Minutes of the 19th Meeting of the Board of Studies of Department of Botany Central University of Jammu

Venue: Office of Head, Department of Botany, CUJ

Date: Friday, 31st January, 2025

Time: 12:30 PM

19th meeting of the Board of Studies, Department of Botany, Central University of Jammu was held on 31st January, 2025 in the office of Head of the Department at 12.30 PM. Following members attended the meeting:

S. No.	Name of the member	Affiliation
1.	Dr. Yogesh Kumar (Chairperson and HOD)	Head, Dept. of Botany, CUJ
2.	Prof. Namrata Sharma (External Expert)	Professor, Dept. of Botany, University of Jammu
3.	Prof. B.S. Bhau (Member)	Professor, Dept. of Botany, CUJ
4.	Prof. Suram Singh (Special Invitee)	Dean Academics, CUJ
5.	Dr. Deepak Bhardwaj (Member)	Associate Professor, Dept. of Botany, CUJ
6.	Dr. Ashok Kumar (Member)	Assistant Professor, Dept. of Botany, CUJ
7.	Dr. Vikas Srivastava (Special Invitee)	Assistant Professor, Dept. of Botany, CUJ
8.	Dr. Sapna Devi (Special Invitee)	Assistant Professor, Dept. of Botany, CUJ

Prof. Uday Pratap Singh (Associate Dean, Academics) was invited to attend the meeting but was unable to do so as he was on leave.

Dr. Shweta Yadav (Member), Assistant Professor, Department of Environmental Studies, CUJ, was also on leave and could not attend the meeting.

1. **Opening remarks by the Chair.**

   Dr. Yogesh Kumar, Head of Department and Chairperson, welcomed all the members and expressed his gratitude for their presence at the meeting.

2. **To consider and approve course contents for Core Courses and Skill Enhancement Courses (SECs) under New Education Policy for VII to X semester of Integrated B.Sc. - M.Sc. Botany programme.**

   The Board reviewed and approved the course structures and contents for the Core Courses and Skill Enhancement Courses (SECs) for students in the VII to X semesters of the Integrated B.Sc. - M.Sc. Botany program under the New Education Policy from Academic Session 2025-26 onwards.

   As per the NEP guidelines, students with a CGPA of 7.5 or higher will have the option to pursue a four-year undergraduate degree with research. However, students with a CGPA below 7.5 will be required to complete the five-year Integrated program. The board has approved the respective course structures for semesters VII and VIII of the four-year UG degree with research, as well as semesters VII to X of the five-year Integrated program, with detailed course contents provided in Annexure-I, as follows:

Four-year B.Sc. Botany with Research

Semester VII

Course Title	**Category**	**Course Type**	**Credits**	**L**	**T**	**P**
Mycology and Phytopathology	Core	Theory + Lab (3+1)	4	3	0	2
Phycology, Bryology and Pteridology	Core	Theory + Lab (3+1)	4	3	0	2
Molecular Cell Biology	Core	Theory + Lab (3+1)	4	3	0	2
Dissertation Part-I	Dissertation	Dissertation	2	-	-	-
# Open Elective Courses (Disciplinary/interdisciplinary minors)			8	-	-	-
		Total	**22**	-	-	-

The student must earn a minimum of 22 credits during Semester VII. In addition to three core courses of 4 credits each (comprising 3 credits for theory and 1 credit for lab) and 2 credits for Dissertation Part-I, the student must earn 8 additional credits from the open elective basket offered by the Department, other Departments, or through MOOC courses on the SWAYAM platform.

Semester VIII

Course Title	**Category**	**Course Type**	**Credits**	**L**	**T**	**P**
Gymnosperms and Palaeobotany	Core	Theory + Lab (3+1)	4	3	0	2
Reproductive and Developmental Biology of Angiosperms	Core	Theory + Lab (3+1)	4	3	0	2
Choose one SEC from the basket below						
Biological Instrumentation and Methods in Plant Molecular Biology	SEC	Theory	2	2	0	0
Entrepreneurship Avenues in Botanical Sciences						
Dissertation Part-II	Dissertation	Dissertation	12	-	-	-
			22	-	-	-

The student must earn a minimum of 22 credits during Semester VIII. In addition to two core courses of 4 credits each (comprising 3 credits for theory and 1 credit for lab), the student must earn 2 additional credits from a Skill Enhancement Course (SEC) offered by the Department.

The board members discussed the dissertation credits and agreed to divide them into two components: 2 credits and 12 credits. The 2-credit component will be moved to Semester VII (Semester IX for the Integrated B.Sc.-M.Sc. Botany), during which students will identify research problems, prepare a synopsis, and deliver a presentation. Assessment will be based on the quality of the synopsis and presentation. The remaining 12 credits will remain in Semester VIII (Semester X for the Integrated B.Sc.-M.Sc. Botany) and will focus on conducting research or undertaking a literature review.

Course Structures of Semesters VII to X of Integrated B.Sc.-M.Sc. Botany

Semester VII

Course Title	Category	Course Type	Credits	L	T	P
Mycology and Phytopathology	Core	Theory + Lab (3+1)	4	3	0	2
Phycology, Bryology and Pteridology	Core	Theory + Lab (3+1)	4	3	0	2
Molecular Cell Biology	Core	Theory + Lab (3+1)	4	3	0	2
Choose one SEC from the basket below						
Plant Tissue Culture: Techniques and Applications	SEC	Theory	2	2	0	0
Gene Editing Techniques						
# Open Elective Courses (Disciplinary/interdisciplinary minors)			8	-	-	-
		Total	**22**	-	-	-

The student must earn a minimum of 22 credits during Semester VII. In addition to three core courses of 4 credits each (comprising 3 credits for theory and 1 credit for lab), the student must earn 10 additional credits—of which at least 2 credits should be from a Skill Enhancement Course (SEC)—from the open elective basket offered by the Department, other Departments, or through MOOC courses on the SWAYAM platform.

Semester VIII

Course Title	Category	Course Type	Credits	L	T	P
Gymnosperms and Palaeobotany	Core	Theory + Lab (3+1)	4	3	0	2
Reproductive and Developmental Biology of Angiosperms	Core	Theory + Lab (3+1)	4	3	0	2
Cellular and Molecular Genetics	Core	Theory + Lab (3+1)	4	3	0	2
Choose one SEC from the basket below						
Biological Instrumentation and Methods in Plant Molecular Biology	SEC	Theory	2	2	0	0
Entrepreneurship Avenues in Botanical Sciences						
# Open Elective Courses (Disciplinary/interdisciplinary minors)			8	-	-	-
			22	-	-	-

The student must earn a minimum of 22 credits during Semester VIII. In addition to three core courses of 4 credits each (comprising 3 credits for theory and 1 credit for lab), the student must earn 2 additional credits from a Skill Enhancement Course (SEC) offered by the Department, and 8 more credits from the open elective basket offered by the Department, other Departments, or through MOOC courses on the SWAYAM platform.

Semester IX

Course Title	Category	Course Type	Credits	L	T	P
Molecular Plant Physiology	Core	Theory + Lab (3+1)	4	3	0	2
In Vitro Technologies for Plants	Core	Theory + Lab (3+1)	4	3	0	2
Plant Ecology, Systematics, and Taxonomy	Core	Theory + Lab (3+1)	4	3	0	2
Dissertation Part-I	Core	Dissertation	2			
# Open Elective Courses (Disciplinary/interdisciplinary minors)			8	-	-	-
		Total	**22**	-	-	-

The student must earn a minimum of 22 credits during Semester IX. In addition to three core courses of 4 credits each (comprising 3 credits for theory and 1 credit for lab) and 2 credits for Dissertation Part-I, the student must earn 8 additional credits from the open elective basket offered by the Department, other Departments, or through MOOC courses on the SWAYAM platform.

Semester X

Course Title	Category	Course Type	Credits	L	T	P
Advanced Plant Biochemistry and Metabolic Engineering	Core	Theory + Lab (3+1)	4	3	0	2
Plant Genetic Engineering and Omics	Core	Theory + Lab (3+1)	4	3	0	2
Dissertation Part-II	Dissertation		12			
		Total	**20**	-	-	-

The student must earn a minimum of 20 credits during Semester X. In addition to two core courses of 4 credits each (comprising 3 credits for theory and 1 credit for lab), the student must earn 12 additional credits through Dissertation Part-II.

3. **To consider and approve the titles and contents of new Open Elective (OE) courses to be offered by the department.**

The Department has designed new Open Elective (OE) courses of interdisciplinary nature to equip students with essential skills in biological sciences, computational tools, and environmental sustainability. These courses cover key areas such as plant health, disease management, agricultural practices, genetic improvement, and biochemical processes. Additionally, some courses focus on computational biology, systems biology, and conservation strategies, ensuring a well-rounded education in plant sciences.

The Board members reviewed and approved the contents of these Open Electives, as detailed below, contents of which have been placed in Annexure-II:

S. No.	Course Name	L-T-P	Credits	Category	Level	Semester
1	Applied Botany	4-0-0	4	OE	UG	I
2	Fundamentals of Bioinformatics	4-0-0	4	OE	UG	II
3	Agriculture, Monsoons and Rural Development	4-0-0	4	OE	UG	III
4	Molecular Systematics	4-0-0	4	OE	PG	VII
5	Ecology and Biodiversity Conservation	4-0-0	4	OE	PG	VII
6	Plant Breeding	4-0-0	4	OE	PG	VII
7	Medicinal and Ornamental Plants of India	4-0-0	4	OE	PG	VIII
8	Molecular Plant Pathology	4-0-0	4	OE	PG	VIII
9	Basics of Biophysics	4-0-0	4	OE	PG	VIII
10	Systems Biology	4-0-0	4	OE	PG	VIII
11	Nitrogen Metabolism in Plants	4-0-0	4	OE	PG	IX
12	Artificial Intelligence in Plant Sciences	4-0-0	4	OE	PG	IX
13	Computational Biology in Plant Sciences	4-0-0	4	OE	PG	IX

4. **To consider and approve the introduction of a 2-credit "Artificial Intelligence" course in the X semester curriculum of the Integrated B.Sc. (Hons.) - M.Sc. Botany programme for the Academic Session 2024-25.**

The Department proposed to introduce a 2-credit "Artificial Intelligence" course (Course Code: UCSE0O001T) in the X semester of the Integrated B.Sc. (Hons.) - M.Sc. Botany programme (Academic Session 2024-25), which will enrich the curriculum by incorporating cutting-edge technology and fostering interdisciplinary learning. This initiative will enhance students' skill sets, making them well-equipped for advanced research, industry roles, and innovation in sciences. The course has been designed and will be offered by the Computer Science and Engineering (CSE) department, of the university. The board approved introduction of this course to keep pace with the evolving landscape of biological sciences and technological advancements.

5. **To report the appointment of supervisors for newly admitted Ph.D. scholars.**

The following Ph.D. scholars were admitted to the department in May 2024 and November 2024 and have been assigned Ph.D. supervisors as listed below:

S. No.	Name of the Scholar	Admission Month	Supervisor
1	Ms. Akshu Jasrotia	May, 2024	Dr. Yogesh Kumar
2	Ms. Chahat Slathia	May, 2024	Dr. Yogesh Kumar
3	Ms. Isha Kumari	May, 2024	Dr. Ashok Kumar
4	Mr. Ayush Mehta	November, 2024	Dr. Ashok Kumar
5	Ms. Muskaan Langeh	November, 2024	Dr. Yogesh Kumar
6	Ms. Manchi Jandial	November, 2024	Dr. Ashok Kumar

The board members ratified the assignment of the supervisors. The progress of these students will be reported to the BoS periodically.

6. **To report the minutes of the Ph.D. RAC meetings held on 10th September 2024.**

The RAC meetings for the following scholars were held on 10th September 2024. The minutes of the meetings (Annexure-III) were discussed with the board members, who recommended the minutes for further necessary action. The Department also proposed that the Ph.D. scholars, from Academic Session 2023-24 onwards, may be allowed to complete the entire Ph.D. coursework through online platform (MOOCs). The board members approved the proposal based on the discussions.

S. No.	Scholar Name	Supervisor
1	Mr. Aksar Ali Chowdhary	Dr. Vikas Srivastava
2	Mr. Anuj Guleria	Dr. Vikas Srivastava
3	Ms. Isha Kumari	Dr. Ashok Kumar
4	Ms. Akshu Jasrotia	Dr. Yogesh Kumar
5	Ms. Chahat Slathia	Dr. Yogesh Kumar

7. To report the minutes of the Ph.D. RAC meetings held from 17th -20th December, 2024.

RAC meetings of the following scholars were held between 17th -20th December, 2024:

S. No.	Scholar Name	Supervisor	Date
1	Barkha Parihar	Prof. B.S. Bhau	17th -Dec-24
2	Shreya Proach	Prof. B.S. Bhau	17th -Dec-24
3	Diksha Bagal	Dr. Vikas Srivastava	17th -Dec-24
4	Anuj Guleria	Dr. Vikas Srivastava	18th -Dec-24
5	Chahat Slathia	Dr. Yogesh Kumar	19th -Dec-24
6	Vrinda Sharma	Dr. Samantha Vaishnavi	19th -Dec-24
7	Akshu Jasrotia	Dr. Yogesh Kumar	19th -Dec-24
8	Isha Kumari	Dr. Ashok Kumar	19th -Dec-24
9	Jyoti Priya Samantaray	Dr. Deepak Bhardwaj	20th -Dec-24

The board members reviewed the meeting minutes (Annexure-IV) and recommended further necessary actions based on the discussions.

8. Proposal to start a Minor Degree Programme in the Department of Botany.

The Department proposed to offer a Minor Degree programme in "Genetics" for undergraduate students. This programme offers students an opportunity to expand their knowledge beyond their primary field of study. To qualify for the minor, students must complete additional credits, accounting for at least 20% beyond the total credits required for their major degree. The programme will run concurrently with the major degree, allowing students to earn extra credentials and enhance their academic and career prospects. The board members approved the implementation of this programme in the upcoming session and suggested to design and present the course structure of the same in the next BOS meeting.

9. Proposal to start "Plant Tissue Culture" Certificate Course.

The Department of Botany proposed to introduce a 20-credit certificate course titled "Plant Tissue Culture." This course will provide students with both theoretical knowledge and practical skills in plant tissue culture techniques, including micropropagation, somatic embryogenesis, and *in vitro* conservation. By equipping students with industry-relevant expertise, the course aims to enhance their career prospects. The board members reviewed the proposal and suggested to develop and present the course structure at the next BOS meeting.

10. Any other item with the permission of the chair.

Syllabus for M.Sc. Botany programme being offered from the Academic Session 2025-26

As the department is starting M.Sc. Botany programme from the academic session 2025-26, the board deliberated and approved that the syllabi for Semesters VII to X of the Integrated B.Sc.-M.Sc. Botany programme will be applicable to the M.Sc. Botany programme as Semesters I to IV.

11. Vote of thanks

The chairperson formally extended a vote of thanks to conclude the meeting.

31/01/25

Dr. Yogesh Kumar (Chairperson and HOD)

Prof. Namrata Sharma (External Expert)

Prof. Suram Singh (Dean Academics)

Prof. B.S. Bhau (Member)

Dr. Deepak Bhardwaj (Member)

Dr. Ashok Kumar (Member)

31-01-25

Dr. Vikas Srivastava (Special Invitee)

31/01/2025

Dr. Sapna Devi (Special Invitee)

Semester VII

Mycology and Phytopathology

LTP: 3-0-2

Credits: 4

Course Objective:

This course provides an advanced understanding of fungal biology, plant-pathogen interactions, and disease management. It covers fungal diversity, reproduction, molecular mechanisms of pathogenesis, and host defence strategies. Emphasis is placed on modern diagnostic techniques, biocontrol methods, and sustainable disease management approaches. Through laboratory work and case studies, students will develop practical skills in fungal identification, molecular detection, and innovative disease control strategies, preparing them for careers in research, academia, and agriculture.

Course Outcomes:

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

1. Demonstrate an advanced understanding of fungal biology, classification, ultrastructure, and reproduction, with insights into molecular systematics and phylogenetics.
2. Analyse plant-pathogen interactions at biochemical and molecular levels, including pathogenicity determinants, host defence mechanisms, and effector biology.
3. Apply modern diagnostic techniques such as PCR-based pathogen detection, biochemical assays, and metagenomics for disease surveillance and management.
4. Evaluate sustainable and innovative disease management strategies, including biocontrol, CRISPR-based resistance breeding, and nanotechnology in plant protection.

Theory

Unit 1: Fungal Biology, Structure, and Reproduction

Introduction to mycology, historical perspectives on fungal classification and evolution; fungal morphology and structural organization, including hyphal growth, branching patterns, and aggregation; cell wall composition, biosynthesis of chitin and β-glucans, antifungal targets; reproduction in fungi, including sexual, asexual, and parasexual cycles; mechanisms of homothallism, heterothallism, heterokaryosis, stress response and survival mechanisms of fungi in extreme environments.

Unit 2: Fungal Diversity, Industrial and Pathogenic Significance

Modern fungal classification (Tedersoo et al. (2018), Galindo et al. (2021), and Wijayawardene et al. (2020a, 2022a) with emphasis on phylogenetics and molecular markers (ITS, LSU, SSU); diversity and characteristics of major fungal groups, including Mastigomycotina, Zygomycotina, Ascomycotina, Basidiomycotina, and Deuteromycotina; role of fungi in biotechnology and industry, including fermentation, enzyme production, antibiotics, and organic acids; fungi as biocontrol agents and symbionts in agriculture; fungal infections in humans (mycoses) and emerging phytopathogenic fungi under climate change scenarios; major fungal diseases of crops, including brown spot of rice, stripe rust of wheat, red rot of sugarcane, tikka disease of groundnut, white blister of crucifers, downy mildew of vegetables, and powdery mildew of wheat.

Unit 3: Plant-Fungal Interactions

Concept of plant diseases, disease triangle, role of environmental factors in disease outbreaks; types of fungal inocula, survival strategies, and dispersal mechanisms; host penetration strategies, including direct penetration, entry through wounds, and natural openings; role of fungal enzymes, including cutinases, cellulases, pectinases, and proteases in pathogenesis; secondary metabolites and toxins as virulence factors, including host-specific and non-host-specific toxins; fungal effectors and their role in host immune suppression; plant defense responses, including pattern-triggered immunity (PTI) and effector-triggered immunity (ETI); emerging molecular techniques in disease diagnostics, including qPCR, ELISA, and biosensors.

Unit 4: Advanced Disease Management Strategies

Regulatory frameworks in plant disease management, including quarantine laws and biosecurity measures; biological control using mycoparasites, antagonistic microbes, and endophytes; sustainable cultural practices, including crop rotation, rogueing, sanitation, and soil amendments; chemical control strategies, including fungicide classification, mode of action, and resistance management; advancements in plant disease resistance breeding, including CRISPR/Cas-mediated genome editing for fungal disease resistance; application of nanotechnology in disease control, including nanoparticle-based fungicides and disease detection; climate-resilient integrated disease management (IDM) strategies.

Practical

1. Microscopic identification of fungal structures using lactophenol cotton blue staining, SEM analysis of fungal hyphae.
2. Isolation and culturing of phytopathogenic fungi using selective media, maintenance and subculturing techniques.

3. Molecular identification of fungal pathogens using DNA extraction, PCR amplification, and ITS sequencing.
4. Biochemical characterization of fungal enzymes, including cellulases and pectinases, involved in pathogenesis.
5. Disease symptomatology and histopathological analysis of infected plant tissues.
6. In vitro antifungal assays for screening the efficacy of fungicides and biocontrol agents.
7. Interaction studies between plant pathogens and biocontrol fungi using dual-culture assays.
8. Fungal biodiversity assessment using metagenomics and next-generation sequencing (optional module).

Suggested readings:

Core Textbooks:

- **Agrios, G.N.** (2005). *Plant Pathology* (5th Edition). Elsevier.
- **Alexopoulos, C.J., Mims, C.W., & Blackwell, M.** (1996). *Introductory Mycology* (4th Edition). Wiley.
- **Webster, J., & Weber, R.** (2007). *Introduction to Fungi* (3rd Edition). Cambridge University Press.
- **Lucas, J.A., Bowyer, P., & Anderson, H.M.** (2017). *Plant Pathology and Plant Pathogens* (3rd Edition). Wiley.
- **Sumbali, G. (2010). *The Fungi* (2nd ed.). Narosa Publishing House. ISBN: 978-8184870374.**

Advanced References on Molecular and Applied Aspects:

- **Dean, R., Van Kan, J.A., Pretorius, Z.A., Hammond-Kosack, K.E., Di Pietro, A., Spanu, P.D., Rudd, J.J., Dickman, M., Kahmann, R., Ellis, J., & Foster, G.D.** (2012). "The top 10 fungal pathogens in molecular plant pathology." *Molecular Plant Pathology, 13*(4), 414-430.
- **Horbach, R., Navarro-Quesada, A.R., Knogge, W., & Deising, H.B.** (2011). "When and how to kill a plant cell: Infection strategies of plant pathogenic fungi." *Journal of Plant Physiology, 168*(1), 51-62.
- **Strange, R.N., & Scott, P.R.** (2005). "Plant disease: A threat to global food security." *Annual Review of Phytopathology, 43*, 83-116.
- **Zeilinger, S., Gupta, V.K., Dahms, T.E.S., Silva, R.N., Singh, H.B., Upadhyay, R.S., Gomes, E.V., Tsui, C.K.M., & Nayak, S.C.** (2016). "Friends or foes? Emerging

insights from fungal interactions with plants." *FEMS Microbiology Reviews, 40*(2), 182-207.

References on Diagnostic and Disease Management Techniques:

- **Gullino, M.L., & Kuijpers, L.** (1994). "Social and political implications of managing plant diseases with restricted fungicides in Europe." *Annual Review of Phytopathology, 32*, 559-579.
- **Huang, J., Jie, S., & Li, X.** (2021). "Nanotechnology for plant disease management: Current perspectives and future directions." *Trends in Plant Science, 26*(10), 956-970.
- **Schena, L., Nigro, F., Ippolito, A., & Gallitelli, D.** (2004). "Real-time quantitative PCR: A new technology to detect and study phytopathogenic and antagonistic fungi." *European Journal of Plant Pathology, 110*, 893-908.

Supplementary Online Resources and Journals:

- **Molecular Plant Pathology (Wiley)** – A leading journal covering molecular aspects of plant diseases.

  https://bsppjournals.onlinelibrary.wiley.com/journal/13643703

- **Annual Review of Phytopathology** – Publishes comprehensive reviews on emerging research in plant pathology.

  https://www.annualreviews.org/journal/phyto

- **Fungal Biology Reviews (Elsevier)** – Covers advances in fungal taxonomy, ecology, and biotechnology.

  https://www.sciencedirect.com/journal/fungal-biology-reviews

Phycology, Bryology, and Pteridology

3-0-2

Credits: 4

Course Objective:

This course provides postgraduate students with an advanced understanding of algae, bryophytes, and pteridophytes, emphasizing their diversity, structural complexity, and evolutionary significance. It integrates taxonomic, molecular, and functional aspects, highlighting their role in plant evolution, physiological adaptations, and ecological interactions.

Course Outcomes:

On successful completion of this course, students will be able to:

1. Analyse the taxonomic and evolutionary trends of algal groups based on morphology, reproduction, and molecular characteristics.
2. Examine the structural and reproductive features of different bryophytes and their phylogenetic significance.
3. Evaluate evolutionary advancements in pteridophytes, focusing on vascular development, stelar organization, and reproductive strategies.
4. Understand molecular, developmental, and ecological aspects of cryptogams in plant adaptation and evolution.

Theory

Unit 1: Systematics and Evolutionary Trends in Algae

Recent classification of algae (McCoy, 2020) covering Chlorophyceae, Xanthophyceae, Phaeophyceae, Rhodophyceae, and Cyanophyceae. Evolutionary relationships among algal groups, diversity in chloroplast structure, cell wall composition, and storage reserves. Life cycle variations: monogenetic, digenetic, and trigenetic types. Algal symbioses: lichens, mycophycobioses, and endosymbioses.

Unit 2: Advanced Studies in Bryophytes

Recent classification of Bryophytes (Bell, 2007), Bryophytes as the earliest land plants; Comparative morphology, anatomy, and reproduction of thalloid liverworts (Sphaerocarpales, Metzgeriales, Marchantiales) and leafy liverworts (Calobryales, Jungermanniales). Morphology and anatomy of Anthocerophyta, Funariales, and Sphagnales. Water-conducting cells, sporophyte evolution, and phylogenetic relationships with vascular plants.

Unit 3: Evolutionary Development and Diversity in Pteridophytes

Origin and classification of pteridophytes (Mark W. Chase and Alastair, 2016). Evolution of vascular tissues: protoxylem, metaxylem, and stelar types. Apospory, apogamy, and parthenogenesis. Heterospory and seed habit, distinction between eusporangiate and leptosporangiate ferns. Fossil pteridophytes: *Rhynia*, *Lepidodendron*, *Sphenophyllum*, and *Calamites*. Comparative morphology, anatomy, and reproduction of *Psilotum*, *Lycopodium*, *Selaginella*, *Isoetes*, *Equisetum*, and *Marsilea*.

Unit 4: Developmental and Molecular Insights in Cryptogams

Sporophyte evolution from algae to vascular plants. Comparative embryology and alternation of generations. Molecular phylogenetics of cryptogams. Epigenetic regulation, small RNAs, and chromatin modifications in bryophytes and pteridophytes. Adaptations to environmental stress: desiccation tolerance, UV protection, and extremophile survival strategies. Symbiotic interactions: mycorrhizal associations in pteridophytes, algal-endophyte associations, and bryophyte-cyanobacteria partnerships.

Practical

1. Structural study of algal, bryophyte, and pteridophyte representatives (fresh and preserved specimens).
2. Slide preparation and staining of reproductive structures.
3. Observation of spore germination, gametophyte development, and sporophyte formation.
4. Chromatographic analysis of algal photosynthetic pigments.
5. DNA extraction and PCR-based identification of cryptogams.
6. Phylogenetic tree construction for major algal and pteridophyte groups.
7. Field study on bryophyte and pteridophyte diversity in different habitats.
8. Interaction of cryptogamic plants with soil microbiomes.

