MASTER OF SCIENCE
IN

PLANT MOLECULAR BIOLOGY AND BIOTECHNOLOGY

TWO YEAR FULL TIME PROGRAMME

DEPARTMENT OF PLANT MOLECULAR BIOLOGY
FACULTY OF INTERDISCIPLINARY AND APPLIED SCIENCES
UNIVERSITY OF DELHI, SOUTH CAMPUS
NEW DELHI – 110 021, INDIA

Introduction

The M.Sc. in Plant Molecular Biology and Biotechnology (PMBB) is a two years programme consisting of two parts i.e. Part I (sem. I & II) and Part II (sem. III and IV), each having two semesters. Semester-1 has four core theory papers of 4 credits each (100 marks each) and one practical paper of 8 credits (200 marks) based on theory papers. Semester-2 has three core theory and two internal elective theory papers of 4 credits each (100 marks each), one open elective paper of 2 credits (50 marks), and one practical paper of 6 credits (150 marks). Semester-3 has three core theory and two internal elective theory papers of 4 credits each (100 marks each), and one practical paper of 8 credits (200 marks). The entire semester-4 would have dissertation work of 24 credits (600 marks). In both semester 2 and 3, candidates can chose any one of the internal elective theory papers. In general, while the core theory papers provide basic and updated information about the subject, the internal electives theory papers have been designed to provide much more detailed and advance information on the subject whose basics have been covered in the core papers. The open elective paper has been designed to provide in-depth and advanced training to a wider community of life science students in an emerging field of biological sciences.

All theory, practicals and dissertation will have 30% marks reserved for Internal Assessment (IA). Each theory examination will be of three hours durations and practical examination will be for 12 hours (8+4 hours) spread on two days. Dissertation will carry marks for continuous assessment, dissertation/thesis, presentation and viva-voce.

The detailed syllabus for each paper is appended with a list of suggested readings, which would be further supplemented with other books/papers and be modified as new material becomes available. While the students will be advised to refer to older editions of books for some of the topics, the books generally prescribed would consist of the latest editions. To reflect the same, edition numbers have not been mentioned in the suggested readings.

Rules, Regulations and Course Content

The M. Sc. Course in Plant Molecular Biology and Biotechnology at the Department of Plant Molecular Biology (PMB), UDSC has been designed to expose students to the latest developments in the exciting and burgeoning areas of modern Plant Sciences. This course will prepare students to take research in Plant Molecular Biology and allied areas as a possible career option as well as will enable generation of manpower for the emerging Plant Biotechnology industry.

The course comprises classroom teaching, laboratory practicals, tutorials in the form of seminars and a Dissertation. All the internal elective theory papers would also have a fair share of hands-on training aimed to better the understanding of the subject. Students will be offered a total of ten core theory papers (4 credits each), one open elective (2 credits), four internal elective papers (4 credits), three practical papers (two 8 credits and one 6 credits) and dissertation (24 credits). Candidate can select any one internal elective paper per semester. Similarly, an open elective paper can be selected from the ones offered by either the parent department or by any of the sister departments within the Faculty of Interdisciplinary and Applied Sciences (FIAS), UDSC. A minimum of 4 students must opt for a particular elective paper to be offered in any semester. The summary of the entire course is as below:

Course Structure

- Total credits of the course = 96
- Number of papers = 16
- Theory = 13
    - No. of core theory papers = 10 (4 credits)
    - Number of internal elective papers = 02 (4 credits each)
    - Number of open elective paper = 01 (2 credits)
- Practical = 3 (8+6+8 = 22 credits)

Semester	Core Courses			Internal Elective Course			Open Elective Course			Total Credits
	No. of papers	Credits (L+T/P)	Total Credits	No. of papers	Credits (L+T)	Total Credits	No. of papers	Credits (L+T)	Total Credits	
I	5	16/8	24	0	0	0	0	0	0	**24**
II	4	12/6	18	1	4	4	1	2	2	**24**
III	4	12/8	20	1	4	4				**24**
IV	Dissertation		24	0	0	0	0	0	0	**24**
									Total Credits	**96**

- Dissertation = 1 (24 credits)

Course contents

The first semester has four core theory papers and one practical paper offered by the PMB Department. The theory papers deal with **'Genetics and Molecular Biology of Prokaryotes**, **'Molecular Cell Biology'**, **'Recombinant DNA technology: concepts, techniques and applications'** as well as **'Introduction to Bioinformatics'**.

In the second semester, three core theory papers viz **'Molecular Basis of Plant Growth and Development', 'Plant Biochemistry and Metabolism'** and **'Proteomics and Metabolomics'** would be offered. Further two internal elective theory papers namely **'Biotechnological Approaches in Control of Plant Form and Function'** and **'Advanced Plant Imaging Techniques'** will also be offered. Candidates may select any one of these internal elective papers. Moreover, the Department would also offer an open elective theory paper namely **'Data analytics and Biocuration'** which can be opted by the students of the department or from any of the sister Departments within the faculty (FIAS). The semester will also have one practical paper based on molecular biology techniques.

Similarly, the third semester will have three advanced core theory papers, namely **'Structure and Function of Eukaryotic Genome', 'Pattern Formation and Differentiation'** and **'Agricultural Biotechnology'**, A total of two internal elective papers would also be offered namely **'Plant Stress Biology'** and **'Small RNA Biology and Epigenetics'**. Candidates may select any one of these internal elective papers. Further practicals related to the all theory papers have been designed to provide students hands-on training. Tutorials in each paper will consist of seminars on selected topics to be delivered by students. This semester will also have a practical paper based on molecular biology techniques.

In the fourth semester, students will devote their entire time for dissertation work under the guidance of faculty members. Dissertation work will involve detailed studies pertaining to a specific research problem and will provide direct experience to the students for conducting research in a modern laboratory environment.

Students will be evaluated on the basis of written examinations and practical examinations to be held at the end of each semester and also on the basis of tutorials and class tests throughout the semester for each paper.

Affiliation

The proposed programme shall be governed by the Department of Plant Molecular Biology, Faculty of Interdisciplinary and Applied Sciences (F.I.A.S.), University of Delhi South Campus, New Delhi-110021.

Programme Structure

The Master of Science Programme in Plant Molecular Biology and Biotechnology is divided into two parts as under. Each part will consist of two Semesters to be known as Semester-1 and Semester-2.

Part I	First Year	Semester-1	Semester-2
Part II	Second Year	Semester-3	Semester-4

The schedule of papers prescribed for various semesters shall be as follows:

PART I : Semester-1

Paper PMBB 0701 - Genetics and Molecular Biology of Prokaryotes
Paper PMBB 0702 - Molecular Cell Biology
Paper PMBB 0703 – Recombinant DNA technology: concepts, techniques and applications
Paper PMBB 0704 - Introduction to Bioinformatics
Paper PMBB 0705 - Practicals

PART I : Semester-2

Paper PMBB 0801 - Molecular Basis of Plant Growth and Development
Paper PMBB 0802 - Plant Biochemistry and Metabolism
Paper PMBB 0803 - Proteomics and Metabolomics
Paper PMBB 0804 - Data Analytics and Biocuration*
Paper PMBB 0805 - Practicals
Paper PMBB 0806 - Biotechnological Approaches in Control of Plant Form and Function**
Paper PMBB 0807 - Advanced Plant Imaging Techniques **

PART II : Semester-3

Paper PMBB 0901 - Structure and Function of Eukaryotic Genome
Paper PMBB 0902 - Concepts of Pattern Formation and Differentiation
Paper PMBB 0903 - Agricultural Biotechnology
Paper PMBB 0904 - Plant Stress Biology**
Paper PMBB 0905 - Practicals
Paper PMBB 0906 - Small RNA Biology and Epigenetics**

PART II: Semester-4

Paper PMBB 1001 - Dissertation

*Open Elective theory paper (student can chose either PMBB 0804 or any other open elective paper offered by any the sister departments within the Faculty of Interdisciplinary and Applied Sciences (FIAS), UDSC). A minimum of 4 students must opt for the elective to be offered during the semester.

