (2006). Genetics-From Genes to Genomes, McGraw Hill
3. Lewin B. (2008). Genes IX, Jones and Barlett Publishers. 9. Hartl D. L. and Jones E. W. (2007). Genetics-Analysis of Genes and Genomes, Jones and Barlett publishers.

DISCIPLINE SPECIFIC ELECTIVE- 7:

Advanced concepts and methods in Genomics and Proteomics

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		
Advanced concepts and methods in Genomics and Proteomics DSE- 07	**4**	**2**	**0**	**2**	**Graduate with Botany as one of the subjects**	**Nil**

Course Objectives:

This course aims to provide a knowledge to modern *omics* approaches by integrating genome-wide and proteome-wide analysis with functional genomics. It aim to have an understanding of genome sequencing strategies, high-throughput sequencing technologies, sequence alignment, gene annotation, and methods for studying differential gene expression. The course will emphasize forward and reverse genetic approaches, including gene tagging, promoter trapping, and knockout/knockdown mutants, to decipher gene function, along with comparative genomics and dynamic modulation of protein structure. Students will also learn the principles of gene silencing, RNA interference (RNAi), small RNA biogenesis, epigenetic regulation, and chromatin-level control. The course will introduce biophysical and biochemical tools, including UV-visible spectroscopy, fluorescence spectroscopy, circular dichroism, and NMR, as well as mass spectrometry-based protein identification (PMF, tandem MS/LC–MS), 2D-PAGE workflows, and database-based protein analysis. Students will explore gel-free proteomics, comparative proteomics, interactomics, protein chips, proteogenomics, and the applications and future potential of protein engineering and omics technologies in biological research.

Course Learning Outcomes:

Student will be learning:

1. Principles of DNA sequencing, Sequencing technologies from classical Sanger methods to next-generation sequencing, including the significance of genomic variations and their applications.
2. Genome-wide gene expression data and evaluate the utility of different expression profiling approaches.
3. Apply concepts of forward and reverse genetics to understand gene function, and interpret how mutant populations can be used to study genome-wide changes in gene expression.

4. Comparative genomics datasets and explain how cross-species comparisons contribute to understanding genome organization and evolution.
5. Mechanisms of transcriptional and post-transcriptional regulation, including genome imprinting, small RNA biogenesis, and heterochromatin formation.
6. Demonstrate an understanding of plant proteomics, including its scope, types, methodologies, limitations, and relevance to biological research.
7. Key tools and techniques in proteome analysis, including biophysical, biochemical, and mass spectrometry–based approaches.
8. Design, plan, and execute a basic proteomics experiment, incorporating appropriate analytical workflows and data interpretation.
9. Applications of proteomic technologies in plant sciences and articulate their broader significance in research, biotechnology, and daily life.

THEORY: (15 X 2= 30 hours)

Unit I- Genomics I: Genome Sequencing and Annotation (7 hours)

Genome sequencing strategies and large-scale sequencing programs; New technologies for high-throughput sequencing; Methods for sequence assembly, alignment, and gene annotation.

Unit II- Genomics II: Gene Expression, Functional Genomics, and Epigenomics (8 hours)

Approaches to analyze differential gene expression: ESTs, SAGE, microarrays and their applications; Concepts of forward and reverse genetics for genome-wide functional screening; Gene tagging, promoter trapping, knockout and knock-down mutants; Dynamic modulation of protein structure and function; Introduction to comparative genomics of model plants and crop species; Introduction to RNAi and gene silencing; Genome imprinting; small RNAs and their biogenesis; Role of small RNAs in heterochromatin formation and gene silencing; Genomic tools to study DNA methylation, histone modifications, and chromatin structure

Unit III- Proteomics I: Protein Analysis and Mass Spectrometry (7 hours)

Protein analysis by biophysical and biochemical methods-Circular dichroism (CD), NMR spectroscopy and UV–visible and fluorescence spectroscopy; Introduction to proteomics: scope, need, types, and tools; Mass spectrometry based protein identification- PMF (Protein Mass Fingerprinting) and Tandem MS/LC–MS; Protein identification and analysis using databases (e.g., ExPASy); Gel-based proteome analysis- Protein extraction and lysis, Resolution on 2D–PAGE, Image acquisition, gel matching, master gel creation, and data analysis

Unit IV- Proteomics II: Advanced Proteomics and Applications (8 hours)

Gel-free proteomics: label-based and label-free methods; Comparative proteomics and interactomics; Protein chips and protein arrays; Proteogenomics; Future directions and applications of proteome analysis

Practicals: **(15 X 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. **Genomic DNA Isolation and Quality Assessment:** Extraction of high-quality genomic DNA from plant tissue and evaluation of purity and integrity using spectrophotometry and agarose gel electrophoresis.
2. **RNA Isolation, cDNA Synthesis and Semiquantitative PCR:** Isolation of total RNA, preparation of first-strand cDNA using reverse transcriptase, and comparison of relative transcript levels using semiquantitative PCR.
3. **Real-Time PCR (qPCR) for Gene Expression Analysis:** Quantitative assessment of gene expression using SYBR Green-based qPCR, including melt curve analysis and basic $\Delta\Delta$Ct calculations.
4. **Primer Design for PCR and qPCR:** In silico design of gene-specific primers for conventional PCR and qPCR using appropriate online tools and evaluation of primer parameters.
5. **Site-Directed Mutagenesis:** Introduction of a defined point mutation or small insertion/deletion into a plasmid by PCR-based mutagenesis and verification by restriction analysis or sequencing (concept/demo if full experiment is not feasible).
6. **Genotyping of Arabidopsis Knockout Mutants (T-DNA Lines):** PCR-based genotyping of *Arabidopsis* T-DNA insertion lines using gene-specific and border primers to distinguish wild-type, heterozygous, and homozygous plants.
7. **Design of CRISPR Guide RNAs (In Silico):** Use of web-based tools (e.g., CHOPCHOP/CRISPR-P) to design guide RNAs for genome editing and evaluation of predicted on-target and off-target sites.
8. **Analysis of Differential Gene Expression (In Silico):** Retrieval and basic analysis of microarray or RNA-seq datasets to identify differentially expressed genes and perform simple functional annotation.
9. **Gateway Cloning:** Recombination-based cloning of a gene of interest into a Gateway destination vector, followed by transformation and screening of recombinant colonies.
10. **Transient Expression in Tobacco (Agroinfiltration):** Introduction of an expression construct into *Nicotiana benthamiana* leaves by Agrobacterium-mediated infiltration and monitoring of transient expression (e.g., visual reporter or documented example).
11. **Protein Extraction and Quantification:** Isolation of soluble protein from plant tissue and estimation of protein concentration using Bradford or BCA assays.
12. **Gel Filtration Chromatography for Desalting:** Use of size-exclusion (gel filtration) chromatography to desalt or perform buffer exchange of a protein sample, followed by assessment of recovery and purity.
13. **Two-Dimensional (2D) Electrophoresis with Differential Staining:** Separation of proteins by IEF followed by SDS–PAGE and visualization using Coomassie, silver, or MS-compatible stains; comparison of staining methods and protein spot patterns.

14. **Western Blotting for Protein Detection:** Resolution of proteins by SDS–PAGE, transfer to membrane, antibody-based detection of a target protein, and interpretation of band intensity and specificity.
15. **Mass Spectrometry Data Interpretation:** Interpretation of provided MS or MS/MS spectra for peptide and protein identification using suitable databases (e.g., Mascot/ExPASy) and discussion of confidence scores and coverage.

Suggested Readings:

1. Brown, T.A. (2017). Genomes 4. CRC Press.
2. Armstrong, L. (2013). Epigenetics. CRC Press.
3. Dale, J.W., Schantz, M.V. and Plant, N. (2011). From Genes to Genomes: Concepts and Applications of DNA Technology. Third edition. John Wiley & Sons, UK.
4. Green, M.R. and Sambrook, J. (2012) Molecular Cloning: A Laboratory Manual. Fourth edition. CSHL Press, USA.
5. Leibler, D.C. (2006). Introduction to Proteomics: tools for the new biology, Humana Press.

Additional Readings:

1. Walker, J.M. (2005). The Proteomics Protocols Handbook, Humana Press, Totowa, New Jersey, USA.

DISCIPLINE SPECIFIC ELECTIVE- 8:

ADVANCES IN ARCHEGONIATAE

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 Archegoniatae DSE 08	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives

This course aims to provide advanced knowledge about the adaptive strategies during land plant diversification, their physiological and molecular innovations, ecological significance, and bioprospecting potential of archegoniate groups (Bryophytes, Pteridophytes, and Gymnosperms).

Course Learning Outcomes

The students will be learning

1. Plant hormones in bryophytes and their role in regulating growth and development.
2. Water and photosynthate conduction mechanisms and interactions with microorganisms across bryophytes, pteridophytes, and gymnosperms.
3. Molecular mechanisms of desiccation tolerance and identify bryophyte and pteridophyte model systems.
4. Habitat-driven developmental responses of fern gametophytes.
5. Environmental conditions required for conifer seed germination, seedling development, and regeneration.

Theory **(15 X 2= 30 hours)**

Unit I: Bryophytes – Evolutionary diversification and Adaptation strategies **(8 hours)**

Spore germination and protonema differentiation; hormonal regulation of gametophyte development; ecological interactions with microorganisms and animals; responses to climate variability; dispersal and colonization patterns; sexual dimorphism; mineral nutrition and substrate dependence; peatland structure and ecological services; desiccation tolerance mechanisms; biotic stress responses and protective metabolites; organismal and ecological emphasis.

Unit II: Pteridophytes – Morphological and Reproductive innovations (8 hours)

Phenology and habitat specificity; xeric adaptations; life-cycle biology and sex expression in gametophytes; polyploidy, apogamy and vegetative reproduction; ecological and economic significance of ferns; biology and applied importance of *Azolla–Anabaena* symbiosis; conservation biology of threatened taxa; evolutionary perspectives on leaf development, vascular differentiation and reproductive structures; classical and ecological themes.

Unit III: Gymnosperms –Ancient Forests and Ecosystem Dynamics (8 hours)

Pollination biology in Coniferales and Gnetales; seed and seedling ecology, including dormancy and regeneration dynamics; nutrient cycling and litter decomposition rates; conifer plantations as seed traps; ecological impacts of large-scale conifer plantations; acclimatization and adaptive responses of conifers to environmental stresses; fire-adapted traits and post-fire recovery mechanisms; conservation and restoration strategies for gymnosperms; ecological and industrial relevance of secondary metabolites; and the impacts of climate change on gymnosperm diversity and ecosystem functioning.

Unit IV: Molecular Blueprints of Archegoniates – Genomes, Development and Stress Biology (6 hours)

Genome sequencing and molecular evolution; comparative and functional genomics of Bryophytes, Pteridophytes and Gymnosperms; model systems—*Physcomitrium patens*, *Marchantia polymorpha*, *Ceratopteris*, *Selaginella*, *Ginkgo biloba*, *Picea abies*; genetic control of developmental cascades and morphogenesis; photoreceptor-mediated photomorphogenesis; molecular and physiological aspects of water conduction and photosynthate transport; habitat-linked developmental responses; molecular mechanisms of desiccation tolerance; drought, cold, salinity and UV-stress adaptation pathways; biotic stress signaling; conservation genetics and population genomics; environmental regulation of germination; micropropagation, somatic embryogenesis, synthetic seed technology and tissue-culture-based conservation tools.

Practical: (15 X 4= 60 hours)

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Comparative morphological analysis of representative taxa of Marchantiophyta.
2. Comparative morphological study of selected moss taxa.
3. Study of adaptation for water conservation in the plant samples
4. Field studies for niche studies, sampling techniques, diversity mapping, collection of plant samples for studies in the lab studies.
5. Determination of water-holding capacity in Bryophytes.