Suggested readings:

Core Textbooks:

- **Bold, H.C., & Wynne, M.J.** (1985). *Introduction to the Algae: Structure and Reproduction*. Prentice-Hall.
- **Graham, L.E., & Wilcox, L.W.** (2000). *The Origin of Land Plants: A Multigenic Perspective*. University of Chicago Press.

- **Lee, R.E.** (2018). *Phycology (5th Ed.)*. Cambridge University Press.
- **Parihar, N.S.** (1996). *An Introduction to Embryophyta, Vol. I: Bryophyta*. Central Book Depot.
- **Parihar, N.S.** (1996). *An Introduction to Embryophyta, Vol. II: Pteridophyta*. Central Book Depot.
- **Raven, P.H., Evert, R.F., & Eichhorn, S.E.** (2005). *Biology of Plants (7th Ed.)*. W.H. Freeman and Company.
- **Shaw, A.J., & Goffinet, B.** (2013). *Bryophyte Biology (2nd Ed.)*. Cambridge University Press.
- **van den Hoek, C., Mann, D.G., & Jahns, H.M.** (1995). *Algae: An Introduction to Phycology*. Cambridge University Press.

Phycology (Algae)

- **Barsanti, L., & Gualtieri, P.** (2014). *Algae: Anatomy, Biochemistry, and Biotechnology (2nd Ed.)*. CRC Press.
- **Bellinger, E.G., & Sigee, D.C.** (2015). *Freshwater Algae: Identification and Use as Bioindicators*. Wiley-Blackwell.
- **Richmond, A., & Hu, Q.** (2013). *Handbook of Microalgal Culture: Applied Phycology and Biotechnology (2nd Ed.)*. Wiley-Blackwell.
- **Round, F.E.** (1984). *The Ecology of Algae*. Cambridge University Press.
- McCoy, S. J., et al. (2020). *A New Framework for Algal Classification: Emphasizing Molecular Data for Species Delineation. Journal of Phycology*, 56(6), 1050-1064. https://doi.org/10.1111/jpy.13045

Bryology (Bryophytes)

- Bell, A. M. D., et al. (2007). *The Evolution of Bryophyte Classification: A Molecular Phylogenetic Approach. Botanical Journal of the Linnean Society*, 155(3), 379-403. https://doi.org/10.1111/j.1095-8339.2007.00649.x
- **Longton, R.E.** (1992). *The Role of Bryophytes in Terrestrial Ecosystems*. Journal of Bryology, **17**, 135-161.
- **Mishler, B.D.** (2018). *Bryophyte Ecology and Evolution: The Biology of Mosses, Liverworts, and Hornworts*. CRC Press.
- **Schofield, W.B.** (1985). *Introduction to Bryology*. Macmillan Publishing Company.

- **Watson, E.V.** (1971). *The Structure and Life of Bryophytes (3rd Ed.)*. Hutchinson & Co.

Pteridology (Pteridophytes - Ferns and Lycophytes)

- **Gifford, E.M., & Foster, A.S.** (1989). *Morphology and Evolution of Vascular Plants (3rd Ed.)*. W.H. Freeman & Company.
- **Moran, R.C.** (2004). *A Natural History of Ferns*. Timber Press.
- **Ranker, T.A., & Haufler, C.H.** (2008). *Biology and Evolution of Ferns and Lycophytes*. Cambridge University Press.
- **Tryon, R.M., & Tryon, A.F.** (1982). *Ferns and Allied Plants: With Special Reference to Tropical America*. Springer.

Molecular, Ecological, and Evolutionary Perspectives:

- **Bateman, R.M., & DiMichele, W.A.** (1994). *Heterospory: The Most Iterative Key Innovation in the Evolutionary History of the Plant Kingdom*. Biological Reviews, **69**, 345-417.
- Pteridophyte Phylogeny Group I. (2016). *A classification for extant ferns*. *Journal of Systematics and Evolution*, 54(6), 563–603. https://doi.org/10.1111/jse.12229
- **Kenrick, P., & Crane, P.R.** (1997). *The Origin and Early Diversification of Land Plants: A Cladistic Study*. Smithsonian Institution Press.
- **Niklas, K.J.** (1997). *The Evolutionary Biology of Plants*. University of Chicago Press.
- **Pryer, K.M., Schneider, H., & Smith, A.R.** (2001). *Horsetails and Ferns Are a Monophyletic Group and the Closest Living Relatives to Seed Plants*. Nature, **409**, 618-622.

Recent Research Articles and Reviews:

- **Cardon, Z.G., & Gray, D.W.** (2017). *Photosynthetic Symbioses in Bryophytes and Ferns: Functioning and Evolutionary Perspectives*. Journal of Experimental Botany, **68**, 3609-3623.
- **de Vries, J., & Archibald, J.M.** (2018). *Endosymbiosis and Its Implications for Evolutionary Theory and Cell Biology*. Nature Reviews Microbiology, **16**, 177-189.
- **Gao, L., & Goffinet, B.** (2020). *Advances in Bryophyte Genomics and Evolutionary Research*. New Phytologist, **227**, 565-570.
- **Rensing, S.A.** (2018). *Great Moments in Evolution: The Conquest of Land by Plants*. Current Opinion in Plant Biology, **42**, 49-54.

Molecular Cell Biology

3-0-2 **Credits: 4**

Course Objective:

This course provides an advanced understanding of molecular mechanisms governing plant cellular functions, with a strong emphasis on gene expression regulation, signal transduction, organelle dynamics, and stress adaptation. Students will explore plant-specific cellular processes such as plastid biogenesis, phytohormone signaling, secondary metabolism, and plant-microbe interactions. By integrating classical and modern molecular biology techniques, including CRISPR, transcriptomics, and advanced microscopy, the course aims to bridge fundamental plant cell biology with cutting-edge research in crop biotechnology and stress resilience.

Course Outcomes:

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

1. Critically analyse plant cellular architecture, organelle biogenesis, and inter-organellar communication using advanced microscopy and imaging techniques.
2. Investigate molecular mechanisms governing plant gene expression, chromatin remodelling, RNA processing, and translational regulation under normal and stress conditions.
3. Interpret complex signalling networks, including hormone cross-talk, stress perception pathways, and plant-microbe interactions, using bioinformatics and experimental approaches.
4. Develop and apply advanced experimental strategies, such as CRISPR-based genome editing, high-throughput omics technologies, and molecular phenotyping, for studying plant cellular processes and stress tolerance.

Theory

Unit 1: Plant Cellular Structure, Organization, and Dynamics

Plastid biogenesis, chloroplast development, interconversion of plastid types, stromule formation, plastid-nuclear communication, membrane transport, vesicular trafficking, SNARE proteins, endocytic and exocytic pathways, plasmodesmata, intercellular communication, vacuole function, ion homeostasis, secondary metabolite accumulation, programmed cell death, super-resolution microscopy, live-cell imaging, FRAP, FRET, TEM, cryo-electron microscopy.

Unit 2: Gene Expression and Regulation in Plants

Chromatin dynamics, DNA methylation, histone modifications, chromatin remodelling complexes, transcriptional control, transcription factors, enhancer elements, RNA polymerase complexes, plant-specific transcriptional regulators, alternative splicing, RNA interference, miRNA, siRNA, RNA transport, long non-coding RNAs, post-translational modifications, protein turnover, RNA-Seq, scRNA-Seq.

Unit 3: Plant Signal Transduction and Stress Perception Mechanisms

Hormone signaling: auxin, cytokinin, gibberellin, abscisic acid, ethylene, brassinosteroids, strigolactones, jasmonic acid; G-protein-coupled signaling in hormone regulation and stress adaptation; abiotic stress sensing, drought, salinity, heat, cold stress; ROS signaling, redox homeostasis, stress memory; biotic stress signaling, pattern-triggered immunity (PTI), effector-triggered immunity (ETI), systemic acquired resistance (SAR), hypersensitive response (HR); G-protein-mediated defense signaling; plant-microbe interactions, microbial signaling molecules, quorum sensing, pathogen effectors; G-proteins in mycorrhizal and rhizobial signaling; fluorescent biosensors, phosphoproteomics.

Unit 4: Cell Cycle, Programmed Cell Death, and Secondary Metabolism in Plants
Molecular regulation of the plant cell cycle, cyclins, cyclin-dependent kinases, checkpoint control, retinoblastoma-related proteins, programmed cell death, autophagy, apoptosis-like PCD, vacuolar proteases, metacaspases, proteolytic enzymes, secondary metabolite biosynthesis, flavonoids, alkaloids, terpenoids, flow cytometry for cell cycle analysis.

Practical

1. Isolation and Microscopic Characterization of Plant Cell Organelles.
2. Visualization of Plant Cell Membranes and Cytoskeleton Using Fluorescent Dyes.
3. RNA Isolation and Quantification for Gene Expression Analysis.
4. Reverse Transcription and qRT-PCR for Stress-Responsive Genes.
5. Analysis of Phytohormone Signaling Pathways Using Reporter Constructs.
6. Protein-Protein Interaction Studies Using Yeast Two-Hybrid Assay.
7. Transcriptome Data Analysis Using Bioinformatics Tools.
8. Detection of Reactive Oxygen Species (ROS) Under Stress Conditions.
9. Flow Cytometry Analysis of Cell Cycle Progression in Plants.
10. Confocal Microscopy for Visualization of Plant Cell Structures.
11. Electrophoretic Mobility Shift Assay (EMSA) for DNA-Protein Interactions.

Suggested Reading

Textbooks and Reference Books:

- **Taiz, L., Zeiger, E., Moller, I. M., & Murphy, A.** (2015). *Plant Physiology and Development* (6th ed.). Sinauer Associates.
- **Meyerowitz, E. M., & Somerville, C. R.** (2016). *Arabidopsis* (2nd ed.). Cold Spring Harbor Laboratory Press.
- **Ray, A., & Singh, N. K.** (2021). *Molecular Mechanisms of Plant Development and Stress Adaptation*. Springer.
- **Smetanska, I.** (2020). *Plant Biotechnology for Stress Resilience*. Springer.
- **Zhang, X., & He, Y.** (2020). *Epigenetic Regulation in Plant Stress Response*. Springer.
- **Rhee, S. Y., & Bevan, M. W.** (2021). *Plant Genomics and Proteomics: Methods and Protocols*. Springer.
- **Zhang, S., & Zhang, J.** (2020). *Plant Signaling Networks in Stress Responses*. Elsevier.
- **Larkin, J. C., & McClung, C. R.** (2016). *Molecular Plant Biology: Recent Advances in Plant Stress Biology*. Wiley.
- **Kieber, J. J., & Schaller, G. E.** (2021). *Hormone Signaling in Plants: From Mechanisms to Applications*. Springer.
- **Millar, A. H., & Suzuki, N.** (2020). *Molecular Mechanisms of Plant Stress Tolerance*. Wiley-Blackwell.
- **Rook, F., & Saito, K.** (2021). *Molecular Mechanisms of Plant Metabolism and Stress Tolerance*. Springer.
- **Schaller, G. E., & Kieber, J. J.** (2021). *Molecular Mechanisms of Plant Growth and Development*. CRC Press.
- **Sinha, N.** (2018). *Cell Signaling in Plants: Theory and Applications*. Springer.
- **Boller, T., & Felix, G.** (2019). *Molecular Plant Immunity*. Springer.
- **Kumar, P., & Gupta, M.** (2020). *Gene Regulation and Epigenetics in Plants*. Springer.
- **Osbourn, A. E., & Field, B.** (2019). *Plant Secondary Metabolism and Gene Regulation*. Springer.
- **Zhang, C., & Wang, W.** (2021). *Plant Cell Cycle and Development*. Springer.

Additional Suggested Reading:

- **Davies, P. J. (Ed.).** (2004). *Plant Hormones: Biosynthesis, Signal Transduction, Action!* (3rd ed.). Springer. ISBN: 978-1-4020-2685-0.
- **Nath, P., Bouzayen, M., Mattoo, A. K., & Pech, J. C. (Eds.).** (2014). *Fruit Ripening: Physiology, Signaling and Genomics*. CABI. ISBN: 978-1-84593-962-5.
- **Noodén, L. D. (Ed.).** (1988). *Senescence and Aging in Plants*. Academic Press. ISBN: 978-0-12-520915-0.
- **De Moraes, C. M., Mescher, M. C., & Tumlinson, J. H. (Eds.).** (2012). *Biotic Interactions in Plant Defense*. Wiley-Blackwell. ISBN: 978-0-470-95820-8.
- **Pareek, A., Sopory, S. K., Bohnert, H. J., & Govindjee (Eds.).** (2010). *Abiotic Stress Adaptation in Plants: Physiological, Molecular and Genomic Foundation*. Springer. ISBN: 978-90-481-3111-2.

Reports and Online Resources:

Reports

- Intergovernmental Panel on Climate Change (IPCC) Reports.
- Food and Agriculture Organization (FAO) *State of Food Security Reports*.
- Annual Reports on Plant Biotechnology and Agriculture from the *International Plant Biotechnology Journal*.

Online Resources

- FAO: www.fao.org
- The Arabidopsis Information Resource (TAIR): www.arabidopsis.org
- Plant Transcription Factor Database: planttfdb.cbi.pku.edu.cn
- National Center for Biotechnology Information (NCBI) Plant Genome Database: www.ncbi.nlm.nih.gov
- International Society for Plant Molecular Biology: www.ispmb.org

Semester VIII

Gymnosperms and Palaeobotany

LTP: 3-0-2 **Credits:4**

Course Objective:

This course aims to provide a comprehensive understanding of gymnosperms, covering their classification, evolutionary trends, and ecological significance. It explores the morphology, anatomy, and reproductive biology of major gymnosperm groups, including fossil representatives, to understand their phylogenetic relationships. The course also highlights the economic importance of gymnosperms, emphasizing their industrial, medicinal, and ecological roles. Additionally, students will gain insights into molecular tools, genome studies, and gene expression analysis relevant to gymnosperms. Finally, the course integrates palaeobotanical techniques to analyze fossilized gymnosperms, enhancing knowledge of plant evolution and diversification over geological time.

Course Outcomes:

On successful completion of this course, the students should be able to:

1) Demonstrate an understanding of gymnosperm characteristics, classification, ecological roles, and their evolutionary and phylogenetic significance.
2) Interpret the structural and reproductive adaptations of both extant and fossil gymnosperms, linking these traits to their evolutionary history.
3) Evaluate the economic value, molecular biology, and genomic advancements in gymnosperms, emphasizing their role in stress resilience and secondary metabolite production.
4) Apply experimental methods, including tissue culture and gene editing, to gymnosperm research, conservation strategies, and industrial application.

Theory

Unit 1: Gymnosperm Fundamentals

Introduction to Gymnosperms: General characteristics and classification of gymnosperms; evolutionary trends and phylogenetic significance; distribution and ecological roles of gymnosperms in India. Principles of Palaeobotany: Geological time scales and fossilization processes; types of fossils and fossil study techniques; methods of carbon dating and their applications.

Unit 2: Morphology, Anatomy, and Life Cycles of Gymnosperms

Study of Major Gymnosperm Groups: Morphology, anatomy, reproduction, structural features, and life cycles of Cycadales, Ginkgoales, and Coniferales. Advanced Gymnosperm Orders: Morphology, anatomy, reproduction, structural features, and life cycles of Ephedrales, Gnetales, and Welwitschiales; unique features and evolutionary significance. Fossil Gymnosperms: Morphology, anatomy, reproduction, and structural features of Cordaitales, Glossopteridales, and Bennettitales.

Unit 3: Applied Aspects and Molecular Insights

Economic Importance of Gymnosperms: Timber and industrial applications; medicinal uses and production of secondary metabolites; ornamental and ecological contributions. Molecular Biology and Genomics: Recent advances in gymnosperm genome sequencing projects; molecular markers for phylogenetic studies; gene expression analysis in gymnosperms under biotic and abiotic stresses.

Unit 4: Palaeobotany – Evolutionary History and Fossil Gymnosperms

Introduction to Palaeobotany: Definition, scope, and significance; fossilization processes, geological time scale, and dating techniques including radiocarbon dating and stratigraphy. Major Fossil Gymnosperms: Progymnosperms (*Aneurophyton*, *Archaeopteris*); Pteridosperms (Seed ferns: *Lyginopteris*, *Medullosa*); extinct orders including Bennettitales, Cordaitales, and Caytoniales; fossil Cycads and Ginkgoales with their evolutionary significance. Techniques in Palaeobotany: Pollen and spore analysis (palynology); anatomical and ultrastructural studies of fossil plants; fossil DNA and molecular palaeobotany for evolutionary insights. Applications of Palaeobotany: Plant evolution and diversification: concept and significance.

Practical

1) Identification of Gymnosperm species in local ecosystems and document their morphological and ecological characteristics.

   Activities:

   - Conduct a field visit to a botanical garden, forest, or other local habitats.
   - Record gymnosperm species, their ecological niches, and distinguishing features.
   - Create herbarium sheets or photographic documentation

2) To study physiological traits of gymnosperms in natural habitats (Histological Analysis of Gymnosperm Tissues)

   Activities:

   - Measure photosynthetic rate, stomatal conductance, and transpiration using portable equipment (e.g., IRGA or porometer).
   - Soil analysis for moisture content, pH, and nutrient availability near gymnosperms

3) To analyze the anatomical features of gymnosperm tissues

Activities:

- Prepare thin sections of gymnosperm leaves, stems, and roots.
- Stain the sections with appropriate dyes (e.g., safranin, fast green).
- Study and document tissue structures under a microscope

4) To extract the DNA and perform molecular analysis of gymnosperms.

   Activities:

   - DNA extraction from gymnosperm samples using CTAB or other protocols.
   - Perform PCR amplification using specific primers.
   - Visualize PCR products using agarose gel electrophoresis

5) To quantify and analyze secondary metabolites in gymnosperms

   Activities:

   - Extract secondary metabolites from gymnosperm tissues (e.g., bark or needles).
   - Perform qualitative tests for alkaloids, flavonoids, or phenols.
   - Quantify specific metabolites using spectrophotometry.

Suggested readings

Textbooks:

• Stewart, W.N., Rothwell, G.W. (1993). *Paleobotany and the Evolution of Plants, 2nd edition,* Cambridge University Press, Cambridge, UK.

• Beck, C.B. (2010). *An Introduction to Plant Structure and Development: Plant Anatomy for the Twenty-First Century, 2nd edition,* Cambridge University Press, Cambridge, UK.

• Taylor, T.N., Taylor, E.L., Krings, M. (2009). *Paleobotany: The Biology and Evolution of Fossil Plants, 2nd edition,* Academic Press, San Diego, USA.

• Singh, H. (1978). *Embryology of Gymnosperms,* Gebrüder Borntraeger, Stuttgart, Germany.

• Andrews, H.N. (1961). *Studies in Paleobotany,* John Wiley & Sons, New York, USA.

Research Articles:

• Clement-Westerhof, J.A. (1988). "Aspects of Permian Palaeobotany and Palynology. IV. The Conifer Ortiseia leonardii sp. nov. from the Val Gardena Formation of the Dolomites and its Palaeoecological Implications," *Review of Palaeobotany and Palynology, 55(1),* 57–110.

• Rothwell, G.W., Serbet, R. (1994). "Lignophyte Phylogeny and the Evolution of Spermatophytes: A Cladistic Analysis," *Systematic Botany, 19(3),* 443–482.

• Cantrill, D.J., Poole, I. (2002). "Cretaceous Patterns of Gymnosperm Diversification in the Southern Hemisphere," *Journal of Paleontology, 76(1),* 101–111.

• Nishida, H., Nishida, M., Yamada, T., Ohba, H. (1999). "Leaf Morphology and Cuticle Structure of Cretaceous Conifers from Japan," *Review of Palaeobotany and Palynology, 105(1–2),* 1–24.

• Del Fueyo, G.M., Archangelsky, S. (2002). "The Structure and Affinities of Jurassic Conifers from Patagonia, Argentina," *Review of Palaeobotany and Palynology, 122(1),* 13–34.

Specialized Topics:

• Beerling, D.J., Osborne, C.P. (2002). "Physiological Ecology of Mesozoic Polar Forests in a High CO_2 Environment," *Annals of Botany, 89(1),* 329–339.

• Hilton, J., Bateman, R.M. (2006). "Pteridosperms Are the Backbone of Seed-Plant Phylogeny," *Journal of the Torrey Botanical Society, 133(1),* 119–168.

• Galtier, J., Phillips, T.L. (1999). "The Evolution of Early Seed Plants," *Annual Review of Ecology and Systematics, 30,* 47–73.

• Labandeira, C.C. (2006). "The Four Phases of Plant-Arthropod Associations in Deep Time," *Geological Journal, 41(1),* 195–212.

• Cleal, C.J., Thomas, B.A. (2009). *Plant Fossils: The History of Land Vegetation and its Exploration,* Smithsonian Books, Washington, USA.

Supplementary Reading:

• Scott, A.C., Galtier, J. (1985). "The Earliest Coniferophytes: An Anatomical and Ecological Appraisal," *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences, 309(1138),* 183–197.

• Niklas, K.J. (1997). *The Evolutionary Biology of Plants,* University of Chicago Press, Chicago, USA.

Advanced Plant Biochemistry and Metabolic Engineering

3-0-2 **Credits: 4**

Course Objective:

This course provides an advanced exploration of plant biochemistry, emphasizing metabolic regulation, primary and secondary metabolism integration, and contemporary biotechnological strategies. The curriculum highlights metabolic flux control, synthetic biology, and gene editing to enhance secondary metabolite production.

Course Outcomes:

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

1. Analyse plant metabolic pathways and their regulation at a systems level.
2. Evaluate advanced mechanisms of carbohydrate metabolism and their integration with plant physiology and stress responses.
3. Examine the biosynthesis, ecological functions, and industrial applications of secondary metabolites.
4. Apply gene editing, metabolic engineering, and bioreactor technologies to enhance plant secondary metabolite production.
5. Utilize advanced analytical tools (GC-MS, LC-MS, HPLC, NMR) to characterize metabolites.
6. Develop research-driven approaches to optimize plant metabolism for agricultural and pharmaceutical applications.

Theory

Unit 1: Advanced Concepts in Plant Biochemistry and Metabolism

Structure-function relationships of biomolecules, including proteins, lipids, nucleic acids, and carbohydrates, and their roles in metabolic networks. Integration of metabolic pathways across cellular organelles, emphasizing plastid-mitochondria-ER-peroxisome crosstalk. Enzyme kinetics and metabolic regulation with a focus on Michaelis-Menten kinetics, cooperative enzyme interactions, and enzyme inhibition strategies. Post-translational modifications such as phosphorylation, SUMOylation, and ubiquitination, and their regulatory effects on metabolic pathways. Systems biology approaches, incorporating metabolomics, transcriptomics, and proteomics for metabolic network analysis.

Unit 2: Carbohydrate Metabolism and Energy Dynamics

Regulatory mechanisms governing carbon partitioning, including starch-sucrose balance, enzyme-mediated control of starch biosynthesis, and plastid-localized metabolic flux. Carbon-Fixation and assimilation pathways. Photorespiration and metabolic engineering strategies, focusing on carbon salvage mechanisms, synthetic photorespiration pathways, and Rubisco modifications for enhanced efficiency. Mitochondrial respiration and alternative carbon metabolism, highlighting cyanide-resistant respiration, alternative oxidase functions, TCA cycle flux regulation, and mitochondrial retrograde signaling. Carbon fixation in stress adaptation, discussing C4 and CAM metabolism, engineering CAM traits into non-CAM species, and their significance in drought and salinity tolerance. Synthetic biology applications in carbohydrate metabolism, including carbon fixation pathways, genetic modifications for high-yield crops, and case studies in rice, wheat, and bioenergy plants.

Unit 3: Secondary Metabolites – Biosynthesis, Regulation, and Applications

Classification of secondary metabolites, including alkaloids, terpenoids, flavonoids, phenolics, and glucosinolates, with emphasis on their biosynthesis and ecological roles. Regulation of secondary metabolisrn through transcription factors (MYB, bHLH, WRKY), epigenetic control mechanisms, and metabolic pathway interactions. Case studies on medicinal plants such as *Catharanthus*, *Rauwolfia*, *Atropa*, and *Papaver*, highlighting their biosynthetic pathways and metabolic engineering strategies. High-resolution analytical techniques, including GC-MS, LC-MS, HPLC, and NMR, for secondary metabolite characterization and quantification.

Unit 4: Biotechnological Interventions for Secondary Metabolite Production

Metabolic engineering approaches, including pathway refactoring, enzyme promiscuity, flux balance analysis, and CRISPR-Cas9-based regulation of secondary metabolism. Functional genomics strategies such as RNA interference, overexpression studies, and synthetic pathway design in microbial and plant systems. Plant culture-based production systems, covering cell suspension and hairy root cultures, media optimization, precursor feeding, elicitor-induced metabolite accumulation, and co-culture techniques for enhanced production. Bioreactor technologies and industrial applications, emphasizing single-use bioreactors, biosensor integration for real-time metabolite synthesis, and case studies on large-scale production of secondary metabolites for pharmaceutical and nutraceutical industries.

Practical

1) Estimation of total carbohydrates, reducing sugars, and non-reducing sugars using colorimetric assays.
2) Protein estimation using Bradford and Lowry's method.
3) Lipid extraction and estimation by gravimetric and TLC methods.
4) Extraction and spectrophotometric analysis of chlorophyll, carotenoids, and anthocyanins.
5) Total phenolics and flavonoid content estimation using Folin-Ciocalteu and aluminum chloride assays.
6) Separation and Identification of Plant Secondary Metabolites.
7) TLC and HPTLC profiling of alkaloids, flavonoids, and terpenoids.
8) Column chromatography for fractionation of plant extracts.
9) Demonstration of GC-MS for volatile compound analysis in medicinal plants.
10) Determination of amylase, peroxidase, and polyphenol oxidase activity in plants.
11) Transformation of plant tissues using *Agrobacterium rhizogenes* for hairy root culture.
12) Quantification of secondary metabolites in transformed vs. non-transformed roots.
13) Extraction and Purification of Bioactive Compounds.
14) Demonstration of stirred-tank bioreactors for large-scale plant metabolite production.