**Internal Elective theory paper (Students have to opt for any one in a semester). A minimum of 4 students must opt for any particular elective to be offered during the semester.

Scheme of Examination

1. English shall be the medium of instruction and examination.
2. Examinations shall be conducted at the end of each semester as per the academic calendar notified by the University of Delhi.
3. The summary of the examinations shall be as follows:

PART I: SEMESTER-1			
		Duration (hrs)	Max. marks
Paper PMBB 0701	Genetics and Molecular Biology of Prokaryotes	3	100
Paper PMBB 0702	Molecular Cell Biology	3	100
Paper PMBB 0703	Recombinant DNA technology: concepts, techniques and applications	3	100
Paper PMBB 0704	Introduction to Bioinformatics	3	100
Paper PMBB 0705	Practicals	12	200
	Total Maximum Marks		**600**
PART I: SEMESTER-2			
Paper PMBB 0801	Molecular Basis of Plant Growth and Development	3	100
Paper PMBB 0802	Plant Biochemistry and Metabolism	3	100
Paper PMBB 0803	Proteomics and Metabolomics	3	100
Paper PMBB 0804*	Data Analytics and Biocuration	3	50
Paper PMBB 0805	Practicals	12	150
Paper PMBB 0806**	Biotechnological Approaches in Control of Plant Form and Function	3	100
Paper PMBB 0807**	Advanced Plant Imaging Techniques	3	100
	Total Maximum Marks		**600**
PART II: SEMESTER-3			
Paper PMBB 0901	Structure and Function of Eukaryotic Genome	3	100
Paper PMBB 0902	Concepts of Pattern Formation and Differentiation	3	100
Paper PMBB 0903	Agricultural Biotechnology	3	100
Paper PMBB 0904**	Plant Stress Biology	3	100
Paper PMBB 0905	Practicals	12	200
Paper PMBB 0906**	Small RNA Biology and Epigenetics	3	100
	Total Maximum Marks		**600**
PART II: SEMESTER-4			
Paper PMBB 1001***	Dissertation		
	Total Maximum Marks		**600**

*Open Elective theory paper

** Internal Elective theory paper (Students have to opt for any one in a semester)

Each core and elective theory paper will consist of written examination (70 marks) and internal assessment (30 marks). Internal assessment will consist of seminar presentations (12 marks), class-tests (12 marks) and attendance (6 marks).

The open elective theory paper will have a written examination (35 marks) and internal assessment (15 marks). Internal assessment of the open elective paper will consist of class-test (12 marks) and attendance (3 marks).

The practical examinations in sem. 1 and 3 will consist of attendance (10 marks), Practical records (50 marks), Viva-voce/internal assessment (40 marks) and Practical examination (100 marks). However, practical examination in sem. 2 will consist of attendance (5 marks), Practical records (40 marks), Viva-voce/internal assessment (30 marks) and Practical examination (75 marks)

*** Dissertation work will consist of internal evaluation by the concerned supervisor based on general performance during the Project work as internal assessment (180 marks), and project work (320 marks) and seminar/viva-voce (100 marks) evaluated by a Board comprising all teachers in the Department.

4. The detailed description of the examination process is as follows:

4.1 All core and internal elective theory paper will carry 100 marks of which 30% marks shall be reserved for internal assessment based on classroom participation, seminar, term courses, tests, viva-voce and laboratory work and attendance. The open elective paper will carry 50 marks of which 30% marks shall be reserved for internal assessment based on classroom participation, tests and attendance The weightage given to each of these components shall be decided and announced at the beginning of the semester by the individual teacher responsible for the course. Any student who fails to participate in classes, seminars, term courses, test, viva-voce, practical and laboratory work will be debarred from appearing in the end-semester examination in the specific course and no internal Assessment marks will be awarded. His/her Internal Assessment marks will be awarded as and when he/she attends regular classes in the courses in the next applicable semester. No special classes will be conducted for him/her during other semesters.

4.2 Practical paper in sem. 1 and 3 will be of 200 marks of which 30% marks will be reserved for internal assessment. However, practical paper in sem. 3 will be of 150 marks with 30% marks reserved for internal assessment. The duration of written examination for each paper shall be three hours and Practical examination shall be for 12 hours spread over two days (8+4 hours).

4.3 As regards Project Work/Dissertation (PMBB 1001), the scheme of evaluation shall be as follows:

4.3.1 Project Work/Dissertation shall be in Semester-4. It will be evaluated at the end of Semester-4.

4.3.2 The candidate has to submit dissertation in a bound form at the end of Semester-4. Total marks for dissertation shall be 600 and evaluation will be as follows:

Continuous evaluation	=	400 marks
Dissertation	=	100 marks
Presentation and viva-voce	=	100 marks
Total	=	**600 marks**

5. Examinations for courses shall be conducted only in the respective odd and even Semesters as per the Scheme of Examination. Regular as well as Ex-Students shall be permitted to appear/reappear/improve in courses of odd semesters only at the end of odd semesters and for even semester with the even.

Pass Percentage

Students are required to pass separately in theory, practical and dissertation examinations. Minimum marks for passing the examination shall be 45% in aggregate in theory courses, 45% in practical courses and 45% marks in dissertation by scoring at least 40% in each theory paper.

Promotion Criteria

SEMESTER TO SEMESTER: Within the same Part, the candidate will be promoted from a Semester to the next Semester (Semester-1 to Semester-2 and Semester-3 to Semester-4), provided the candidate has passed at least two of the papers of the current semester by securing at least 40% marks in each paper.

Note: 1. A candidate who does not appear in a theory paper will be allowed ONLY ONE more attempt to pass the paper. No further attempts for improvement will be allowed.

2. A candidate will not be allowed to reappear (even if he/she is absent) in the practicals .

PART I TO PART II: Admission to Part II of the program shall be open to only those students who have fulfilled the following criteria:

1. have scored at least 45% marks in the practical papers of both Semester-1 and -2 taken together,
2. have passed at least 75% of the theory papers (6 papers) offered in courses of Part I comprising of Semester-1 and Semester-2 by securing at least 40% marks in each of these six papers and
3. have secured at least 45% in aggregate of all theory papers of Part I.

Note: The candidate however will have to clear the remaining papers while studying in Part II of the programme.

Award Of Degree

A candidate will be awarded M.Sc. degree at the end of Semester-4 provided he/she has:

1. passed all the theory papers of Part I (Semester-1&-2) and Part II (Semester-3&-4) by securing at least 40% marks in each paper and has also obtained at least 45% in aggregate of Part I & Part II,
2. passed the practical examination by securing at least 45% in aggregate of Part I and Part II, separately and
3. passed dissertation by securing at least 45% marks.

Candidates who have fulfilled criteria 2 and 3 (wherever applicable) but not criteria 1:

1. Can reappear for theory papers as per University rules.

   A candidate must pass the M.Sc. examination within span period.
2. No candidate shall be allowed to reappear for practical or dissertation.

Scope For Improvement

As per University rules

Division Criteria

Successful candidates will be classified on the basis of the combined results of Part I and Part II examinations as follows:

Candidates securing 60% and above	:	1st Division
Candidates securing 50% and above but less than 60%	:	2nd Division
Candidates securing 45% and above but less than 50%	:	Pass

Span Period

No student shall be admitted as a candidate for the examination for any of the Parts/Semesters after the lapse of four years from the date of admission to the Part I/Semester-1 of the M.Sc. program.