6. Separation and profiling of secondary metabolites in Bryophytes using Thin Layer Chromatography (TLC).
7. Cytological examination of Bryophytes using squash and staining techniques.
8. Taxonomic identification of Bryophyte taxa using diagnostic characters and standard keys.
9. Study and identification of herbarium specimens of Pteridophytes.
10. Microscopic examination of mycorrhizal associations in Pteridophytes.
11. Study of soral arrangement and sporangial patterns in Pteridophytes.
12. Analysis of phytochemical constituents of pteridophytes through Thin Layer Chromatography (TLC).
13. Study of the symbiotic association between *Azolla* and *Anabaena*.
14. Morphological and anatomical examination of sporocarps in aquatic ferns.
15. Anatomical study of stem and leaf tissues in selected Gymnosperm taxa.
16. Observation of pollen types and assessment of pollen germination in Gymnosperms.
17. Study of male and female cones in Gymnosperms, including morphology and developmental stages.

Suggested Readings:

1. Goffinet, B., Shaw, A. J. (Edited) (2008). Bryophyte biology. 2nd ed. – XIV + 565 pp. Cambridge University Press, Cambridge. ISBN 978-0-521-69322-6.

2. Schofield, WB. (1985). Introduction to Bryology. Macmillan. ISBN, 0029496608, 9780029496602.

3. Ranker, T.A. and Haufler, C.H. (2008). Biology and Evolution of Ferns and Lycophytes. Cambridge University Press, Cambridge

4, Bhatnagar, S.P. and Moitra, A. (1996). Gymnosperms. New Age International P Limite. Publishers, New Delhi.

5. Dyer, A.F. (1979). Experimental Biology of Ferns. Academic Press

Additional readings:

Bryophytes

1. Vanderpoorten, A., & Goffinet, B. (2009). *Introduction to Bryophytes.* Cambridge University Press.
2. Oliver, M.J., Velten, J., & Mishler, B.D. (2005). Desiccation tolerance in bryophytes. *Integrative and Comparative Biology*, 45(5), 788–799.
3. Rensing, S.A. (Ed.). (2016). *Genomes and Evolution of Charophytes, Bryophytes, Lycophytes and Ferns.* Advances in Botanical Research, Vol. 78. Academic Press.
4. Cove, D. J., Perroud, P.-F., Charron, A. J., McDaniel, S. F., Khandelwal, A. & Quatrano, R. S. (2009). *The moss Physcomitrella patens: a novel model system for plant development and genomic studies.* **Cold Spring Harbor Protocols**, February 2009 (2009 (2): pdb.emo115). doi:10.1101/pdb.emo115.

5. 3. 4. Dyer, A.F. and Duckett, J.G. (1984). Experimental Biology of Bryophytes. Orlando, Academic Press.

Pteridophytes

1. Fernández, H., Kumar, A. and Revilla, M.A. (eds.) (2011). Working with Ferns: Issues and Applications, Springer Science+Business Media, LLC20
2. Mehlereter, K., Walker, L.A. and Sharpe, J.M. (Eds.) (2010). Fern Ecology. Cambridge University Press, Cambridge
3. Ranker, T.A., & Haufler, C.H. (Eds.). (2008). *Biology and Evolution of Ferns and Lycophytes.* Cambridge University Press.
4. Fernández, H., Kumar A., & Revilla, M.A. (Eds.). (2010). *Working with Ferns: Issues and Applications.* Springer.
5. Plackett, A.R.G., Huang, L., Sanders, H.L., & Langdale, J.A. (2014). High-efficiency stable transformation of the model fern *Ceratopteris richardii* via microparticle bombardment. *Plant Physiology*, 165(1), 3–14.
6. Plackett, A.R.G., Di Stilio, V.S., & Langdale, J.A. (2015). Ferns: The missing link in shoot evolution and development. *Frontiers in Plant Science*, 6, 972.
7. Banks, J.A., et al. (2011). The *Selaginella* genome identifies genetic changes associated with the evolution of vascular plants. *Science*, 332(6032), 960–963.

Gymnosperms

1. Nystedt, B., et al. (2013). The Norway spruce genome sequence and conifer genome evolution. *Nature*, 497, 579–584.
2. Leitch, A.R. & Leitch, I.J. (2012). *Ecological and genetic factors linked to contrasting genome dynamics in seed plants.* New Phytologist, 194(3), 629-646. doi:10.1111/j.1469-8137.2012.04105.x.
3. Ahuja, M.R. & Libby, W.J. (eds.) (1993) *Clonal Forestry I: Genetics and Biotechnology*. Springer-Verlag, Berlin & Heidelberg.
4. Singh, H. (1978). Embryology of Gymnosperms. Encyclopedia of Plant Anatomy. Gebruder Bomtraegro, Berlin.

Molecular, Genomic & Evo-Devo Perspectives

1. Bowman, J.L., et al. (2017). Insights into land plant evolution from the *Marchantia polymorpha* genome. *Cell*, 171(2), 287–304.
2. Wickett, N.J., et al. (2014). Phylotranscriptomic analysis of the origin and early diversification of land plants. *PNAS*, 111(45), E4859–E4868.
3. Lüttge, U., Beck, E., & Bartels, D. (Eds.). (2011). *Plant Desiccation Tolerance.* Springer.
4. Harrison, C.J. (2017). Development and genetics in the evolution of land plant body plans. *Philosophical Transactions of the Royal Society B*, 372(1713), 20150490.
5. Rensing, S.A. (2018). Great moments in evolution: Bryophytes. *Current Opinion in Plant Biology*, 42, 88–95.

DISCIPLINE SPECIFIC ELECTIVE – 9:

Molecular Interactions of Plants with Symbionts, Pathogens and Pests

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		
Molecular Interactions of Plants with Symbionts, Pathogens and Pests DSE-9	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives: This paper aims to introduce various aspects of biochemical and molecular interactions of plants with symbionts, pathogens and pests at an advanced level.

Course Learning Outcomes:

The students will be learning:

1. Concepts, techniques and applications related to the plant interactions with microbes (symbionts and pathogens)
2. Plant responses to biotic components of their environments

Theory: **(15 X 2= 30 hours)**

Unit I: **(4 hours)**
Introduction to biotic interactions of plants. Evolutionary perspectives on host-microbe co-adaptation

Unit II: **(8 hours)**
Recent advances in plant-pathogen interactions: Stages of pathogenesis, Structural and biochemical host defense mechanisms against pathogens and pests, Basal resistance, Non-host resistance, effector triggered responses and immune suppression by pathogens. Distinction between necrotrophic and biotrophic pathogens.

Unit III: (10 hours)

Genetics, genomics and applications: Genetics, genomics and applications: Gene-for-gene concept, Models for perception of effector proteins by plants, Cloning of resistance genes (R genes) and avirulence genes (Avr genes) from plants and pathogens, Genetic engineering for the production of resistance plants to pathogens and pests. Cross talk between SA and JA dependent defence responses.

Unit IV: (8 hours)

Recent advances in symbiotic interactions with plant with special references to mycorrhizae and root nodule symbiosis.

Practicals: (15 X 4= 60 hours)

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Histochemical staining using DAB (3,3'-diaminobenzidine) for hydrogen peroxide or NBT (Nitroblue tetrazolium) for superoxide to visualize oxidative burst (ROS like hydrogen peroxide or superoxide release) by plants upon fungal chitin or effector recognition.
2. Callose deposition assay (Aniline blue staining and Fluorescence microscopy to visualize physical reinforcement of cell walls preventing fungal penetration).
3. Diffusion assay (to detect pectinase/cellulose secreted by fungi to break down fungal cell wall, demonstrating production of virulence factors essential for pathogenesis).
4. Enzyme (Pr1 Protease) assay to study the molecular mechanism by which fungi breach pests.
5. Dual confrontation assay to study mycoparasitism exhibited by pathogenic fungi.
6. Study of mycorrhizal symbiosis/rhizobial-legume symbiosis.
7. Study of necrotrophic and biotrophic pathogens.

Suggested Readings:

1. Strange, R.N. (2003). Introduction to Plant Pathology. John Wiley & Sons, USA.33
2. Dickinson, M. (2003). Molecular Plant Pathology, Bios Scientific Publishers, London.
3. Burchett, S. and Burchett, S. (2018). Plant Pathology. Garland Science, USA
4. Mehrotra, R.S. (2017). Plant Pathology, 3rd Edition, McGraw-Hill Education, New Delhi.
5. Recent and important review articles from scientific journals

DISCIPLINE SPECIFIC ELECTIVE-10:

Recent Trends in Plant Systematics

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		
Recent trends in Plant Systematics DSE-10	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

This course aims to introduce the students to the advanced concepts and principles of taxonomy, evolutionary inference of important morphological characters, biodiversity assessment through field studies in various agroclimatic zones of India, important families of flowering plants, their classification, and role of important characters and application of standard barcode markers in delineating species boundaries.

Course Learning Outcomes:

The students will be learning

1. Principles, historical development, and modern relevance of plant systematics, including species concepts, nomenclature rules, and the role of herbaria and field studies in biodiversity and climate-change research.
2. Morphological characters delineate flowering plants and their classification up to the generic level, and how can this knowledge be applied in biodiversity assessment and conservation.
3. Phylogenetic trees, and how are they used to study evolution, trace traits, and guide conservation efforts?
4. Plant DNA barcoding, and how do standard barcode markers contribute to plant identification, conservation, and the detection of biopiracy or adulteration in herbal drug products.
5. Applications of Next Generation Sequencing in plant systematics?

Theory: **(15 x 2= 30 hours)**

Unit I: Introduction to Advanced Plant Systematics: (8 hours)

Major objectives and applications of systematics; Relevance to society and science. Taxonomic History: Natural systems to cladistics. Species concepts and their evolving interpretations; The role of field studies and herbaria in contemporary research and climate-change studies. Application of nomenclature in herbarium curation, phylogenetic revisions, and taxonomic databases. The plant systematics community: Professional organizations; Work environment; Activities.

Unit II: Introduction to the angiosperms: (8 hours)

General characteristics; Evolutionary history; Basal angiosperms and Magnoliids; Basal monocots; Petaloid monocots; Commelinids; Basal eudicots and Caryophyllids; Superrosids; Superasterids. Classification: The components of classification; Characters and their states; Sources of characters; Evaluation of characters. Systematic evidence: Morphology, Anatomy, and ultrastructure; Embryology; Palynology; Cytology; Phytochemistry.

Unit III: Molecular Systematics: (10 hours)

Plant genomes: nuclear, mitochondrial, chloroplast; Molecular markers; Generating molecular data: restriction site mapping, gene sequencing. Large phylogenies; Introduction to transcriptomic approaches for phylogeny reconstruction and their role in resolving complex plant lineages.

Unit IV: **DNA Barcoding (4 hours)**

Barcoding concept; standard barcode markers: nrDNA, cpDNA, and mtDNA; role of DNA barcoding in plant identification, conservation, and detection of biopiracy or adulteration in herbal drug products. Superbarcoding.

Practicals: (15 x 4= 60 hours)

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. To examine taxonomic literature to understand the rules of nomenclature as per ICNafp.
2. Field studies: Plant collection, herbarium and preservation techniques
3. To study basal angiosperms and magnoliids using morphological characters.
4. To study monocots using morphological characters.
5. To study eudicots using morphological characters.
6. To understand the role of palynology in plant systematics.
7. To understand the role of cytology in plant systematics.
8. To analyze taxonomic data using molecular tools.
9. To interpret large phylogenies using latest tools and software.
10. To interpret transcriptome-based phylogenies using latest tools and software.

11. To understand the role of DNA barcoding using different software.

Suggested Readings:

1. Angiosperm Phylogeny Group (2016). An update of the Angiosperm Phylogeny Group Classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnaean Society 181: 1-20.
2. Pandey, A.K. and Kasana, S. (2021). Plant Systematics. CRC Press / Taylor & Francis, New York, NY.
3. Stuessy, T.F. (2008). Plant Taxonomy: The systematic Evaluation of Comparative Data. Columbia University Press, New York.
4. Pandey, A.K., Choudhary, R.K., Dwivedi, M.D. and Kasana, S. (2024). Plant Molecular Systematics: A Laboratory Manual. Deepika Book Agency, New Delhi.
5. Pandey, A.K., Choudhary, R.K., Dwivedi, M.D. and Kasana, S. (2025). Plant Molecular Systematics. CRC Press / Taylor & Francis, New York, NY.