Suggested Readings:

Core Textbooks:

- Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2014). *Molecular Biology of the Cell* (6th Edition). Garland Science.
- Buchanan, B.B., Gruissem, W., & Jones, R.L. (2015). *Biochemistry and Molecular Biology of Plants* (2nd Edition). Wiley.
- Heldt, H.-W., & Piechulla, B. (2010). *Plant Biochemistry* (4th Edition). Academic Press.
- Nelson, D.L., & Cox, M.M. (2017). *Lehninger Principles of Biochemistry* (7th Edition). W.H. Freeman and Company.
- Srivastava, V., Mishra, S., Mehrotra, S., & Upadhyay, S. K. (Eds.). (2022). *Plant Transcription Factors: Contribution in Development, Metabolism, and Environmental Stress.* Elsevier.
- Taiz, L., Zeiger, E., Møller, I.M., & Murphy, A. (2015). *Plant Physiology and Development* (6th Edition). Sinauer Associates.

Advanced References on Molecular and Applied Aspects:

- Ermakova, M., Danila, F.R., & von Caemmerer, S. (2023). "Engineering C4 and CAM metabolism into C3 plants for stress tolerance." *Journal of Experimental Botany*, 74(2), 395–411.

- Li, Y., Wang, Y., & Tang, W. (2023). "Post-translational modifications in metabolic regulation: Phosphorylation, ubiquitination, and SUMOylation in plants." *Plant Physiology, 191*(2), 456–468.
- Sandalio, L.M., Rodríguez-Serrano, M., & Romero-Puertas, M.C. (2022). "Cross-talk between organelles: The dynamic interplay among plastids, mitochondria, and peroxisomes in plant metabolism." *Journal of Experimental Botany, 73*(5), 1420–1436.
- South, P.F., Walker, B.J., & Ort, D.R. (2021). "Synthetic photorespiration pathways: Improving plant carbon efficiency." *Plant Physiology, 185*(1), 34–48.

References on Plant Metabolism and Biotechnology:

- Ashihara, H., Crozier, A., & Komamine, A. (Eds.). (2011). *Plant Metabolism and Biotechnology*. Wiley-Blackwell.
- Blankenship, R.E. (2014). *Molecular Mechanisms of Photosynthesis* (2nd Edition). Wiley-Blackwell.
- Eaton-Rye, J.J., Tripathy, B.C., & Sharkey, T.D. (Eds.). (2012). *Photosynthesis: Plastid Biology, Energy Conversion, and Carbon Assimilation*. Springer.
- Gang, D.R. (Ed.). (2013). *Plant Secondary Metabolism: Engineering and Applications*. Springer.
- Ramirez-Prado, J.S., Abulfaraj, A.A., Rayapuram, N., Benhamed, M., & Hirt, H. (2021). "Epigenetic modifications in plant secondary metabolite production." *Trends in Plant Science, 26*(7), 670–683.
- Verpoorte, R., & Alfermann, A.W. (Eds.). (2000). *Metabolic Engineering of Plant Secondary Metabolism*. CRC Press.
- Verpoorte, R., & Alfermann, A.W. (Eds.). (2000). *Plant Biotechnology and Secondary Metabolism*. CRC Press.
- Wink, M. (2010). *Plant Secondary Metabolites: Biosynthesis, Regulation, and Functions*. Wiley-Blackwell.
- Zhao, J., Davis, L.C., & Verpoorte, R. (2022). "Elicitor-induced secondary metabolite accumulation in plant cultures." *Biotechnology Advances, 42*, 107586.
- Zhou, M., & Memelink, J. (2022). "Regulation of secondary metabolism by transcription factors: MYB, bHLH, and WRKY networks." *Phytochemistry Reviews, 21*(3), 623–639.

References on Synthetic Biology and Large-Scale Production:

- Kayser, O., & Quax, W. (2018). *Synthetic Biology in Plant Biotechnology*. Wiley-VCH.
- Varma, A., & Tripathi, S. (2019). *Industrial Biotechnology of Secondary Metabolites*. Springer.
- Jinek, M., Chylinski, K., Fonfara, I., Hauer, M., Doudna, J.A., & Charpentier, E. (2023). "CRISPR-Cas-based metabolic engineering for secondary metabolite biosynthesis." *Nature Biotechnology, 41*(5), 1024–1039.
- Smetanska, I. (2023). "Bioreactor technologies for large-scale secondary metabolite production." *Applied Microbiology and Biotechnology, 107*(6), 2369–2387.

Cellular and Molecular Genetics

3-0-2

Credits: 4

Course Objective:

This course aims to provide a comprehensive understanding of plant biochemistry and molecular biology, focusing on metabolic pathways, gene regulation, and signal transduction. Students will gain hands-on experience with molecular techniques and explore applications in plant stress responses, crop improvement, and biotechnology.

Course Outcomes:

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

1. Comprehend Core Concepts – Demonstrate a strong foundation in plant biochemistry and molecular biology, including metabolic pathways, enzyme functions, and genetic regulation in plants.

2. Apply Molecular Techniques – Utilize modern molecular biology techniques such as PCR, qRT-PCR, CRISPR, and transcriptomics to investigate plant metabolic and regulatory processes.

3. Analyze Plant Responses – Evaluate plant biochemical and molecular responses to environmental stresses, such as drought, salinity, and pathogen attacks, and propose strategies for crop improvement.

4. Develop Research Proficiency – Design and execute experiments, analyze data, and critically interpret scientific literature related to plant molecular biology, fostering innovation in plant sciences and biotechnology.

Theory

Unit 1: Advanced Cellular Genetics and Genome Organization

Genome architecture includes the complexity of prokaryotic and eukaryotic genomes, the presence of transposable elements, and repetitive DNA. Chromatin dynamics and regulation involve the histone code hypothesis, chromatin remodeling complexes, and their implications for gene regulation. The cell cycle is regulated through checkpoints, cyclins/CDKs, and plays crucial roles in development, cancer, and stem cell biology. Genome stability and evolution are influenced by chromosomal rearrangements, segmental duplications, and whole-genome duplication events. Genetic and epigenetic regulation of development involves epigenetic memory, paramutation, and imprinting, with applications in both plants and animals.

Unit 2: Mendelian and Non-Mendelian Inheritance in Disease and Evolution

Extensions of Mendelian genetics encompass phenomena such as epistasis, pleiotropy, penetrance, and expressivity. Quantitative genetics and association studies utilize QTL mapping and GWAS to improve traits of interest. Cytoplasmic inheritance and endosymbiotic gene transfer highlight the roles of mitochondria and plastids in heredity. Sex determination and dosage compensation mechanisms vary across taxa and include processes like X-chromosome inactivation, Y chromosome evolution, concept of neo sex chromosome in papaya. Human genetic disorders and population genetics explore Hardy-Weinberg equilibrium, founder effects, and disease susceptibility.

Unit 3: Molecular Mechanisms of Gene Function and Regulation

Genomic organization and replication involve the origin of replication, telomere biology, and replication-associated disorders. Gene expression is regulated through transcription factors, enhancers, silencers, and chromatin looping. RNA biology and post-transcriptional regulation include microRNAs, long non-coding RNAs, RNA stability, and RNA editing. Genome-wide regulation is studied through transcriptomics, epigenomics, and single-cell genomics. Environmental and stress-induced genetic regulation influences gene expression in response to abiotic and biotic stresses.

Unit 4: Cutting-Edge Technologies in Molecular Genetics and Functional Genomics

Genome engineering approaches, including CRISPR-Cas9, prime editing, and base editing, enable targeted modifications. High-throughput sequencing and omics approaches, such as RNA-seq, ChIP-seq, and ATAC-seq, have broad applications in genomics research. Synthetic biology and functional genomics involve the construction of gene circuits, synthetic promoters, and engineered regulatory networks. Epigenetic therapeutics and precision medicine utilize CRISPR-epigenome editing, small-molecule inhibitors, and gene therapy strategies. Computational genetics and artificial intelligence in genomics support AI-driven gene annotation, predictive modeling, and precision breeding.

Practical

1. Advanced DNA and RNA extraction methods, including ChIP-extracted DNA and small RNA isolation.

2. Quantification and quality control of nucleic acids using Nanodrop and Qubit fluorometers.
3. Agarose and polyacrylamide gel electrophoresis for nucleic acid and protein separation.

4. Molecular cloning strategies, such as ligation-independent cloning and site-directed mutagenesis.

5. CRISPR-Cas9 gene editing demonstration, including gRNA design and plasmid construction.

6. Chromatin Immunoprecipitation (ChIP) and qPCR analysis for epigenetic studies.

7. DNA-protein interaction studies using electrophoretic mobility shift assay (EMSA) and yeast one-hybrid.

8. RNA-seq library preparation and data analysis for transcriptomic research.

9. Quantitative PCR (qPCR) and digital PCR (dPCR) for gene expression profiling.

10. In silico genetic variant analysis, including SNP discovery and phylogenetics using bioinformatics tools.

11. High-throughput genome annotation using NGS-based computational approaches.

12. Hands-on training in molecular databases and bioinformatics tools (NCBI, Ensembl, UCSC Genome Browser.

Suggested Readings

Textbooks:

- Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2022). **Molecular Biology of the Cell** (7th ed.). Garland Science.
- Lodish, H., Berk, A., Kaiser, C. A., Krieger, M., Bretscher, A., Ploegh, H., & Matsudaira, P. (2021). **Molecular Cell Biology** (9th ed.). W. H. Freeman.
- Snustad, D. P., & Simmons, M. J. (2020). **Principles of Genetics** (7th ed.). Wiley.
- Brown, T. A. (2020). **Genomes 4.** Garland Science.
- Klug, W. S., Cummings, M. R., Spencer, C. A., Palladino, M. A., & Killian, D. J. (2021). **Concepts of Genetics** (12th ed.). Pearson.
- Nelson, D. L., & Cox, M. M. (2021). **Lehninger Principles of Biochemistry** (8th ed.). W. H. Freeman.
- Buchanan, B. B., Gruissem, W., & Jones, R. L. (2015). **Biochemistry & Molecular Biology of Plants** (2nd ed.). Wiley-Blackwell.
- Watson, J. D., Baker, T. A., Bell, S. P., Gann, A., Levine, M., & Losick, R. (2017). **Molecular Biology of the Gene** (7th ed.). Pearson.
- Slatkin, M., & Veuille, M. (2006). **Modern Developments in Theoretical Population Genetics**. Oxford University Press.

Research Papers and Reviews:

Epigenetics and Gene Regulation

- Zhu, J., et al. (2020). *The role of histone modifications in gene regulation and development. Nature Reviews Genetics*, **21**, 41–56.

CRISPR and Genome Editing in Plants

- Zhang, Y., Malzahn, A. A., Sretenovic, S., & Qi, Y. (2019). *The emerging and uncultivated potential of CRISPR technology in plant sciences. Nature Plants*, **5**, 778–794.

Plant Stress Responses and Molecular Adaptation

- Shankar, R., et al. (2022). *Molecular mechanisms underlying plant responses to abiotic stressors: Insights from omics approaches. Frontiers in Plant Science*, **13**, 998523.

RNA Biology and Functional Genomics

- Bartel, D. P. (2018). *Metazoan MicroRNAs. Cell*, **173**(1), 20–51.

High-Throughput Sequencing and Computational Genomics

- Stark, R., Grzelak, M., & Hadfield, J. (2019). *RNA sequencing: The teenage years. Nature Reviews Genetics*, **20**, 631–656.

Synthetic Biology in Plant Science

- Liu, W., Stewart, C. N. (2016). *Plant synthetic biology. Trends in Plant Science*, **21**(8), 622–630.

Population Genetics and Evolutionary Studies

- Ellegren, H., & Galtier, N. (2016). *Genome evolution: Causes and consequences of genetic variation. Nature Reviews Genetics*, **17**, 422–437.

Online Resources & Databases:

- **NCBI (National Center for Biotechnology Information)** – https://www.ncbi.nlm.nih.gov/
- **Ensembl Genome Browser** – https://www.ensembl.org/
- **UCSC Genome Browser** – https://genome.ucsc.edu/
- **PlantGDB (Plant Genome Database)** – http://www.plantgdb.org/
- **The Arabidopsis Information Resource (TAIR)** – https://www.arabidopsis.org/

Semester IX

Molecular Plant Physiology

3-0-2 **Credits:4**

Course Objective:

This course provides an in-depth understanding of the molecular, physiological, and biochemical mechanisms governing plant development and stress responses. It will emphasize advanced concepts in fruit and seed development, programmed cell death, senescence, plant-microbe and plant-pathogen interactions, and molecular responses to abiotic stress.

Course Outcomes:

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

1. Develop a comprehensive understanding of the molecular and biochemical processes regulating fruit and seed development, including genetic control, phytohormonal regulation, and post-harvest modifications.
2. Analyze the mechanisms of programmed cell death (PCD), including autophagic processes, oxidative stress-mediated senescence, and their implications in plant longevity.
3. Evaluate molecular defense strategies in plant-pathogen interactions, including hormonal crosstalk, signal transduction pathways, and systemic acquired resistance.
4. Explore abiotic stress adaptation mechanisms, including stress-responsive genes, epigenetic regulation, and metabolic reprogramming.
5. Gain expertise in computational tools for gene expression analysis, metabolic pathway prediction, and data interpretation in plant molecular physiology.
6. Understand the translational aspects of molecular plant physiology in agricultural biotechnology and stress-resilient crop development.

Theory

Unit 1: Molecular Mechanisms in Plant Development

Molecular mechanisms underlying fruit initiation, development, and ripening; regulation of fruit ripening through transcriptional and hormonal networks including ethylene, auxins, gibberellins, and ABA; post-harvest modifications focusing on genetic engineering for extended shelf life and molecular aspects of transgenic fruits; seed development regulated by genetic and epigenetic factors, hormonal interplay such as ABA-GA balance, and dormancy regulation; mobilization of stored reserves during seed germination and associated signaling pathways; advanced functional genomics approaches including RNA interference (RNAi), overexpression studies, and proteomics-based techniques.

Unit 2: Cell Death, Senescence, and Aging Mechanisms

Programmed cell death (PCD) and its molecular mechanisms, involvement of reactive oxygen species (ROS), mitochondrial and ER-mediated pathways; leaf senescence regulated by WRKY, NAC, and bZIP transcription factors along with hormonal signaling; stress-induced versus developmental senescence with molecular signatures and functional implications; role of small RNAs and epigenetics in regulating senescence; computational approaches employing bioinformatics tools for senescence-related gene expression analysis.

Unit 3: Molecular Plant Defense and Biotic Interactions

Molecular basis of plant-microbe symbiosis; arbuscular mycorrhizal fungi (AMF) interactions, rhizobial nodulation, mycorrhizal signaling pathways; plant defense mechanisms, pathogen-triggered immunity (PTI), effector-triggered immunity (ETI), systemic acquired resistance (SAR), induced systemic resistance (ISR); phytohormonal crosstalk in defense, jasmonic acid (JA), salicylic acid (SA), ethylene in plant defense; genomic and transcriptomic approaches to plant-pathogen interactions; computational tools for gene regulatory networks in plant immunity; yeast two-hybrid screening, functional characterization of defense proteins.

Unit 4: Molecular Responses to Abiotic Stress

Molecular basis of stress perception and signaling networks involving stress-responsive transcription factors such as DREB, NAC, and MYB families; stress-induced post-translational modifications including phosphorylation, ubiquitination, and SUMOylation; role of osmoprotectants, compatible solutes, and antioxidants in plant stress tolerance; epigenetic regulation of abiotic stress responses through DNA methylation and histone modifications; systems biology approaches for studying plant responses to multiple abiotic stresses; industrial and translational aspects focusing on stress-resilient crop development using molecular tools.

Practical

1. Analysis of seed germination and seedling growth under salt and drought stress conditions.
2. Quantification of chlorophyll and proline accumulation in plants under abiotic stress.
3. Enzymatic assays to assess antioxidant activity in plant tissues.
4. Estimation of total phenolics and flavonoids to evaluate stress-induced biochemical changes.

5. Detection of reactive oxygen species (ROS) and cell death using nitroblue tetrazolium (NBT) and Evans blue staining methods.

6. Assessment of microbial influence on plant growth and stress tolerance.

7. Measurement of chlorophyll fluorescence to evaluate photosynthetic performance under abiotic stress.

8. Investigation of phytohormonal effects on seed germination, leaf senescence, and root elongation.

9. Extraction and qualitative analysis of key secondary metabolites such as alkaloids, flavonoids, and terpenoids in stressed plants.

10. Evaluation of pathogen-induced defense responses in plant leaves using bioassays.

Suggested reading:

Core Textbooks:

- Taiz, L., Zeiger, E., Møller, I. M., & Murphy, A. (2018). *Plant Physiology and Development* (6th ed.). Sinauer Associates, Oxford University Press.
- Buchanan, B. B., Gruissem, W., & Jones, R. L. (2020). *Biochemistry & Molecular Biology of Plants* (2nd ed.). Wiley-Blackwell.
- Sessa, G. (Ed.). (2012). *Molecular Plant Immunity*. Wiley-Blackwell.
- Davies, P. J. (2010). *Plant Hormones: Biosynthesis, Signal Transduction, Action!* (3rd ed.). Springer.
- Nooden, L. D. (2014). *Senescence and Cell Death in Plants*. Academic Press, Elsevier.
- Singh, V. P., Singh, S., & Prasad, S. M. (2017). *Reactive Oxygen Species in Plants: Boon or Bane – Revisiting the Role of ROS*. Wiley-Blackwell.
- Kumar, A., Gill, S. S., & Tuteja, N. (2021). *Plant Responses to Drought and Salinity Stress: Developments in Molecular Biology and Genetic Engineering*. Springer.
- Ruan, J. (2018). *Computational Systems Biology in Plants*. Springer.

References

- Giovannoni, J. (2004). Genetic regulation of fruit development and ripening. *The Plant Cell*, 16(suppl_1), S170-S180.

- Klee, H. J., & Giovannoni, J. J. (2011). Genetics and control of tomato fruit ripening and quality attributes. *Annual Review of Genetics*, 45, 41-59.
- Kumar, S., & Pandey, P. (2010). Genetic engineering of fruit crops for extended shelf life. *Plant Cell Reports*, 29(9), 703-710.
- Holdsworth, M. J., Bentsink, L., & Soppe, W. J. (2008). Molecular networks regulating Arabidopsis seed maturation, after-ripening, dormancy, and germination. *New Phytologist*, 179(1), 33-54.
- Pérez-Rodríguez, P., Riaño-Pachón, D. M., Corrêa, L. G., Rensing, S. A., Kersten, B., & Mueller-Roeber, B. (2010). PlnTFDB: Updated content and new features of the plant transcription factor database. *Nucleic Acids Research*, 38(suppl_1), D822-D827.
- Van Doorn, W. G., & Woltering, E. J. (2005). Many ways to exit? Cell death categories in plants. *Trends in Plant Science*, 10(3), 117-122.
- Guo, Y., & Gan, S. (2005). Leaf senescence: signals, execution, and regulation. *Current Topics in Developmental Biology*, 71, 83-112.
- Ay, N., Irmler, K., Fischer, A., Uhlemann, R., Reuter, G., & Humbeck, K. (2009). Epigenetic programming via histone methylation at WRKY53 controls leaf senescence in *Arabidopsis thaliana*. *The Plant Journal*, 58(2), 333-346.
- Oldroyd, G. E., & Downie, J. A. (2008). Coordinating nodule morphogenesis with rhizobial infection in legumes. *Annual Review of Plant Biology*, 59, 519-546.
- Jones, J. D., & Dangl, J. L. (2006). The plant immune system. *Nature*, 444(7117), 323-329.
- Pieterse, C. M., Van der Does, D., Zamioudis, C., Leon-Reyes, A., & Van Wees, S. C. (2012). Hormonal modulation of plant immunity. *Annual Review of Cell and Developmental Biology*, 28, 489-521.
- Agarwal, P. K., Agarwal, P., Reddy, M. K., & Sopory, S. K. (2006). Role of DREB transcription factors in abiotic and biotic stress tolerance in plants. *Plant Cell Reports*, 25(12), 1263-1274.
- Stone, S. L., & Callis, J. (2007). Ubiquitin ligases mediate growth and development by promoting protein death. *Current Opinion in Plant Biology*, 10(6), 624-632.
- Chinnusamy, V., & Zhu, J. K. (2009). Epigenetic regulation of stress responses in plants. *Current Opinion in Plant Biology*, 12(2), 133-139.

Additional Suggested Reading:

- Davies, P. J. (Ed.). (2004). *Plant Hormones: Biosynthesis, Signal Transduction, Action!* (3rd ed.). Springer. ISBN: 978-1-4020-2685-0.
- Nath, P., Bouzayen, M., Mattoo, A. K., & Pech, J. C. (Eds.). (2014). *Fruit Ripening: Physiology, Signalling and Genomics*. CABI. ISBN: 978-1-84593-962-5.
- Noodén, L. D. (Ed.). (1988). *Senescence and Aging in Plants*. Academic Press. ISBN: 978-0-12-520915-0.
- De Moraes, C. M., Mescher, M. C., & Tumlinson, J. H. (Eds.). (2012). *Biotic Interactions in Plant Defense*. Wiley-Blackwell. ISBN: 978-0 470-95820-8.
- Pareek, A., Sopory, S. K., Bohnert, H. J., & Govindjee (Eds.). (2010). *Abiotic Stress Adaptation in Plants: Physiological, Molecular and Genomic Foundation*. Springer. ISBN: 978-90-481-3111-2.

Reports and Online Resources:

1. Reports

- Intergovernmental Panel on Climate Change (IPCC) Reports.
- Food and Agriculture Organization (FAO) State of Food Security Reports.
- Annual Reports on Plant Biotechnology and Agriculture from the International Plant Biotechnology Journal.

2. Online Resources

- **FAO**: www.fao.org
- **The Arabidopsis Information Resource (TAIR)**: www.arabidopsis.org
- **Plant Transcription Factor Database**: planttfdb.cbi.pku.edu.cn
- **National Center for Biotechnology Information (NCBI) Plant Genome Database**: www.ncbi.nlm.nih.gov
- **International Society for Plant Molecular Biology**: www.ispmb.org

In Vitro Technologies for Plants

LTP: 3-0-2 **Credits: 4**

Course Objective:

This course aims to provide advanced theoretical and practical knowledge of plant in vitro technologies, with a focus on genetic transformation, secondary metabolite production, and bioreactor systems. It integrates machine learning (ML) and artificial intelligence (AI) into plant tissue culture and prepares students for research and industrial applications in plant biotechnology. The course emphasizes on innovation and problem-solving through case studies.

Course Outcomes:

On successful completion of this course, the students should be able to:

1. Utilize specialized media for efficient callus induction, micropropagation, and somatic embryogenesis.

2. Apply genetic transformation techniques for creating transgenic plants and conducting functional studies.

3. Optimize secondary metabolite production using in vitro techniques and bioreactor systems.

4. Integrate ML and AI tools to enhance tissue culture efficiency and reproducibility.

5. Critically analyse case studies to address complex problems in plant tissue culture and biotechnology.

Theory

Unit 1: Media and Culture Techniques

Preparation of specialized culture media including Murashige and Skoog (MS), Gamborg's (B5), Woody Plant Media, and Orchid culture media. Role of plant growth regulators (auxins, cytokinins, gibberellins) in tissue culture. Factors influencing callus induction, micropropagation, and somatic embryogenesis, including somaclonal variation and synthetic seed production. Molecular mechanisms underlying callus induction, micropropagation, and somatic embryogenesis. Case studies of successful applications in forestry and horticulture, with focus on Jammu & Kashmir.

Unit 2: Embryo Rescue, Haploids, Triploids, and Genetic Transformation

Embryo rescue techniques and their applications. Haploid production through androgenesis and gynogenesis. Endosperm culture and triploid production techniques. Methods of genetic transformation such as Agrobacterium-mediated, biolistic, electroporation, and CRISPR-based approaches. Selection markers and reporter genes in transformation studies. Current status and implications of transgenic crops, including benefits, concerns, and ethical issues.

Unit 3: Secondary Metabolite Production, Bioreactors, and Scaling-Up Processes Secondary metabolite production through elicitation, precursor feeding, and metabolic engineering. Role of hairy root cultures in metabolite synthesis. Types of bioreactors such as stirred tank, airlift, and temporary immersion bioreactors. Applications of bioreactors in large-scale plant tissue culture and metabolite production. Challenges in scaling up tissue culture processes and ensuring quality control. Case studies on transgenic plants for pharmaceuticals and secondary metabolite production.

Unit 4: Integration of ML and AI in Plant Tissue Culture

Applications of machine learning and artificial intelligence in optimizing biological systems. Tools and algorithms for optimizing culture conditions, media formulation, and growth predictions. Integration of AI with bioreactors for real-time monitoring. Case studies focusing on predictive modeling for somatic embryogenesis and culture success rates.

Practical

1. Preparation of different stock solutions (MS, B5, WPM) for media preparation.
2. Collection, preparation, and sterilization of various explants.
3. Callus induction and plant regeneration from somatic embryos.
4. Production of synthetic seeds.
5. Genetic transformation experiments using Agrobacterium and model plants.
6. Bioreactor operation for scaling up plant tissue culture.
7. Application of ML tools (e.g., Python, R) for analyzing tissue culture data.
8. Designing and interpreting AI-based models for tissue culture optimization.

Suggested Readings:
Textbooks:

- George, E. F., Hall, M. A., & De Klerk, G.-J. (2008). *Plant Propagation by Tissue Culture* (3rd ed.). Springer.
- Trigiano, R. N., & Gray, D. J. (2011). *Plant Tissue Culture, Development, and Biotechnology*. CRC Press.
- Bhojwani, S. S., & Razdan, M. K. (1996). *Plant Tissue Culture: Theory and Practice*. Elsevier.
- Smith, R. H. (2012). *Plant Tissue Culture: Techniques and Experiments* (3rd ed.). Academic Press.
- Razdan, M. K. (2003). *Introduction to Plant Tissue Culture* (2nd ed.). Oxford & IBH Publishing.