Attendance Requirement

No student shall be considered to have pursued a regular course of study and be eligible to take examination unless he/she has attended 75% of the total number of lectures, tutorials, seminars and practicals conducted in each semester, during his/her course of study. Under special circumstances, the Head of the Department may allow students with at least 65% attendance to take the examination.

Semester System Course Details

Paper PMBB 0701

Genetics And Molecular Biology of Prokaryotes

Content

- **Historical and General Aspects** -- Important discoveries on the genetic material; Relationship between genotype and phenotype; Introduction to Mendelian Genetics; Gene mapping in prokaryotes.
- **DNA Replication** -- Biochemical and genetic tools to study replication; DNA polymerases and accessory proteins; Proteins at the replication origin and the replication fork; Concept of replicon; Linear replicons and their maintenance; Control of replication of chromosomes and extra-chromosomal elements; Telomeres.
- **Maintenance of Genomic Flexibility and Integrity** -- Spontaneous and induced mutations; Mutagens; Mechanisms of homologous and site-specific recombinations; DNA repair and retrieval systems; Transposons and retro-transposons.
- **Regulation of Transcription** -- Discovery of RNA; Promoters and other control elements; RNA polymerases and accessory factors; Sigma factors and their interactions with promoters; Transcriptional controls; Concept of operons; Controls at transcription termination; *Rho* factor and polar mutations.
- **Bacteriophages as Models for Gene Regulation** -- Bacteriophage lambda; Lysogenic and lytic cycles; gene expression circuits; Bacteriophage T_4 and T_7; Temporal control of gene expression in bacteriophages.
- **Translation and its Mechanism** -- Initiation, elongation and termination of translation and the accessory proteins; Structural and functional studies on ribosome; Ribosomal RNAs; Ribosomal proteins; Mapping the decoding and peptidyl transferase sites of ribosome; Accuracy during translation.
- **Transfer RNAs and Genetic Code** -- Biogenesis, structure and function of transfer RNAs; Suppressor mutations; Post-translational control; Genetic code and its characteristics; Wobble phenomenon; Codon bias.

Suggested Readings

1. Clarke, D. and Pazdernik, N. (2013) Molecular Biology. Academic Cell, USA
2. Griffiths, A. J., Gelbart, W. M., Lewontin, R. C. and Miller, J. H. (2002) Modern Genetic Analysis. W. H. Freeman, USA.
3. Krebs, J. E., Goldstein, E. S. and Kilpatrick, S. T. (2013) Lewin's Genes XI. Jones and Bartlett Publishers, Inc., USA.
4. Tropp, B. E. (2014) Principles of Molecular Biology, Jones and Bartlett, USA.

5. Weaver, R. F. (2012) Molecular Biology. McGraw Hill, UK.

Course outcome

Prokaryotic systems are regularly used as tools for various molecular biology investigations. Further, plant-microbe interactions are important aspects of plant biology. Thus, this course will provide expertise in prokaryotic biology and gene expression, which is essential to lay a strong foundation for understanding the molecular biology of plant systems.

Paper PMBB 0702

Molecular Cell Biology

Content

- **Investigating the Cell** -- Cell theory; Fundamentals of microscopy and imaging.
- **Cell Wall** -- Cell wall composition and architecture; Biogenesis and assembly; Dynamic aspects of cell wall during growth and differentiation
- **Membrane Systems** -- Structural models; Composition and dynamics; Transport of ions and macromolecules; Pumps, carriers and channels; Sensory physiology; Endo- and exo-cytosis; Membrane proteins & carbohydrates and their significance in cellular recognition.
- **Mitochondria** -- Structure; Organization; Structure-function relationship; Mitochondrial genetic machinery and male sterility; Biogenesis, origin and evolution.
- **Chloroplast and Photosynthetic Systems** -- Structure; Organization; Structure-function relationship; Chloroplast genetic machinery and its significance; Chloroplast biogenesis, origin and evolution.
- **Nucleus** -- Structure and function (architecture); Chromatin organization and packaging; Macromolecular trafficking.
- **Endomembrane Systems** -- Structure and function of Golgi apparatus, lysosomes and endoplasmic reticulum and microbodies; Membrane maturation and specialization.
- **Cytoskeleton and Cellular Motility** -- Organization and role of microtubules and microfilaments; Actin-binding proteins and their significance; Molecular motors; Intermediate filaments.

Suggested readings

1. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K. and Walter, P. (2015) Molecular Biology of the Cell. Garland Publishing, Taylor & Francis Group, USA.
2. Karp, J. G. (2013). Cell and Molecular Biology. John Wiley & Sons, USA.
3. Kleinsmith, L. J. and Kish, V. M. (1996) Principles of Cell & Molecular Biology. Harper Collins College Publishers, USA.
4. Lodish, H., Berk, A., Kaiser, C. A., Krieger, M., Bretsher, A., Ploegh, H., Amon, A., Martin, K. (2016) Molecular Cell Biology. Freeman & Co., USA.
5. Ruzin, S. E. (1999) Plant Microtechnique and Microscopy. Oxford University Press, USA.

Course outcome

This paper is devised to provide a detailed knowledge of the cell biology, which is important to understand various molecular and biochemical processes operating at cellular level.

Paper PMBB 0703

Recombinant DNA Technology: Concepts, Techniques and Applications

Contents

- **Basics of Nucleic Acids** -- Types, occurrence, structure, topology and dynamics, functions; Methods for isolation and purification of nucleic acids.
- **Physicochemical and Separation Techniques** -- Principles and biological applications of spectrometry, centrifugation, chromatography, electrophoresis, radioactivity measurements.
- **Basics of DNA Cloning** -- Gene cloning methodologies, restriction enzymes and nucleic acid modifying enzymes, TA cloning, topoisomerase-based cloning, ligation independent cloning, GATEWAY technology; Vectors for gene cloning - plasmids, phages, phagemids, cosmids, shuttle vectors, artificial chromosomes, plant viruses and other advanced vectors; Methods for selection and screening of recombinant clones, selection and screening of clones (marker genes, reporter genes, positive and negative selection, insertion inactivation, alpha-complementation); Bacterial transformation methods.
- **Isolation of Gene(s) of Interest** -- Direct selection, construction and screening of genomic and cDNA libraries, labelling and detection of nucleic acids, enriching clones by subtractive cloning and differential screening, differential display.
- **Polymerase Chain Reaction** -- Concept and enzymes employed, optimization of PCR, types of PCR (touch-down, hot-start, inverse, nested, gradient, RACE, semi-quantitative and quantitative, overlapping and multiplex), applications of PCR.
- **Methods to Study Gene Expression** -- Gene expression analyses at transcriptional level (Northern blotting and its variants, real-time PCR, S1 nuclease mapping, *in situ* hybridization, RNase protection, nuclear run-on assays, DNA microarrays), translational level (Western blotting, ELISA and immunofluorescence assays).
- **Methods to Study Biomolecular Interactions** -- DNA-protein (EMSA, DNase I footprinting, ChIP, Y-1-H), RNA-protein (Y-3-H, north western, RIP) and protein-protein interaction (Y-2-H, pull down, CoIP, FRET, BiFC) method; Real-time label-free detection by Surface Plasmon Resonance (SPR).
- **Basics of Genome Sequencing** -- DNA sequencing methods (Maxam-Gilbert, Sanger, automated sequencing, Next Generation Sequencing or NGS platforms); Introduction to mapping and sequencing of genomes (whole genome shotgun and clone-by-clone approach of genome sequencing).
- **Protein Expression and Engineering** -- Tagging and overexpression of proteins in heterologous systems: *E. coli*, yeast, baculovirus and mammals; Methods for mutagenesis of genes for obtaining altered proteins.
- **Applications and ethics of Recombinant DNA Technology** -- Production of useful recombinant molecules, improving agronomic traits, diagnostic and therapeutic applications in

human diseases; Impact and safety, moral, social, regulatory & ethical issues associated with recombinant DNA technology.