Additional Readings:

1. Hollingsworth, P.M., Bateman, R.M. and Gornall, R.J. (1999). Molecular Systematics and Plant Evolution. Taylor and Francis, London.
2. Judd. W.S., Campbell, C.S., Kellogg, E.A., Stevens, P.A. and Donoghue, M.J. (2002). Plant Systematics: A Phylogenetic Approach. SinauerAssociaes, Inc., Massachusetts.
3. Patané, J.S.L., Martins, J. and Setubal, J.C. (2018). Phylogenomics. In: Setubal J., Stoye J., Stadler P. (eds) Comparative Genomics. Methods in Molecular Biology, vol 1704. Humana Press, New York, NY.
4. Simpson, M.G. (2006). Plant Systematics. Elsevier, Amsterdam.
5. Cronquist, A. (1981). An Integrated System of Classification of Flowering Plants. Columbia University Press, New York.

DISCIPLINE SPECIFIC ELECTIVE -11:

Algae, Environment and Human Welfare

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		
Algae, Environment and Human Welfare DSE 11	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

The course will deal with the basic and advanced topics in phycology, and phycological research, including the role of algae in the environment and their impact on human welfare, and their potential utilization in biotechnology, bioremediation, and sustainable development.

Course Learning Outcomes:

1. Understand the diversity and ecology of algae
2. Analyze the role of algae in aquatic ecosystems and their impact on environment
3. Evaluate the applications of algae in biotechnology, bioremediation, and human welfare
4. Discuss the challenges and opportunities of algal-based solutions for sustainable development

Theory **(15 X 2= 30 hours)**

Unit I: Introduction to algal world **(6 hours)**

Brief classification on algae, Algal growth in Raceway Ponds and Photobioreactors, Life cycles of important algae from Chlorophyceae, Phaeophyceae and Rhodophyceae, Advances in algal biotechnology.

Unit II: Environment & Energy **(8 hours)**

Phycoremediation of wastewater / heavy metals and pollutants, CO_2 sequestration and climate change mitigation, Algal indicators of water quality and pollution, Ocean afforestation through algae. Biofuels from algae such as Biodiesel, Bioethanol

Unit III: Algae in agriculture, food & nutraceuticals **(7 hours)**

N_2 fixation, assimilation and biofertilization. Seaweed Extracts and Seaweed biostimulants/fertilizers in agriculture. Use of algae as food and food additives. Production of PUFA, various antioxidants & pigments.

Unit IV: Other emerging fields of algae **(9 hours)**

Genetic engineering & mutation of algae. IMTA (Integrated Multi-Trophic Aquaculture), Ecological restoration through artificial reef formation, Algal biopolymer, Algal-concrete, Bioactive compounds from Algae, Advancement in photosynthesis.

Practicals: **(15 X 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Culturing of microalgae using various solid & liquid media
2. Identification of various microalgae from water samples
3. Agar extraction from *Gracilaria*
4. Extraction of algal lipids
5. Carrageenan extraction from *Kappaphycus*
6. Preparation of Seaweed Extract and its application on seed germination
7. Algal isolation & estimation / quantification of various algal pigments
8. Phycoremediation of wastewater through algal culture
9. Herbarium & museum sample specimen preparation
10. To study thallus and reproductive structure of *Gracilaria*
11. To study thallus and reproductive structure of *Kappaphycus*
12. To study thallus and reproductive structure of *Sargassum*
13. To study thallus and reproductive structure of *Ulva* / *Enteromorpha*

Suggested Readings:

1. Sahoo, D. (2000). Farming the ocean: seaweeds cultivation and utilization. 1st edition. Aravali International, New Delhi.
2. Barsanti, L., & Gualtieri, P. (2006). Algae: Anatomy, Biochemistry, and Biotechnology. CRC Press.
3. Borowitzka, M. A., & Moheimani, N. R. (2013). Algae for Biofuels and Energy. Springer.
4. Sahoo, D. and Seckbech, J. (Eds) (2015). The Algae World, 1st edition. Springer, Dordrecht.
5. Lee, R. E. (2018). Phycology. Cambridge University Press.
6. Sahoo, D. (2010). Common seaweeds of India. I.K. International Publishing House Pvt. Ltd. New Delhi.
7. Levine, I.A. & Sahoo, D. (2010). Porphyra: Harvesting gold from the sea. I.K. International Publishing House Pvt. Ltd. New Delhi.

DISCIPLINE SPECIFIC ELECTIVE– 12:

Bioinformatics, Computational Biology and Biostatistics

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		
Bioinformatics, Computational Biology and Biostatistics DSE - 12	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

This course has a strong interdisciplinary component and is designed to equip students with essential skills in bioinformatics (at basic and advanced levels). It will introduce applications of computational biology in diverse areas of biological sciences and provide training in the use of statistics in biological sciences.

Course Learning Outcomes:

The students will learning:

1. Skills in the use of databases and online tools related to biological data.
2. Developing algorithms and write programs for analysis of biological data using PERL.
3. Next Generation Sequencing (NGS) technologies and analysis of NGS data.
4. Principles of *in silico* drug design and molecular modeling using online tools.
5. Statistical concepts and principles relevant to biological data and their applications.

Theory **(15 x 2= 30 hours)**

Unit I **(12 hours)**

Databases and online tools, Fundamentals of computer programming and algorithm development; Programming in PERL for analysis of nucleotide sequences: development of PERL scripts for analysis of sequence length, nucleotide composition, percent GC, generation of complementary and reverse complement sequences, restriction mapping, melting temperature, homology analysis between sequences, translation of mRNA, codon usage analysis.

Unit II **(12 hours)**

Next Generation Sequencing (NGS) technologies and introduction to NGS data analysis.

Unit III **(6 hours)**

Introduction to *in silico* drug design and molecular modeling.

Unit IV **(10 hours)**

Biostatistics: Conceptual understanding of Statistic and Statistics. Concepts of populations and samples. Types of Data: attributes and variables, discrete & continuous data. Measures of Central Tendency: Mean, mode, median; measures of dispersion and variability. Normal and standard normal distribution. Calculating areas under the normal distribution, tests of normality; z- scores; one sample and two-sample z-test. Confidence Intervals and Hypothesis testing (critical region, level of significance, P-value, concept and rationale of null hypothesis, One- and Two- tailed hypothesis, type-I and type-II errors). Sampling Distributions: t-distribution. One sample t-test; two- (independent and paired) sample t-tests; Chi-square test and its applications.

Practical **(15 x 4= 60 hours)**

A 4-hour lab exercises per week for hands on practical exercises on the subject.

Suggested Readings:

1. Attwood, T.K. and Parry-Smith, D.J. (2004). Introduction to Bioinformatics, Pearson Education (Singapore) Pvt. Ltd.
2. Edwards, D. (Ed.) (2007). Plant Bioinformatics: Methods and Protocols, Humana Press, New Jersey, USA.
3. Kulas, J.T. (2008). SPSS Essential: Managing and Analyzing Social Science Data. John Wiley & Sons, New York.
4. Pagano, M. and Gauvreau, K. (2007). Principles of Biostatistics. Thomson India Edition, New Delhi.
5. Zar, J.H. (2010). Biostatistical analysis. 5th Edition. Prentice Hall

Additional Readings:

1. Schwartz, R., Phoenix, T. and d Foy, B. (2005). Learning Perl (4th edition), O'Reilly & Associates, ISBN: 0-596-10105-8.
2. Dwyer, R.A. (2004). Genomic Perl: From Bioinformatics Basics to Working Code, Cambridge University Press, 1st South Asian Edition.
3. Rosenkrantz, W.A. (2009). Introduction to Probability and Statistics for Science, Engineering and Finance. CRC Press, Boca Raton.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 13:

Functional Foods and Nutraceuticals

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		
Functional Foods and Nutraceuticals DSE 13	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:
This course aims to provide advanced knowledge on production, characterization and application of functional foods and nutraceuticals. Further, the course will provide information of foodomic approaches in functional food development and regulatory aspects related to functional food industry.

Course Learning Outcomes:
The students will be learning:

1. Role of functional foods and nutraceuticals during metabolic disorders.
2. Molecular mechanisms of specific nutraceuticals in relation to its health benefits.
3. Concepts of foodomics approaches applied in plant based functional food production and validation

Theory **(15 x 2= 30 hours)**

Unit I: Functional foods and nutraceuticals **(6 hours)**

Plant based-Functional food, nutraceuticals, and natural health products, Plant based-nutrient-disease relationships - Bioactive ingredients and their metabolic basis, Food derived bioactive metabolites - sources, chemical structure, metabolic aspects and role in prevention of coronary heart diseases, hypertension, diabetes, and obesity. Food Processing techniques for enhancing functionality and bioavailability, Food fortification.

Unit II: Smart Proteins – the next generation alternative **(5 hours)**

Nutritional aspects, Categories (Plant, Fungi and Algae-based, cultivated meat), Importance of smart proteins in modern era, Challenges associated with smart protein production and consumer adoption, Industrial potential of smart proteins (Upscaling, marketing, and entrepreneurial opportunities).

Unit III: Microbial based functional foods - Biotics and fermented functional foods **(8 hours)**

Plant based fermented functional products, Biotransformation of plant based-food bioactives during fermentation, Reduction of antinutritional factors. Health benefits of probiotics, prebiotics, synbiotics, and postbiotics. Diversity of International and Indian Traditional Fermented foods, Interplay between plant-based biomolecules and gut microbiome and its effect on health, Mechanism of action, Functional and Safety aspects, Artificial Gut model for understanding gut microbiome.

Unit IV: Foodomics and computational tools in functional foods and nutraceuticals (7 hours)

Foodomics: Introduction, concepts and scopes, Omics Techniques and computational tools in food research, metagenomics, metabolomics, metatranscriptomics, and peptidomics. Role of computational tools in discovery of novel nutraceuticals and functional food. Challenges and future perspectives. Nutrigenomics: Key concepts, Molecular mechanisms of nutrient-gene interactions.

Unit V: Bioentrepreneurship and Regulatory aspects of functional foods and nutraceuticals (4 hours)

Industrial perspectives and challenges in functional foods, Upscaling, Marketing – Demand and consumer acceptance and readiness, Challenges for marketers at the food-drug interface, Regulatory status and laws governing functional foods and nutraceuticals, Food Safety and Standard Authority of India, European Union - Novel Food Regulations, Japan - Foods of Special Health Use (FOSHU), The Food and Drug Administration (FDA), Bioentrepreneurship.

Practicals (15 x 4= 60 hrs.)

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Assessment of Bile tolerance test of selected lactic acid bacteria.
2. Assessment of acid tolerance test of selected lactic acid bacteria and yeast.
3. Assessment of antioxidant potential of peptides produced on solid state fermentation.
4. Protein extraction and estimation from functional foods.
5. Extraction of functional lipids from microalgae.
6. Production of probiotic and bioactive peptides enriched curd
7. Estimation of flavonoids in green leafy vegetables.
8. Development of functional soybean based functional foods.
9. Extraction and estimation of bioactive compounds from mushroom.
10. Estimation of lactose degradation by this thin layer chromatography.
11. Estimation of free polyphenols in microbially fermented products.

Suggested Readings:

1. Rai AK, Anu A. (2021). Bioactive compounds in Fermented Foods: Health Aspects, CRC Press, USA.ISBN: 9780367136000
2. Li, Y., & Qi, B. (Eds.). (2022). Phytochemicals in soybeans: bioactivity and health benefits. CRC Press.

3. Rai, AK, Singh SP. Sacool CS, C Larroche, Pandey P, (2022). Technologies for production of nutraceuticals and functional food products. Elsevier, USA ISBN: 9780128235065.