Reference Books

- Thorpe, T. A. (2007). *History of Plant Tissue Culture*. Molecular Biotechnology, 37(2), 169–180.
- Kumar, A., & Sharma, M. (2017). *Somatic Embryogenesis and Its Applications in Horticulture*. Springer.
- Hall, R. D. (2011). *Plant Cell Culture: Essential Methods*. Wiley-Blackwell.
- Giri, A., & Dhingra, V. (2014). *Bioreactors for Plant Cell and Tissue Culture*. Springer.
- Lorz, H., & Wenzel, G. (2005). *Molecular Marker Systems in Plant Breeding and Crop Improvement*. Springer.

Research Articles and Journals:

- Murashige, T., & Skoog, F. (1962). *A Revised Medium for Rapid Growth and Bio Assays with Tobacco Tissue Cultures*. Physiologia Plantarum, 15(3), 473–497.
- Sugimoto, K., Jiao, Y., & Meyerowitz, E. M. (2010). *Arabidopsis Regeneration from Tissue Culture: Developmental and Molecular Aspects*. Annual Review of Plant Biology, 61, 709–739.
- Wang, X., & Zhang, Z. (2020). *Machine Learning and AI Applications in Plant Biotechnology*. Trends in Plant Science, 25(10), 933–944.
- Tripathi, L., Ntui, V. O., & Tripathi, J. N. (2021). *CRISPR/Cas9-based Genome Editing in Crop Improvement: Progress and Prospects*. Plant Biotechnology Journal, 19(6), 1244–1262.
- Ochoa-Villarreal, M., Howat, S., Sun, Y., et al. (2016). *Bioreactors for Plant Research: Present and Future Developments*. Biotechnology Advances, 34(8), 1329–1355.

Online Resources:

- NCBI GenBank: Plant genome sequencing and transformation resources.
- KEGG Pathway Database: Biosynthetic pathways of secondary metabolites.
- The International Society for Plant Pathology (ISPP): Advances in plant biotechnology.
- AI & Machine Learning in Plant Science (Google AI Blog): Real-time applications in plant tissue culture.
- FAO Biotechnology Portal: Global trends in plant biotechnology and genetic transformation.

Plant Ecology, Systematics, and Taxonomy

LTP 3-0-2

Credits- 4

Course Objective:

Understanding plant ecology, biodiversity, and conservation through ecological theories, molecular techniques, and computational models. Emphasis on plant population dynamics, species interactions, evolutionary processes, and conservation strategies. Application of GIS, bioinformatics, and molecular ecology in biodiversity assessment and ecosystem management.

Course Outcomes:

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

1. Analyse plant population dynamics, competition, and ecological interactions using mathematical models and field data.
2. Integrate molecular phylogenetics, population genetics, and computational tools in plant biodiversity studies.
3. Apply conservation genomics, GIS-based habitat modelling, and ecological restoration strategies for species conservation.
4. Evaluate environmental laws, sustainable agriculture practices, and technological advancements in plant ecology.

Theory

Unit I: Plant Population Ecology and Evolutionary Biology

Ecology concepts – environmental laws, limiting factors, stochasticity in plant populations. Demographic parameters – survivorship curves, life tables (cohort vs. static), reproductive allocation. Population growth models – exponential, logistic, θ-logistic growth, density dependence, regulation mechanisms. Plant demography methods – quadrat, transect, capture-recapture, Bayesian hierarchical models. Intra-specific competition – Lotka-Volterra competition model, Grime's CSR strategy theory. Evolutionary ecology – natural selection, microevolution, speciation, phylogenetic systematics. Macroevolution – molecular clock, adaptive radiation, biogeography, phylogenetic inference.

Unit II: Plant Community Ecology and Species Interactions

Community structure and competition – niche differentiation, resource partitioning, Gause's principle. Mathematical models – competition coefficients, Holling's Type II & III functional responses. Mutualistic networks – pollination syndromes, seed dispersal, mycorrhizal interactions. Plant-herbivore interactions – Lotka-Volterra predator-prey model, herbivory defense mechanisms. Co-evolution – Red Queen Hypothesis, Geographic Mosaic Theory, allelopathy in plants. Parasitism and commensalism – host-parasite adaptations, plant allelopathy, competition theory.

Unit III: Systematics, Phylogenetics, and Molecular Taxonomy

Plant classification – historical systems (Bentham & Hooker, Engler & Prantl), modern molecular-based classification. APG IV (2016) system – molecular phylogenetics, DNA-based taxonomy, evolution of angiosperms. Molecular phylogenetic methods – Bayesian inference, Maximum Likelihood, molecular clock estimation. Species concepts – morphological, biological, phylogenetic, and integrative taxonomy. DNA barcoding and molecular markers – ITS, rbcL, matK, and whole-genome approaches. Bioinformatics in systematics – sequence alignment, phylogenetic tree construction, species delimitation. Chemotaxonomy and morphometric analysis – secondary metabolites, quantitative trait analysis in taxonomy.

Unit IV: Biodiversity Conservation, Environmental Science, and Sustainability

Biodiversity metrics – species richness, diversity indices, species-area relationships, metacommunity theory. Conservation strategies – in-situ and ex-situ conservation, ecological corridors, genetic rescue. Molecular tools in conservation – eDNA, metagenomics, NGS for species identification, conservation genomics. Population genetics – Hardy-Weinberg equilibrium, F-statistics, effective population size (Ne), migration models. Species distribution modelling – MaxEnt, BioClim, GIS-based habitat modelling, climate change projections. Population viability analysis (PVA) – deterministic vs. stochastic modelling for extinction risk assessment. Environmental laws and policies – CBD, Nagoya Protocol, Biodiversity Act, Forest Conservation Act. Sustainable agriculture – agroecology, permaculture, climate-resilient crops, ecosystem restoration. Technological applications – AI, big data, remote sensing, GIS, hyperspectral imaging in biodiversity research.

Practical

1. Plant Population Growth Analysis: Quadrat, transect, capture-recapture methods.
2. Phylogenetic Tree Construction: Bayesian inference, Maximum Likelihood, molecular clock analysis.
3. Network Ecology in Plant Interactions: R-based network visualization (igraph, bipartite).
4. Plant Competition Modelling: Lotka-Volterra simulations, coexistence modelling.
5. Molecular Taxonomy and DNA Barcoding: PCR amplification, sequencing, species identification.
6. Metagenomics and eDNA in Conservation: High-throughput sequencing for biodiversity assessment.
7. GIS & Remote Sensing for Plant Ecology: Habitat mapping, conservation planning, species distribution modelling.
8. Quantitative Biodiversity Indices: Shannon, Simpson, Chao1 indices, rarefaction analysis.

9. Population Viability Analysis (PVA): Climate change impact simulation, extinction risk modelling.

10. AI & Machine Learning in Taxonomy: Automated species identification, digital herbarium databases

Suggested Readings

Core Textbooks:

- Barbour, M.G., Burk, J.H., & Pitts, W.D. (1999). *Terrestrial Plant Ecology (3rd Edition)*. Benjamin Cummings.
- Begon, M., Townsend, C.R., & Harper, J.L. (2021). *Ecology: From Individuals to Ecosystems (5th Edition)*. Wiley-Blackwell.
- Cain, M.L., Bowman, W.D., & Hacker, S.D. (2020). *Ecology (4th Edition)*. Sinauer Associates.
- Heywood, V.H., Brummitt, R.K., Culham, A., & Seberg, O. (2007). *Flowering Plant Families of the World*. Kew Publishing.
- Judd, W.S., Campbell, C.S., Kellogg, E.A., Stevens, P.F., & Donoghue, M.J. (2015). *Plant Systematics: A Phylogenetic Approach (4th Edition)*. Sinauer Associates.
- Simpson, M.G. (2019). *Plant Systematics (3rd Edition)*. Academic Press.
- Raven, P.H., Evert, R.F., & Eichhorn, S.E. (2013). *Biology of Plants (8th Edition)*. W. H. Freeman and Company.

Advanced References on Molecular Phylogenetics and Taxonomy:

- Angiosperm Phylogeny Group IV (2016). *An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV.* Botanical Journal of the Linnean Society, 181(1), 1-20.
- Chase, M.W., Christenhusz, M.J.M., Fay, M.F., Byng, J.W., Judd, W.S., Soltis, D.E., Mabberley, D.J., Sennikov, A.N., Soltis, P.S., & Stevens, P.F. (2016). *An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV.* Botanical Journal of the Linnean Society, 181(1), 1-20.
- Gitzendanner, M.A., Soltis, P.S., Wong, G.K.S., Ruhfel, B.R., & Soltis, D.E. (2018). *Plastid phylogenomic analysis of green plants: A billion years of evolutionary history.* American Journal of Botany, 105(3), 291-301.
- Christenhusz, M.J.M., & Byng, J.W. (2016). *The Global Flora: A Practical Guide to Vascular Plant Families.* Plant Gateway Ltd.
- Soltis, D.E., Soltis, P.S., & Endress, P.K. (2018). *Phylogeny and Evolution of Angiosperms (2nd Edition).* University of Chicago Press.

References on Ecological Concepts and Modelling:

- Gotelli, N.J. (2008). *A Primer of Ecology (4th Edition).* Sinauer Associates.
- Molles, M.C., & Sher, A. (2018). *Ecology: Concepts and Applications (8th Edition).* McGraw Hill.
- Tilman, D. (1982). *Resource Competition and Community Structure.* Princeton University Press.
- Hubbell, S.P. (2001). *The Unified Neutral Theory of Biodiversity and Biogeography.* Princeton University Press.
- Connell, J.H. (1961). *The Influence of Interspecific Competition and Other Factors on the Distribution of the Barnacle Chthamalus Stellatus.* Ecology, 42(4), 710-723.

References on Conservation and Environmental Laws:

- Primack, R.B. (2022). *Essentials of Conservation Biology (7th Edition).* Oxford University Press.
- Sodhi, N.S., & Ehrlich, P.R. (2010). *Conservation Biology for All.* Oxford University Press.
- Mace, G.M., Norris, K., & Fitter, A.H. (2012). *Biodiversity and ecosystem services: A multilayered relationship.* Trends in Ecology & Evolution, 27(1), 19-26.
- Convention on Biological Diversity (CBD) (2022). *Global Biodiversity Outlook 5.* United Nations Environment Programme (UNEP).
- Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-Being: Biodiversity Synthesis.* World Resources Institute.

Supplementary Online Resources and Journals:

- Journal of Ecology (British Ecological Society) – Publishes research on plant population and community ecology.
  https://besjournals.onlinelibrary.wiley.com/journal/13652745
- Systematic Biology (Oxford University Press) – Covers evolutionary biology and systematics research.
  https://academic.oup.com/sysbio
- Taxon (International Association for Plant Taxonomy) – Publishes research on plant nomenclature and classification.
  https://onlinelibrary.wiley.com/journal/19968175
- New Phytologist – Covers plant science, ecology, and systematics.
  https://nph.onlinelibrary.wiley.com

Semester X

Reproductive And Developmental Biology of Angiosperms

LTP: 3-0-2

Credits: 4

Course Objective:

This course aims to provide an in-depth understanding of the molecular and cellular mechanisms governing plant development, reproduction, and adaptation. Students will explore key regulatory pathways, including genetic, hormonal, and epigenetic controls, that shape plant growth and response to environmental signals. Through an integrative approach, the course will link fundamental developmental processes with applied perspectives in plant breeding, stress resilience, and crop improvement.

Course Outcomes:

On successful completion of this course, the students should be able to:

1. Gain foundational knowledge of molecular, genetic, and hormonal regulation of plant growth, tissue differentiation, and secondary growth.
2. Understand the genetic and environmental regulation of gametophyte development, pollination, fertilization, and seed formation.
3. Explore applications of plant developmental biology in improving yield, stress tolerance, and reproductive efficiency in agriculture.
4. Develop skills to analyze and interpret recent advancements in plant developmental biology and integrate them into research or applied contexts.

Theory

Unit 1: Advanced Molecular and Cellular Basis of Plant Development

Molecular regulation of plant growth, differentiation, and cellular specialization. Signal transduction mechanisms involved in plant cell differentiation. Detailed cellular organization and regulatory pathways in the development of specialized plant cell types, including modifications in parenchyma, collenchyma, and sclerenchyma. Molecular basis of vascular tissue differentiation (xylem and phloem), with an emphasis on secondary cell wall formation, lignification, and cell fate determination. Advanced meristem biology, including the molecular interplay between RAM & SAM, the CLAVATA-WUSCHEL feedback loop, auxin-cytokinin crosstalk, and epigenetic regulation of meristem maintenance. Mechanisms governing epidermal differentiation, including transcriptional and hormonal control of stomatal patterning

(SPCH, MUTE, FAMA), trichome development (GLABRA genes), and the formation of specialized secretory structures and laticifers.

Unit 2: Tissue Organization, Secondary Growth, and Senescence

Vascular cambium organization and its role in secondary growth, including the formation of secondary xylem and phloem, and annual ring formation. Hormonal regulation of cambial activity involving genes such as PHB and WOX4, and the influence of auxins and gibberellins on wood formation. Leaf morphogenesis governed by phyllotaxy and venation patterns. Senescence and programmed cell death (PCD), metabolic shifts, transcription factors such as ORE1 and NACs, autophagy, ROS signaling, and hormonal regulation of senescence.

Unit 3: Plant Reproductive Strategies and Gametophyte Development

Modes of reproduction, including sexual and asexual strategies, apomixis, and variability in sex expression. Genetic and hormonal control of floral transition regulated by FT, SOC1, and FLC genes. Floral evocation and development through autonomous, photoperiodic, and vernalization pathways. Floral organogenesis following the ABCDE model, regulatory genes such as AP1 and LFY, and epigenetic mechanisms influencing floral development. MADS box genes and their regulation. Anther structure, male gametophyte development, including microsporogenesis and microgametogenesis, tapetum function, transcriptional regulation by bHLH and MYB genes, and deposition of pollen surface components. Female gametophyte development, including ovule formation, molecular control of megasporogenesis, megagametogenesis, and the organization of mature embryo sacs.

Unit 4: Pollination, Fertilization, Embryogenesis, and Endosperm Development

Pollination mechanisms, Extracellular components of stigma and their significance in reproduction, pollen-pistil interactions, pollen germination, pollen tube growth through style and compatibility factors ensuring reproductive success. Self-incompatibility mechanisms governed by S-locus RNases and SRK-SCR interactions, with genetic and regulatory controls. Pollen tube growth regulated by specific signaling pathways leading to double fertilization and seed development. Genetic regulation of embryo patterning, zygotic development, and hormonal influences such as auxin and cytokinin. Embryogenesis and accumulation of storage products essential for seed viability. Endosperm development, types, detailed structures and development in maize; storage product accumulation. Seed dormancy regulated by transcriptional and hormonal networks. Polyembryony and its significance in crop improvement.

Practical

1. Preparation of permanent slides; differential staining of parenchyma, collenchyma, and sclerenchyma.
2. Microscopic examination of shoot and root apical meristems (SAM & RAM) in monocots and dicots.
3. Study of primary and secondary xylem and phloem in stem and root sections using double staining techniques.
4. Analysis of annual rings, wood anatomy, and development of vascular cambium in woody plants.
5. Stomatal distribution and trichome types in different plant species; calculation of stomatal index.
6. Comparative study of flowers at different developmental stages to understand floral organ initiation.
7. In vitro pollen germination using Brewbaker and Kwack medium; effect of temperature and sucrose concentration on germination.
8. Microscopic examination of anther dehiscence, microsporogenesis, and pollen structure in different plant species.
9. Study of ovule development and embryo sac organization using cleared ovule preparations.
10. Study of different pollination mechanisms and analysis of compatible and incompatible pollen-pistil interactions using fluorescence microscopy.
11. Dissection and observation of embryo development in monocots and dicots.
12. Histochemical staining of starch, protein, and lipid bodies in different seed types.

Suggested readings:

Core Textbooks:

- Beck, C. B. (2010). *An Introduction to Plant Structure and Development: Plant Anatomy for the Twenty-First Century* (2nd Edition). Cambridge University Press.
- Bowman, J. L. (2016). *Arabidopsis: An Atlas of Morphology and Development.* Springer.
- Evert, R. F. (2006). *Esau's Plant Anatomy: Meristems, Cells, and Tissues of the Plant Body – Their Structure, Function, and Development.* Wiley.

- Hopkins, W. G., & Hüner, N. P. A. (2019). *Introduction to Plant Physiology* (5th Edition). Wiley.
- Meyerowitz, E. M., & Somerville, C. (Eds.). (1994). *Arabidopsis*. Cold Spring Harbor Laboratory Press.
- Niklas, K. J. (1997). *The Evolutionary Biology of Plants*. University of Chicago Press.
- Raghavan, V. (2000). *Developmental Biology of Flowering Plants*. Springer.
- Raven, P. H., Evert, R. F., & Eichhorn, S. E. (2012). *Biology of Plants* (8th Edition). W. H. Freeman.
- Shivanna, K. R., & Tandon, R. (2014). *Reproductive Ecology of Flowering Plants: A Manual*. Springer.
- Taiz, L., Zeiger, E., Møller, I. M., & Murphy, A. (2023). *Plant Physiology and Development* (7th Edition). Sinauer Associates.

Research Articles and Reviews:

- De Rybel, B., Möller, B., Yoshida, S., & Weijers, D. (2016). "Plant Vascular Development: From Early Specification to Differentiation." *Nature Reviews Molecular Cell Biology, 17*, 30–40.
- Dresselhaus, T., & Franklin-Tong, V. E. (2013). "Male–Female Cross-Talk During Pollen Germination, Tube Growth, and Guidance, and Double Fertilization." *Molecular Plant, 6*(4), 1018–1036.
- Feng, X., Dickinson, H. G., & Thomas, S. G. (2020). "The Molecular Regulation of Gametophyte Development in Flowering Plants." *New Phytologist, 225*(2), 684–699.
- Goetz, M., Hooper, L. C., Johnson, S. D., & Koltunow, A. M. G. (2017). "Seed and Fruit Development in Apomixis: A Model for Sexual and Asexual Reproduction." *The Plant Journal, 90*(3), 524–535.
- Higashiyama, T., & Takeuchi, H. (2015). "The Mechanisms and Key Molecules Involved in Pollen Tube Guidance." *Annual Review of Plant Biology, 66*, 393–413.
- Kelliher, T., & Walbot, V. (2012). "Hypoxia Triggers Meiotic Skipping in Maize." *Science, 337*(6092), 345–348.
- Lafon-Placette, C., & Köhler, C. (2016). "Endosperm-Based Postzygotic Hybridization Barriers: Developmental Mechanisms and Evolutionary Implications." *Molecular Ecology, 25*(11), 2620–2629.
- Stahl, Y., & Simon, R. (2010). "Plant Primary Meristems – Shoot and Root Apical Meristems." *Current Opinion in Plant Biology, 13*(1), 53–58.

- Woo, H. R., Kim, H. J., Lim, P. O., & Nam, H. G. (2019). "Leaf Senescence: Systems and Dynamics Aspects." *Annual Review of Plant Biology, 70*, 347–376.
- Zoulias, N., Brown, J.W.S., & Leymarie, J. (2018). "Regulation of Stomatal Development and Patterning." *New Phytologist, 217*(3), 1009–1023.

Recommended Journals (For Latest Research Updates):

- *The Plant Cell* (American Society of Plant Biologists)
- *Plant Physiology* (American Society of Plant Biologists)
- *Development* (Company of Biologists)
- *Nature Plants* (Nature Publishing Group)
- *Trends in Plant Science* (Elsevier)
- *Journal of Experimental Botany* (Oxford University Press)
- *Annual Review of Plant Biology* (Annual Reviews)

Online Databases & Open-Access Resources:

- **The Arabidopsis Information Resource (TAIR):** https://www.arabidopsis.org
- **Plant Ontology Database (PO):** http://www.plantontology.org
- **Floral Genome Project:** http://www.floralgenome.org
- **Gene Ontology Consortium:** http://geneontology.org

Plant Genetic Engineering and Omics

LTP: 3-0-2 **Credits: 4**

Course Objective:

This course provides an advanced understanding of plant genetic engineering and omics technologies, integrating concepts of gene editing, functional genomics, epigenomics, and synthetic biology. Students will develop expertise in state-of-the-art methodologies, high-throughput sequencing, genome-wide association studies (GWAS), systems biology, and computational tools applied to plant biotechnology. The course will also explore the socioeconomic, ethical, and regulatory dimensions of genetic engineering and omics research in plants.

Course Outcomes:

Upon completion of this course, students will be able to:

1. Analyze and apply advanced genetic engineering techniques, including site-directed mutagenesis, synthetic biology, and genome editing tools (CRISPR-Cas, TALENs, ZFNs).
2. Critically evaluate the molecular mechanisms underlying stress tolerance, metabolic pathways, and trait enhancement in genetically modified (GM) plants.
3. Design and interpret multi-omics experiments using genomics, transcriptomics, proteomics, metabolomics, and epigenomics for plant research.
4. Apply bioinformatics tools and machine learning approaches for large-scale data analysis, gene annotation, and molecular marker identification in breeding programs.
5. Assess the ethical, ecological, and biosafety implications of plant genetic engineering and synthetic biology for sustainable agriculture and biodiversity conservation.

Theory

Unit 1: Advanced Concepts in Plant Genetic Engineering

Molecular biology of gene cloning – vector-host systems, recombinant DNA strategies, Agrobacterium-mediated transformation, biolistic methods, nanoparticle-based gene delivery; synthetic biology approaches in plant biotechnology – gene circuit design, chassis engineering, synthetic metabolic pathways; CRISPR-Cas gene editing – mechanisms, base editing, prime editing, applications in crop improvement; comparative analysis of genome editing technologies – TALENs, Zinc Finger Nucleases (ZFNs), CRISPR for precise genome modifications; epigenetic modifications in transgenic plants – DNA methylation, histone modifications, chromatin remodeling, role in gene expression regulation.

Unit 2: Applications of Genetic Engineering in Sustainable Agriculture

Abiotic stress tolerance in crops – genetic engineering for drought, salinity, heat resistance; biotic stress resistance strategies – engineering insect-resistant (Bt crops), virus-resistant, fungal-resistant plants; gene silencing and RNA interference (RNAi) – applications in plant defense mechanisms; gene stacking – challenges, advancements, transgene pyramiding strategies for durable resistance; metabolic engineering in crops – biofortification approaches, Golden Rice, provitamin A enhancement, engineered secondary metabolites; plant-based biopharmaceuticals – edible vaccines, transgenic plants for antibody production, therapeutic proteins; regulatory framework and risk assessment – Cartagena Protocol, biosafety laws, environmental impact assessment, public perception of genetically modified organisms (GMOs).

Unit 3: Advanced Omics Technologies in Plant Science

Functional genomics – genome-wide association studies (GWAS), RNA sequencing (RNA-Seq), single-cell transcriptomics, comparative genomics for gene function analysis; epigenomics techniques – bisulfite sequencing for DNA methylation profiling, ATAC-Seq for chromatin accessibility, chromatin conformation capture (Hi-C) for genome architecture studies; proteomics applications – high-throughput mass spectrometry techniques such as MALDI-TOF and ESI-MS, post-translational modification (PTM) analysis; metabolomics approaches – metabolic fingerprinting, fluxomics, isotope labeling techniques for understanding biochemical pathways; integrative omics – multi-omics approaches, predictive modeling, pathway reconstruction for comprehensive plant metabolic analysis; high-performance computing (HPC) and big data analytics – cloud-based storage, artificial intelligence (AI)-driven data interpretation, machine learning applications in plant sciences.

Unit 4: Computational and Systems Biology Approaches in Omics

Computational tools for plant genomics and transcriptomics – NCBI, Ensembl Plants, Phytozome, KEGG databases for functional annotation and pathway analysis; systems biology applications – modeling plant stress responses, metabolic engineering, network-based crop improvement strategies; metagenomics and microbiome engineering – functional profiling of plant-associated microbiomes, role in enhancing plant productivity; artificial intelligence (AI) and machine learning applications in plant sciences – AI-driven plant bioinformatics, precision breeding, real-time crop monitoring; nanotechnology applications in plant biotechnology – nanoparticle-mediated gene delivery, nano-enabled biosensors for plant disease diagnostics, precision agriculture innovations; future perspectives in plant genetic engineering – climate-resilient crops, precision agriculture, personalized plant breeding strategies, lab-grown plant-based food systems.

Practical

1) Isolation and quantification of high-quality genomic DNA and total RNA from plant tissues.
2) Site-directed mutagenesis and verification using sequencing techniques.
3) Agrobacterium-mediated transformation and validation using qPCR and reporter gene assays.
4) Analysis of transcriptomic data using RNA-Seq pipeline: Differential gene expression analysis (DESeq2).
5) Protein profiling and post-translational modifications analysis using 2D-PAGE and LC-MS/MS.
6) Metabolite profiling using GC-MS and metabolic pathway mapping using KEGG database.
7) Bioinformatics pipeline for genome annotation, sequence alignment, and functional characterization.
8) Use of AI-based algorithms for gene function prediction and marker-assisted breeding.
9) High-throughput phenotyping: Image-based trait analysis using deep learning models.
10) Application of metagenomics approaches to analyze plant-associated microbiomes.
11) Molecular docking and molecular dynamics simulations for protein-ligand interaction studies.
12) Virtual lab simulations for CRISPR-Cas genome editing workflows.

Suggested Readings:

Core Textbooks:

- Gelvin, S.B. (2017). *Agrobacterium Biology: From Basic Science to Biotechnology Applications.* Springer. ISBN: 978-3319444299.
- Hansen, G., & Wright, M.S. (2011). *Methods in Molecular Biology: Plant Genetic Transformation Methods.* Humana Press. ISBN: 978-1607617997.
- Nicholl, D.S.T. (2021). *An Introduction to Genetic Engineering* (4th Edition). Cambridge University Press. ISBN: 978-1108730744.
- Primrose, S.B., & Twyman, R.M. (2016). *Principles of Gene Manipulation and Genomics* (8th Edition). Wiley-Blackwell. ISBN: 978-1405135443.

- Slater, A., Scott, N.W., & Fowler, M.R. (2008). *Plant Biotechnology: The Genetic Manipulation of Plants* (2nd Edition). Oxford University Press. ISBN: 978-0199282616.