Suggested readings

1. Brown, T. A. (2016) Gene Cloning and Analysis: An Introduction. Wiley-Blackwell Publishing, UK.
2. Dale J. W., Schantz M. V. and Plant N. (2011) From Genes to Genomes: Concepts and Applications of DNA Technology. John Wiley & Sons, UK.
3. Glick B. R., Pasternak J. J. and Patten C. L. (2010) Molecular Biotechnology: Principles and Applications of Recombinant DNA. ASM Press, USA.
4. Green M. R. and Sambrook J. (2012) Molecular Cloning: A Laboratory Manual. CSHL Press, USA.
5. Metzler, D. E. (2003) Biochemistry. Academic Press, USA.
6. Primrose, S. B. and Twyman, R. M. (2006) Principles of Genetic Manipulation and Genomics. Blackwell Publishing, UK.
7. Voet, D., Voet, J. G. and Pratt C. W. (2012) Principles of Biochemistry. John Wiley & Sons, UK.
8. Wilson, K. and Walker, J. (2010) Principles and Techniques of Biochemistry and Molecular Biology. Cambridge University Press,USA.

Course outcome

The course work will provide an in-depth knowledge on principles and applications of the versatile instrumentation, basic and cutting-edge tools and techniques in recombinant DNA technology. Students will be acquainted with designing/conducting and analysing experiments and experimental data, respectively. Integration of theory and problem-solving exercises will motivate students to take keen interest in research and enhance their understanding in the topics they are taught. The course will not only help in developing molecular/technical skills but will also provide a foundation which would enable students to understand the advanced courses in the succeeding semesters.

Paper PMBB 0704
Introduction to Bioinformatics

Contents

- **Introduction to Computers and Bioinformatics** -- Types of operating systems, concept of networking and remote login, basic fundamentals of working with unix.
- **Biological Databases** -- Overview, modes of database search, mode of data storage (Flat file format, db-tables), flat-file formats of GenBank, EMBL, DDBJ, PDB.
- **Sequence Alignment** -- Concept of local and global sequence alignment; Pairwise sequence alignment, scoring an alignment, substitution matrices, multiple sequence alignment.
- **Phylogenetic Analysis** -- Basic concept of phylogenetic analysis, rooted/uprooted trees, approaches for phylogenetic tree construction (UPGMA, neighbour joining, maximum parsimony, maximum likelihood).
- **Analysis of High Throughput Sequence Data** -- Assembly pipeline for clustering of HTGS data, introduction to NGS data analysis, de-novo vs genome reference assembly, analysis file formats (BAM, SAM, ACE, BED), quality assessment of genomic assemblies; International norms for sequence data quality.
- **Functional Annotation and Molecular Metworks** -- Identification of various genomic elements (protein coding genes, repeat elements); Strategies for annotation of whole genome; gene ontology (GO) consortium, molecular networks, 'systems' biology approach.
- **Structure Predictions for Nucleic Acids and Proteins** -- Approaches for prediction of RNA secondary and tertiary predictions, energy minimization and base covariance models; Basic approaches for protein structure predictions, comparative modeling, fold recognition/'threading', and *ab-initio* prediction.

Suggested readings

1. Baxevanis, A. D. and Ouellette, B. F. F. (2005) Bioinformatics: A Practical Guide to the Analysis of Genes and Proteins. John Wiley and Son Inc., USA.

2. Mount, D. W. (2004) Bioinformatics Sequence and Genome Analysis. CSHL Press, USA.

3. Tramontano, A. (2007) Introduction to Bioinformatics. Chapman & Hall/CRC, USA.

4. T. W., Tan and Lee, E. (2018) Beginners guide to Bioinformatics for High Throughput Sequencing. World Scientific Publishing Co Pte. Ltd, USA.

5. Zvelebil, M. and Baum, J. O. (2008) Understanding Bioinformatics. Taylor and Francis, USA.

Course outcome

This paper aims to provide the basic skills required to perform computational analysis of biological data at various levels.

PMBB 0705
Practicals

List of Practicals

1. Isolate chloroplasts from the given plant material, quantitate proteins using dot blot assay, and resolve the proteins by SDS-PAGE to identify major chloroplast proteins.
2. Isolate mitochondria from the given plant material and demonstrate the activity of its marker enzyme, succinate dehydrogenase.
3. To study the effect of physical and chemical permeabilizing agents on membrane permeability.
4. To isolate protoplasts from flower petals and leaves of different plants and demonstrate protoplast fusion via PEG.
5. Perform (i) Desalting of proteins and (ii) resolve proteins of various molecular weights (between 20 to 200 kDa) using gel filtration chromatography.
6. To extract proteins from the given plant material and estimate soluble protein content by Bradford method.
7. To resolve soluble proteins by discontinuous, SDS-gel electrophoresis under denaturing conditions followed by staining with Coomassie Brilliant Blue R-250.
8. To resolve soluble proteins by gradient gel electrophoresis under denaturing conditions, for optimal separation of proteins followed by staining with silver staining method.
9. To isolate native proteins for resolving isozymes using native, non-denaturing polyacrylamide gel electrophoresis.
10. To prepare electro-competent cells of *E. coli* and transform them by plasmid using electroporator.
11. To study the growth characteristics of *E. coli* by turbidometry and plating methods.
12. Effect of nutrient starvation (Nitrogen, Sulphur, phosphate) on growth kinetics of bacteria.
13. To isolate plasmid from *E. coli* culture (miniprep) and estimate the DNA by fluorometry.
14. To clone a DNA fragment in plasmid vector by ligation, transformation of ligation mix in *E. coli* cells and selection of transformants.
15. To perform 'Colony PCR' to screen for the positive *E. coli* transformants containing the ligated product and perform restriction digestion of the positive clone.
16. Text-based search of the NCBI database.
17. Sequence (DNA/Protein) alignment based database search, multiple sequence alignment and phylogenetic analysis.

Course outcome

The paper is designed to provide practical expertise in basic molecular biology techniques.

Paper PMBB 0801

Molecular Basis of Plant Growth and Development

Contents

- **Light Control of Plant Development** -- Skotomorphogenesis and photomorphogenesis; Discovery of phytochromes and cryptochromes, their structure, biochemical properties and cellular distribution; Molecular mechanisms of light perception, signal transduction and gene regulation; Biological clocks and their genetic and molecular determinants.
- **Floral Induction and Development** -- Photoperiodism and its significance; Vernalization and hormonal control; Inflorescence and floral determination; Molecular genetics of floral development and floral organ differentiation.
- **Biosynthesis of Plant Hormones and Elicitors** -- Structure and metabolism of auxins, gibberellins, cytokinins, abscisic acid, ethylene, brassinosteroids, salicylic acid, jasmonates and related compounds.
- **Molecular Mechanism of Hormone Action** -- Hormone signal perception, transduction and regulation of gene expression during plant development; Role of mutants in understanding hormone action; Phospholipids and Ca^{2+}-calmodulin cascade; MAP kinase cascade; Two-component sensor-regulator system.
- **Seed Development, Dormancy and Seed Germination** -- Hormonal control of seed development; Seed maturation and dormancy; Hormonal control of seed germination and seedling growth; Mobilization of food reserves during seed germination.
- **Senescence and Programmed Cell Death (PCD)** – Molecular mechanism of PCD in animals, Senescence and its regulation; Hormonal and environmental control of senescence; PCD in the life cycle of plants; Differences and similarities in PCD and senescence.