4. Farnworth, E. R. T. (2008). Handbook of fermented functional foods. CRC press.

5. Rai, AK. Sirhoi R, Vandenberghe L, Parameswaran P, (2022). 'Microbial enzymes in functional food and health', CRC Press, USA. ISBN: 9781032317564

Additional Readings:

1. Sun, X., & Udenigwe, C. (Eds.). (2025). Bioavailability of Nutraceuticals and Bioactive Compounds. CRC Press.
2. Sirhoi R, Rai AK, Vandenberghe L, Parameswaran B. (2023). Microbial enzymes and metabolites for health and well-being CRC Press, USA. ISBN: 9781003369295

GENERIC ELECTIVE- 03

Nano-Biotechnology

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		
Nano-Biotechnology GE- 03	**4**	**3**	**1**	**0**	**Graduate in any discipline**	**Nil**

Course Objectives

This course aims to introduce the students with the exciting science nano-science and its utilization in life as nanobiotechnology.

Course Learning Outcomes

The students will be learning

1. The properties of nanoparticles and a comparison between bulk and nano.
2. Techniques to analyse different properties of nanoparticles.
3. Types of nano-particles.
4. Synthesis of nano-particles, comparison between green and chemical synthesis.
5. Applications of nano-particles and nano-material in different facets of life.
6. Nnao-toxicity and nano-safety what, why and regulations.

Theory: **(15 X 3= 45 hours)**

Unit I **(4 hours)**

Nanoparticles – Types, Morphology (Shapes), properties of nano-material, comparison with bulk material. Characterization of nano-particles, using techniques-UV-visible spectroscopy, SEM, TEM, DLS Zeta, XRD

Unit II **(4 hours)**

Green and chemical methods for the synthesis of nanoparticles, comparison between the two methods, detailed synthesis of two types of each.

Unit III **(10 hours)**

Nano-machines, biology at the nanoscale with examples like myosin, kinesin and ATPases.

Unit IV **(12 hours)**

Applications of nanomaterials in daily life (water purification, paints, fabric, cosmetics, food) in biomedicine (drug delivery, drug targeting, drugs) and in agriculture (sensors, nano-pesticides, nano-fertilizers, nanopriming). Nano-toxicity and nano-safety.

Suggested Readings:

1. Madhuri Sharon, Maheshwar Sharon, Sunil Pandey and Goldie Oza 2013. Bionanotechnology concepts and applications. Ane books Pvt Ltd , New Delhi .ISBN 978- 93-8116-236-. 389 pages.
2. Tuan vo dinh 2018. Nanotechnology in Biology and medicine : methods, devices and applicationas. CRC press, Taylor and Francis grp, Florida, USA. ISBN 13:978-1-4398-9378-4. 739 Pages.
3. David S. Goodsell 2018 Bio-nanotechnology lessons from nature, Wiley Pvt Ltd, India Edition, ISBN 9788126539362.

Tutorials **(15 X 1= 15 hours)**

Tutorials will provide an opportunity for students to discuss issues raised during the lectures.

Semester II

DISCIPLINE SPECIFIC CORE - 09

Plant Cell 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 Cell Biology DSC-9	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

The objectives of this course are to provide a foundation and understand application-oriented concepts in cellular and acellular entities in plants; architecture of the cell, nucleus and organelles; membranes in prokaryotes and eukaryotes; macromolecules and natural biopolymers; cell division, motility and secretion; advanced techniques in the study of normal and aberrant plant cells

Course Learning Outcomes:

The students will be learning about:

1. Acellular entities including infective particles comprising only protein or RNA, which are parasites of plants and/or animals; the observations/proposals which challenge established dogmas, such as, a cell being the basic unit of life or that higher plants are multicellular rather than supracellular, as well as the current state of knowledge about the plant cell structure and their turn over, starting from cell wall to chromatin, in relation to their functions.
2. What are the components of endo-membrane systems and mechanisms governing intracellular trafficking in plant cells? What are the diverse types and applications of membrane vesicles?
3. What is the role of the plant cytoskeleton and accessory proteins in major cellular processes of plants? What are major constituents of cellular components in plants, their origin, assembly, characteristics and applications?
4. How does cellular organization change in plant tissues that undergo maturation and differentiation under normal and stressed conditions? What are commonly used advanced imaging techniques that can be used to study plant ultrastructure?

Theory (15 x 2= 30 hrs.)

Unit I: Infective Particles, Cell Continuity and Supracellular Organization (6 hours)

Prions and viroids: nature, structure, infectivity, cellular and ultrastructural effects; cell theory and cell body concept, multicellularity and supracellularity in plants and coenocytic systems

Unit II: Cell Wall, Bio-membranes and Cytoplasmic Systems (10 hours)

Cell Wall: temporal and spatial dynamics; structure–function relationships; cell wall biotechnology; Bio-membranes: evolution from PLP model to Dynamically Structured Mosaic Model; membrane domains, lipid rafts, supramolecular lipid–protein assemblies; Cytoplasmic systems: endomembrane organization; organelle architecture; protein sorting; vesicular trafficking networks; ER-Golgi dynamics and stress.

Unit III: Biopolymers and Cytoskeleton (6 hours)

Cytoskeleton: microtubules, microfilaments, intermediate filaments: structure, dynamics, functions; motor proteins and cytoskeletal coordination; cytoskeleton-linked signaling; genomic and proteomic diversity of plant cytoskeletal proteins; applications in agrobiotechnology.

Unit IV: Nuclear Architecture and Cell Cycle (8 hours)

Nuclear architecture: nuclear envelope, nuclear pore complex, nucleocytoplasmic transport; chromosome condensation and packaging; transcription- and replication-linked chromatin states; chromatin remodeling complexes; Cell cycle & cell turnover: mitosis and meiosis; checkpoint control; breakdown of regulation; plant senescence and programmed cell death (PCD).

Practicals (15 x 4= 60 hours)

Practicals will be based on the theoretical content of the syllabus. A representative list of type of practical exercises is provided below:

1. To isolate chloroplast from plant leaves and to measure chlorophyll content as an indicator of photosynthetic activity.

2. To determine the succinate dehydrogenase activity in isolated mitochondria of the given plant material and to check the effect of competitive inhibitor on the enzymatic activity.

3. To separate and compare chlorophylls and carotenoids from control and stress–treated leaves using TLC and relate pigment changes to chloroplast function under stress.

4. To extract total lipids from control and salt-stressed seedlings, separate neutral lipids and phospholipids by TLC, and compare lipid profiles as an indicator of membrane re-modelling under stress.

5. To study structure- function relationships of genes encoding components of the plant cytoskeletons using PCR amplifications and/or histochemical staining with GUS-cytoskeleton (actin) gene fusion constructs

6. Ultra-structures of cell types and organelles in tissues of normal- and diseased plant types

Suggested Readings:

1. Alberts, B., Johnson, A.D., Lewis, J., Morgan, D., Raff, M. and Roberts, K. (2014). Molecular Biology of the Cell. CRC Press, Taylor & Francis Group, USA.; 1464 pages

2. Karp, J.G. (2007) Cell and Molecular Biology. John Wiley & Sons, USA.

3. Brown, T. A. (2017). Genomes 4. CRC Press, Taylor & Francis Group, USA. 524 pages

4. Berk, A., Kaiser, C.A., Lodish, H., Amon, A., Ploegh, H, Bretscher (Author), Monty Krieger, A., Martin, K.C. (Eds). (2016) Molecular Cell Biology. Freeman & Co., USA.

5. Buchanan, B.B., Gruissem, W. and Jones, R.L (2015). Biochemistry and molecular biology of plants. Wiley Publisher; pages: 1264p

DISCIPLINE SPECIFIC CORE COURSE -10:

Plant Biotechnology and Resource Applications

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 Biotechnology and Resource Applications DSC-10	**4**	**2**	**0**	**2**	**Graduate with Botany as one of the subjects**	**Nil**

Course Objectives:

This course would provide students with an understanding of principles and techniques of plant tissue culture, concepts and methods associated with development and analysis of transgenic plants, and their applications in basic and applied research. In addition, students would be exposed to the economic importance and current research paradigms in various categories of commercially cultivated plants.

Course Learning Outcomes:

The students will learning:

1. Concepts, tools and techniques related to *in vitro* propagation of plants.
2. Methods used for genetic transformation of plants, use of *Agrobacterium* as a vector for plant transformation, components of a binary vector system.
3. Case studies related to basic and applied research in plant sciences using transgenic technology.
4. Principles and methods used for phenotypic, genetic and molecular analysis of transgenic plants
5. Uses and current research paradigms in various plants of economic value.

Theory: **(15 X 2= 30 hours)**

Unit I **(6 hours)**

Plant tissue culture – history; concepts of cell differentiation and totipotency; pathways for *in vitro* regeneration: organogenesis, somatic and gametic embryogenesis; protoplast isolation, culture and regeneration; somatic hybridization; Applications: micro-propagation, meristem culture, embryo rescue, synseed production, somaclonal and androclonal variations, cryopreservation and germplasm storage.

Unit II. **(5 hours)**

Principles and methods of genetic transformation – Introduction; direct gene transfer methods: particle bombardment, electroporation, PEG-mediated and floral-dip; marker and reporter genes; *Agrobacterium* biology and biotechnology; plant – *Agrobacterium* interactions; chloroplast transformation.

Unit III **(15 hours)**

Applications of genetic transformation – case studies on use of transgenic technology for basic studies and crop/plant improvement; phenotypic, genetic and molecular analysis of transgenic plants; factors influencing transgene expression levels; transgene silencing; marker-free transgenics; genome editing for crop improvement; environmental, social and legal issues.

Unit IV **(4 hours)**

Plant resource utilization – centres of primary diversity and secondary centres of cultivated plants; crop domestication genes; introduction to current research paradigms in major cereals, oilseeds, legumes, medicinal plants, forest trees, non-alcoholic beverages.

Practicals: **(15 X 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Preparation of different types of plant tissue culture media.
2. Surface sterilization of seeds and their inoculation.
3. Preparation of hypocotyl explants and study of their regeneration response on appropriate media.
4. Tissue culture and propagation of shoot apices and nodal explants.
5. Recursive PCR for construction of a synthetic DNA sequence.
6. SOE-ing PCR for assembly of a gene expression cassette.
7. Inoculation of Agrobacterium cultures.
8. Comparison of morphological features of economically important plants and their common adulterants.
9. Study of economically important plants and their uses.
10. Identification of important forest tree species and assessment of their threat status.
11. Extraction of natural plant dyes.
12. Fibre extraction from commonly available plants.
13. Documentation of plant resources of botanical garden/museum/herbarium.

Suggested Readings:

1. 1 Adrian, S., Nigel, W.S. and Mark, R.F. (2008). Plant Biotechnology: The genetic manipulation of Plants, Oxford University Press.
2. Buchanan, B.B., Gruissem, W. and Jones, R.L. (2015). Biochemistry and Molecular Biology of Plants, John Wiley and Sons Ltd., UK.
3. Butenko, R.G. (2000). Plant Cell Culture, University Press of Pacific.
4. Davies, P.J. (2010). Plant Hormones, Kluwer Academic Publishers, Netherlands.
5. Halford, N. (2006). Plant Biotechnology - Current and future applications of genetically modified crops, John Wiley and Sons, England.

Additional Readings:

1. Kirakosyan, A. and Kaufman, P.B. (2016). Recent Advances in Plant Biotechnology, Springer, UK.
2. Kochhar, S.L. (2016). Economic Botany: A comprehensive study, Fifth edition, Cambridge University Press, NY.
3. Primrose, S.B. and Twyman, R.M. (2016). Principles of Gene Manipulation, 8th edition, John Wiley and Sons Ltd., Chicester, UK.
4. Ricroch, A., Chopra, S. and Fleischer, S.J. (2014). Plant Biotechnology: Experiences and future prospects, Springer International Publishing AG, Springer, Switzerland.
5. Wickens, G.E. (2004). Economic Botany: Principles and Practices, Springer, ISBN 978-0-7923-6781-9.

Research articles and review articles related to the course contents provided by faculty during the course.