Genome Editing and CRISPR in Plants:

- Jung, C., & Kang, B.C. (2023). *CRISPR-Cas in Plant Biotechnology.* Elsevier. ISBN: 978-0128215320.
- Puchta, H., & Fauser, F. (2018). *CRISPR-Cas in Plants: Advances and Applications.* Springer. ISBN: 978-3030033286.
- Qi, Y. (2019). *Plant Genome Editing with CRISPR Systems.* Humana Press. ISBN: 978-3030115807.
- Zhang, F., & Voytas, D.F. (2020). *Genome Engineering: CRISPR, ZFNs, TALENs, and More.* Academic Press. ISBN: 978-0128179967.

Genomics, Functional Genomics, and Omics Technologies:

- Bhat, V., & Dey, S. (2022). *Advanced Plant Omics: Concepts and Applications.* Springer. ISBN: 978-3030793005.
- Kaufmann, M., & Klinger, C. (2011). *Functional Genomics: Methods and Protocols.* Humana Press. ISBN: 978-1617793393.
- Mir, R.A., Shafi, S.M., & Zargar, S.M. (2023). *Principles of Genomics and Proteomics.* Elsevier. ASIN: B0BT4V6XL2.
- Ratcliffe, M.J. (2022). *Systems Biology and Omics Approaches to Plant Metabolism.* Wiley. ISBN: 978-3527347584.
- Thangadurai, D., & Sangeetha, J. (2015). *Genomics and Proteomics: Principles, Technologies, and Applications.* Apple Academic Press. ISBN: 978-1771880807.

Metabolomics and Systems Biology:

- Hall, R.D. (2010). *Plant Metabolomics: Applications and Opportunities.* Wiley-Blackwell. ISBN: 978-1444318871.
- Patti, G.J., & Siuzdak, G. (2016). *Metabolomics: A Primer.* Wiley. ISBN: 978-1605359530.
- Saito, K., Dixon, R.A., & Willmitzer, L. (2019). *Plant Metabolomics: Methods and Protocols.* Springer. ISBN: 978-1493993774.

- Weckwerth, W. (2013). *Molecular Methods in Metabolomics: Techniques and Applications.* Wiley-Blackwell. ISBN: 978-1119941286.

Bioinformatics and Computational Biology in Plant Sciences:

- Baumbach, J. (2015). *Computational Biology: Data Integration and Knowledge Discovery.* Springer. ISBN: 978-3319117247.
- Bourne, P.E., & Weissig, H. (2018). *Structural Bioinformatics* (2nd Edition). Wiley-Blackwell. ISBN: 978-0470181058.
- Graham, N., et al. (2023). *Bioinformatics for Plant Sciences: Data Analysis, Computational Modeling, and Machine Learning.* CRC Press. ISBN: 978-1032349071.
- Orengo, C.A., Jones, D.T., & Thornton, J.M. (2020). *Bioinformatics: Genes, Proteins, and Computers.* Garland Science. ISBN: 978-0815345118.
- Wibowo, A., & Lestari, R. (2022). *AI and Machine Learning in Plant Bioinformatics and Biotechnology.* Springer. ISBN: 978-3030922795.

Biotechnology, GM Crops, and Biosafety:

- Dunwell, J.M., & Ford, C.S. (2019). *Genetically Modified Crops and Agricultural Development.* Cambridge University Press. ISBN: 978-1107199580
- Miller, H.I., & Conko, G. (2019). *The Frankenfood Myth: How Protest and Politics Threaten the Biotech Revolution.* Greenwood. ISBN: 978-0275987408.
- Nap, J.P., Atanassov, A., & Stiekema, W.J. (2019). *Biosafety of Genetically Modified Organisms.* Elsevier. ISBN: 978-0128196803.
- Van Montagu, M. (2020). *Plant Biotechnology and Agriculture: Prospects for the 21st Century.* Elsevier. ISBN: 978-0128122512.

Skill enhancement courses

Plant Tissue Culture: Techniques and Applications

LTP: 2-0-0 **Credits: 2**

Course Objective:

This course aims to provide a thorough understanding of the principles and techniques of plant tissue culture, emphasizing its industrial applications across various sectors. Students will explore the economic and environmental significance of plant tissue culture, analyse associated challenges, and examine future directions for its use in industrial applications.

Course Outcomes:

On successful completion of this course, the students should be able to:

1. Understand plant tissue culture principles, media preparation, explant selection, and contamination control.
2. Explore industrial applications of plant tissue culture, including micropropagation and biotechnological uses.
3. Understand challenges in tissue culture industries, including technology, economics, regulations, and future trends.

Theory

Unit 1: Introduction to Plant Tissue Culture

Definition and History of Plant Tissue Culture (PTC); Fundamental, Principles and Culture types (Callus culture, Organogenesis, Somatic embryogenesis); Plant Growth Regulators in PTC and significance of hormones; Composition of Media (Murashige and Skoog medium, Gamborg's B5 medium); Sterilization Techniques; Factors Affecting Plant Growth (Light, Temperature, Humidity); Contamination Control in Tissue Culture Labs; Explant Selection and Surface Sterilization; Establishment of Cultures and Maintenance.

Unit 2: Industrial Applications of Plant Tissue Culture

Micropropagation: Techniques and Benefits; Case Studies: Commercial Micropropagation in Orchids, Strawberries, and Banana; Use of Tissue Culture in Developing Disease-resistant Crops; Application of Somatic Hybridization and Protoplast Fusion; Genetic Transformation

Using *Agrobacterium*-mediated Transformation; Production of Secondary Metabolites (Alkaloids, Flavonoids, etc.) and Role of Tissue Culture in Pharmaceutical and Nutraceutical Industries: Case Study- Atropine, Reserpine, and Taxol production; Cell-suspension and hairy roots for secondary metabolite production; Techniques for Cryopreservation and Seed Storage; Use of Tissue Culture in Genetic Resource Conservation; Industrial Role in Protecting Plant Biodiversity; Clonal Propagation in Forestry; Horticultural Plant Production (e.g., Flowering Plants, Fruit Trees); Landscape and Greenhouse Applications.

Unit 3: Challenges and Future Directions in Plant Tissue Culture Industry

Cost-related Issues in Industrial PTC; Scaling Up from Laboratory to Commercial Production; Overcoming Contamination, Variability, and In Vitro Selection; Ethical Concerns in Genetic Engineering and Biotechnology; Regulatory Framework for Biotech Products and GMOs; Intellectual Property Rights in Plant Biotechnology; Use of Bioreactors for Enhanced Productivity; Role of Automation and Robotics in Large-scale Production; Future of Automated Tissue Culture Systems; Integration of CRISPR and Gene Editing with Tissue Culture; Application of Artificial Intelligence in Plant Biotechnology; Contribution to Sustainable Agricultural Practices.

Suggested Readings

Core Textbooks:

- Bajpai, P.K. (2006). *Biological Instrumentation and Methodology*. S. Chand & Company Ltd.
- Brown, T.A. (2016). *Gene Cloning and DNA Analysis: An Introduction (7th Edition)*. Wiley-Blackwell.
- Chain, E.B., & Bonner, P.L.R. (1998). *Cell Biology: A Laboratory Handbook (3rd Edition)*. Academic Press.
- Green, M.R., & Sambrook, J. (2012). *Molecular Cloning: A Laboratory Manual (4th Edition)*. Cold Spring Harbor Laboratory Press.
- Green, M.R., & Sambrook, J. (2012). *Molecular Cloning: A Laboratory Manual (4th Edition)*. Cold Spring Harbor Laboratory Press.
- Howe, C. (2007). *Gene Cloning and Manipulation (2nd Edition)*. Cambridge University Press.
- Lesk, A.M. (2019). *Introduction to Bioinformatics (5th Edition)*. Oxford University Press.

- Lewin, B. (2017). *Genes XII*. Jones & Bartlett Learning.
- Skoog, D.A., & West, D.M. (2014). *Fundamentals of Analytical Chemistry (9th Edition)*. Cengage Learning.
- Skoog, D.A., Holler, F.J., & Crouch, S.R. (2017). *Principles of Instrumental Analysis (7th Edition)*. Cengage Learning.

Plant Biotechnology and Tissue Culture:

- Davey, M.R., & O'Brien, P.J.L. (2010). *Plant Cell and Tissue Culture*. Wiley-Blackwell.
- Khurana, S.P.S., & Bhatia, M.S. (2018). *Plant Tissue Culture: Techniques and Applications*. Springer.
- Latest journal articles and industry reports on plant tissue culture applications.
- Singh, R.A. (2015). *Plant Biotechnology and Transgenic Plants*. CRC Press.
- Srivastava, V., Mehrotra, S., & Mishra, S. (Eds.). (2018). *Hairy Roots: An Effective Tool of Plant Biotechnology*. Springer.

Advanced References in Molecular Biology and Bioinformatics:

- Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2014). *Molecular Biology of the Cell (6th Edition)*. Garland Science.
- Lodish, H., Berk, A., Kaiser, C.A., Krieger, M., Bretscher, A., Ploegh, H., Amon, A., & Martin, K.C. (2021). *Molecular Cell Biology (9th Edition)*. W.H. Freeman.
- Mount, D.W. (2004). *Bioinformatics: Sequence and Genome Analysis (2nd Edition)*. Cold Spring Harbor Laboratory Press.
- Pevsner, J. (2015). *Bioinformatics and Functional Genomics (3rd Edition)*. Wiley-Blackwell.
- Watson, J.D., Baker, T.A., Bell, S.P., Gann, A., Levine, M., & Losick, R. (2013). *Molecular Biology of the Gene (7th Edition)*. Pearson.

References on Laboratory Techniques and Instrumentation:

- Day, R.A., & Underwood, A.L. (2010). *Quantitative Chemical Analysis (6th Edition)*. Prentice Hall.
- Ninfa, A.J., Ballou, D.P., & Benore, M. (2009). *Fundamental Laboratory Approaches for Biochemistry and Biotechnology (2nd Edition)*. Wiley.

- Switzer, R.L., & Garrity, L.F. (1999). *Experimental Biochemistry (3rd Edition).* W.H. Freeman.
- Voet, D., Voet, J.G., & Pratt, C.W. (2018). *Fundamentals of Biochemistry: Life at the Molecular Level (5th Edition).* Wiley.
- Wilson, K., & Walker, J. (2018). *Principles and Techniques of Biochemistry and Molecular Biology (8th Edition).* Cambridge University Press.

Supplementary Online Resources and Journals:

- *Nucleic Acids Research (Oxford Academic)* – Covers advances in bioinformatics, genomics, and molecular biology.
  - https://academic.oup.com/nar
- *Nature Methods (Springer Nature)* – Focuses on novel laboratory techniques and bioinformatics tools.
  - https://www.nature.com/nmeth/
- *Cold Spring Harbor Protocols* – A leading source for laboratory methods in molecular biology.
  - https://cshprotocols.cshlp.org/

Gene Editing Techniques

LTP: 2-0-0 **Credits: 2**

Course Objective:

This course aims to provide students with a comprehensive understanding of gene editing technologies, their applications and implications in agriculture, medicine, and biotechnology. Students will learn about the fundamentals of gene editing in particular the advanced CRISPR tools, and their ethical considerations, along with exploring the role of gene editing in functional genomics, gene regulation, and crop improvement.

Course Outcomes:

On successful completion of this course, the students should be able to:

1. Understand the significance, technologies, mechanisms, and ethical considerations of gene editing.
2. Explore the components, advanced tools, and applications of CRISPR-Cas systems in gene editing.
3. Understand the applications of gene editing for functional genomics, gene regulation, and crop improvement.

Theory

Unit 1: Fundamentals of Gene Editing

Introduction to gene editing and its significance; overview of genome-editing technologies: meganucleases, zinc-finger nucleases (ZFNs), transcription activator-like effector nucleases (TALENs), and CRISPR-Cas systems; mechanisms of double-strand break repair: non-homologous end joining (NHEJ) and homology-directed repair (HDR); applications in agriculture, medicine, and biotechnology; ethical considerations and regulatory frameworks.

Unit 2: CRISPR-Cas Systems and Applications

Components and mechanisms: crRNA, tracrRNA, and Cas proteins; classification of CRISPR systems and their characteristics; guide RNA design for targeted editing and strategies to minimize off-target effects; advanced CRISPR techniques: base editing, prime editing, CRISPR interference (CRISPRi), and CRISPR activation (CRISPRa); delivery methods: viral and non-viral systems; multiplex genome editing and its potential applications.

Unit 3: Functional Genomics and Gene Regulation

Gene editing for functional genomics: knockout and knock-in models; RNA interference (RNAi) and CRISPR-Cas9 in gene function studies; gene regulation via CRISPRi and CRISPRa; epigenome editing for transcriptional modulation; transgenic vs. gene-edited organisms: key differences and implications; gene therapy advancements using CRISPR; agricultural applications: disease resistance, abiotic stress tolerance, and quality enhancement.

Suggested Readings

Core Textbooks:

- Doudna, J. A., & Sternberg, S. H. (2017). *A Crack in Creation: Gene Editing and the Unthinkable Power to Control Evolution*. Houghton Mifflin Harcourt.
- Carroll, D. (2017). *Genome Editing: Principles and Applications*. CABI.
- Barrangou, R., & van der Oost, J. (2012). *CRISPR-Cas Systems: RNA-mediated Adaptive Immunity in Bacteria and Archaea*. Springer.
- Ishino, Y., & Koonin, E. V. (2021). *CRISPR: A New Era in Genome Editing*. Elsevier.
- Komor, A. C., Badran, A. H., & Liu, D. R. (2018). *The Expanding Toolbox of CRISPR-Based Genome Editing Technologies*. Nature Reviews Molecular Cell Biology, 19(3), 167–180.

Reference Books:

- Hsu, P. D., Lander, E. S., & Zhang, F. (2014). *Development and Applications of CRISPR-Cas9 for Genome Engineering*. Cell, 157(6), 1262–1278.
- Niemann, H., & Kues, W. A. (2020). *Applications of CRISPR/Cas in Livestock Genetics and Breeding*. Animal Frontiers, 10(3), 48–52.
- Ran, F. A., et al. (2013). *Genome Engineering Using the CRISPR-Cas9 System*. Nature Protocols, 8(11), 2281–2308.

- Zhang, Y., et al. (2022). *Prime Editing: Advances and Challenges in Precision Genome Editing*. Trends in Genetics, 38(1), 44–57.
- Gaudelli, N. M., et al. (2017). *Programmable Base Editing of A•T to G•C in Genomic DNA without DNA Cleavage*. Nature, 551(7681), 464–471.

Research Articles and Journals:

- Jinek, M., et al. (2012). *A Programmable Dual-RNA-Guided DNA Endonuclease in Adaptive Bacterial Immunity*. Science, 337(6096), 816–821.
- Cong, L., et al. (2013). *Multiplex Genome Engineering Using CRISPR/Cas Systems*. Science, 339(6121), 819–823.
- Komor, A. C., et al. (2016). *Programmable Editing of a Target Base in Genomic DNA without Double-Stranded DNA Cleavage*. Nature, 533(7603), 420–424.
- Anzalone, A. V., et al. (2019). *Search-and-Replace Genome Editing without Double-Strand Breaks or Donor DNA*. Nature, 576(7785), 149–157.
- Knott, G. J., & Doudna, J. A. (2018). *CRISPR-Cas Guides the Future of Genetic Engineering*. Science, 361(6405), 866–869.

Online Resources:

- Broad Institute CRISPR Guide: https://www.broadinstitute.org/what-broad/areas-focus/project-spotlight/crispr
- NCBI Genome Editing Resources: https://www.ncbi.nlm.nih.gov/genome/editing/
- Addgene CRISPR Resources: https://www.addgene.org/crispr/
- Horizon Discovery Gene Editing Tools: https://horizondiscovery.com/en/genome-editing.

Entrepreneurship Avenues in Botanical Sciences

LTP: 2-0-0 **Credits: 2**

Course Objectives

On successful completion of this course, students will be able to understand the entrepreneurial potential within different areas of botany; develop business ideas based on plant resources, biotechnology, and ecological conservation; learn sustainable and innovative approaches for plant-based enterprises; identify career prospects in various fields of plant sciences; gain insights into industry trends and employment opportunities in India.

Course Outcomes

On successful completion of this course, students should be able to:

- Explain the role of plant taxonomy in conservation, forensic science, and industry.
- Describe plant biotechnology applications in agriculture, medicine, and bio-based industries.
- Analyze urban farming, food processing, and climate-related entrepreneurship.
- Explore career opportunities in plant sciences, research, and startups.

Theory

Unit 1: Plant Diversity, Taxonomy, and Sustainable Entrepreneurship

Plant Taxonomy and Systematics – Role of plant taxonomists in conservation and industry; digital herbariums; AI-based plant identification; entrepreneurship in botanical survey and biodiversity documentation. Forensic Botany and Plant Anatomy in Investigation – Role of plant anatomy in forensic investigations; application of plant DNA in criminal case solving; entrepreneurship in forensic consulting. Economic Botany and Ethnobotany – Medicinal and aromatic plants—cultivation, processing, commercialization; traditional plant-based industries—herbal cosmetics, natural dyes, organic fibers; value-added plant products—essential oils, herbal extracts, nutraceuticals. Sustainable Harvesting and Conservation – Agroforestry and non-timber forest products as business opportunities; ecological entrepreneurship; biodiversity conservation startups.

Unit 2: Plant Biotechnology, Molecular Biology, and Bio-based Industries

Plant Tissue Culture and Micropropagation – Commercial applications in horticulture, forestry, pharmaceuticals; entrepreneurship in mass propagation; seedling production. Genetically Modified Crops and Molecular Biology – CRISPR and gene editing—market trends; regulatory frameworks; commercialization; biotechnology startups—high-yield and climate-resilient crops. Industrial Applications of Algae and Fungi – Algae-based biofuels; bioplastics; pharmaceuticals; myco-entrepreneurship—mushroom farming; fungal biofertilizers; enzymes.

Biofertilizers, Biopesticides, and Sustainable Agriculture – Role of beneficial microbes in agriculture; organic and sustainable farming-based enterprises. Synthetic Biology and Innovations in Cosmetics, Food, and Medicine – Plant-based biopolymers; plant-derived pharmaceuticals; herbal cosmetics—organic skincare, haircare, aromatherapy products.

Unit 3: Agri-business, Urban Farming, and Career Avenues in Plant Sciences

Organic and Urban Farming Innovations – Hydroponics; aeroponics; vertical farming—business models; market potential; smart agriculture—IoT, AI, precision farming applications; seed production; plant breeding entrepreneurship. Value Addition in Food Processing and Functional Foods – Herbal teas; plant-based beverages; superfoods; entrepreneurship in farm-to-fork and organic food startups. Ecology, Environment, and Climate Change Entrepreneurship – Carbon credit trading; afforestation projects; waste management; bioremediation startups; role of ecologists in environmental impact assessments. Careers in Plant Sciences – Taxonomist; forensic botanist; plant molecular biologist; ecologist; opportunities in government agencies, research institutions, biotech companies.

Suggested Readings

Textbooks:

- Judd, W.S., Campbell, C.S., Kellogg, E.A., Stevens, P.F. (2015). Plant Systematics: A Phylogenetic Approach, 4th edition, Sinauer Associates, Sunderland, USA.
- Simpson, M.G. (2019). Plant Systematics, 3rd edition, Academic Press, London, UK.
- Raven, P.H., Evert, R.F., Eichhorn, S.E. (2012). Biology of Plants, 8th edition, W.H. Freeman, New York, USA.
- Buchanan, B.B., Gruissem, W., Jones, R.L. (2015). Biochemistry & Molecular Biology of Plants, 2nd edition, Wiley-Blackwell, Oxford, UK.
- Slater, A., Scott, N., Fowler, M. (2008). Plant Biotechnology: The Genetic Manipulation of Plants, 2nd edition, Oxford University Press, Oxford, UK.
- Taiz, L., Zeiger, E., Møller, I.M., Murphy, A. (2023). Plant Physiology and Development, 7th edition, Sinauer Associates, Sunderland, USA.

Entrepreneurship and Business in Plant Sciences:

- Hisrich, R.D., Peters, M.P., Shepherd, D.A. (2020). Entrepreneurship, 11th edition, McGraw-Hill, New York, USA.
- Schaper, M., et al. (2014). Entrepreneurship and Small Business, 4th edition, Wiley, Australia.
- Kuckertz, A. (2019). Sustainable Entrepreneurship: A Systematic Review of the Field, Springer, Berlin, Germany.
- Thiel, P. (2014). Zero to One: Notes on Startups, or How to Build the Future, Crown Business, New York, USA.
- Goleman, D. (2021). Ecological Intelligence: The Hidden Impacts of What We Buy, Broadway Books, New York, USA.
- Reddy, P. (2019). Agri-Entrepreneurship: Innovation, Management & Business Opportunity, Springer, Singapore.
- Mukherjee, P.K. (2017). Quality Control and Evaluation of Herbal Drugs, Elsevier, Amsterdam, Netherlands.

Research Articles:

- Chen, S., et al. (2019). "Applications of AI in Plant Taxonomy and Identification," Trends in Plant Science, 24(10), 855–868.
- Pardo, G., et al. (2020). "Sustainable Agriculture and the Role of Biofertilizers," Frontiers in Plant Science, 11, 1018.
- Liu, X., et al. (2021). "CRISPR-Based Gene Editing in Plants: Advances and Applications," Nature Plants, 7(8), 791–805.
- Mishra, A., et al. (2022). "Plant-Based Bioplastics: Sustainable Innovations," Journal of Environmental Management, 312, 114807.
- Ferrer, A., et al. (2020). "The Future of Myco-Entrepreneurship: Applications of Fungi in Industry," Applied Microbiology and Biotechnology, 104(5), 2081–2095.

Specialized Topics:

- Mukherjee, P.K., et al. (2017). Quality Control and Evaluation of Herbal Drugs, Elsevier, Amsterdam, Netherlands.
- Sharma, S., Kumar, N. (2020). Plant-Based Natural Products for Sustainable Health, Springer, Singapore.
- Karp, G. (2018). Cell and Molecular Biology: Concepts and Experiments, 8th edition, Wiley, New Jersey, USA.
- Altman, A., Hasegawa, P.M. (2012). Plant Biotechnology and Agriculture: Prospects for the 21st Century, Academic Press, London, UK.
- Esser, K., et al. (2014). The Mycota: Industrial Applications, Springer, Berlin, Germany.

Supplementary Reading:

- Schiebinger, L., Swan, C. (2007). Colonial Botany: Science, Commerce, and Politics in the Early Modern World, University of Pennsylvania Press, Philadelphia, USA.
- Cragg, G.M., Newman, D.J. (2012). Natural Products: A Continuing Source of Novel Drug Leads, Biochimica et Biophysica Acta (BBA) - General Subjects, 1830(6), 3670–3695.
- Chandra, R., Sharma, S. (2017). Bioremediation of Agrochemicals, CRC Press, Boca Raton, USA.
- Singh, H. (2006). Mycoremediation: Fungal Bioremediation, Wiley-Interscience, Hoboken, USA.
- Leopold, A. (1949). A Sand County Almanac, Oxford University Press, New York, USA.

Online Sources:

- The Plant List – www.theplantlist.org (Comprehensive database of plant taxonomy)
- KEW Science Plants of the World Online – powo.science.kew.org (Global database for plant diversity)
- NCBI GenBank – www.ncbi.nlm.nih.gov/genbank/ (Molecular sequences and plant genomics)
- FAO Agroforestry Guidelines – www.fao.org/agriculture/forestry (Sustainable agriculture and biodiversity conservation)
- The Bioplastic Guide – www.bioplastic.com (Information on plant-derived bioplastics and innovations)
- World Bank Agribusiness Reports – www.worldbank.org/en/topic/agribusiness

Biological Instrumentation and Methods in Plant Molecular Biology

LTP: 2-0-0 **Credits: 2**

Course Objective:

This course provides a comprehensive understanding of the principles, applications, and methodologies used in biological and plant molecular research. It aims to equip students with theoretical knowledge and practical skills in biological instrumentation, molecular characterization, bioanalysis, and gene expression techniques. Students will develop expertise in operating key instruments, analysing biological molecules, and applying advanced molecular techniques in plant biotechnology.

Course Outcomes:

On successful completion of this course, the students should be able to:

1. Understand the principles, operation, and calibration of key biological instruments and their applications in research.
2. Gain proficiency in spectrophotometry, chromatography, electrophoresis, PCR, ELISA, and flow cytometry for molecular and cellular analysis.
3. Develop expertise in nucleic acid isolation, quantification, and assessment techniques for plant molecular studies.
4. Learn the principles of PCR, cloning strategies, and transformation techniques used in plant biotechnology.
5. Explore gene expression analysis methods, including RNAi and bioinformatics tools.
6. Understand the applications of emerging technologies such as high-throughput sequencing, biosensors, microfluidics, and 3D-bioprinting in biological research.

Theory

Unit 1: Principles and Applications of Biological Instrumentation

Introduction to biological instrumentation; Principles of operation and calibration of biological instruments; Microscopes: light, electron, and fluorescence; Spectrometers: UV-Vis, fluorescence, IR, and mass spectrometry; Chromatography: HPLC, GC; Electrophoresis: gel, capillary, and SDS-PAGE; Centrifuges and ultracentrifuges. Methods for isolation of plant genomic DNA, RNA, and plasmid DNA; Quality and quantity assessment using spectrophotometry, fluorometry, and agarose gel electrophoresis; Southern, northern, and western blotting techniques; Restriction enzyme digestion and analysis of DNA fragments; Preparation of competent cells and bacterial transformation techniques.

Unit 2: Analytical and Molecular Techniques in Biological Research

Spectrophotometry and spectrometry for molecular analysis; Fluorescence-based detection and applications; Enzyme-linked immunosorbent assays (ELISA); Western blotting and flow cytometry; Principles of polymerase chain reaction (PCR) and its types: conventional PCR, RT-PCR, qPCR, and multiplex PCR; Primer designing and optimization of PCR conditions; Gene cloning techniques: vectors (plasmids, phagemids, and binary vectors) and their properties; Ligation strategies: sticky-end and blunt-end ligation; Agrobacterium-mediated and direct DNA transformation in plants; Screening and selection of recombinants.