Suggested Readings

1. Alberts B., Johnson, A., Lewis, J., Raff, M., Roberts, K. and Walter, P. (2015) Molecular Biology of the Cell. Garland Publishing, Taylor & Francis Group, USA.
2. Buchanan, B. B., Gruissem, W. and Jones, R. L. (2015) Biochemistry and Molecular Biology of Plants. John Wiley & Sons and American Society of Plant Biologists, USA.
3. Hopkins, W. G. and Huner, N. P. A. (2008) Introduction to Plant Physiology. John Wiley, UK.
4. Jones, R. L, Ougham, H., Thomas, H. and Waaland, S. (2012) The Molecular Life of Plants. Wiley-Blackwell and American Society of Plant Biologists, USA.
5. Srivastava, L. M. (2002) Plant Growth and Development: Hormones and Environment. Academic Press, USA.
6. Taiz, L. and Zeiger, E., Moller, I. M. and Murphy, A.(2015) Plant Physiology and Development. Sinauer Associates Inc. Publishers, USA.

Course outcome

This course gives an in-depth knowledge about the various molecular and biochemical processes that regulate different aspects of plant development.

Paper PMBB 0802

Plant Biochemistry and Metabolism

Contents

- **Carbon Assimilation** -- Light absorption and energy conversion; Calvin Cycle; Hatch-Slack pathway; Reductive pentose phosphate pathway; Carbon dioxide uptake and assimilation; Photorespiration; Glycolate metabolism.
- **Biological Oxidation and Release of Energy** -- Glycolytic pathway; Kreb's cycle; High energy compounds; Oxidative phosphorylation; Chemiosmotic hypothesis; Pentose phosphate shunt pathway.
- **Metabolism of Macromolecules** -- Biosynthesis and inter-conversion of carbohydrates; Biosynthesis, inter-conversion and degradation of lipids; Metabolism of nucleotides and amino acids.
- **Nitrogen, Sulphur and Phosphorus Metabolism** -- General aspects of nitrogen economy; Nitrate reduction; Pathways of ammonia assimilation; Reductive amination; Trans-amination; Regulation of nitrogen assimilation; Uptake, transport and assimilation of sulphate and phosphate.
- **Nitrogen Fixation** -- Symbiotic and non-symbiotic nitrogen fixation; Role of lectins; nod genes; nif genes; Structure, function and regulation of nitrogenase; Leghaemoglobin; Nodulins; Regulation and enhancement of nitrogen fixation.
- **Long-distance Transport Mechanisms** -- Turgor and stomatal movements; Solute movement; Source-sink relationship; Water relations.
- **Secondary Metabolism** -- Importance of secondary metabolites; Biosynthesis of phenolic compounds, isoprenoids, alkaloids and flavonoids.

Suggested readings

1. Buchanan, B., Gruissem, W. and Jones, R. (2000) Biochemistry & Molecular Biology of Plants. American Society of Plant Physiologists, USA.
2. Dey, P. M. and Harborne, J. B. (1997) Plant Biochemistry. Academic Press, USA.
3. Metzler, D. E. (2007) Biochemistry. Academic Press, USA.
4. Nelson D. L. and Cox, M. M. (2008) Principles of Biochemistry. W H Freeman & Co., USA.
5. Stryer L., Berg, J. M. and Tymoczko, J. L. (2006) Biochemistry. W.H. Freeman & Co., USA.

Course outcome

This paper would lead to a detailed understanding of the different metabolic processes operating in a plant system. The paper would provide a view into structural diversity of various biomolecules, their movement, synthesis and turn over. It would help in understanding the key points in pathways of metabolism where the efforts can be focused for the genetic improvement of quality traits.

Paper PMBB 0803
Proteomics And Metabolomics

Contents

- **Introduction to Proteomics --** Protein structure and folding, basic concepts and techniques, proteome, basics and workflow design of proteomics technology, comparative proteomics, importance of proteomics.
- **Tools and Techniques in Proteomics --** Principles and applications of the separation technology, I-D and 2-D Polyacrylamide Gel Electrophoresis (PAGE), workflow, high-throughput methods, importance and applications in proteomics.
- **Proteomic Profiling --** Protein sequencing, MS analysis and related techniques (LC-MS/MS), advanced methods in proteomics (microfluidic chips, ICAT, iTRAQ, AQUA, ESI-Q-IT-MS, SELDI-TOF-MS) database search, relative quantification, analysis and interpretation, quantitative proteomics, post-translational modifications and their profiling, high-throughput methods for interaction of proteins with and other biomolecules.
- **Immunology and Immuno-techniques --** Overview of immune systems, antigens, epitopes, haptens, immunogens and immunoglobulins, antigen-antibody interaction, utility of antibodies in routine laboratory experiments, proteomics and diagnostics.
- **Basics of Metabolomics** -- Definition and scope, metabonomics, small metabolites, separation methods, Gas chromatography (GC), High Performance Liquid Chromatography (HPLC), detection methods such as Mass Spectrometry (MS), Secondary ion MS (SIMS), Desorbtion Electron Spray Ionization (DESI), Laser Ablation ESI (LAESI), NMR, statistical analysis of the data, XCMS, MetAlign LCMStats.
- **Applications and Future Challenges in Proteomics and Metabolomics** -- Impact in agriculture and health.

Suggested readings

1. Antonio, C. (2018) Plant Metabolomics: Methods and Protocols (Methods in Molecular Biology). Humana Press, USA.
2. Branden, C. I. and Tooze, T. (1999) Introduction to Protein Structure. Garland Publishing, USA.
3. Saito, K., Dixon, R. A. and Willmitzer, L. (2006) Plant Metabolomics (Biotechnology in Agriculture and Forestry). Springer, USA.
4. Lesk, A. M. (2010) Introduction to Protein Science: Architecture, Function and Genomics. Oxford University Press, UK.
5. Lammerhofer, M. and Weckwerth, W. (2013). Metabolomics in Practice: Successful Strategies to Generate and Analyze Metabolic Data. Oxford University Press, UK.
6. Weckwerth, W. (2006) Metabolomics: Methods and Protocols (Methods in Molecular Biology). Humana Press, USA.

Course outcome

Protein and metabolite profile in living systems are important in order to understand the regulatory and metabolic capacity of the system. Thus, this paper provides basic concepts in the study of the proteome and metabolome of an organism.

Paper PMBB 0804
Data Analytics and Biocuration

Contents

- **Data Analytics using 'R' Statistical Package** -- Introduction to the 'R' data analysis package, basic work environment, syntax, introduction to the 'Bioconductor' packages for data analysis.
- **Application of the Bioconductor Packages** -- Application of bioconductor packages in the analysis of RNA-seq, chromatin immune-precipitation, bisulphite sequencing data, data analysis and visualization.
- **Basics of Programming and Database Management** -- Perl, Bioperl and MySQL.
- **Data standards, Integration and Visualization** -- BioDbCore guide lines, FAIRsharing. Ethics in data sharing, Introduction to machine-learning and artificial intelligence approaches in data integration and interpretation and predictive modeling. Visualization tools such as Gbrowse.
- **Introduction to Biocuration** -- Basics, International society of Biocuration, various methods of biocuration,
- **Ontologies** -- Basics and importance of ontology development, OBO (Open Biological and Biomedical Ontology) format, OBO foundary, biomedical and plant based ontologies.
- **Literature-Based Curation** -- Text/Literature-based curation, text mining approaches, introduction to tools such as Textpresso.
- **Data Digitization Aspects** -- Importance of digitization of experimental data, experimental data submission repositories and formats.