DISCIPLINE SPECIFIC ELECTIVE-14:

Reproductive Biology of Flowering Plants

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		
Reproductive Biology of flowering plants DSE-14	**4**	**2**	**0**	**2**	**Graduate with Botany as one of the subjects**	**Nil**

Course Objectives:

Reproductive success among the angiosperms is significantly dependent on the innate biology and immediate ecological conditions of plants. The outcome of reproductive effort may vary among different ecological conditions in the same species. This course is meant to answer how the fitness attributes of plants are influenced by a variety of developmental and ecological constraints.

Course Learning Outcomes

The students will be learning:

1. Proximate causes and consequences of transition in the reproductive attributes of flowering plants
2. Theoretical assumptions, and evidences in the evolution of gender in flowering plants?
3. Accomplishment of male sterility in plants is naturally or artificially, and the use of mechanism in yield improvement.
4. Stages of concealment of ovules in angiosperms
5. Breakdown in self-incompatibility to self-compatibility.
6. Dynamics of plant-pollinator interaction.
7. Breeding system analysis in a plant and relative contribution of selfing and outcrossing
8. Interdependency of development of embryo and endosperm, and their exceptions to this interdependence?
9. Ratio of flowers to fruit and that of ovule to seed .
10. Differentiation of aposporous and sexual modes of reproduction?

Theory: **(15 x 2= 30 hours)**

Unit I: **(8 hours)**

Mechanistic diversity in the reproductive modes of flowering plants; Floral contrivances and outbreeding devices; Molecular regulation of pistil and ovule development; Signal transduction during pollen-pistil interaction and double fertilization; Embryogenesis and embryonic pattern formation.

Unit II: **(7 hours)**

Pollination Ecology: Floral display, attractants and rewards; pollen presentation; foraging behavior of pollinators, applied pollination ecology; Diversity and quantitative estimation of breeding and mating systems; Resource allocation patterns

Unit III: **(8 hours)**

Evolutionary transitions in reproductive attributes: Flower (architecture, colour), Pollination modes; Mating patterns (Self-incompatibility, Self-fertilization); Sexual systems (Dioecy, sex determination mechanisms); Sexual selection and gene-flow patterns; Diaspore dispersal and natural recruitment patterns.

Unit IV: **(7 hours)**

Endosperm Development and Imprinting; Seed development: pattern, regulation of gene expression; Agamospermy and parthenocarpy; Embryo and endosperm culture; Male sterility and its applications for crop improvement.

Practicals: **(15 x 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Screening of ovaries showing apomictic and sexual modes of reproduction in *Cenchrus ciliaris*, using methyl salicylate clearing, DIC and Confocal microscopy.
2. Determination of mating systems using MLTR software.
3. Performing cross-hybridization studies.
4. Demonstration of RNA in situ hybridization technique using slides, micrographs and published papers.
5. Estimation of the stigma receptivity by localizing enzymes and pollen viability
6. Estimation of floral rewards by rapid test methods.
7. Establishing the breeding system by semi-vivo pollination studies, bagging experiments, and computing the pollen:ovule ratio
8. Determining the visual spectrum of flower colour in relation to possible flower visitors.
9. Plant-pollinator network analysis by employing suitable software packages.

10. Anther and ovary culture to demonstrate non-zygotic embryo formation.

Suggested Readings:

1. Barrett, S.C.H. (2008). Major Evolutionary Transitions in Flowering Plant Reproduction. Univ. of Chicago Press.
2. Faegri, K. and van der Pijl, L. (1979). The Principles of Pollination Ecology. Pergamon Press, Oxford. 291 pp.
3. Harder, L.D. and Barrett, S.C.H. (2006). Ecology and Evolution of Flowers, Oxford Univ. Press.
4. O'Neill, S.D. and Roberts, J.A. (2002). Plant Reproduction, Sheffield Academic Press.
5. Raghavan, V. (1997). Molecular Embryology of Flowering Plants, Cambridge Univ. Press.

Additional Readings:

1. Raghavan, V. (2000). Developmental Biology of Flowering Plants, Springer Verlag, New York.
2. Richards, A.J. (1986). Plant Breeding System, George Allen and Unwin, UK.
3. Scott, R.J. and Stead, A.D. (2008). Molecular and Cellular Aspects of Plant Reproduction. Society for Experimental Biology, Seminar Series 55.
4. Shivanna, K.R. (2003). Pollen Biology and Biotechnology. Enfield, New Hampshire, U.S.A.: Science Publishers.
5. Shivanna, K.R. and Johri, B.M. (1985). The Angiosperm Pollen: Structure and Function. New Delhi, India: Wiley-Eastern.
6. Shivanna, K.R. and Rangaswamy, N.S. (1992). Pollen Biology: A Laboratory Manual, Springer Verlag, Berlin
7. Shivanna, K.R. and Tandon, R. (2014). Reproductive Ecology of Flowering Plants: A Manual, Springer

DISCIPLINE SPECIFIC ELECTIVE-15

Concepts and advances in Genetics, Genomics and Molecular 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		
Concepts and advances in Genetics, Genomics and Molecular Breeding DSE-15	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

The paper aims to develop an understanding of the relationship between genetics and genomics. It will also help in comprehending how genomic information is related to chromosomes and its usage in developing tools for genetics and molecular breeding.

Course Learning Outcomes:

The students will be learning:

1) Genetic and molecular basis of domestication in selected taxa. - conservation and effective utilization of existing diversity for crop improvement.
2) Breeding methods employed for different type of crops.
3) Basis of developing different molecular markers systems, and advancements made in post-genomic era.
4) The key concepts and methodologies for construction of linkage maps, mapping of quantitative traits and association mapping.
5) Integrating molecular methods with conventional improvement strategies to accelerate plant breeding.

Theory: (15 x 2= 30 hours)

Unit I: Genetics and genomics of crop domestication (8 hours)

Molecular basis of domestication, domestication syndrome, archaeological and molecular evidence, consequences of domestication, genetic erosion. Case studies: Maize, Coffee, Safflower etc.

Unit II: **Genetic systems and breeding methods** **(5 hours)**
Selection and breeding strategies. Self-incompatibility, male sterility. Genetics and molecular basis of heterosis; Types of heterosis, genetic and molecular basis of inbreeding and heterosis, utilization in crop improvement.

Unit III: **Molecular markers and Genetic maps** **(8 hours)**
Development of molecular markers: trends and progress, NGS-based markers. Applications of molecular markers. Construction of linkage maps, principles and methods, development of mapping populations, high density genetic maps, integration of genetic maps with physical maps.

Unit IV: Molecular breeding and identification of trait loci **(9 hours)**
QTL mapping: principles, methods, estimation of gene effects, fine mapping of QTL. identification of candidate gene/s. Linkage disequilibrium; factors, parameters of estimation. Association mapping; principles, GWAS, genomics selection, Gene tagging, Marker Assisted Selection (MAS), Bulk Segregation Analysis (BSA)**.**

Practicals: **(15 x 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Basics of Linux
2. Quality assessment of short read NGS data using FastQC
3. Genome assembly using MASURCA
4. Isolation of microsatellites using MISA
5. De-novo Transcriptome assembly using TRINITY
6. SNP analysis using GATK pipeline.
7. Genotyping with microsatellite and intron polymorphism markers
8. Linkage analysis with DNA markers
9. Construction of linkage map using program JoinMap4
10. Mapping of trait locus using linkage map
11. Assessment of Genetic diversity
12. Estimating population structure using the software STRUCTURE
13. To study and analyse domestication traits in crop plants
14. To study self-compatibility / incompatibility through manual- / reciprocal crosses
15. To study linkage of molecular markers associated with a trait using bulked-segregant analysis

Suggested Readings:

1. Recent reviews and relevant reading material will be provided to the students for the topics covered in theory as well as in laboratory exercises.
2. Acquaah G (2012). Principles of Plant Genetics and Breeding, Blackwell Publishing Ltd. USA. Print ISBN:9780470664766 |Online ISBN:9781118313718
3. Allard RW (1999). Principles of Plant Breeding (2nd Edition), John Wiley and Sons, ISBN 0471023094, 9780471023098.
4. Hartl and Cochrane (2019). Genetics – Analysis of Genes and Genomes, 9th edition, Jones and Barlett publishers.
5. Jocelyn E. Krebs, Benjamin Lewin, Elliott S. Goldstein, Stephen T. Kilpatrick Jones and Barlett (2014). Lewin's Genes XI. Jones and Barlett Publishers, ISBN. 1449659055, 9781449659059.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 16

Agricultural Ecology

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		
Agricultural Ecology DSE - 16	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

This course aims to introduce the students to the application of concepts and principles of ecology to human managed ecosystems.

Course Learning Outcomes:

The students will be learning

1. The meaning of terms agriculture, domestication and selection.
2. What are the ecological principles that are applicable in managed ecosystems such as agriculture systems?
3. The relationship of domesticated biodiversity with its wild biodiversity?
4. How ecological problems influence the agriculture and human food security?

Theory **(15 x 2= 30 hours)**

Unit I: **(7 hours)**

Agroecology – definitions of terms, scope of the discipline, approaches and viewpoints, domestication, selection and protection of crop plants and farm animals, wild relatives of the crops, ecological experimentation in agriculture.

Unit II: **(8 hours)**

Ecosystem functioning of farming systems – energy and material flows, trophic relations, spatial scales and ecological footprints, organic farming, earth overshoot day, conservative and conventional agriculture, genetically modified organisms and their implications, climate change – agriculture and adaptation mechanisms.

Unit III: **(7 hours)**

Ecological problems of crop cultivation and solutions – pollution, leakage and erosion, land development, diseases, weeds and pests, chemical, biological and ecological control.

Unit IV: **(8 hours)**

Interactions between farming systems and biodiversity – biodiversity in farming systems, landscape fragmentation, relationships and interdependencies of biodiversity within farming systems with outside farming systems. Case studies of farming systems of India.

Practical **(15 x 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Field visits to agricultural fields in Delhi and adjoining areas. Study of agrobiodiversity, microclimatic variables, interaction with farmers about farming practices (preparation of field, irrigation, fertilizers, harvest, storage etc), soil sampling for nutrient analysis from different agricultural systems,
2. Processing of soil samples, homogenization and drying.
3. Field preparation for garden experiment: Plantation of seeds in the prepared seed beds for understanding land equivalent ratio (Monocropping and intercropping), effect of weeding, density and light intensity on economic and biological yield.
4. Seed viability test, germination experiment and determination of Mean germination time (MGT) for different crop species.
5. Determination of mean seed weight, seed viability, and mean germination rate and time for seasonal crop species.
6. Sieving of soil collecting from different agroecosystems and determination of soil moisture, soil pH, electrical conductivity, and salinity using specific probes.
7. To estimate soil organic carbon in different agroecological soil samples using Walkley Black Titration method.
8. To estimate Phosphorous as orthophosphates in different agroecological soil samples using ammonium molybdenum blue method.
9. To estimate Sulphur as Sulphates in different agroecological soil samples using turbidimetric method
10. To estimate extractable Magnesium in different agroecological soil samples using EDTA complexometric titration method
11. To estimate extractable Calcium in different agroecological soil samples using EDTA complexometric titration method.
12. To estimate Ammonium Nitrogen in different agroecological soil samples using modified Berthelot's reaction.

13. Harvest of crops from garden experiment and determining the land equivalent ratio (Monocropping and intercropping), effect of weeding, density and light intensity on economic and biological yield.
14. To estimate Nitrate Nitrogen in different agroecological soil samples using salicylic acid.
15. To study the impact of light and shade environment on plant pigments (chlorophylls and carotenoids).

Suggested Readings:

1. Connor, D.J. Loomis, R.S. and Cassman, K.G. (2011). Crop ecology: Productivity and management in agricultural systems. 2nd Edition. Cambridge University press.
2. Gliessman, S.R. (2015). Agroecology: The Ecology of Sustainable Food Systems. CRC Press. ISBN 978 14398956 10; 978 1439895764, 371pp.
3. Vandermeer, J.H. (2011). The ecology of agroecological systems. Jones and Barlett publishers.
4. Altieri, M.A. (2018). Agroecology: The Science of Sustainable Agriculture. Second Edition. CRC press. ISBN 0429975090, 400pp.
5. Gliessman, S.R. (2014). Field and Laboratory Investigations in Agroecology. Third Edition. CRC Press. ISBN 1498728499. 241pp.