Unit 3: Advanced Techniques and Emerging Technologies in Biological Research

Techniques for gene expression analysis: reporter genes (GUS, GFP, and LUC), microarrays, and RNA sequencing; In situ hybridization for gene expression localization; Protein expression and purification: expression systems, affinity tags, and purification methods; Bioinformatics tools for sequence alignment, primer design, and phylogenetic analysis; Advances in high-throughput sequencing technologies; Applications in genomics, transcriptomics, proteomics, and metabolomics; Instruments for gene editing and delivery systems (microinjection, electroporation); Biosensors: electrochemical, optical, and piezoelectric sensors; Applications in disease detection, environmental monitoring, and wearable devices; Microfluidics and lab-on-a-chip devices for real-time biological analysis; 3D-bioprinting.

Suggested Readings

Core Textbooks:

- Bajpai, P.K. (2006). *Biological Instrumentation and Methodology*. S. Chand & Company Ltd.
- Brown, T.A. (2016). *Gene Cloning and DNA Analysis: An Introduction (7th Edition)*. Wiley-Blackwell.
- Chain, E.B., & Bonner, P.L.R. (1998). *Cell Biology: A Laboratory Handbook (3rd Edition)*. Academic Press.
- Green, M.R., & Sambrook, J. (2012). *Molecular Cloning: A Laboratory Manual (4th Edition)*. Cold Spring Harbor Laboratory Press.
- Howe, C. (2007). *Gene Cloning and Manipulation (2nd Edition)*. Cambridge University Press.
- Lesk, A.M. (2019). *Introduction to Bioinformatics (5th Edition)*. Oxford University Press.
- Lewin, B. (2017). *Genes XII*. Jones & Bartlett Learning.
- Skoog, D.A., & West, D.M. (2014). *Fundamentals of Analytical Chemistry (9th Edition)*. Cengage Learning.

- Skoog, D.A., Holler, F.J., & Crouch, S.R. (2017). *Principles of Instrumental Analysis (7th Edition).* Cengage Learning.

Advanced References in Molecular Biology and Bioinformatics:

- Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2014). *Molecular Biology of the Cell (6th Edition).* Garland Science.
- Lodish, H., Berk, A., Kaiser, C.A., Krieger, M., Bretscher, A., Ploegh, H., Amon, A., & Martin, K.C. (2021). *Molecular Cell Biology (9th Edition).* W.H. Freeman.
- Mount, D.W. (2004). *Bioinformatics: Sequence and Genome Analysis (2nd Edition).* Cold Spring Harbor Laboratory Press.
- Pevsner, J. (2015). *Bioinformatics and Functional Genomics (3rd Edition).* Wiley-Blackwell.
- Watson, J.D., Baker, T.A., Bell, S.P., Gann, A., Levine, M., & Losick, R. (2013). *Molecular Biology of the Gene (7th Edition).* Pearson.

References on Laboratory Techniques and Instrumentation:

- Day, R.A., & Underwood, A.L. (2010). *Quantitative Chemical Analysis (6th Edition).* Prentice Hall.
- Ninfa, A.J., Ballou, D.P., & Benore, M. (2009). *Fundamental Laboratory Approaches for Biochemistry and Biotechnology (2nd Edition).* Wiley.
- Switzer, R.L., & Garrity, L.F. (1999). *Experimental Biochemistry (3rd Edition).* W.H. Freeman.
- Voet, D., Voet, J.G., & Pratt, C.W. (2018). *Fundamentals of Biochemistry: Life at the Molecular Level (5th Edition).* Wiley.
- Wilson, K., & Walker, J. (2018). *Principles and Techniques of Biochemistry and Molecular Biology (8th Edition).* Cambridge University Press.

Supplementary Online Resources and Journals:

- *Nucleic Acids Research (Oxford Academic)* – Covers advances in bioinformatics, genomics, and molecular biology. https://academic.oup.com/nar
- *Nature Methods (Springer Nature)* – Focuses on novel laboratory techniques and bioinformatics tools. •https://www.nature.com/nmeth/
- *Cold Spring Harbor Protocols* – A leading source for laboratory methods in molecular biology. https://cshprotocols.cshlp.org/

Fundamentals of Bioinformatics

LTP: 4-0-0

Credits: 4

Course Objective:

This course is designed to provide students with a thorough knowledge of innovative and evolving field of bioinformatics with a multi-disciplinary approach. It aims to equip students with the knowledge and skills to analyse and interpret biological data using computational methods.

Course Outcomes:

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

1. Describe the history, scope and importance of Bioinformatics
2. Explain about the methods to characterise and manage different types of biological data.
3. Classify different types of Biological Databases.
4. Explore basics of sequence alignment and analysis.
5. Overview biological macromolecular structures and structure prediction methods.

Theory

Unit 1: Introduction and needs of bioinformatics technology.

Aim, branches and application of bioinformatics; role of internet in bioinformatics; basic biomolecular concepts: protein and amino acid, DNA & RNA, sequence, structure and function; forms of biological information, types of nucleotide sequence: genomic DNA, complementary DNA (cDNA), recombinant DNA (rDNA), expressed sequence tags (ESTs) and genomic survey sequences (GSSs).

Unit 2: Bioinformatics Resources: Tools and Knowledge bases I

DNA sequencing methods: basic and automated DNA sequencing, DNA sequencing by capillary array and electrophoresis, gene expression data. Databases and related tools (NCBI, EBI, RCSB, DDBJ); organization of databases, data contents, purpose and utility; open access bibliographic resources and literature databases: PubMed, BioMed Central, Public Library of Sciences (PloS), CiteXplore.

Unit 3: Bioinformatics Resources: Tools and Knowledge bases II

Nucleic acid sequence databases (GenBank, EMBL, DDBJ); protein sequence databases (Uniprot-KB, SWISS-PROT, TrEMBL, UniParc); structure databases (PDB, NDB, PubChem, ChemBank);

sequence file formats for bio-molecular sequences: GenBank, FASTA, GCG; Proteomics tools, Computation of various parameters.

Unit 4: Sequence Alignments and Visualization

Introduction to sequences, basic concept of sequence alignments and its significance; local alignment and global alignment, pairwise sequence alignment and multiple sequence alignment; methods for presenting biological data, sequence viewers, 3D structure viewers, anatomical visualization.

Unit 5: Phylogenetic Analysis and Genome Annotation:

Introduction to phylogenetic analysis and its application; types of phylogenetic trees, different approaches of phylogenetic tree construction-UPGMA, neighbour joining, maximum parsimony, maximum likelihood; Concept of genome annotation, methods of gene identification; tools of gene identification: GenScan, Grail.

Suggested Readings

Textbooks:

- Mount, D. W. (2004). *Bioinformatics: Sequence and Genome Analysis* (2nd ed.). Cold Spring Harbor Laboratory Press.
- Pevsner, J. (2015). *Bioinformatics and Functional Genomics* (3rd ed.). Wiley-Blackwell.
- Lesk, A. M. (2019). *Introduction to Bioinformatics* (5th ed.). Oxford University Press.
- Baxevanis, A. D., & Ouellette, B. F. F. (2005). *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins* (3rd ed.). Wiley-Interscience.
- Krane, D. E., & Raymer, M. L. (2003). *Fundamental Concepts of Bioinformatics*. Benjamin Cummings.

Reference Books:

- Durbin, R., Eddy, S. R., Krogh, A., & Mitchison, G. (1998). *Biological Sequence Analysis: Probabilistic Models of Proteins and Nucleic Acids*. Cambridge University Press.
- Higgs, P. G., & Attwood, T. K. (2013). *Bioinformatics and Molecular Evolution*. Wiley-Blackwell.
- Zvelebil, M., & Baum, J. O. (2008). *Understanding Bioinformatics*. Garland Science.
- Xiong, J. (2006). *Essential Bioinformatics*. Cambridge University Press.

- Claverie, J.-M., & Notredame, C. (2006). *Bioinformatics for Dummies*. Wiley.

Research Articles and Journals:

- Altschul, S. F., et al. (1990). *Basic Local Alignment Search Tool (BLAST)*. Journal of Molecular Biology, 215(3), 403–410.
- Benson, D. A., et al. (2017). *GenBank*. Nucleic Acids Research, 45(D1), D37–D42.
- UniProt Consortium. (2019). *UniProt: A Worldwide Hub of Protein Knowledge*. Nucleic Acids Research, 47(D1), D506–D515.
- Tamura, K., et al. (2021). *MEGA11: Molecular Evolutionary Genetics Analysis Version 11*. Molecular Biology and Evolution, 38(7), 3022–3027.
- Kanehisa, M., et al. (2017). *KEGG: New Perspectives on Genomes, Pathways, Diseases, and Drugs*. Nucleic Acids Research, 45(D1), D353–D361.

Online Resources:

- **NCBI (National Center for Biotechnology Information)**: https://www.ncbi.nlm.nih.gov/
- **EMBL-EBI (European Bioinformatics Institute):** https://www.ebi.ac.uk/
- **RCSB Protein Data Bank (PDB)**: https://www.rcsb.org/
- **DDBJ (DNA Data Bank of Japan)**: https://www.ddbj.nig.ac.jp/
- **UniProt Knowledgebase (UniProt-KB)**: https://www.uniprot.org/
- **Phylogenetics Analysis Tools (MEGA, PhyML, MrBayes)**: https://www.megasoftware.net/

Applied Botany

LTP: 4-0-0 **Credits: 4**

Course Objective: To equip students with comprehensive knowledge of the economic, cultural, and ecological significance of plants, and impart on thempractical skills in plant breeding, horticulture, phytochemistry, and sustainable practices, for contributing to biodiversity conservation, crop improvement, and the development of plant-based innovations.

Course Outcomes

On successful completion of this course, the students should be able to:

1. Understand the economic and cultural importance of plants and the role of ethnobotany in biodiversity conservation and sustainability.
2. Apply plant breeding techniques to develop improved, resilient crop varieties using conventional and biotechnological approaches.
3. Implement horticultural and floricultural practices for efficient crop production, landscaping, and post-harvest management.
4. Analyse phytochemicals, explore their medicinal applications, and contribute to the development of herbal drugs and nutraceuticals.
5. Evaluate plants' roles in ecosystem services, biodiversity conservation, and renewable energy while promoting sustainable practices.

Theory

Unit 1: Economic Botany and Ethnobotany

Study of economically important plants: cereals, pulses, oilseeds, fibers, and timber-yielding plants; medicinal and aromatic plants; beverages: tea, coffee, and cocoa; spices and condiments; sugar and starch-yielding plants; rubber and resins. Ethnobotany: traditional knowledge of plants, role of indigenous plants in food, medicine, and rituals; importance of ethnobotanical studies in biodiversity conservation and sustainable development.

Unit 2: Plant Breeding and Crop Improvement

Principles and methods of plant breeding and hybridization, selection, their role in development of high-yielding, disease-resistant, and stress-tolerant crop varieties; Concept of inbreeding depression, heterosis and hybrid vigor; Mutation breeding, polyploidy and its role in crop improvement; use of molecular markers in plant breeding; role of biotechnology in improving crops.

Unit 3: Horticulture and Floriculture

Principles and practices of horticulture: propagation techniques, greenhouse cultivation, and hydroponics; production technology for fruits, vegetables, and ornamental plants; landscaping and garden design; post-harvest management of horticultural crops; floriculture: cultivation of cut flowers, foliage plants, and potted plants; importance of tissue culture in horticulture and floriculture.

Unit 4: Phytochemistry and Pharmacognosy

Phytochemical constituents of plants: alkaloids, flavonoids, tannins, terpenoids, and glycosides; methods of extraction, purification, and analysis of plant-derived compounds; medicinal properties and applications of bioactive plant metabolites; role of plants in modern and traditional medicine; standardization and quality control of herbal drugs; development of nutraceuticals and functional foods.

Unit 5: Environmental Botany and Sustainable Development

Role of plants in ecosystem services: carbon sequestration, phytoremediation, and soil conservation; afforestation and reforestation strategies; impact of climate change on plants and ecosystems; importance of biodiversity and its conservation; sustainable utilization of plant resources; principles of agroforestry and organic farming; plants as renewable energy sources: biofuels and biogas.

Suggested Readings

Textbooks:

- Simpson, B. B., & Ogorzaly, M. C. (2012). *Economic Botany: Plants in Our World* (4th ed.). McGraw-Hill.
- Kochhar, S. L. (2016). *Economic Botany: A Comprehensive Study*. Cambridge University Press.
- Hill, A. F. (1952). *Economic Botany: A Textbook of Useful Plants and Plant Products*. McGraw-Hill.
- Wickens, G. E. (2001). *Economic Botany: Principles and Practices*. Springer.
- Pandey, B. P. (2017). *Economic Botany*. S. Chand Publishing.

Reference Books:

- Jain, S. K. (1989). *Methods and Approaches in Ethnobotany*. Society of Ethnobotanists.
- Sharma, A. K., & Sharma, A. (1999). *Plant Breeding and Biotechnology: Societal Context and the Future of Agriculture*. CRC Press.

- Hartmann, H. T., Kester, D. E., Davies, F. T., & Geneve, R. L. (2014). *Plant Propagation: Principles and Practices* (8th ed.). Pearson.
- Evans, W. C. (2009). *Trease and Evans' Pharmacognosy* (16th ed.). Saunders Ltd.
- Kumar, H. D. (2002). *Sustainable Development and Environmental Management*. Blackwell Science.

Research Articles and Journals:

- Balick, M. J., & Cox, P. A. (1996). *Plants, People, and Culture: The Science of Ethnobotany*. Scientific American Library.
- Bohra, A., et al. (2014). *Genomics and Molecular Breeding in Horticultural Crops: Progress and Prospects*. Frontiers in Plant Science, 5, 240.
- Rastogi, S., & Pandey, M. M. (2017). *Phytochemistry and Pharmacognosy of Medicinal Plants: Advances and Challenges*. Journal of Ethnopharmacology, 197, 100–118.
- Tester, M., & Langridge, P. (2010). *Breeding Technologies to Increase Crop Production in a Changing World*. Science, 327(5967), 818–822.
- van der Hoek, J. P. (2014). *A Vision for Water Supply and Sanitation Beyond 2025: Climate Change, Sustainable Development, and Innovative Technologies*. Environmental Science & Technology, 48(12), 6690–6696.

Online Resources:

- **The International Society for Ethnopharmacology (ISE)**: Research updates on medicinal plants and phytochemistry.
- **FAO Crop Database**: Information on plant breeding, hybridization, and genetic improvement.
- **Royal Horticultural Society (RHS)**: Resources on horticulture, floriculture, and landscaping.
- **The Pharmacopoeia of India (IP)**: Guidelines for herbal drug standardization and quality control.
- **UNEP Biodiversity Portal**: Reports on plant-based ecosystem services and conservation strategies.

Agriculture, Monsoons and Rural Development

LTP: 4-0-0 **Credits: 4**

Course Objective:

This course aims to provide an understanding of monsoon patterns in India, their regional variations, and their impact on agriculture. It examines the effects of climate change on monsoon dynamics and crop production, explores sustainable practices for resilience, and analyzes socio-economic implications on rural livelihoods. Additionally, it highlights innovations in agricultural technologies and policies for climate-resilient farming.

Course Outcomes:

On successful completion of this course, the students should be able to:

1. Identify the various monsoon patterns in India and evaluate their influence on crop yield and water management strategies.
2. Gain an understanding of how climate change is altering monsoon patterns and agricultural productivity and will propose strategies to adapt to these changes.
3. Demonstrate knowledge of sustainable farming techniques such as water conservation, drought-resistant crops, and agroecological practices to enhance resilience in monsoon regions.
4. Critically assess the socio-economic challenges and opportunities in rural areas dependent on monsoon agriculture, with an emphasis on poverty, migration, and livelihood diversification.
5. Evaluate the role of advanced technologies, government policies, and global frameworks in developing climate-smart and digitally enhanced agricultural practices.

Theory

Unit 1: Monsoon Patterns and Agriculture

Monsoon formation; atmospheric dynamics; El Niño, La Niña, Indian Ocean Dipole; regional variations; rainfall distribution, intensity, duration; agroclimatic zones; impact on crop yields, soil health, agricultural cycles; Kharif, Rabi cropping systems; water management; rainfed, irrigated agriculture; traditional, modern irrigation; crop adaptation; agronomic practices; crop rotation; varietal selection; historical trends; future projections; GIS-based agroclimatic mapping.

Unit 2: Climate Change and Its Impact on Monsoon Agriculture

Climate change; monsoon dynamics; shifts in onset, duration, rainfall distribution; impact on agricultural calendars, crop suitability, cropping systems; climate-induced risks; floods, droughts, extreme weather; soil fertility, crop productivity, food security; climate-resilient crops; innovation in agriculture; adaptation case studies; resilience building; climate modeling tools; Indigenous Knowledge Systems (IKS).

Unit 3: Sustainable Agricultural Practices for Monsoon Regions

Soil, water conservation; mulching, contour plowing, cover cropping, organic matter; rainwater harvesting; traditional methods, farm ponds, check dams; drought-resistant, flood-resistant crops; food security; integrated water management; agroecology, organic farming; crop diversification; intercropping, mixed cropping; sustainable farming case studies; biochar, vermicomposting, integrated nutrient management; policy support; subsidies, farmer incentives.

Unit 4: Rural Development and Livelihoods in Monsoon-Dependent Areas

Monsoon agriculture; rural economy; employment, income, food security; challenges; poverty, migration, social inequalities; government policies; MGNREGA, Pradhan Mantri Fasal Bima Yojana; livelihood diversification; agro-industries, vocational training, entrepreneurship; local knowledge; traditional practices; adaptive strategies; off-farm employment, agri-startups; gender roles; agribusiness; organic products, food processing.

Unit 5: Innovation and Policy for Climate-Resilient Agriculture

Remote sensing, GIS; soil health, crop monitoring, rainfall patterns; precision farming; automated irrigation, drones, sensors; climate-smart agriculture; mitigation, adaptation, productivity; government policies; National Mission on Sustainable Agriculture, Paris Agreement; digital agriculture, AI, predictive analytics; blockchain, supply chain management; sustainable food systems; youth, innovation, public-private partnerships; AI, ML in agriculture; global adaptation case studies; agrivoltaics, energy-resilience integration.

Suggested readings:

Agriculture and Monsoons:

- Gadgil, S., & Gadgil, S. (2006). *The Indian Monsoon, GDP, and Agriculture*. Economic and Political Weekly, 41(47), 4887-4895.
- Ray, D. K., Gerber, J. S., MacDonald, G. K., & West, P. C. (2015). *Climate variation explains a third of global crop yield variability*. Nature Communications, 6(1), 5989.
- Mall, R. K., Gupta, A., Singh, R., Singh, R. S., & Rathore, L. S. (2006). *Water resources and climate change: An Indian perspective*. Current Science, 90(12), 1610-1626.

Rural Development:

- Chambers, R. (1997). *Whose Reality Counts? Putting the First Last*. Intermediate Technology Publications.
- Ellis, F., & Biggs, S. (2001). *Evolving themes in rural development 1950s-2000s*. Development Policy Review, 19(4), 437-448.
- Hazell, P., & Ramasamy, C. (1991). *The Green Revolution Reconsidered: The Impact of High-Yielding Rice Varieties in South India*. Johns Hopkins University Press.

Agricultural Practices and Challenges:

- Swaminathan, M. S. (2007). *An Evergreen Revolution*. In *Science and Sustainable Food Security*. World Scientific.
- Jodha, N. S. (1986). *Common property resources and rural poor in dry regions of India*. Economic and Political Weekly, 21(27), 1169-1181.
- Paroda, R. S., & Kumar, P. (2000). *Food production and demand in South Asia*. Agricultural Economics Research Review, 13(1), 1-24.

Monsoons and Climate Impact:

- Webster, P. J., & Fasullo, J. (2003). *Monsoons: Processes, predictability, and the prospects for prediction*. Journal of Geophysical Research: Atmospheres, 108(D24).
- Krishnan, R., Sabin, T. P., & Vellore, R. (2016). *The Asian Monsoon in a Changing Climate*. Current Climate Change Reports, 2(2), 145-162.

Policy and Socio-Economic Perspectives:

- Singh, R. B. (2000). *Environmental consequences of agricultural development: A case study from the Green Revolution state of Haryana, India*. Agriculture, Ecosystems & Environment, 82(1-3), 97-103.
- World Bank. (2008). *World Development Report 2008: Agriculture for Development*. Washington, DC: World Bank.
- Mishra, S. K., & Reddy, M. N. (2021). *Agrarian Crisis in India: Farmers' Distress and Rural Development Strategies*. Routledge.

Additional Suggested Reading:

- *India's Agricultural Economy: A Survey of Recent Developments* by C. H. Hanumantha Rao.
- *Monsoons over India* by P. S. S. Rao.
- *Small Farmers in South Asia: Their Characteristics, Productivity, and Efficiency* by Inderjit Singh.
- *The Future of Indian Agriculture: Technology and Institutions* edited by M. S. Swaminathan.
- *Climate Change and Agriculture in India: Impact and Adaptation* by S. K. Sinha and M. J. Swaminathan.
- *Groundwater Governance in India: Stumbling, Dragging, or Running?* by A. Sharma and S. Mukherjee.

Reports and Online Resources:

1. **Reports**
   - Intergovernmental Panel on Climate Change (IPCC) Reports.
   - *National Policy for Farmers 2007*, Ministry of Agriculture, Government of India.
   - *Agricultural Statistics at a Glance* (Annual), Directorate of Economics and Statistics, India.
2. **Online Resources**
   - Food and Agriculture Organization (FAO): www.fao.org
   - Indian Meteorological Department (IMD): www.imd.gov.in
   - National Innovation Foundation (NIF): www.nif.org.in
   - Research Papers on Agrarian Studies: www.epw.in

Systems Biology

LTP: 4-0-0 **Credits: 4**

Course Objective

The course aims to introduce the fundamental concepts and principles of systems biology and its importance in modern biological research. Students will become familiar with computational tools for modelling biological networks and gain insights into high-throughput technologies used in systems-level studies. The course will explore dynamic behaviours of biological systems through network theory and systems modelling and develop the ability to apply systems biology approaches to biological and biomedical challenges.

Course Outcomes

On successful completion of this course, students should be able to:

1. Comprehend the fundamental principles and methodologies of systems biology.
2. Analyse complex biological systems using mathematical and computational models.
3. Interpret high-throughput biological data to understand system-wide interactions.
4. Apply network theory to investigate cellular and molecular processes.
5. Design systems biology-based approaches to solve real-world biological and biomedical problems.

Theory

Unit 1: Introduction to Systems Biology

Definition, scope, and evolution from reductionism to holistic approaches; integration of experimental and computational methods; key breakthroughs—Human Genome Project, metabolic engineering, synthetic biology; comparison of reductionist vs. systems-level approaches; applications in modeling biological systems.

Unit 2: High-Throughput Technologies

Overview of high-throughput data generation; Genomics—whole genome sequencing, structural variation, epigenomics; Transcriptomics—RNA sequencing, single-cell analysis; Proteomics—quantification, post-translational modifications, interaction studies; Metabolomics—mass spectrometry, flux analysis; multi-omics integration and analysis tools.

Unit 3: Biological Networks

Types of biological networks—gene regulatory, protein-protein interaction, and metabolic networks; topological properties—robustness, modularity, redundancy; network motifs and functional implications; dynamic modeling approaches—Boolean networks, differential equations; applications in signaling pathways and metabolic regulation; visualization tools (e.g., Cytoscape).

Unit 4: Computational Modeling in Systems Biology

Computational and mathematical modeling approaches; Deterministic models—ODEs for pathway dynamics; Stochastic models—Monte Carlo simulations, Gillespie algorithms; Agent-based models—cellular interactions; applications—biochemical pathways, disease progression, therapeutic predictions; modeling software—MATLAB, COPASI, SBML, BioNetGen.

Unit 5: Applications of Systems Biology

Disease modeling—cancer, metabolic disorders, neurodegenerative diseases; Drug discovery—target identification, multi-omics integration; Synthetic biology—engineering biological circuits; Agriculture—crop improvement, stress tolerance, plant-pathogen interactions; Personalized medicine—omics-based tailored therapies; ethical considerations—data privacy, reproducibility, bioengineering implications.

Suggested Readings

Textbooks:

- Ertel, W. (2024). *Introduction to Artificial Intelligence*. Springer Nature.
- Finlay, J. (1996). *An Introduction to Artificial Intelligence* (1st ed.). CRC Press.
- Mitchell, T.M. (1997). *Machine Learning*. McGraw Hill Education.
- Goodfellow, I., Bengio, Y., Courville, A. (2016). *Deep Learning*. MIT Press.
- Russell, S., Norvig, P. (2021). *Artificial Intelligence: A Modern Approach* (4th ed.). Pearson.

Reference Books:

- Harkut, G.D. (2019). "Artificial Intelligence: Scope and Limitations," IntechOpen.
- Boden, M.A. (2018). *Artificial Intelligence: A Very Short Introduction*. Oxford University Press.
- Lane, D. (2021). *Machine Learning for Kids: A Project-Based Introduction to Artificial Intelligence*. No Starch Press.
- Domingos, P. (2015). *The Master Algorithm: How the Quest for the Ultimate Learning Machine Will Remake Our World*. Basic Books.
- Flach, P. (2012). *Machine Learning: The Art and Science of Algorithms That Make Sense of Data*. Cambridge University Press.

Research Articles and Journals:

- AlQuraishi, M. (2019). "AlphaFold at CASP13," *Bioinformatics*, 36(4), 1081–1082.
- Esteva, A., et al. (2017). "Dermatologist-Level Classification of Skin Cancer with Deep Neural Networks," *Nature*, 542, 115–118.
- Jumper, J., et al. (2021). "Highly Accurate Protein Structure Prediction with AlphaFold," *Nature*, 596(7873), 583–589.
- Zhang, Z., et al. (2021). "AI-Powered Genomics for Precision Medicine," *Genome Biology*, 22(1), 130.

Specialized AI in Biology Resources:

- Tarca, A.L., Carey, V.J., et al. (2013). "Machine Learning for Genomics and Proteomics: Applications in Biological Research," *PLoS Computational Biology*, 9(10), e1003325.
- Angermueller, C., et al. (2016). "Deep Learning for Computational Biology," *Molecular Systems Biology*, 12(7), 878.
- Lecun, Y., Bengio, Y., Hinton, G. (2015). "Deep Learning," *Nature*, 521, 436–444.