Suggested readings

1. Bessant, C., Shadforth, I. and Oakley, D. (2009) Building Bioinformatics Solutions: with Perl, R and MySQL. Oxford University Press, UK.
2. Tisdall, J. (2001). Beginning Perl for Bioinformatics. O'Reilley Media, USA.
3. Tisdall, J. (2010). Mastering Perl for Bioinformatics: Perl programming for Bioinformatics. O'Reilley Media, USA.
4. Buffalo, V., (2015) Bioinformatics Data Skills: Reproducible and robust research with open source tools. O'Reilley Media, USA.
5. Web link: www.bioconductor.org.
6. Web link: www.obofoundary.org; www.oboedit.org
7. Web link: www.biocuration.org

Course outcome

This paper provides requisite skills for core computer programming, in-depth data analysis, database development and management.

PMBB 0805
Practicals

List of Practicals

1. To prepare yeast competent cells and transform yeast cells with plasmid DNA.
2. To learn basics of microscopy and differentiate dicot and monocot morpho- histological characteristics by using respective model systems, viz. Arabidopsis and rice. Visualization of GFP expression in transgenic Arabidopsis by using fluorescence microscope.
3. Induction of a protein in *E. coli* by IPTG and checking its expression by SDS-PAGE.
4. To perform amplification of cDNA by PCR and to perform 3'-RACE (Rapid amplification of cDNA ends).
5. To isolate plant DNA from different sources and perform restriction digestion and Southern blotting.
6. To perform Southern hybridization of plant genomic DNA.
7. Demonstrate red/far-red reversibility of seed germination in Arabidopsis using wild- type and mutant strains.
8. Demonstrate rapid induction of gene expression by auxin in coleoptile segments of dark-grown rice seedlings.
9. Effect of different abiotic stresses on seed germination of wild type and mutant *Arabidopsis thaliana*.
10. To study the effect of calcium on pollen viability and germination assay.
11. To study substrate inducibility of nitrate reductase (NR) enzyme.
12. Determination of optimal pH for nitrate reductase activity.
13. Spectrophotometric assay of acid phosphatase.
14. Protein-protein interaction analysis by filter-lift assay and color development in yeast two-hybrid methodologies.

Course outcome

This paper comprises of practical exercises for analysis of some basic molecular and metabolic plant processes such as gene expression, hormone signaling and enzyme activity.

PMBB 0806

Biotechnological Approaches in Control of Plant Form and Function

Contents

- **Regulation of Plant Architecture** -- Leaf, root, and shoot meristem, floral transition, inflorescence.
- **Male Sterility and Heterosis** -- Formation of male gametes, male sterility, hybrid vigour.
- **Seed Development and Yield** -- Formation of female gametes, pollination and fertilization, fruit and seed development, genetic improvement of yield.
- **Phenomic Analysis** -- Plant phenotype reflects genotype and environment interaction, phenomic platforms, Role of phenomics in crop improvement.
- **Post-harvest Waste Management** -- Types of agriwastes, Biological treatments for waste management, Alternate treatment technologies for product development.
- **Biosafety Risk Assessment & Regulatory Aspects** -- Biodiversity conservation and protection; Environment Protection; Comparative account of national and international rules for GMOs and their release.
- **Hands-on Training** -- Molecular analysis of transgenics, Expression analysis of organ-specific marker genes

Suggested readings

1. Buchanan, B. B., Gruissem, W., Jones, R. L. (2015) Biochemistry & Molecular Biology of Plants. John Wiley & Sons, Ltd, UK.
2. Fritsche-Neto, R., Borem, A. (2015) Phenomics. Springer International Publishers, Switzerland.
3. Stewart Jr. C. N. (2016). Plant Biotechnology and Genetics: Principles, Techniques and Applications. John Wiley & Sons, Inc., USA.
4. Thomas, J. A., Fuchs, R. L. (2002) Biotechnology & Safety Assessment. Academic Press, USA.
5. Traynor, P. L. (2002) Biosafety & Risk Assessment in Agricultural Biotechnology. Agricultural Biotechnology Support Project, Mich. State Univ, USA.
6. Wolpert, L., Tickle, C., Martinez, A. (2015) Principles of Development. Oxford Publishers, UK.

Course outcome

This course is designed to develop skills and understanding with relevance to frontier areas of plant biotechnology and control of function in plants.

PMBB 0807

Advanced Plant Imaging Techniques

Contents

- **Fundamental Principles of Microscope design** -- Image formation, resolution and contrast. Transmitted light and fluorescence microscopy techniques. Cameras, signal to noise ratio, digital image recording, processing and analysis, multispectral imaging. Advanced fluorescence – fluorescent probes, fluorescent biosensors, confocal laser scanning microscopy.
- **Tissue Fixation, Embedding and Sectioning** --Theoretical aspects, discussions and practical training sessions focused on the underlying principles related to tissue fixation, dehydration, paraffin embedding & microtomy, de-paraffinization, slide preparation.
- **Imaging Applications in Plants** -- Organelle-specific stains, intracellular localization of fluorescently-labeled chimeric proteins, protein-protein interaction analysis by BiFC, Ca^{++} dynamics in a cell.
- **Lab Biosafety Aspects** -- Chemical safety including handling of acids/bases, volatiles and organic compound related to microscopy techniques. Bio-hazard safety, proper handling and disposal of biological material used in microscopy techniques. High-energy radiation safety, appropriate handling of high-energy radiation such as UV-light and Laser etc.
- **Hands-on Training** -- Tissue preparation (Tissue fixation, Embedding and sectioning), staining and visualization; Localization of Fluorescent-tagged protein in the plant cell by transient expression analysis; Protein-interaction analysis by co-localization of fluorescent tagged proteins by FRET and or BiFC methods.

Suggested Readings

1. Imaging/Microscopy, general. Cold Spring Harbour Protocols: Web link: http://cshprotocols.cshlp.org/site/ Taxonomy/imaging_microscopy_l1.xhtml.
2. Imaging of Protein: Protein Interactions. Cold Spring Harbour Protocols; Web link: http://cshprotocols.cshlp.org/cgi/collection/imaging_of_protein:protein_interactions.
3. Imaging Protein Interactions by FRET Microscopy: FRET Measurements by Acceptor Photobleaching. Cold Spring Harbour Protocols: Web Links: http://cshprotocols.cshlp.org /content/2006 /6/pdb.prot4598.abstract.
4. Paddock, S. W. (2014) Confocal Microscopy: Methods and Protocols. Humana Press, USA.
5. Ruzin, S.E. (1999) Plant Microtechnique and Microscopy. Oxford University Press, USA.
6. Schwartzbach, S. D., Skalli, O. and Schikorski, T. (2016) High-Resolution Imaging of Cellular Proteins. Humana Press, USA.
7. Yolanda, M. and Hartmann, H. (2017) Light Microscopy, Methods and Protocols. Humana Press, USA.

Course outcome

Students would acquire specific practical skills regarding various sample preparations and imaging techniques which are essential for conducting advanced plant science research.