Additional Readings:

1. Wojtkowski, P.A. (2006). Introduction to Agroecology: Principles and Practices. Food Products Press. ISBN-10 1-56022-317-0. 407pp.
2. Alagh, Y.K. (2013). The Future of Indian Agriculture. ISBN 8123767366, ISBN 9788123767369. 220pp.
3. Mazoyer, M. and Roudart, L. (Translated by Membrez, J.H.). (2014). A History of World Agriculture: From the Neolithic Age to the Current Crisis. Monthly Review Press, New York. ISBN 1-58367-121-8. 527pp.

DISCIPLINE SPECIFIC ELECTIVE-17

Molecular Dynamics of the Genome and Developmental Mechanisms

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		
Molecular Dynamics of the Genome and Developmental Mechanisms DSE 17	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

The module introduces a unified view of genome structure and regulatory mechanisms shaping development and adaptation, with emphasis on plants. It covers cellular and molecular processes governing developmental pathways, including epigenetic regulation during vegetative and reproductive phases, and adaptive responses. Relevant insights from non-plant systems will be included when helpful. The course also provides an overview of essential strategies and methods used to study these processes.

Course Learning Outcomes:

The students will be learning:

1. Eukaryotic nuclear and organellar genome, principal mechanisms of genome replication, maintenance, transcriptional regulation of gene expression; fidelity of translational process, and,
2. Role of regulatory RNAs and epigenetics in eukaryotic gene regulation
3. Various factors such as genetic, environmental, and hormones that govern developmental events
4. Cellular processes such as inter-cellular and intra-cellular signal transduction and cross-talks regulating development
5. Cell cycle regulation, including PCD and senescence
6. Molecular and cellular events/processes that regulate meristem development and maintenance; vegetative and reproductive organ development
7. Genetic and molecular elements of epigenetic/chromatin and how chromatin remodeling/epigenetics regulates development and adaptation

Theory: **(15 x 2= 30 hours)**

Unit I: Molecular Biology **(7 hours)**

Eukaryotic nuclear and organellar genome structure and variation; gene promoter architecture-diversity and structure; Replicative machinery of eukaryotic genome-initiation, fidelity, end-replication, Polymerase-structure function relationship; Transcriptional, co-transcriptional, and post-transcriptional machinery and processes; Translational processes and fidelity; RNA surveillance mechanism and Pioneering round of translation; Alternative reading frames and Peptide diversity; small ORFs (sORFs) and Micropeptides (mPIPs)

Unit II. Regulation of development **(8 hours)**

Positional information and Cell fate; morphogenetic gradient; polarity determination; commitment, differentiation; Genetic (molecular), environmental (light, temperature, gravity, etc.), and hormonal regulation and cross-talk during basic development processes
Cell cycle regulation; Cancer v/s plant tumors; Programmed cell death and senescence; Cytoskeleton and signal transduction.

Unit III. Vegetative and reproductive development **(8 hours)**

Comparative account of the organization of shoot and root apical meristems; Regulation of meristem size and maintenance; Tools and strategies to understand development; Organ initiation from root and shoot meristems (root and leaf development).
Transition from vegetative to reproductive phase; Molecular basis of flower development and its regulation; Molecular and hormonal control of fruit and seed development.

Unit IV. Chromatin organization, remodeling, and development **(7 hours)**

Gene regulation via regulatory RNA, and epigenetics; Small RNA as regulatory molecule; Epigenetics-Role of histones and small RNA in chromatin organization; RdDM; paramutations, genomic imprinting; gene dosage; Chromatin remodelling-factors, models and processes; Chromatin state during replication and transcription, and inheritance of epigenetics; Epigenetic regulation of developmental processes (vegetative and reproductive processes; stress responses).

Practicals **(15 x 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. To study gene structure and detect presence of exons-introns
2. To study replication, transcription and translational control using inhibitors on growth of *Saccharomyces cerevisiae* (budding yeast)
3. To study the application of organellar genome as molecular marker through PCR-RFLP

4. To study distribution patterns of biomolecules using histochemical and fluorescent dyes during development and stress
5. To study transcriptional regulation associated with developmental events and stress responses
6. To study hormonal regulation of transcriptional processes and developmental events
7. To study natural variation of developmental traits and analyse patterns of growth through morphometry
8. To generate gene silencing constructs using RNAi / artificial miRNA, and analyse developmental mutants
9. To isolate protoplasts from Arabidopsis leaves and demonstrate protoplast viability via vital staining using fluorescein-diacetate and propidium iodide.
10. To prepare permanent leaf impressions of Arabidopsis wild type and mutant leaves to study the effect of a mutation on stomata density and index.
11. To study the ploidy level of different plant tissues using flow cytometry
12. To study transient gene expression using Agrobacterium infiltration into tobacco leaves.
13. To study the effect of expression of a gene on the expression pattern/localization of another interacting gene/protein through GUS staining in Arabidopsis.
14. To test the effect of a gene’s mutation (Arabidopsis mutant) on seed viability using the 2,3,5-triphenyltetrazolium chloride /TTC seed staining method
15. To study vegetative and reproductive organ developmental events (eg. leaf, ovule, anther)
16. To study various cellular changes during fruit development
17. To study root and shoot apical meristems, including the development of leaf primordia
18. To demonstrate apical dominance and the inhibitory effect of the shoot apex on lateral bud outgrowth

Suggested Readings:

1. Beck, C. (2010). An Introduction to Plant Structure and Development. Cambridge University Press, 465pp.
2. Steeves, T.A. and Sussex, I.M. (1989). Patterns in plant development. Cambridge University Press, 405pp.
3. Inz´e, D. (Ed.) (2007). Cell Cycle Control and Plant Development, Blackwell Publishing Ltd. 394pp.
4. Whitelam, G.C. and Halliday, K.J. (2007). Light and Plant Development. Blackwell Publishing Ltd, 350pp.
5. Meyer, P. (Ed.) (2005). Plant Epigenetic. Blackwell Publishing Ltd. 281pp.

Additional Readings:

1. Gerald Karp, Janet Iwasa, Wallace Marshall (2020) Karp's Cell and Molecular Biology, 9th Edition. John Wiley & Sons, USA.

2. Harvey Lodish, Arnold Berk, Chris A. Kaiser, Monty Krieger, Anthony Bretscher, Hidde Ploegh, Angelika Amon, Matthew P. Scott (2021) Molecular Cell Biology. W.H. Freeman & Company.
3. Leyser, O. and Day, S. (2003). Mechanism in Plant Development. Blackwell Publishing Ltd. 241pp.
4. Timmermans, M. (2010). Plant Development. Academic Press, 480pp.
5. Howell, S.J. (1998). Molecular Genetics of Plant Development. Cambridge University Press, 365pp.
6. Davies, P.J. (ed.) (2010). Plant Hormones: Biosynthesis, Signal Transduction, Action. Springer, Netherlands, 802pp.
7. Karp, J.G. (2007). Cell and Molecular Biology. John Wiley & Sons, USA.
8. Buchanan, B.B., Gruissem, W. and Jones, R.L. (2015). Biochemistry and Molecular Biology of Plants. Wiley Publisher, 1264pp.
9. Research and review articles on relevant topics

DISCIPLINE SPECIFIC ELECTIVE-18

Recent Developments in Plant Physiology and Biochemistry

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		
Recent Developments in Plant Physiology and Biochemistry DSE - 18	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives:

The course will deal with advanced topics on stress physiology, physiology of programmed cell death, seed dormancy, fruit development and ripening.

Course Learning Outcomes:

The students will be learning

1. Abiotic stress signaling, stress tolerance/adaptive physiological and biochemical changes focusing on mechanism (s). They should be in a position to extrapolate this knowledge for creating stress tolerance crops.
2. Redox changes in normal growth and development as well as during stress are important. These redox changes decide the fate of plant. Reactive oxygen species (ROS) and Reactive nitrogen species (RNS) are the main players. Students would be able to understand the biosynthesis of these redox species in biological systems as well as the antioxidative defense and significance of these in various physiological functions.
3. Physiological, molecular and biochemical basis of seed dormancy, fruit development and ripening is an important aspect of plant development, understanding of this process can help in preventing post harvest losses. Student would acquire a detailed understanding of major regulatory (biochemical/molecular) framework for the process.
4. Physiology of plant programmed cell death and senescence, molecular mechanism and physiological changes that a cell undergoes during these processes.

Theory **(15 X 2= 30 hours)**

Unit I: Stress Physiology **(4 hours)**

Freezing, heat, salinity, and heavy metals stresses in plants; plant responses to abiotic stresses, molecular mechanisms of stress tolerance in plants.

Unit II: Oxidative and nitrosative stress and antioxidative strategies **(7 hours)**

Nitrosative and oxidative stress - causes and effects, nitric oxide biosynthesis and metabolism, NO mediated signaling, markers of nitrosative stress, cross talk between ROS and RNS in plants; antioxidants defense mechanism(s) in plants.

Unit III: Programmed cell death (PCD) **(10 hours)**

Concept of PCD and its types in plants during various plant development stages. stress-induced PCD. Senescence as programmed cell death and it characteristics. Leaf and flower senescence. Altered metabolism during senescence and its regulation. The oxidative stress and the anti-oxidative strategies. Hormonal. Environmental, genetic and molecular regulation during cell death processes.

Unit IV: Physiology of seed, fruit development, and ripening **(9 hours)**

Regulation of seed development and maturation, mobilization of food reserves during seed germination, dormancy, stages of fruit development and their regulation, biochemical and related events during fruit ripening in climacteric and non-climacteric fruits, physiology and biochemistry of fruit abscission, post-harvest changes, production of transgenic fruits.

Practical **(15 X 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Estimation of Chlorophyl a, Chlorophyll b and carotenoids in leaves undergoing various stages of senescence
2. Estimation of protease activity in leaves undergoing various stages of senescence.
3. Estimation of superoxide production during PCD/senescence using NBT (nitrobluetetrazolium)
4. Visualization of DNA fragmentation during cell death processes.
5. CAT activity in the leaf samples of plant and determine the stressed and control samples based on the CAT activity comparison
6. Ascorbate peroxidase (APX) activity determination for ROS scavenging potential of plant
7. Quantification of reduced glutathione (GSH) a central antioxidative molecule in leaf samples of plant
8. Demonstration of heavy metals analysis in plant tissue and soil samples
9. Experiment on Seed dormancy, climacteric and non-climacteric fruit determination
10. Measuring electrical conductivity under temperature (high and low) stress and control plants.
11. To measure hydrogen peroxide content in salinity stress.

Suggested Readings:

1. Buchanan, B., Gruissem, G. and Jones, R. (2015). Biochemistry and Molecular Biology of Plants. 2nd Edition, American Society of Plant Physiologists, USA.
2. Davies P J. (2010). Plant Hormones: Biosynthesis, Signal Transduction, Action. 3rd Edition, Kluwer Academic Publisher, Dordrecht, The Netherlands.
3. Jordan, B.R. (2006). The Molecular Biology and Biotechnology of Flowering, 2nd Edition, CAB International, U.K.
4. Nelson, D.L., and Cox, M.M. (2021). *Lehninger Principles of Biochemistry* (8th edition). W.H. Freeman & Co., New York.
5. Taiz, L. and Zeiger, E., Møller, I.M., Murphy, A. (2023) Plant Physiology and Development.. 7th Edition. Sinauer Associates, USA.

Additional Readings:

1. Heldt, H-W. and Piechulla, B. (2024). Plant Biochemistry, 6th Edition. Academic Press, NY.
2. Bhatla, S.C., Lal, M.A. (2024). Plant Physiology, Development and Metabolism. 7th Edition. Springer Nature, Singapore.