Online Resources:

- Stanford University's CS229: *Machine Learning Course Materials.*
- MIT OpenCourseWare: *Introduction to Deep Learning.*
- Kaggle: Hands-on AI projects and biological datasets for practice.
- Google AI Blog: Cutting-edge AI innovations, including AI applications in life sciences.

Medicinal and Ornamental Plants of India

Credits: 4

LTP: 4-0-0

Course Objective:

The course introduces the historical and traditional significance of medicinal plants in healthcare systems like Ayurveda. It covers plant identification, cultivation, conservation strategies, and their commercial applications. Additionally, students will explore entrepreneurial opportunities in the cultivation, processing, and marketing of medicinal and ornamental plants.

Course outcomes:

Successful completion of this course will help the students to:

1. Understand Medicinal Plants: Students will gain a comprehensive understanding of the importance, bioactive compounds, and conservation strategies of medicinal plants in traditional and modern healthcare systems.
2. Have Cultivation Knowledge: Students will be able to identify and describe the medicinal and ornamental properties, cultivation practices, and post-harvest processing of commonly used plants in India.
3. Gain Ecological Awareness: Students will appreciate the ecological role of ornamental plants in biodiversity conservation, landscaping, and carbon sequestration.
4. Apply propogationTechniques: Students will demonstrate proficiency in commercial propagation methods such as seed propagation, vegetative propagation, tissue culture, and micropropagation.
5. Gain Industrial and Entrepreneurial Skills: Students will be equipped to explore careers in the pharmaceutical, herbal product, and flower-based industries, leveraging knowledge of value addition and commercial cultivation.

Theory

Unit 1: Introduction to Medicinal Plants

Historical perspective and importance of medicinal plants in traditional systems of medicine: Ayurveda, Unani, Siddha, and folk medicine; distribution of medicinal plants in India; major bioactive compounds: alkaloids, glycosides, flavonoids, tannins, and essential oils; role of medicinal plants in healthcare and pharmaceutical industries; conservation strategies for medicinal plants: *ex situ* and *in situ* ccnservation.

Unit 2: Important Medicinal Plants of India

Taxonomical details, Botanical nomenclature, important secondary metabolites, uses of common Indian medicinal plants: *Rauvolfia serpentina* (Sarpagandha), *Withania somnifera*

(Ashwagandha), *Azadirachta indica* (Neem), *Ocimum sanctum* (Tulsi), *Phyllanthus emblica* (Amla), *Tinospora cordifolia* (Giloy), *Centella asiatica* (Brahmi), *Curcuma longa* (Turmeric), *Aloe vera* (Ghritkumari), *Bacopa monnieri* (Brahmi), *Terminalia bellerica* (Bibhitaki), *Terminalia chebula* (Haritaki), *Aegle marmelos* (Bel); Medicinal properties and their uses; Cultivation practices, post-harvest processing of medicinal plants.

Unit 3: Introduction to Ornamental Plants

Overview of ornamental plants and their role in landscaping and aesthetic gardening; classification of ornamental plants: flowering plants, foliage plants, and succulents; importance of indigenous ornamental plants in India; principles of garden design and landscape architecture; ecological significance of ornamental plants: role in biodiversity conservation and carbon sequestration.

Unit 4: Important Ornamental Plants of India

Taxonomical details, Botanical nomenclature, important secondary metabolites, uses of common Indian medicinal plants Cultivated ornamental plants: *Hibiscus rosa-sinensis* (China Rose), *Bougainvillea spectabilis* (Bougainvillea), *Chrysanthemum indicum* (Chrysanthemum), *Rosa* spp. (Roses), *Tagetes* spp. (Marigold), *Jasminum* spp. (Jasmine), *Ficus benjamina* (Weeping Fig), *Dracaena* spp., and *Asparagus* spp.; indigenous ornamental trees and shrubs: *Cassia fistula* (Amaltas), *Delonix regia* (Gulmohar), and *Plumeria alba* (Frangipani); cultivation and maintenance practices.

Unit 5: Conservation and Commercial Applications

Conservation of medicinal and ornamental plants: challenges and strategies; role of botanical gardens, nurseries, and gene banks in conservation; commercial propagation techniques: seed propagation, vegetative propagation, tissue culture, and micropropagation; value addition in medicinal and ornamental plants: extraction of bioactive compounds, preparation of herbal products, and flower-based industries; entrepreneurship opportunities in medicinal and ornamental plant cultivation.

Suggested Readings

Textbooks:

- Nambiar, V.P.K., Kutty, C.R. (2007). *Indian Medicinal Plants: A Compendium of 500 Species*, 2nd edition, Orient Blackswan, Hyderabad, India.
- Evans, W.C. (2009). *Trease and Evans' Pharmacognosy*, 16th edition, Elsevier, New York, USA.
- Chopra, R.N., Nayar, S.L., Chopra, I.C. (1999). *Glossary of Indian Medicinal Plants*, National Institute of Science Communication, New Delhi, India.
- Warrier, P.K., Nambiar, V.P.K., Ramankutty, C. (1996). *Indian Medicinal Plants: A Dictionary*, Orient Blackswan, Hyderabad, India.

- Hooker, J.D. (1999). *The Flora of British India*, Volumes 1–7, Bishen Singh Mahendra Pal Singh, Dehradun, India.

Books on Medicinal Plants:

- Kumar, N., Kumar, S. (2020). *Phytochemical Analysis and Medicinal Properties of Medicinal Plants*, Springer, Cham, Switzerland.
- Sharma, R. (2003). *Medicinal Plants of India: An Encyclopedia*, Daya Publishing House, New Delhi, India.
- Pandey, A.K., Singh, R.P. (2012). *Medicinal Plants: Conservation, Cultivation and Utilization*, CABI, Wallingford, UK.

Books on Ornamental Plants:

- Randhawa, G.S., Mukhopadhyay, A. (1986). *Floriculture in India*, Allied Publishers, New Delhi, India.
- Arora, J.S. (2006). *Introductory Ornamental Horticulture*, Kalyani Publishers, Ludhiana, India.
- Bhattacharjee, S.K. (2006). *Ornamental Plants and Garden Design*, Pointer Publishers, Jaipur, India.

Specialized Topics:

- Awasthi, M. (2017). *Conservation of Medicinal and Aromatic Plants*, Scientific Publishers, Jodhpur, India.
- Chadha, K.L. (1995). *Advances in Horticulture: Ornamental Plants*, Malhotra Publishing House, New Delhi, India.

Supplementary Reading:

- Singh, V., Jain, A.K. (2003). *Taxonomy of Angiosperms and Utilization of Plants*, Rastogi Publications, Meerut, India.
- Kaushik, P. (2020). *Bioactive Compounds from Medicinal Plants: Mechanism and Therapeutic Applications*, Springer, Singapore.

Molecular Plant Pathology

LTP: 4-0-0 **Credits: 4**

Course Objective: This course aims to provide students with an in-depth understanding of molecular plant pathology, covering plant-pathogen interactions, plant defence mechanisms, molecular signalling, and advanced genomics and proteomics tools used to study plant diseases. Students will also learn about biotechnological strategies for disease management and the development of disease-resistant crops.

Course Outcomes

On successful completion of this course, the students should be able to:

1. Understand plant-pathogen interactions, the classification of plant pathogens, and the molecular basis of pathogenicity.
2. Learn about plant defence mechanisms, including innate immunity, resistance proteins, and systemic resistance pathways.
3. Explore molecular signalling pathways in plant-pathogen interactions, focusing on plant hormones and small RNAs in immune responses.
4. Understand the applications of genomics and proteomics in plant pathology to study pathogen-host interactions and disease resistance.
5. Gain knowledge of biotechnological approaches for developing disease-resistant plants and molecular techniques for disease diagnosis and management.

Theory

Unit 1: Introduction to Molecular Plant Pathology

Overview of plant-pathogen interactions; classification and characteristics of plant pathogens: fungi, bacteria, viruses, nematodes, and phytoplasmas; molecular basis of pathogenicity: virulence factors, toxins, and effector proteins; infection process: adhesion, penetration, colonisation, and systemic infection; molecular Koch's postulates and their applications.

Unit 2: Plant Defence Mechanisms

Innate immunity in plants: pathogen-associated molecular patterns (PAMPs) and pattern recognition receptors (PRRs); effector-triggered immunity (ETI) and resistance (R) proteins; hypersensitive response (HR), systemic acquired resistance (SAR), and induced systemic resistance (ISR); production of reactive oxygen species (ROS), phytoalexins, and pathogenesis-related (PR) proteins; role of secondary metabolites in defence; epigenetic regulation of plant immunity.

Unit 3: Molecular Signalling in Plant-Pathogen Interactions

Plant hormone signalling pathways in defence: salicylic acid (SA), jasmonic acid (JA), ethylene (ET), and abscisic acid (ABA); crosstalk between signalling pathways; role of small RNAs in regulating plant immunity; signalling molecules: nitric oxide, calcium ions, and MAPK cascades; quorum sensing in plant pathogens; role of microbial effectors in modulating host signalling.

Unit 4: Genomics and Proteomics in Plant Pathology

Applications of genomics in plant pathology: pathogen genome sequencing and annotation; comparative genomics of plant pathogens and their hosts; transcriptomics to study host-pathogen interactions; proteomics to identify pathogen effectors and plant defence proteins; metabolomics in understanding disease resistance and susceptibility; use of molecular markers in disease diagnosis and resistance breeding.

Unit 5: Biotechnology and Disease Management

Development of disease-resistant plants using genetic engineering: overexpression of R genes, antimicrobial peptides, and RNAi technology; CRISPR-Cas systems for editing pathogen resistance genes; development of pathogen-resistant crops through transgenic approaches; molecular techniques for disease diagnosis: ELISA, PCR, qPCR, and LAMP; use of beneficial microorganisms in biocontrol: PGPR, mycorrhizae, and endophytes; strategies for integrated disease management (IDM).

Suggested Readings:

Textbooks:

- Agrios, G. N. (2005). *Plant Pathology* (5th ed.). Elsevier Academic Press.
- Dickman, M. B., & de Figueiredo, P. (2017). *Molecular Plant Pathology*. Wiley-Blackwell.
- Jones, J. D. G., & Dangl, J. L. (2006). *The Plant Immune System*. Nature Publishing Group.
- Zipfel, C. (2014). *Plant Pattern-Recognition Receptors*. Trends in Immunology.
- Dodds, P. N., & Rathjen, J. P. (2010). *Plant Immunity: Towards an Integrated View of Plant–Pathogen Interactions*. Nature Reviews Genetics.

Reference Books:

- Glazebrook, J. (2005). *Mechanisms of Defense Against Biotrophic and Necrotrophic Pathogens*. Annual Review of Phytopathology.
- McDowell, J. M., & Woffenden, B. J. (2003). *Plant Disease Resistance Genes: Recent Insights and Potential Applications*. Trends in Biotechnology.

- Collinge, D. B., Jørgensen, H. J. L., Lund, O. S., & Lyngkjær, M. F. (2010). *Engineering Pathogen Resistance in Crop Plants*. Annual Review of Phytopathology.
- Boller, T., & Felix, G. (2009). *Elicitors: Perception of Microbe-Associated Molecular Patterns and Danger Signals by Pattern-Recognition Receptors*. Annual Review of Plant Biology.
- Pieterse, C. M. J., Van der Does, D., Zamioudis, C., Leon-Reyes, A., & Van Wees, S. C. M. (2012). *Hormonal Modulation of Plant Immunity*. Annual Review of Cell and Developmental Biology.

Research Articles and Journals:

- Thomma, B. P. H. J., Nürnberger, T., & Joosten, M. H. A. J. (2011). *Of PAMPs and Effectors: The Blurred PTI-ETI Dichotomy*. The Plant Cell, 23(1), 4–15.
- Chisholm, S. T., Coaker, G., Day, B., & Staskawicz, B. J. (2006). *Host-Microbe Interactions: Shaping the Evolution of the Plant Immune Response*. Cell, 124(4), 803–814.
- Tsuda, K., & Katagiri, F. (2010). *Comparing Signaling Mechanisms Engaged in Pattern-Triggered and Effector-Triggered Immunity*. Current Opinion in Plant Biology, 13(4), 459–465.
- López-González, S., Pascual-Pardo, D., Soler, R., & Pozo, M. J. (2021). *Harnessing Beneficial Microbes for Plant Health: Establishing Holistic Principles for Biocontrol and Disease-Suppressive Soils*. FEMS Microbiology Ecology, 97(3), fiaa256.
- Goyal, R. K., & Mattoo, A. K. (2014). *Plant Small RNAs: Biogenesis, Regulation, and Their Role in Stress Responses*. Molecular Plant Pathology, 15(8), 791–804.

Online Resources:

- The American Phytopathological Society (APS): Research articles and plant pathology resources.
- The Plant Journal – Molecular Plant Pathology Special Issues.
- KEGG Pathway Database: Pathogen-host interactions and molecular signaling pathways.
- NCBI GenBank: Plant pathogen genome sequences and annotation tools.
- EMBL-EBI InterPro: Protein function classification and pathogen effector analysis.

Basics of Biophysics

Credits: 4

LTP: 4-0-0

Course Objective:

This course provides an understanding of the basic principles of physics and their applications to biological systems. It covers the physical and chemical properties of biomolecules and their roles in biological processes, introduces bioenergetics and thermodynamics in living systems, and familiarizes students with experimental techniques and computational tools used in biophysics. The course aims to foster a quantitative and interdisciplinary approach to studying biology.

Course Outcomes:

On successful completion of this course, students should be able to:

1. Explain how physical principles govern the structure and dynamics of biological systems.
2. Demonstrate an understanding of molecular interactions and biophysical techniques.
3. Analyze thermodynamic principles in metabolic and energy-related biological processes.
4. Apply biophysical models to interpret biological phenomena at the molecular and cellular levels.
5. Integrate mathematical and computational tools for solving problems in biophysics.

Theory

Unit 1: Introduction to Biophysics

Definition, scope, and historical evolution; interdisciplinary nature integrating physics, chemistry, and biology; role of physics in biological systems—mechanics, energy transfer, thermodynamics; structure-function relationships in biomolecules (proteins, nucleic acids, lipids, carbohydrates); biophysical approaches to cellular systems.

Unit 2: Biomechanics and Structural Biophysics

Mechanical properties of biological materials—elasticity, plasticity, viscosity, stress-strain behavior; biomechanics of cellular components—cytoskeleton, extracellular matrix, motility; biophysical principles of muscle contraction, molecular motors; structural characterization—X-ray crystallography, cryo-electron microscopy; computational modeling of macromolecules.

Unit 3: Bioenergetics and Membrane Biophysics

Laws of thermodynamics in biological systems; energy transformations—photosynthesis, respiration, ATP synthesis; free energy, enthalpy, entropy in biochemical reactions; principles of membrane transport—diffusion, osmosis, facilitated transport, ion pumps; membrane potential and action potential in cellular communication.

Unit 4: Molecular Biophysics

Forces in molecular interactions—hydrogen bonding, van der Waals, hydrophobic, electrostatic effects; protein structure and dynamics—folding, stability, misfolding disorders; DNA biophysics—structural polymorphism, supercoiling, chromatin organization; enzyme kinetics—catalysis, substrate specificity, allosteric regulation; ligand-binding studies in drug design.

Unit 5: Methods and Applications in Biophysics

Spectroscopic methods—UV-Vis, fluorescence, circular dichroism, NMR; microscopy—fluorescence, atomic force, confocal; computational biophysics—molecular dynamics, docking, Monte Carlo methods; applications in biomedical sciences—drug discovery, personalized medicine, tissue engineering; emerging trends—quantum biology, nanobiophysics.

Suggested Readings

Textbooks:

- Cotterill, R.M.J. (2002). Biophysics: An Introduction. Wiley.
- Glaser, R. (2012). Biophysics: An Introduction (2nd ed.). Springer.
- Schiessel, H. (2014). Biophysics for Beginners: A Journey through the Cell Nucleus. Pan Stanford Publishing.
- Nelson, P.C., Radosavljevic, M., & Bromberg, S. (2014). Biological Physics: Energy, Information, Life (Updated 1st ed.). W.H. Freeman.
- Boal, D. (2012). Mechanics of the Cell (2nd ed.). Cambridge University Press.

Reference Books:

- Misra, G. (Ed.). (2017). Introduction to Biomolecular Structure and Biophysics: Basics of Biophysics. Springer.

Springer Link:

- Volkenshtein, M.V. (1983). Biophysics. Mir Publishers.

Internet Archive:

- Phillips, R., Kondev, J., Theriot, J., & Garcia, H.G. (2012). Physical Biology of the Cell (2nd ed.). Garland Science.
- Tuszynski, J.A., & Kurzynski, M. (2003). Introduction to Molecular Biophysics. CRC Press.
- Jackson, M.B. (2006). Molecular and Cellular Biophysics. Cambridge University Press.

Research Articles and Journals:

- Leake, M.C. (2012). "The Physics of Life: One Molecule at a Time," arXiv preprint arXiv:1211.4366.
- M. McMahon (2019) Plant Science: Growth, Development, and Utilization of Cultivated Plants, Pearson Publishers, 6th edition; 978-0135184820
- R.A. Larson (2013) Introduction to Floriculture, Academic Press; 2nd edition; ASIN: B01M0176CN
- J. E. Preece and P. E. Read (2005) The Biology of Horticulture: An Introductory Textbook, 2nd Edition, Wiley
- Publishers; ISBN: 978-0471465799

Molecular Systematics

LTP: 4-0-0

Credits: 4

Course Objectives

This course aims to provide a comprehensive understanding of molecular systematics, integrating molecular techniques with traditional taxonomy to study biodiversity and evolutionary relationships. It will cover the principles of molecular evolution, the use of molecular markers in species identification and phylogeography, and advanced phylogenetic analysis methods. Students will explore the molecular basis of speciation, population genetics, and adaptive evolution. The course will also highlight recent advancements in next-generation sequencing, bioinformatics, and their applications in conservation and ecological research.

Course Outcomes

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

1. Explain the principles of molecular systematics and its integration with traditional taxonomy.
2. Utilize molecular markers for species identification, phylogeography, and biodiversity studies.
3. Analyse evolutionary relationships using phylogenetic tree construction and molecular data.
4. Interpret molecular evidence in speciation, population genetics, and evolutionary processes.
5. Apply bioinformatics and next-generation sequencing tools in molecular systematics research.

Theory

Unit 1: Foundations of Molecular Systematics

Concept and significance: scope, integration with traditional taxonomy, applications in biodiversity and agriculture; Historical development: transition from morphology to molecular methods, key milestones, role of sequencing technologies; Molecular evolution: mutation, substitution, molecular clock hypothesis, evolutionary rates; Concepts of homology and analogy in molecular data; Role of molecular systematics in evolutionary biology and taxonomy.

Unit 2: Molecular Markers and Data Analysis in Systematics

Types of molecular markers: allozymes, RFLP, RAPD, AFLP, ISSR, SSR, mitochondrial DNA, chloroplast DNA, and nuclear DNA; Genome-wide approaches: SNPs, transcriptomics, and comparative genomics; Methods for marker selection, experimental design, and data analysis; Role of molecular markers in species identification, phylogeography, and biodiversity assessment; Applications in conservation genetics and population studies.

Unit 3: Phylogenetic Analysis and Evolutionary Relationships

Methods of phylogenetic analysis: distance-based (UPGMA, Neighbor-Joining) and character-based (Maximum Parsimony, Maximum Likelihood, Bayesian Inference); Sequence alignment techniques: multiple sequence alignment and its significance; Phylogenetic tree construction and interpretation; Bootstrapping and statistical reliability of phylogenies; Molecular clocks and evolutionary dating; Resolving species complexes and cryptic species identification.

Unit 4: Molecular Basis of Speciation and Evolutionary Processes

Molecular insights into speciation: sympatric and allopatric speciation; Adaptive radiation and evolutionary convergence; Comparative genomics: identifying orthologous and paralogous genes; Molecular divergence and gene flow in evolutionary studies; Genetic signatures of hybridization and introgression; Population genetics and its role in understanding evolutionary dynamics.

Unit 5: Advances and Applications in Molecular Systematics

DNA barcoding: concept, workflow, case studies, applications in forensic botany and conservation; Integration of molecular and morphological data in systematic studies; Biogeography and ecological niche modeling using molecular data; Next-generation sequencing and bioinformatics tools for systematics; Ethical considerations and challenges in molecular systematics; Future directions: genomics-driven taxonomy and AI in systematics research.

Suggested Readings

Textbooks:

- Avise, J.C. (2000). *Phylogeography: The History and Formation of Species*, Harvard University Press, Cambridge, USA.
- Hillis, D.M., Moritz, C., Mable, B.K. (1996). *Molecular Systematics*, 2nd edition, Sinauer Associates, Sunderland, USA.
- Freeman, S., Herron, J.C. (2020). *Evolutionary Analysis*, 6th edition, Pearson, New York, USA.
- Nei, M., Kumar, S. (2000). *Molecular Evolution and Phylogenetics*, Oxford University Press, Oxford, UK.
- Jobb, G., et al. (2009). *Phylogenetic Analysis Using Parsimony (and Other Methods): PAUP*, Sinauer Associates, Sunderland, USA.

Books on Molecular Markers:

- Brown, T.A. (2016). *Gene Cloning and DNA Analysis: An Introduction*, 7th edition, Wiley-Blackwell, Oxford, UK.
- Karp, A., et al. (1998). *Molecular Tools for Screening Biodiversity: Plants and Animals*, Springer, Dordrecht, Netherlands.
- Henry, R.J. (2001). *Plant Genotyping: The DNA Fingerprinting of Plants*, CABI Publishing, Wallingford, UK.

Books on Phylogenetics and Tree Construction:

- Felsenstein, J. (2004). *Inferring Phylogenies*, Sinauer Associates, Sunderland, USA.
- Graur, D., Li, W.-H. (2000). *Fundamentals of Molecular Evolution*, 2nd edition, Sinauer Associates, Sunderland, USA.
- Page, R.D.M., Holmes, E.C. (1998). *Molecular Evolution: A Phylogenetic Approach*, Wiley-Blackwell, Oxford, UK.

Books on Applications and Future Perspectives:

- Lemey, P., Salemi, M., Vandamme, A.M. (2009). *The Phylogenetic Handbook: A Practical Approach to Phylogenetic Analysis and Hypothesis Testing*, 2nd edition, Cambridge University Press, Cambridge, UK.
- Wiley, E.O., Lieberman, B.S. (2011). *Phylogenetics: Theory and Practice of Phylogenetic Systematics*, 2nd edition, Wiley-Blackwell, Oxford, UK.

Supplementary Reading:

- Hall, B.G. (2011). *Phylogenetic Trees Made Easy: A How-To Manual*, 4th edition, Sinauer Associates, Sunderland, USA.
- Zhang, Z. (2019). *Phylogenomics: A Primer*, Springer, Cham, Switzerland.

Nitrogen Metabolism in Plants

LTP: 4-0-0 **Credits: 4**

Course Objectives:

This course aims to provide an in-depth understanding of nitrogen metabolism in plants, emphasizing its role in growth, development, and stress adaptation. It covers key processes such as nitrogen fixation, assimilation, and transport, along with the biochemical and molecular regulation of nitrogen-containing compounds. The course also explores the impact of environmental stress on nitrogen metabolism and the application of biotechnology for improving nitrogen use efficiency. Additionally, students will gain insights into sustainable nitrogen management strategies to enhance crop productivity while minimizing environmental impact.

Course Outcomes:

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

1. Explain the significance of nitrogen metabolism and its role in plant growth, development, and productivity.
2. Analyze the mechanisms of nitrogen fixation, assimilation, and transport, including their molecular and biochemical regulation.
3. Evaluate the impact of environmental stresses on nitrogen metabolism and explore strategies for improving nitrogen use efficiency in crops.
4. Apply biotechnological and sustainable approaches to optimize nitrogen management in agricultural systems.

Theory

Unit 1: Introduction to Nitrogen Metabolism

Importance of nitrogen: proteins, nucleic acids, chlorophyll, secondary metabolites. Nitrogen sources: atmospheric, biological, soil organic/inorganic nitrogen, fertilizers. Nitrogen cycling: ammonification, nitrification, denitrification. Microbial role: bacteria, fungi in nitrogen transformations. Environmental impact: eutrophication, soil acidification, climate change. Mitigation strategies: biofertilizers, organic amendments. Evolutionary aspects: nitrogen metabolism in different plant species.

Unit 2: Biological Nitrogen Fixation

Types: symbiotic, non-symbiotic, associative. Symbiosis: *Rhizobium*-legume interaction, nodule formation, nitrogenase enzyme. Role of leghemoglobin. Free-living nitrogen fixers: *Azotobacter*, *Clostridium*, cyanobacteria (*Anabaena, Nostoc*). Rhizobial genomics: *nod, nif, fix* genes, flavonoid signaling. Soil factors: pH, nutrients, heavy metals. Non-legume nitrogen fixation: actinorhizal symbiosis, *Frankia*-plant interactions.

Unit 3: Nitrogen Assimilation and Transport

Nitrogen uptake: nitrate, ammonium transporters, root absorption. Nitrate reduction: nitrate reductase (NR), nitrite reductase (NiR). Ammonium assimilation: GS-GOGAT, glutamate dehydrogenase (GDH) pathways. Carbon-nitrogen interaction: C/N balance, metabolic regulation. Root-to-shoot signaling: regulatory proteins (NLP, NRT1.1, CIPK23). Phytohormonal regulation: auxin, cytokinin, ABA. Nitrogen translocation: phloem and xylem movement, amino acid transport.

Unit 4: Nitrogen-Containing Compounds and Their Role

Amino acid biosynthesis: glutamine, asparagine, proline, arginine. Protein synthesis, nitrogen allocation. Secondary metabolites: alkaloids, glucosinolates, cyanogenic glycosides. Nitrogen in plant hormones: auxins, cytokinins, ethylene, gibberellins. Signaling molecules: nitric oxide (NO) in stress and defense. Nitrogen partitioning: source-sink balance, remobilization during senescence. Role in reproductive development: seed filling, grain protein content.