Paper PMBB 0901

Structure and Function of Eukaryotic Genome

Contents

- **Genomes and Comparative Genomics** -- High throughput genome sequencing; *Arabidopsis*, rice and human genomes; Centromeres and telomeres; Distribution of repeat and transposable elements and their function; Gene order (Colinearity, Identification of orthologs, Functional predictions); Whole genome alignments, phylogenetic footprinting of coding sequences and regulatory regions for annotation; Evolution of genomes.
- **Epigenetic Control of Gene Expression** -- DNA methylation and its role in regulation of gene expression and in maintaining genome stability; chromatin modifications implicated in gene silencing and activation, the role of non-coding RNA, and higher order chromatin structures; Dosage Compensation: X-chromosome inactivation; Epigenetic control of flowering; Resetting the epigenome.
- **Transcriptional Control of Gene Expression** -- Gene architecture; Promoter architecture; Regulatory sequences, enhancers and mechanism of their action; RNA polymerases, Mediator complex and general transcription factors; DNA-protein interactions; Heterogeneous nuclear RNA; Cap structure and function; Polyadenylation; Britten-Davidson model; Transcription factors, DNA-binding and activation domains, activation of latent activators, co-activators.
- **Post-transcriptional Control of Gene Expression** -- Introns and exons - size, distribution and evolution; Mechanism of RNA splicing; Catalytic RNA; Alternative splicing; RNA stability; Small RNAs and RNA interference; Small RNAs in control of gene expression.
- **Protein Level Controls** -- Study of global protein levels (proteomics); Dynamic modulation of protein structure and function; Translational control; Protein modification and degradation.
- **Functional genomics** -- Approaches for differential RNA measurements; Gene tagging; Gene trapping; Gene silencing; Knockout mutants; TILLING; Genome editing.
- **Applications in Agriculture and Human Health**-- Transcriptional control of selected disease and their diagnosis; Promoters and transcription factors for genetic modification of crops.

Suggested Readings

1. Berg, J. M, Tymoczko, J. L., Stryer, L. (2012) Biochemistry. WH Freeman and Company, New York.
2. Buchanan, B. B., Gruissem, W. and Jones, R. (2015) Biochemistry & Molecular Biology of Plants. John Wiley & Sons, Ltd., West Sussex.
3. Kahl, G. and Meksem, K. (2008) The Handbook of Plant Functional Genomics. Wiley-VCH Verlag GmbH & Co., Germany.
4. Krebs, J. E., Goldstein, E. S. and Kilpatrick, S. T. (2014) Lewin's Genes XI. Jones and Bartlett Publishers, LLC, Burlington.
5. Latchman, D. S. (2015) Gene Control. Garland Science, New York.

6. Lodish, H., Berk, A., Kaiser, C. A., Krieger, M., Bretscher, A., Ploegh, H., Amon, A., Martin, K. C. (2016) Molecular Cell Biology. WH Freeman and Company, New York.
7. Stewart Jr., C. N, (2016) Plant Biotechnology and Genetics: Principles, Techniques and Applications. John Wiley & Sons, Inc., New Jersey.

Course outcome

The paper would prime students about eukaryotic genome organization and function in terms of mechanism of regulation of genes expression and its impact on organism and utility of such information in control of useful traits and diagnostics.

Paper PMBB 0902

Concepts of Pattern Formation and Differentiation

Contents

- **Developmental Differences between Animal and Plants** -- Germ line development; Regeneration and totipotency; Post embryonic development.
- **Differentiation in Plants** -- Totipotency, Organogenesis, adventive somatic embryogenesis, Apomixis.
- **Cellular Architecture** -- Cell division cycle; Cell movements and planes of cell division; Regulation of cell size, cell shape and organ initiation.
- **Embryonic Pattern Formation** -- Drosophila, Arabidopsis and maize.
- **Cell Lineages and Developmental Control Genes** -- *Caenorhabditis,* Arabidopsis and Maize.
- **Special Aspects of Plant Differentiation** -- I Trichome differentiation; phloem and xylem differentiation; Phyllotaxy; Sporophytic and gametopytic incompatibility.
- **Molecular Mechanisms for Specialized Cell Types** --
    - **Transcriptional controls**: DNA Rearrangements - Phase changes in Salmonella, mating cell types in yeast, Surface antigens in Trypanosomes, Immunoglobulin diversity production; DNA methylation and developmental decisions - X-chromosome inactivation and Barr body formation; genomic imprinting of Igf2, etc.
    - **Post transcriptional controls** - Alternative RNA splicing (sex determination in Drosophila; muscle protein diversity), RNA transport, mRNA stability and gene expression (With reference to HIV infection and ferretin synthesis).

Suggested Readings

1. Gilbert, S. F. (2000) Developmental Biology. INC Publishers, USA.
2. Westhoff, P. (1998) Molecular Plant Development: from gene to plant. The Bath Press, UK.
3. Wolpert, L., Tickle, C., Martinez, A. (2015) Principles of Development. Oxford Publishers, UK.
4. Turnbill, G.N. (2005) Plant Architecture and its Manipulation: Annual Review of Plant Physiology Vol.17, Blackwell Publ. CRC Press, USA.

Course outcome

This course provides an in-depth understanding of the concepts of plant development taking leads from other model systems as well.

Paper PMBB 0903
Agricultural Biotechnology

Contents

- **Food and Agriculture** -- Food and agriculture; Scenarios of rise in population and food production at National and International levels; Indian farming; Major crop plants; Achievements and limitations of conventional plant breeding science.
- **Molecular Mapping and Marker-assisted Breeding** -- Marker-assisted plant breeding; Relative advantages/ disadvantages in conventional plant breeding and molecular breeding; Molecular polymorphism, Construction of genetic and physical map; Marker Assisted Selection (MAS) for genes of agronomic importance.
- **Plant Biotechnology** -- Historical perspectives of the birth of transgenic science; comparison of transgenic methods over conventional plant breeding methods; Major inputs in production of transgenic plants. Gene discovery.
- **Genetic Transformation**--Various transformation methods; Agrobacterium-mediated gene delivery; Disarming the Ti plasmid; Principles of vector designing; Screenable and selectable markers, Generation of marker-free transgenic methods, chloroplast transformation.
- **Transgenic Crops for Resistance to Biotic/abiotic Stresses and Quality Improvement** -- Viral resistance, fungal resistance, insects and pathogens resistance, drought, salinity, heat stress, low temperature stress, flooding and submergence stress, post-harvest bioengineering, concept of biofactories, herbicide resistance, engineering other traits.
- **Biosafety and IPR-related issues** -- Production and acceptance of transgenic crops; Public and private sectors in plant biotechnology Intellectual property rights (IPR), Plant breeders rights (PBRs) and farmers rights.

Suggested Readings

1. Altman, A. Hasegawa, P. M. (2011) Plant Biotechnology and Agriculture: Prospects for the 21st Century. Academic Press, USA.
2. Gurib-Fakim, A. (2014) Novel Plant Bioresources: Applications in Food, Medicine and Cosmetics. Wiley Blackwell, USA.
3. Kirakosyan, A. (2016) Recent Advances in Plant Biotechnology. Springer, USA.
4. Stewart, C. N. (Jr.) (2016) Plant Biotechnology and Genetics: Principles, Techniques, and Applications. Wiley, USA.

Course outcome

This course deals with various techniques, methodologies and concerns about research on agricultural biotechnology. The content of this course will prepare the students to meet the demands of employment in biotech industries.