DISCIPLINE SPECIFIC ELECTIVE-19

Morphology and Anatomy of Angiosperms

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		
Morphology and Anatomy of Angiosperms DSE-19	**4**	**2**	**0**	**2**	**Graduate with Botany as one of the subjects**	**Nil**

Course Objectives

This course is designed to equip students with skills and mechanisms being discovered in the progressive field of Angiosperm structural biology. Students will gain exposure of important and unique plant structures/their development linked with diverse adaptations, along with biochemical, molecular principles governing them. Emphasis on structures cum developmental mechanism of economically importance plant parts, and specific organs/tissues in plants inhabiting different environments is the course highlight that will bring forth the aspects which are being and can be addressed for crop improvement.

Course Learning Outcomes:

Students will be learning:

1. Diversity in structure and development of cell wall and ergastic substances found in plant cell.
2. Structures involved in physical defense (secretory and non-secretory), mutualistic associations and their developmental mechanisms.
3. Structures and developmental mechanisms that play vital role in angiosperms, including plants like carnivorous plants.
4. Structures associated developmental pathways/mechanisms that allow plants to thrive in different environments.
5. Morphological feature updates and developmental mechanisms associated with structures of economic importance in plants?

Theory: **(15 X 2= 30 hours)**

Unit I: Cellular anatomy **(3 hours)**

Structural diversity and mechanisms behind formation of ergastic substances, cell wall components of plant in different tissues.

Unit II: Unique structures in Angiosperms **(4 hours)**

Morphological variations, developmental mechanism of structures-secretory cum non-secretory structures at macro/micromorphological level in angiosperms (for protection; including wounds), in plants of special categories *viz*. carnivorous plants etc, including structures due to mutualistic associations viz. insects/microbes.

Unit III: Ecological anatomy **(8 hours)**

Case studies on structural adaptations – specific developmental pathways/mechanisms found in plants of different habitat *viz*. hydrophytes, xerophytes (spines etc.), halophytes (salt glands, pnuematophores), epiphytes (surface hairs, aerial roots), climbers/lianas (tendrils, stem secondary growth etc.), tropical plants vs temperate etc. (leaf coloration etc.); general account on structural modifications due to abiotic stress in crop plants.

Unit IV: Economically important plant structures **(15 hours)**

Case studies about structural features, associated molecular and biochemical pathways of development, localization of metabolites in the plant parts of economic importance (such as stem, bark, leaf, root, flowers, fruits, seeds etc.) addressing plants which are starch-sugar yielding (tubers/roots/stem/pulp), oil yielding (seeds/fruits etc.), pulses (legumes seeds etc.), fiber-yielding (surface cum bast fibers etc.), latex yielding (laticifers), timber cum cork yielding (wood, bark), essential oil yielding and spices (ducts, glands etc.), pigment yielding (flower, fruit, leaf), of fumicatory importance (leaves, fruit), horticultural importance: vegetables (fruit shapes etc.), ornamentals (leaf variegation, plant architecture/branching patterns etc.).

Practicals: **(15 x 4= 60 hours)**

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Structural features in model plants (a dicot and a monocot)
2. Field studies, to observe the habitat and plant adaptations
3. Histochemistry Part 1: visible dyes and plant cell component analysis, resin ducts/laticifers content
4. Histochemistry Part 2: Autofluorescent tissues; fluorescent staining of plant tissues
5. Ergastic substances diversity analysis: sectioning, whole mounts
6. Anomalous secondary growth in detail: lianas etc. by sectioning
7. Study of bark types in plants
8. Study of wood types and lignin assay
9. Tissue processing for Anatomy Part 1: embedding/Wax block preparation, leaf clearing
10. Tissue processing for Anatomy Part 2: Permanent slide preparation, double-staining

11. Leaf surface analysis method, SEM basics
12. Pigment characterization/localization from petals of different flowers
13. Study of root/shoot development in seedlings

Suggested Readings:

1. Beck C.B. (2020) An Introduction to Plant Structure and Development: Plant Anatomy for the Twenty-First Century, 2nd Ed. Cambridge University Press.
2. Evert R.F. and Eicchorn S.E. (2005) Esau's Plant Anatomy: meristems, cells, and tissues of the plant body: their structure, function, and development. 3rd Ed. Wiley.
3. Hodson M.J., Bryant J.A. (2012) Functional Biology of Plants. 1st ed. Wiley-Blackwell.
4. Luke (2020) Plant anatomy and morphology: Structure function and development / Fitzgerald. 1st Ed., Callisto, New York.
5. Ottoline Leyser O. and Day S. (2002) Mechanisms in Plant Development. 1st Ed. Wiley-Blackwell.

Additional Readings:

1. Rudall P.J. (2020) Anatomy of Flowering Plants: An Introduction to Structure and Development, 4th Ed. Cambridge University Press.
2. Bowes B.B. and Mauseth J.D. (2008) Plant Structure: A Colour Guide, by, Jones and Bartlett Publishers London: Manson Publishing Ltd.
3. Crang R., Lyons-Sobaski S. and Wise R. (2018) Plant Anatomy: A Concept-Based Approach to the Structure of Seed Plants, 1st ed. Springer

DISCIPLINE SPECIFIC ELECTIVE - 20

Fungal 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		
Fungal Biology DSE 20	2	2	0	2	Graduate in any discipline	Nil

Course Objectives

- To provide an in-depth understanding of fungal biology, ecology and applications.
- To understand the ecological, industrial and sustainable utilization of fungi.
- To study the role of fungi in carbon sequestration and environmental sustainability.
- To explore molecular techniques in fungal identification and phylogeny.
- To understand the use of fungi in biofabrication.
- To understand the role of fungi in bioremediation.
- To develop research skills in mycology through practical and project-based learning.

Course Learning Outcomes:

Students will be learning;

1. Phases of fungal growth and the mechanisms of hyphal extension and branching.
2. Genetic implications of heterokaryosis.
3. Role of specific sex hormones in mediating sexual reproduction in fungi.
4. Potential of emerging antifungal compounds in addressing drug resistance.
5. Health and economic impact of major mycotoxins and propose integrated management strategies for their control.
6. Critical role of fungi in industrial processes.
7. Application of fungi in biofertilizers and biofuel production, bioremediation of pollutants and bio-fabrication of materials.
8. Process of fungal-mediated nanoparticle synthesis.
9. Potential of fungi in carbon sequestration.
10. Ccritical role of fungi in the carbon and nitrogen cycles and the potential impacts of climate change on fungal distribution and ecosystem functioning.

Theory: **(15 X 2= 30 hours)**

Unit 1: Introduction to Fungal Biology **(6 hours)**

Historical development of mycology, Overview of kingdom fungi: Evolution and Phylogeny, Advanced classification systems, Fungal cell structure and ultrastructure, Fungal growth, development, and reproduction, Heterokaryosis and parasexual cycle, Sex hormones in fungi.

Unit 2: Medical and Industrial Mycology (10 hours)

Opportunistic and systemic fungal infections, Invasive mycoses: candidiasis, aspergillosis, mucormycosis, Antifungal agents and emerging compounds, Mycotoxin problems and their management. Fungi in the food industry: Fermentation and enzyme production, Fungi in biofuels, biofertilizers, and bioremediation, Fungi-mediated synthesis of nanoparticles.

Unit 3: Fungal Ecology and Interactions (5 hours)

Fungi in soil and other Ecosystems, Symbiotic associations: Mycorrhizal fungi, Lichens, Endophytes and environmental applications, Role of fungi in biogeochemical cycles, climate change and fungal ecology.

Unit 4: Advanced Techniques and Applications (9 hours)

Microscopy and imaging techniques for fungi, Culture methods of fungal strains, Fungal secondary metabolites, Role of fungi in climate change, carbon sequestration, and in agriculture, Mushrooms cultivation (types, diversity, methods of reproduction, nutritional and medicinal properties of wild and edible mushrooms, products from mushrooms), current research frontiers in mycology.

Practicals (4 X 15= 60 hrs.)

Practicals will be based on the theoretical content of the syllabus. A representative list of practicals is provided below:

1. Isolation and identification of fungal species from specific habitats.
2. Polygenic molecular identification of fungi.
3. Screening of fungal species for the enzymes of industrial importance.
4. Biochemical characterization of enzymes from selected fungal isolates.
5. Preparation of spawn and cultivation of various mushrooms.
6. Biochemical characterization to determine the nutritional values of mushrooms.
7. Use of fungal isolates for the biosynthesis of economically important nanoparticles.

Suggested Readings:

- Introduction to Fungi by Webster & Weber Cambridge University Press in 2007
- The Fungal Kingdom (Joseph Heitman et al. 2017)
- Introductory Mycology (C.J. Alexopoulos, C.W. Mims, and M. Blackwell 2017), Wiley.
- Fungal Biology (J.W. Deacon 2006), Blackwell Publishing Oxford UK.
- Textbook of Fungi and Their Allies (Inderjeet Kaur Sethi and Surinder Kaur Walia 2018), Medtech Scientific International.

Additional Readings:

1. Recent research articles from journals like Fungal diversity, Mycologia, Mycology, Mycological Research, Fungal Genetics and Biology, and Studies in Mycology, The Fungi etc.

DISCIPLINE SPECIFIC ELECTIVE – 21:

Biobased Applications and Entrepreneurships

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		
Biobased Applications and Entrepreneurships DSE-21	4	2	0	2	Graduate with Botany as one of the subjects	Nil

Course Objectives

1. To understand the Carbon Emissions reduction
2. To lean the methods to control plastic pollution by utilizing biodegradable polymers minimizing the accumulation of non-biodegradable plastics
3. To learn the production of biofuel and decrease fossil dependency
4. To have an understanding of converting of organic urban waste into valuable everyday products like textiles, packaging, and fertilizers.
5. Stimulating economic growth and generating skilled employment opportunities, particularly in rural areas.
6. To learn to make natural polymers which offer characteristics such as antimicrobial activity, biocompatibility, and controlled drug delivery.
7. Learning to supply durable, and moisture-resistant materials for sustainable agriculture.

Learning Outcome:

Students shall be learning:

1. Sustainable biomass sourcing, and production systems, with focus on high-value applications and uses and overall resource efficiency
2. Prospecting and sustainably using biological resources

3. Bio-based value chains, materials, including bio-inspired materials, products, services and processes with novel qualities, functionalities and improved sustainability..
4. biotechnology for application in competitive, sustainable and novel industrial processes, environmental services and consumer products;
5. participating in the creation of value, maximising societal impact and public engagement.
6. Increased understanding of the ecological boundaries, metrics and indicators of the environmental sustainability of the bio-based industry, and its synergies and trade-offs with a healthy environment, and with the other sectors of the bioeconomy

Theory **(15 x 2= 30 hours)**

Unit I : Biobased material in Packaging and Textiles: **8 Hours**

Carbohydrate based materials: Chitosan-a biopolymers in food coating and packaging. Amylose and amylopectin in the production of biodegradable bio-plastics. Chitin and cellulose as sources of nanosized reinforcements. Nanocellulosic materials for improving the mechanical, thermal, antimicrobial properties. Nanocrystals and cyclodextrin, alginate, carrageenan, and agar; Protein-Based Materials: protein-based packaging. Gelatin- for the fabrication of biodegradable packaging. Protein-based films, Protein-based bio-nanocomposites suitable for food packaging, gelatin proteins, corn zein, and wheat gluten proteins. Lipid-Based Materials: Lipids for edible films and coatings for food applications, waxes (paraffin, carnauba, beeswax, candelilla, and jojoba), natural resins (chicle, guarana, and olibanum), and emulsifiers and surface-active agents (fatty alcohols, lecithin, and fatty acids), Combination with hydrophilic materials or lamination with a hydrocolloid film lipid layer for improving mechanical properties.

Antibacterial Agents: bacteriocins, ε-polylysine, enzymes, tea polyphenols,), inorganic antibacterial agents (oxidized nanoparticles and metals), and organic synthetic antibacterial agents. Natural antimicrobial peptides-nisin, natamycin, leucocin, enterocin, and pediocin as bio-preservatives. Essential oils with alkaloids, flavonoids, isoflavones, monoterpenes, phenolic acids, carotenoids, and aldehydes. Inorganic antibacterial agents. ZnO, magnesium oxide (MgO), TiO2, and metal oxide nanoparticles (ZnO-NPs, CuO-NPs, TiO2-NPs, SiO2-NPs, Al2O3-NPs, and Ag-NPs), ZnO-NPs for antibacterial process. CuO-NPs as packaging. TiO2 in food packaging materials, cosmetics, and healthcare. SiO2-NPs as a contact surface for food packaging and for generating nonstick coatings for bags, bottles, and jars. Aluminum oxide (Al2O3) coatings for food packaging. Ag-NPs against different pathogenic microorganisms such as viruses, bacteria, and fungi.