Unit 5: Nitrogen Metabolism Under Stress

Abiotic stress: drought, salinity, temperature, oxidative stress. Hormonal regulation: ABA, salicylic acid, jasmonates. Epigenetic control: DNA methylation, histone modifications, miRNA regulation. Biotechnological approaches: transgenic crops, CRISPR, nitrogen-efficient crop varieties. Sustainable agriculture: reducing fertilizer dependency, precision nitrogen management.

Suggested readings:

Textbooks:

- Taiz, L., Zeiger, E., Moller, I.M., Murphy, A. (2018). *Plant Physiology and Development, International 6th edition,* Oxford University Press, Sinauer Associates, New York, USA.
- Buchanan, B.B., Gruissem, W., Jones, R.L. (2015). *Biochemistry and Molecular Biology of Plants, 2nd edition,* Wiley Blackwell, Oxford, UK.
- Lea, P.J., Morot-Gaudry, J.F. (2001). *Plant Nitrogen,* Springer, Berlin, Germany.
- Foyer, C.H., Zhang, H. (2011). *Nitrogen Metabolism in Plants in the Post-genomic Era.* Annual Plant Reviews, Volume 42, Wiley-Blackwell, Oxford, UK.

Research Articles:

- Krapp, A. (2015). "Plant Nitrogen Assimilation and its Regulation: A Complex Puzzle with Missing Pieces," *Current Opinion in Plant Biology, 25,* 115–122.
- Xu, G., Fan, X., Miller, A.J. (2012). "Plant Nitrogen Assimilation and Use Efficiency," *Annual Review of Plant Biology, 63,* 153–182.
- Masclaux-Daubresse, C., et al. (2010). "Nitrogen Uptake, Assimilation and Remobilization in Plants: Challenges for Sustainable and Productive Agriculture," *Annals of Botany, 105(7),* 1141–1157.
- Bloom, A.J. (2015). "The Increasing Importance of Distinguishing Among Plant Nitrogen Sources," *Current Opinion in Plant Biology, 25,* 10–16.
- Hirel, B., Le Gouis, J., Ney, B., Gallais, A. (2007). "The Challenge of Improving Nitrogen Use Efficiency in Crop Plants," *Journal of Experimental Botany, 58(9),* 2369–2387.
- Good, A.G., Beatty, P.H. (2011). "Fertilizing Nature: A Tragedy of Excess in the Commons," *PLoS Biology, 9(8),* e1001124.
- Miller, A.J., Fan, X., Orsel, M., Smith, S.J., Wells, D.M. (2007). "Nitrate Transport and Signaling," *Journal of Experimental Botany, 58(9),* 2297–2306.
- Crawford, N.M., Forde, B.G. (2002). "Molecular and Developmental Biology of Nitrate Transport in Plants," *Annual Review of Plant Biology, 53,* 815–846.
- Wang, R., Xing, X., Crawford, N.M. (2007). "Nitrite Acts as a Transcriptome Signal at Micromolar Concentrations in Arabidopsis Roots," *Plant Physiology, 145(4),* 1735–1745.
- Stitt, M., Krapp, A. (1999). "The Interaction Between Elevated Carbon Dioxide and Nitrogen Nutrition: The Physiological and Molecular Background," *Plant, Cell & Environment, 22(6),* 583–621.

Specialized Topics:

- Coruzzi, G.M., Bush, D.R. (2001). "Nitrogen and Carbon Nutrient and Metabolite Signaling in Plants," *Plant Physiology, 125(1),* 61–64.
- Castaings, L., et al. (2011). "The Nitrate Signaling Pathway in Arabidopsis: Nitrate-Dependent Regulation of Gene Expression, Post-Translational Modification, and Protein Localization," *Journal of Experimental Botany, 62(7),* 2197–2202.

- Kraiser, T., Gras, D.E., Gutierrez, A.G., Gonzalez, B., Gutierrez, R.A. (2011). "A Holistic View of Nitrogen Acquisition in Plants," *Journal of Experimental Botany, 62(4)*, 1455–1466.
- Li, B., et al. (2017). "NRT1.1-Related NH_4^+ Toxicity is Associated with a Disturbed Balance Between NH_4^+ Uptake and Assimilation," *Plant Physiology, 175(4)*, 1479–1492.
- Guan, M., Møller, I.M., Schjoerring, J.K. (2015). "Two Cytosolic Glutamine Synthetase Isoforms Play Different Roles in Ammonium Assimilation and Nitrogen Remobilization in Leaves of Arabidopsis thaliana L.," *Plant Physiology, 168(3)*, 1560–1574

Supplementary Reading:

- Heldt, H.-W., Piechulla, B. (2021). *Plant Biochemistry, 5th edition*, Academic Press, London, UK.

Artificial Intelligence in Plant Sciences

LTP: 4-0-0 **Credits: 4**

Course Objective:

This course aims to provide a foundational understanding of Artificial Intelligence (AI) and machine learning, focusing on their applications in analysing biological datasets, including genomics, proteomics, and bioinformatics. Students will be introduced to AI tools and frameworks used in biology and will develop critical thinking and problem-solving skills for applying AI in biological research. Ethical considerations and challenges in applying AI to biology will also be emphasized throughout the course.

Course Outcomes:

On successful completion of this course, students should be able to:

1. Understand the fundamental principles and algorithms of AI and their relevance to biology.
2. Apply machine learning techniques to analyze and interpret biological data.
3. Use AI tools and frameworks for biological research, such as genome analysis and drug discovery.
4. Evaluate the opportunities and limitations of AI in solving biological problems.
5. Address ethical issues related to AI applications in biological and biomedical sciences

Theory

Unit 1: Introduction to AI in Plant Sciences

Definition, scope, and evolution of AI; key milestones in AI for biology and agriculture; subfields—machine learning, deep learning, reinforcement learning; overview of plant-based data—genomic sequences, phenotypic traits, metabolic pathways, imaging data; challenges in plant data analysis—heterogeneity, noise, and scalability.

Unit 2: Machine Learning in Plant Research

Supervised vs. unsupervised learning; key algorithms—regression, decision trees, random forests, neural networks, clustering methods (K-means, PCA); model evaluation metrics; applications in plant sciences—crop disease detection, plant stress classification, gene expression analysis, and trait prediction.

Unit 3: AI Tools and Techniques in Plant Sciences

Popular AI frameworks—Python, TensorFlow, Keras, Scikit-learn; deep learning in plant image analysis—convolutional neural networks (CNNs) for leaf disease detection and phenotyping; NLP in plant research—mining scientific literature, gene function annotation; predictive modeling—genomic selection, stress resilience prediction, plant-microbe interactions.

Unit 4: AI in Agriculture and Crop Improvement

AI applications in precision farming—remote sensing, yield prediction, smart irrigation; automated disease detection using drone and satellite imagery; AI-driven plant breeding—genomic selection, marker-assisted prediction; ethical considerations—bias, transparency, data privacy in agricultural AI.

Unit 5: Hands-on Applications and Future Trends

Hands-on exercises—training AI models for plant disease classification, plant image segmentation, and text mining for trait discovery; future trends—explainable AI for plant biology, AI-driven climate resilience strategies, AI-integrated smart greenhouses, and automation in sustainable agriculture.

Suggested Readings

Textbooks:

- Ertel, W. (2024). *Introduction to Artificial Intelligence*. Springer Nature.
- Finlay, J. (1996). *An Introduction to Artificial Intelligence* (1st ed.). CRC Press.
- Mitchell, T.M. (1997). *Machine Learning*. McGraw Hill Education.
- Goodfellow, I., Bengio, Y., Courville, A. (2016). *Deep Learning*. MIT Press.
- Russell, S., Norvig, P. (2021). *Artificial Intelligence: A Modern Approach* (4th ed.). Pearson.

Reference Books:

- Harkut, G.D. (2019). "Artificial Intelligence: Scope and Limitations," IntechOpen.
- Boden, M.A. (2018). *Artificial Intelligence: A Very Short Introduction*. Oxford University Press.
- Lane, D. (2021). *Machine Learning for Kids: A Project-Based Introduction to Artificial Intelligence*. No Starch Press.
- Domingos, P. (2015). *The Master Algorithm: How the Quest for the Ultimate Learning Machine Will Remake Our World*. Basic Books.
- Flach, P. (2012). *Machine Learning: The Art and Science of Algorithms That Make Sense of Data*. Cambridge University Press.

Research Articles and Journals:

- AlQuraishi, M. (2019). "AlphaFold at CASP13," *Bioinformatics*, 36(4), 1081–1082.
- Esteva, A., et al. (2017). "Dermatologist-Level Classification of Skin Cancer with Deep Neural Networks," *Nature*, 542, 115–118.
- Jumper, J., et al. (2021). "Highly Accurate Protein Structure Prediction with AlphaFold," *Nature*, 596(7873), 583–589.
- Zhang, Z., et al. (2021). "AI-Powered Genomics for Precision Medicine," *Genome Biology*, 22(1), 130.

Specialized AI in Biology Resources:

- Tarca, A.L., Carey, V.J., et al. (2013). "Machine Learning for Genomics and Proteomics: Applications in Biological Research," *PLoS Computational Biology*, 9(10), e1003325.
- Angermueller, C., et al. (2016). "Deep Learning for Computational Biology," *Molecular Systems Biology*, 12(7), 878.
- Lecun, Y., Bengio, Y., Hinton, G. (2015). "Deep Learning," *Nature*, 521, 436–444.

Online Resources:

- Stanford University's CS229: *Machine Learning Course Materials*.
- MIT OpenCourseWare: *Introduction to Deep Learning*.
- Kaggle: Hands-on AI projects and biological datasets for practice.
- Google AI Blog: Cutting-edge AI innovations, including AI applications in life sciences.

Computational Biology in Plant Sciences

LTP: 4-0-0 **Credits: 4**

Course Objective:

This course aims to provide a comprehensive understanding of computational biology and its applications in plant science. Students will learn to analyze and interpret plant genomic and transcriptomic data using bioinformatics tools and perform functional analyses of gene expression. The course also covers systems biology approaches for studying plant metabolism and signaling pathways, along with machine learning techniques to predict plant traits and responses to environmental factors.

Course Outcomes:

On successful completion of this course, the students should be able to:

1. Understand the role of computational biology in plant science and gain proficiency in basic bioinformatics tools and databases.
2. Learn how to assemble, annotate, and analyze plant genomes using computational tools for genome assembly and functional annotation.
3. Gain the skills to process and analyze RNA-Seq data to study differential gene expression in plants and interpret functional results.
4. Understand and analyze plant metabolic and signaling networks using systems biology tools like Cytoscape to model plant-environment interactions.
5. Apply machine learning techniques to plant genomic and phenotypic data to predict plant traits and improve crop breeding strategies.

Theory

Unit 1: Introduction to Computational Biology in Plant Science

Introduction to computational biology in plant science; Biological data types and formats (FASTA, GenBank, VCF); Data types in plant science (genomic, transcriptomic, proteomic); Programming for bioinformatics: Python and R basics; Key plant bioinformatics resources (Ensembl Plants, PlantGDB, TAIR); Overview of tools for sequence analysis, alignment, and annotation

Unit 2: Plant Genomics and Genome Assembly

Plant genome structure and complexity; Genome assembly techniques (de novo, reference-based); Tools for genome assembly: SPAdes, Velvet; Genome annotation and functional annotation (gene prediction, functional annotation); Addressing challenges in plant genomics (polyploidy, repetitive regions)

Unit 3: Transcriptomics and Gene Expression Analysis in Plants

Overview of transcriptomics and RNA-Seq technology; Data preprocessing and quality control for RNA-Seq data; Differential gene expression analysis with DESeq2, edger; Gene ontology (GO) and pathway analysis; Visualizing gene expression: heatmaps, volcano plots; Application in understanding plant responses to abiotic stress, growth, and development.

Unit 4: Systems Biology and Plant Metabolic Networks

Introduction to systems biology in plants; Metabolic and signaling networks in plants; Gene regulatory networks and their role in plant development; Tools for network construction and analysis: Cytoscape; Modeling plant-environment interactions (drought, stress response); Case studies: Plant metabolic networks and response to abiotic stress

Unit 5: Machine Learning and Predictive Modeling in Plant Biology

Introduction to machine learning in plant science; Supervised vs unsupervised learning for biological data; Applications of machine learning in plant trait prediction (e.g., yield, stress tolerance); Predictive modeling using phenotypic and genomic data; Machine learning tools.

Suggested Readings:

Textbooks (Essential Reading):

- Claverie, J.-M., & Notredame, C. (2003). *Bioinformatics for Dummies*. Wiley.
- Mount, D. W. (2004). *Bioinformatics: Sequence and Genome Analysis*. Cold Spring Harbor Laboratory Press.
- Baxevanis, A. D., & Ouellette, B. F. F. (2001). *Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins*. Wiley-Liss.
- Stewart Jr., C. N. (2014). *Plant Genomics: Methods and Protocols*. Springer.
- Gibbons, T. (2008). *Genome Assembly and Annotation*. Elsevier.
- Ouwerkerk, P. H. C. L. N. M., & de Vries, M. A. J. (2022). *Plant Genome Editing with CRISPR*. Springer.
- Korpelainen, E., & Suomalainen, A. (2017). *RNA-Seq Data Analysis: A Practical Approach*. Springer.
- Patel, D. J. (2018). *Practical Guide to Machine Learning in Bioinformatics*. Springer.
- Ramsundar, B., et al. (2016). *Deep Learning for the Life Sciences: Applying Deep Learning to Genomics, Microscopy, Drug Discovery, and More*. O'Reilly Media.

2. Research Articles and Review Papers:

- Kuroda, S. A., et al. (2018). "Cytoscape: A Software Environment for Integrated Models of Biomolecular Interaction Networks." *Nature Biotechnology*, 36(10): 974–982.
- Sinha, S., et al. (2020). "Applications of Machine Learning in Genomic Prediction of Plant Traits." *Trends in Plant Science*, 25(7): 650–664.
- Cheng, C., et al. (2017). "RNA-Seq: A Comprehensive Approach to Transcriptomics in Plants." *Annual Review of Plant Biology*, 68: 111–134.
- Prathap, A., & Natesan, S. (2022). "Understanding Systems Biology Approaches in Plant Metabolic Networks." *Plant Systems Biology*, 8(1): 28–44.

Recommended Journals (For Latest Research Updates)

- *The Plant Cell* (American Society of Plant Biologists)
- *Plant Physiology* (American Society of Plant Biologists)
- *Trends in Plant Science* (Elsevier)
- *Nature Plants* (Nature Publishing Group)
- *Journal of Experimental Botany* (Oxford University Press)
- *BMC Bioinformatics* (Springer)

Online Databases & Open-Access Resources

- *Ensembl Plants* – https://plants.ensembl.org
- *TAIR (The Arabidopsis Information Resource)* – https://www.arabidopsis.org
- *PlantGDB* – https://www.plantgdb.org
- *NCBI Gene Database* – https://www.ncbi.nlm.nih.gov/gene

Ecology and Biodiversity Conservation

Credits: 4

LTP: 4-0-0

Course Objective:

The course provides a comprehensive understanding of ecosystems, focusing on their structure, functioning, and dynamics. It explores the ecological and economic significance of forest ecosystems, sustainable management, and conservation. Students will also examine phytogeography, conservation biology, and applied concepts like environmental impact assessments and restoration ecology for sustainable development.

Course Outcomes:

On successful completion of this course, the students should be able to:

1. Gain the ability to analyse and evaluate ecosystem processes, including energy flow, biogeochemical cycles, and the impacts of environmental changes.
2. Understand the diversity of forest ecosystems in India and their ecological and economic roles, enabling them to propose sustainable forest management practices.
3. Develop skills to assess phytogeographic principles and analyse factors influencing plant distribution, endemism, and migration across regions.
4. Demonstrate knowledge of biodiversity conservation strategies, legal frameworks, and the integration of traditional ecological knowledge in addressing environmental challenges.
5. Acquire expertise in applied conservation techniques, including EIA, restoration ecology, GIS applications, and community-based initiatives for ecosystem and biodiversity management.

Theory

Unit 1: Environmental Biology

Scope and importance of environmental biology; ecosystem structure and functioning; abiotic and biotic components of the environment; energy flow: food chains, food webs, and ecological pyramids; biogeochemical cycles: carbon, nitrogen, and phosphorus; ecological succession: types and mechanisms; environmental pollution: air, water, and soil pollution, their causes, and mitigation strategies; climate change and its impacts on ecosystems.

Unit 2: Forest Botany

Types of forests in India: tropical, temperate, and alpine forests; structure and composition of forest ecosystems; forest resources and their ecological and economic significance; forest succession and dynamics; non-timber forest products (NTFPs) and their sustainable management; deforestation:

causes, consequences, and afforestation practices; forest conservation strategies: Joint Forest Management (JFM) and agroforestry systems.

Unit 3: Phytogeography

Principles and concepts of phytogeography; phytogeographic regions of India and their floristic composition; factors affecting the distribution of plant species: climatic, edaphic, and biotic factors; endemism: types and significance; plant migration and dispersal; continental drift and its role in species distribution; vegetation types of the world: classification and ecological significance; floristic diversity hotspots in India.

Unit 4: Conservation Biology

Principles and importance of conservation biology; biodiversity: levels, hotspots, and values; causes of biodiversity loss: habitat destruction, overexploitation, invasive species, and climate change; ex situ and in situ conservation strategies: botanical gardens, seed banks, national parks, and wildlife sanctuaries; role of traditional ecological knowledge in conservation; legal frameworks: Forest Conservation Act, Wildlife Protection Act, and Biodiversity Act.

Unit 5: Applied Aspects and Emerging Trends

Role of environmental impact assessments (EIA) in ecosystem management; sustainable development goals (SDGs) and their relevance to environmental and forest conservation; restoration ecology: techniques and challenges; carbon sequestration and forest-based climate solutions; role of remote sensing and GIS in forest and biodiversity management; emerging concepts in conservation: rewilding, assisted migration, and ecological corridors; community-based conservation and eco-tourism.

Suggested Readings

Textbooks

- Odum, E.P., Barrett, G.W. (2005). *Fundamentals of Ecology*, 5th edition, Brooks Cole, Belmont, USA.
- Smith, T.M., Smith, R.L. (2021). *Elements of Ecology*, 10th edition, Pearson, New York, USA.
- Begon, M., Townsend, C.R., Harper, J.L. (2020). *Ecology: From Individuals to Ecosystems*, 5th edition, Wiley-Blackwell, Oxford, UK.
- Primack, R.B. (2020). *Essentials of Conservation Biology*, 7th edition, Oxford University Press, New York, USA.
- Krishnamurthy, K.V. (2017). *An Advanced Textbook on Biodiversity: Principles and Practice*, 3rd edition, Oxford & IBH Publishing Co., New Delhi, India.

Research Articles:

- Vitousek, P.M., et al. (1997). "Human Domination of Earth's Ecosystems," *Science*, 277(5325), 494–499.
- Cardinale, B.J., et al. (2012). "Biodiversity Loss and Its Impact on Humanity," *Nature*, 486, 59–67.
- Tilman, D., et al. (1997). "Biodiversity and Ecosystem Functioning," *Science*, 277(5330), 1300–1302.
- Sala, O.E., et al. (2000). "Global Biodiversity Scenarios for the Year 2100," *Science*, 287(5459), 1770–1774.
- Mace, G.M., et al. (2012). "Biodiversity and Ecosystem Services: A Multilayered Relationship," *Trends in Ecology & Evolution*, 27(1), 19–26.

Specialized Topics:

- Pimm, S.L., et al. (2014). "The Biodiversity of Species and Their Rates of Extinction," *Science*, 344(6187), 1246752.
- Groom, M.J., Meffe, G.K., Carroll, C.R. (2006). *Principles of Conservation Biology*, 3rd edition, Sinauer Associates, Sunderland, USA.
- Chapin, F.S. III, et al. (2000). "Consequences of Changing Biodiversity," *Nature*, 405, 234–242.
- Turner, M.G., Gardner, R.H., O'Neill, R.V. (2001). *Landscape Ecology in Theory and Practice: Pattern and Process*, Springer, New York, USA.
- Sutherland, W.J., et al. (2006). *Ecological Census Techniques: A Handbook*, 2nd edition, Cambridge University Press, Cambridge, UK.

Supplementary Reading:

- Whittaker, R.H., Levin, S.A. (2013). *Niche: Theory and Application in Ecology*, Springer, Berlin, Germany.

Plant Breeding

LTP: 4-0-0 **Credits: 4**

Course Objective:

This course aims to provide students with fundamental knowledge of plant breeding, including its history, significance, and genetic principles. It covers conventional and modern breeding methods for self-pollinated, cross-pollinated, and clonally propagated crops. Students will learn about selection techniques, hybridisation, polyploidy breeding, and the role of biotechnology in crop improvement. The course also addresses challenges in breeding for stress tolerance, quality enhancement, and genetic resource conservation.

Course Outcomes:

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

1. Explain the fundamental principles of plant breeding and its historical, genetic, and agronomic significance in crop improvement.
2. Apply conventional and modern breeding techniques to improve crop yield, stress tolerance, and quality through selection, hybridisation, and genetic manipulation.
3. Utilize molecular and biotechnological tools such as marker-assisted selection, genetic engineering, and genome editing for crop enhancement.
4. Assess the challenges and future prospects of plant breeding in the context of climate change, sustainability, and intellectual property regulations.

Theory

Unit 1: Introduction to Plant Breeding

History and significance of plant breeding; objectives of plant breeding: yield improvement, biotic and abiotic stress resistance, and quality enhancement; modes of reproduction in plants: self-pollination, cross-pollination, and asexual reproduction; genetic consequences of different modes of reproduction; Pure line theory, Heterosis; inbreeding depression- concept and basis, concept of role of genetic diversity in crop improvement.

Unit 2: Methods of Plant Breeding in Self-Pollinated Crops

Principles of selection: mass selection, bulk population breeding, pedigree selection; backcross breeding and gene introgression; hybridisation techniques: emasculation methods (mechanical, chemical, genetic male sterility-based), artificial pollination, selection of desirable recombinants; pure line development and maintenance, genetic purity and seed certification, role of marker-assisted selection (MAS) in self-pollinated crops.

Unit 3: Methods of Plant Breeding in Cross-Pollinated & Clonally Propagated Crops

Hybrid development and utilisation: heterosis, hybrid vigour, CMS (cytoplasmic male sterility), GMS (genic male sterility), three-line and two-line hybrid systems, hybrid seed production in maize and sorghum; synthetic and composite varieties: genetic basis, steps in development, examples in cereals and oilseeds; recurrent selection and population improvement: simple, reciprocal, S1 family selection, half-sib and full-sib selection, index selection, multi-trait selection; clonal selection and breeding in vegetatively propagated crops: somaclonal variation, meristem culture, virus elimination; polyploidy breeding: colchicine-induced polyploidy, autopolyploids vs. allopolyploids, examples in wheat, sugarcane, and ornamentals.

Unit 4: Modern Tools and Techniques in Plant Breeding

Role of biotechnology in plant breeding; mutation and polyploid breeding: chemical mutagens (EMS, sodium azide), radiation mutagens (gamma rays, X-rays), induction, screening, selection and evaluation of mutants; molecular marker-assisted selection (MAS) and its applications; genetic engineering for crop improvement: transgenic plants, CRISPR-Cas systems, and genome editing; tissue culture techniques in plant breeding: somatic hybridisation, micropropagation, and embryo rescue; doubled haploid production; genomic selection and its applications in breeding programmes.

Unit 5: Challenges and Applications of Plant Breeding

Breeding for biotic stress resistance: disease and pest resistance; breeding for abiotic stress tolerance: drought, salinity, and temperature extremes; quality improvement: breeding for nutritional enhancement, seed quality, and post-harvest traits; conservation of genetic resources for plant breeding: gene banks and in situ conservation; intellectual property rights (IPR) and their implications in plant breeding; future prospects of plant breeding in the context of climate change and sustainable agriculture.

Suggested Readings

Textbooks:

- Acquaah, G. (2020). *Principles of Plant Genetics and Breeding*, 3rd edition, Wiley-Blackwell, Oxford, UK.
- Allard, R.W. (1999). *Principles of Plant Breeding*, 2nd edition, Wiley-Blackwell, New York, USA.
- Singh, B.D. (2019). *Plant Breeding: Principles and Methods*, 11th edition, Kalyani Publishers, New Delhi, India.
- Fehr, W.R. (1987). *Principles of Cultivar Development: Theory and Technique*, Macmillan, New York, USA.
- Sharma, J.R. (2003). *Principles and Practice of Plant Breeding*, Oxford & IBH Publishing, New Delhi, India.

Books on Self- and Cross-Pollinated Crops:

- Chahal, G.S., Gosal, S.S. (2002). *Principles and Procedures of Plant Breeding: Biotechnological and Conventional Approaches*, Alpha Science International, Oxford, UK.
- Baker, H.G., Stebbins, G.L. (1965). *The Genetics of Colonizing Species*, Academic Press, London, UK.
- Sprague, G.F., Dudley, J.W. (1988). *Corn and Corn Improvement*, American Society of Agronomy, Madison, USA.

Books on Modern Tools and Techniques:

- Collard, B.C.Y., Mackill, D.J. (2008). *Molecular Breeding for Crop Improvement: Principles and Practices*, Springer, Dordrecht, Netherlands.
- Moose, S.P., Mumm, R.H. (2008). *Molecular Plant Breeding: Integration of Molecular Tools into Traditional Plant Breeding*, Springer, New York, USA.
- Ricroch, A., Chopra, S., Fleischer, S. (2013). *Plant Biotechnology and Agriculture: Prospects for the 21st Century*, Academic Press, London, UK.

Books on Challenges and Applications:

- FAO. (2010). *The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture*, Food and Agriculture Organization, Rome, Italy.
- Tester, M., Langridge, P. (2010). "Breeding Technologies to Increase Crop Production in a Changing World," *Science*, 327(5967), 818–822.
- Lopes, M.S., Reynolds, M.P. (2010). *Breeding for Abiotic Stress Tolerance in Crops*, Springer, Cham, Switzerland.

Supplementary Reading:

- Kingsbury, N. (2009). *Hybrid: The History and Science of Plant Breeding*, University of Chicago Press, Chicago, USA.
- Poehlman, J.M., Sleper, D.A. (2006). *Breeding Field Crops*, 5th edition, Blackwell Publishing, Ames, USA.