Paper PMBB 0904
Plant Stress Biology

Contents

- **Introduction to Stress Biology --** Present-day agriculture and stress conditions, important stresses affecting crop plants in Indian ecosystems; changing stress scenario in view of climate change.
- **Introduction to Abiotic Stresses --** Effects of salt, drought, flooding and heat stresses on crops.
- **Biochemical and Physiological Impacts of Stresses --** Comprehensive molecular changes caused by abiotic stresses in plants; Current knowledge on proteins, genes, promoters, transcription factors and molecular signaling related to stress.
- **Prospects of Managing Damage Due to Abiotic Stress --** Breeding crops resistant to abiotic stresses; Application of genomic tools in plant breeding against abiotic stresses; Transgenic approach in engineering resistance against abiotic stresses.
- **Bacterial and Fungal Pathogenicity --** Biotrophs, necrotrophs and hemibiotrophs; protein secretion systems of plant pathogenic bacteria.
- **Viral Pathogenicity --** Viral gene functions, virus-host and virus-vector interactions; RNA interference and viruses; viral satellites.
- **Plant Disease Resistance Genes --** Gene-for-gene hypothesis; virulence and avirulence; Features of resistance genes.
- **Resistance, Tolerance and Susceptibility --** Acquired and innate immunity in plants; Hypersensitive response; Systemic acquired resistance; Pathogenesis related proteins; Phytoalexins.
- **Signaling in Plant Disease** -- Genetic dissection of resistance pathways; resistance proteins as signaling molecules; Role of hormones in resistance.
- **Hands-on Training --** Assessment of stresses at cell and plant level, comparison of structural features of selected biotic and abiotic resistance genes downloaded from databases, simulation of different abiotic stresses, inoculation of pathogen and study of symptoms, real time PCR-based analysis of selected transcripts of resistant and susceptible lines of plants exposed to biotic/abiotic stresses.

Suggested Reading

1. Tuteja, N. and Gill, S. S. (2013) Climate Change and Plant Abiotic Stress Tolerance. Wiley, USA.
2. Buchanan, B. B., Gruissem, W. and Jones, R. L. (2015) Biochemistry and Molecular Biology of Plants. Wiley, USA.
3. Dickinson, M. (2003) Molecular Plant Pathology. Bios Scientific Publishers, Taylor and Francis Group, USA.

4. Hull, R. (2014) Plant Virology. Academic Press, USA.
5. Jenks, M. A. and Hasegawa, P.M. (2014) Plant Abiotic Stress. Wiley, USA.

Course outcome

Biotic and abiotic stress conditions are major deterrents of plant productivity. This paper aims to develop a deep understanding of plant responses to various stress conditions at both molecular and biochemical levels. It also provides understanding to various approaches that can be taken to engineer/breed biotic and abiotic resistance in crop plants.

PMBB 0905

Practicals

List of Practicals

1. Analysis and interpretation of RNA-seq data.
2. *In silico* identification of SNP and SSR markers in rice.
3. To detect polymorphism between two varieties of *Oryza sativa* using SSR markers.
4. To isolate RNA from a given plant material and to perform the qualitative analysis by formaldehyde agarose gel electrophoresis.
5. Perform real-time PCR analysis for quantification of gene expression.
6. Analysis of sRNAs from NGS (Next Generation Sequencing) data.
7. To confirm T-DNA insertion in an Arabidopsis mutant and identify heterozygous and homozygous plants for insertion using PCR method.
8. To resolve and visualize low molecular weight RNAs by denaturing urea-PAGE.
9. To study organogenesis and differentiation of shoots and roots from various explants.
10. To study somatic embryogenesis in higher plants.
11. To study androgenesis in higher plants.
12. To study cytosine methylation and restriction protection of DNA.
13. To study differences in cytosine methylation at genomic level by methylation dependent PCR.
14. To demonstrate Agrobacterium-mediated gene delivery and study the expression of gus gene by histochemical and fluorimetric methods.
15. To analyze the transgenic plant for the expression of foreign protein by Western blotting method.
16. Detection of viral DNA accumulation in plants using Southern analysis and DIG-labeled probes.
17. Intracellular protein localization by transient expression of protein: GUS/GFP Fusion constructs in onion peel cells assays by particle gun bombardment.

Course outcome

This course is aimed to provide competence in various advanced molecular and data analytics techniques related to plant development, gene expression at both transcript and protein level, molecular marker analysis, as well as transgenic plant analysis.

Paper PMBB 0906
Small RNA Biology and Epigenetics

Contents

- **Chromatin Modeling and Remodeling** -- Polycomb complexes, SWI/SNF1 complexes and other chromatin modifiers.
- **Interpretation of DNA Methylation Marks by Cellular Machinery** -- Study of methylated DNA binding proteins, their structure and function, methods of altering DNA methylation.
- **Study of Histone Modifications** -- Histone modifications, modifying enzymes, histone deacetylase Inhibitors
- **Chromatin Modification and Development** -- Effect on somatic embryogenesis, leaf development, photosynthesis, flowering and ageing.
- **Epigenetics and Environment** -- Role in plant stresses, epigenetic memory.
- **Epigenetics in Human Systems** -- Role in immune response, cancer and cardiovascular diseases.
- **Non-coding RNAs** -- Types and occurrence of non-coding RNAs, small RNAs in different biological systems, diversity and evolution of small RNAs.
- **Identification and Characterization of Small RNAs** -- Discovery, detection and validation of small RNAs, target prediction and validation, databases on small RNAs, an overview of bioinformatics tools in small RNA biology.
- **Small RNA Pathways** - Biogenesis of different classes of small RNAs, components and their characteristic features.
- **Regulation of Gene Expression by Small RNAs** -- Transcriptional gene silencing (TGS), Post-transcriptional Gene Silencing (PTGS), gene activation, evolutionary transition of small RNA-target gene pair.
- **Biological Processes Regulated by Small RNAs** -- Diverse roles of small RNAs in regulating biological processes in different organisms: bacteria, plants & animals, trans-kingdom cross-talk mediated by small RNAs.
- **Small Non-coding RNAs as Effective Tools in Biotechnology** -- amiR technology, siRNA technology, Virus-induced gene silencing (VIGS), RNA Interference (RNAi) and RNA activation (RNAa), target mimicry, Short tandem target mimic technology (STTM) & miR sponges, CRISPR-Cas mediated genome editing technology, crop improvement, diagnostics and therapeutic applications in human diseases.
- **Hands-on Training --** Techniques for studying differential methylation of DNA, gene expression in response to altered DNA methylation, expression profiling of small RNAs, survey of small RNA databases, case studies of plant miRNA families.

Suggested Readings

1. Esteller, M. (2008) Epigenetics in Medicine and Biology. CRC Press, USA
2. Rajewsky, N., Jurga, S. and Barsizewsky, J. (2018) Plant Epigenetics. Springer International Publishing AG, USA
3. Mallick, B. and Ghosh, Z. (2014) Regulatory RNAs: Basics, Methods and Applications. Springer, Germany.
4. Nellan, W. and Hammann, C. (2007) Small RNAs: Analysis and Regulatory Functions. Springer Science and Business Media, USA.
5. Gaur, R. K. and Rossi, J. J. (2009) Regulation of Gene Expression by Small RNAs. CRC Press, USA.

Course outcome

Epigenetic landscape (including both DNA methylation and histone modifications) of an organism has a significant bearing in regulating various developmental and metabolic processes at global level. Similarly sRNAs have emerged as a major modulators of global gene expression patterns. Thus, this course will lead to an in-depth understanding of the interplay of sRNAs and epigenetic modifications in regulating various molecular processes in plants.

Paper PMBB 1001

Dissertation

Dissertation work shall comprise an in-depth study pertaining to a specific research topic under the direct supervision of a faculty member. The student shall spend the entire Semester-4 in experimentation and study on the topic and shall submit the Dissertation in bound form at the end of the semester.

Course outcome

This course is designed to provide extensive practical training to the students so as to enable them to conceive a research problem, design experimental strategy, conduct experiments as well as compile and discuss the results. The students are required to work in the research labs of the Department and thus are exposed to the actual research and development environment in the filed of plant sciences.