Unit II: Organic synthetic polymers **7 Hours**

Organic synthetic polymers- in food packaging, including fermentation-based biopolymers (such as polylactic acid (PLA), polyhydroxyalkanoates (PHA), polyhydroxyvalerate (PHV), poly-b-hydroxyl butyrate (PHB), poly-3-hydroxybutyrate-co-3-hydroxyvalerate (PHBV) and exopolysaccharides (EPS), etc.), and bio-based biopolymers (such as bio-polyethylene (Bio-PE), bio-polyethylene terephthalate (Bio-PET), bio-polypropylene (Bio-PP), etc. Antimicrobial Bio-Nanocomposites. Montmorillonite (MMT), Ag/AgO, ZnO/ZnO2, TiO2, and SiO2 and biodegradable polymers including PLA, polyhydroxylbutyrate (PHB), polybutylene succinate (PBS), polyvinyl alcohol (PVA), and poly-caprolactone (PCL), Clay and silicate-based bio-nanocomposites, biopolymer-based bio-nanocomposites, metallic-based bio-nanocomposites, nano cellulose-based bio-nanocomposites, and layered double hydroxide-based bio-nanocomposites. Natural bio-polymers, fungal mycelium, and agricultural byproducts are engineered into sustainable insulation panels and structural elements. Fungal mycelium, and agricultural byproducts as sustainable insulation panels and structural elements

Unit III: Energy and Environment and Plant based value added products 7 Hours

Hydroponics farming- Importance and relevance of Hydroponics in urban farming: Advantages of hydroponic farming System: Year-Round Crop Production, high Yields and Nutritional Quality and Flavour and pest and Disease Control: Types of Hydroponic Systems: AI-Driven Hydroponics: Factors affecting seed germination and seedling establishment for hydroponics system: effect of support system for plant growth in a hydroponic system: Effect of Nutrients in Hydroponics and its Importance: Advantages of hydroponic smart farming: A sustainable hydroponics approach to the circular economy: Domotics for indoor cultivation- control tools: Data Acquisition for Cultivation: Remote cultivation: Integration of IoT in Vertical Farming: Aeroponics Technology: Aquaponics: Microgreens, Nutritional Value, methods of growing Rooftop Gardens: Nature based purifiers. Bioink, biodetergent and biocontrol agents. Extraction of Carotenoids from Pumpkin Peel and Pulp. Plant based value added nutritional, edible and medicinal products

Unit IV: Chemicals & Cleaning and construction material 8 Hours

Biowaste Valorization: Transforming agricultural, industrial, and municipal waste into high-value biochemicals, biomaterials, Scaling sustainable technologies for biofuel production (such as biodiesel, bioethanol, and biogas), biorefinery processes. Environmental footprints of bio-based processes. Incorporating artificial intelligence, machine learning, and synthetic biology to optimize bioprocesses and accelerate climate action. Organic waste to carbon-rich biochar for water filtration, soil improvement, and concrete additives. Anaerobic digestion converts organic waste and wastewater into biogas and green electricity. Learning: Intelligent algorithms are deployed to predict biomass yields, monitor resource management, and optimize bioprocesses. Biofertilizers, Cultivation systems and photogranules for wastewater treatment, carbon capture, and production of advanced biofuels. Bioelectrochemical Systems: Processes like microbial electrosynthesis turn light-driven bioprocesses into functional energy and materials. Natural fibers (hemp, flax, bamboo) and bio-based adhesives for manufacture eco-efficient insulation boards, low-carbon building materials. biolubricants and plant-based industrial enzymes that allow detergents to work at lower temperatures.

Practicals (15 x 4= 60 hrs.)

1. Extracting starches from potatoes or corn and combining them with plasticizers (like glycerol) and crosslinkers to cast flexible, biodegradable packaging films
2. Cultivating bacteria (such as *Cupriavidus necator*) to synthesize Polyhydroxyalkanoates (PHAs) as an energy storage, followed by extracting and purifying the polymer using solvents like chloroform.

3. Crosslinking sodium alginate with calcium chloride to form beads or scaffolds used in drug delivery or agricultural water retention.

4. Testing the tensile strength, elongation at break, and Young's modulus of biobased films using a texture analyzer to see how they compare to traditional plastics

5. Submerging biopolymer films in enzyme solutions (e.g., amylase for starch, cellulase for cellulose) to track the breakdown of the polymer matrix over time.

6. Extracting essential oils from plant materials or pigments (like anthocyanins) from food waste, and incorporating them into biobased films to give them antimicrobial or antioxidant properties

7. Testing biomass for moisture content, volatile matter, fixed carbon, and ash.

8. Using a bomb calorimeter to measure the higher heating value (calorific value) of solid bio-wastes.

9. Thermally converting biomass into bio-oil and bio-char in a reactor at high temperatures

10. Assaying enzymes like amylase or cellulase to determine optimum pH and temperature for breaking down plant matter.

11. Constructing lab-scale MFCs to extract biochemical energy directly from biomass into electricity.

12. Cultivating specific fungi or bacteria to produce bioethanol or platform chemicals

13. Testing water samples for Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Dissolved Solids (TDS), and heavy metals

14. Designing or simulating bio-aided filtration systems to clean up contaminated water using algae or plant-based wetlands.

15. Using Gas Chromatography (GC) or High-Performance Liquid Chromatography (HPLC) to analyze and quantify bio-oil compositions or sugar concentrations.

Suggested Readings

1. Gronau N., Mϋller C., Uslar M., 2004. The KMDL Knowledge Management Approach: Integrating knowledge conversions and business process modeling in practical aspects of knowledge management. In: Karagiannis, D., Reimer, U. (Eds.), Proceedings of the 5th International Conference on Practical Aspects of Knowledge Management (PAKM), Vienna Austria, December 2004. Springer.
2. Innovating for Sustainable Growth, 2012: Bioeconomy for Europe Publication Office of the European Office, Luxembourg.
3. Zhao L 2025. Research and Applications of Bio-based Degradable Materials. Springer Singapore . https://doi.org/10.1007/978-981-95-1188-4
4. Jingjun G. 2007. Study on the properties and fiber preparation of biodegradable polyester polybutylene succinate (PBS) and polyterephthalate-co-butylene succinate (PBST). Donghua University, Shanghai

5. El-Halwagi MM. 2013. Conserving Material Resources through Process Integration: Material Conservation Networks Woodhead Publishing Limited

Additional Reading

1. China Chemical Fiber Industry Association (2018) Analysis and forecast of China's chemical fiber economic situation in 2018. China Textile University Press, Beijing

2. Guoqiang C, Daixu W (2014) Microbial polyhydroxyalkanoates. Chemical Industry Press, Beijing

3. Perego G, Cella GD (2010) Poly(lactic acid): synthesis, structures, properties, processing, and applications. Poly(Lactic Acid)

4. Bastiaens, L , Van Roy S, Thomassen,G Elst K. 2017. Biorefinery of Algae Elsevier Ltd.

5. Birner R 2018. Bioeconomy Concepts Springer, Berlin Heidelberg , pp. 17-38

6. Corrado, S., . Sala S, 2018. Designing Sustainable Technologies, Products and Policies Springer International Publishing

7. Raman,JK. Gnansounou E. 2017. Life Cycle Assessment of Vetiver-Based Biorefinery With Production of Bioethanol and Furfural Elsevier B.V (2017)

8. Vaskan, P., Pachón, E.R., Gnansounou, E. 2017. Life Cycle Assessment of Sugar Crops and Starch-Based Integrated Biorefineries.

9. Venkata Mohan S. 2014. Reorienting Waste Remediation Towards Harnessing Bioenergy: A Paradigm Shift Elsevier Ltd

10. Auras R, Lim LT, Selke S et al (2011) Poly (lactic acid): synthesis, structures, properties, processing, and applications. Wiley

11. Goosen MFA (1997) Applications of chitin and chitosans. Lancaster, p 297

12. Ahmed S and Annu 2023. Advanced Applications of Biobased Materials. Food, Biomedical, and Environmental Applications. 978-0-323-91677-6. **DOI:** 10.1016/C2021-0-00411-9

GENERIC ELECTIVE - 04

Nature Based Solutions for Sustainable Development

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		
Nature Based Solutions for Sustainable Development GE- 04	4	3	1	0	Graduate in any discipline	Nil

Course Objectives

To understand the impact of urbanization on urban greenery and to learn suitable ways for enhancing urban greens.

Course Learning Outcomes

Students will be learning

1. Importance of nature-based solutions in addressing modern urban planning challenges and enhancing urban well-being.
2. Evaluate major nature-based solutions categories, their benefits, and their suitability across different urban contexts.
3. Ecological design principles to create effective site-level green infrastructure concepts.
4. Navigate policy, regulatory, and governance frameworks that shape nature-based solutions implementation.
5. Engage communities and stakeholders through inclusive strategies that support successful nature-based solutions projects.
6. Assess, measure, and compare nature-based solutions performance using real-world examples to produce a comprehensive, integrated nature-based solution plan.

Theory: (15 X 3= 45 hours)

Unit I: Urban Planning (10 hours)

Uniqueness and significance of urban ecosystem; Concept and scope of urban planning; Benefits (Ecological, Social, Physical; Economic); Types of Urban greens; Government norms and frameworks; Indian and Global Scenario; Urban heat island; Urban sustainability; Climate resilience through green infrastructure and ecosystem services of green planning.

UNIT II: Avenue Trees and Indoor Plants (10 hours)

Properties of avenue trees and Indoor plants; their requirement and maintenance; functional benefits in creating green spaces; examples of species suitable for Delhi. Case studies from metro cities.

UNIT III: Plantation site selection in an urban layout (10 hours)

Factors influencing site selection; layout planning; role of different government agencies. Examples from metro cities.

UNIT IV: Green solutions for limited spaces (15 hours)

Carbon Garden, Urban ecosystem, Mini-Biodiversity Park, Miyawaki forest, vertical gardens, Roof-top gardens: their requirements; maintenance; role in creating green spaces; examples of species suitable for Delhi. Plants for sustainable future.

Tutorials (15 X 1= 15 hours)

Tutorials will provide an opportunity for students to discuss issues raised during the lectures.

Suggested readings

1. Urban Greening Guidelines. Town and Country Planning Organization, Government of India, Ministry of Urban Development, 2014.
2. National Mission for a Green India, Draft submitted to Prime Minister’s Council on Climate Change, Ministry of Environment and Forests, Government of India, 2010.
3. Guidelines for Greening of Urban Areas and Landscaping, Ministry of Urban Affairs and Poverty Alleviation, Government of India, 2000.
4. Green City Guidelines, Advice for the protection and enhancement of biodiversity in medium to high-density urban developments, UCD Urban Institute. Ireland, 2008.
5. Proceedings of Session Challenges of Urban Green Development, Workshop on Climate Change Mitigation and Energy Use Optimization, International Congress on Urban Green Spaces. New Delhi, 2012.

Additional readings

1. Giudice, B., Novarina, G. and Voghera, A. (2023). Green Infrastructure: Planning Strategies and Environmental Design (The Urban Book Series). Springer.
2. Mell, I. (2019). Green Infrastructure Planning: Reintegrating Landscape in Urban Planning. Lund Humphries Publishers Ltd.
3. Good Practices for Urban Greening, Environment Division of the Social Programs and Sustainable Development Department of the Inter-American Development Bank. Washington, 1997.
4. Guide on Plant Materials for Landscaping in India, Town and Country Planning Organization, Ministry of Works and Housing, 1980.
5. Manual on norms and standards for environment clearance of large construction projects, Ministry of Environment and Forests, Government of India, 2005.