M.Sc. (Biochemistry) (AY 2023-24)

Semester wise course details:

Semester – I				
Sl. No.	**Course No.**	**Course Title**	**Credit Hours**	**Faculty**
1	**BIOCHEM 501***	Basic Biochemistry	3+1	**Dr Sujit Kumar Bishi (IIAB)** Dr Sandeep Kumar (NISA) Dr Madan Kumar (IIAB) Guest Faculty (IARI/IISR/IIRR/SAUs)
2	**BIOCHEM 503***	Enzymology	2+1	**Dr Sandeep Kumar (NISA)** Dr Sujit Kumar Bishi (IIAB) **Guest Faculty (IARI/IISR/IIRR/SAUs)**
3	**BIOCHEM 509**	Nutritional Biochemistry	2+1	**Dr Sujit Kumar Bishi (IIAB)** Dr Sandeep Kumar (NISA) Dr Madan Kumar (IIAB) Guest Faculty (IARI/IISR)
Semester – II				
Sl. No.	**Course No.**	**Course Title**	**Credit Hours**	**Faculty**
1	**BIOCHEM 502***	Intermediary Metabolism	3+0	**Dr Sandeep Kumar (NISA)** Dr Sujit Kumar Bishi (IIAB) Dr Soumen Naskar (IIAB) Guest Faculty (IARI/IISR/IIRR/SAUs)
2	**BIOCHEM 504**	Molecular Biology	2+1	**Dr Sujit Kumar Bishi (IIAB)** Dr Binay Kumar Singh (IIAB) Dr Soumen Naskar (IIAB) Dr Madan Kumar (IIAB)
3	**BIOCHEM 505***	Techniques in Biochemistry	2+2	**Dr Sujit Kumar Bishi (IIAB)** Dr Soumen Naskar (IIAB) Dr Sandeep Kumar (NISA) Dr Arnab R Choudhary (NISA) Guest Faculty (IARI/IISR)
4	**BIOCHEM 591**	Master's Seminar	1+0	**Dr Sandeep Kumar (NISA)** Dr Sujit Kumar Bishi (IIAB) Dr Madan Kumar (IIAB)
5	**PP 504**	Physiological and Molecular responses of plants to abiotic stresses	2+1	**Dr Madan Kumar (IIAB)** Dr Vaibhav Lohot (NISA) Dr Sandeep Kumar (NISA) Dr Sujit Kumar Bishi (IIAB) Guest Faculty (IARI/SAUs)
6	**PP510**	Seed Physiology	2+1	**Dr Vaibhav Lohot (NISA)** Dr Madan Kumar (IIAB) Dr Sandeep Kumar (IIAB) Dr Sujit Kumar Bishi (IIAB) Guest Faculty (IARI/SAUs)

Note: ***indicates the core course; Name in bold letter will be course leader***

Course Title with Credit Load
M.Sc. (Ag) in Biochemistry

Code Code	Course Title	Credit Hours
BIOCHEM 501*	Basic Biochemistry	3+1
BIOCHEM 502*	Intermediary Metabolism	3+0
BIOCHEM 503*	Enzymology	2+1
BIOCHEM 504	Molecular Biology	2+1
BIOCHEM 505*	Techniques In Biochemistry	2+2
BIOCHEM 506	Immuno Chemistry	2+1
BIOCHEM 507	Plant Biochemistry	2+1
BIOCHEM 508	Animal Biochemistry	3+0
BIOCHEM 509	Nutritional Biochemistry	2+1
BIOCHEM 510	Nitrogen And Sulphur Metabolism	2+1
BIOCHEM 511	Biochemistry On Xenobiotics	2+0
BIOCHEM 591	Master's Seminar	1+0
BIOCHEM 599	Master's Research	30

*Core course

Course Contents
M.Sc. (Ag) in Biochemistry

I. Course Title : Basic Biochemistry
II. Course Code : BIOCHEM 501*
III. Credit Hours : 3+1

IV. Why this course?

To impart the fundamental knowledge on structure and function of cellular components involved in biological processes and an elementary introduction to the study of molecular biology.

V. Aim of the course

The course is designed to provide elementary knowledge/overview of structure and function of proteins, carbohydrates, lipids, nucleic acids and other biomolecules and their metabolism.

No.	Blocks	Units
1.	Introduction to Biochemistry	1. Scope and importance of biochemistry 2. Foundation of life 3. Water 4. Physical techniques for structure determination
2.	Structure and function of biomolecules	1. Biomolecules 2. Immunoglobulins and PR proteins 3. Plant secondary metabolites
3.	Metabolism – the basics	1. Molecules aiding metabolism 2. Thermodynamics –principles and energetic of life
4.	Catabolism and its regulation	1. Catabolism of energy molecules 2. ATP formation
5.	Fundamentals of Molecular biology and genetic engineering	1. Molecular biology processes 2. Recombinant DNA technology

VI. Theory

Block 1: Introduction to Biochemistry

Unit 1: Scope and importance of biochemistry (1 Lecture)

Biochemistry as modern science and its various divisions, Scope and importance of biochemistry in agriculture and allied sciences.

Unit 2: Foundation of life (2 Lectures)

Fundamental principles governing life, supramolecular structures, significance of weak non covalent interactions in biology

Unit 3: Water (3 Lectures)

Structure of water, ionization of water, acid base concept, pH and buffers, significance of structure-function relationship.

Unit 4: Physical techniques for structure determination (2 Lectures)

General introduction to physical techniques for determination of structure of biopolymers.

Block 2: Structure And Function of Biomolecules

Unit 1: Biomolecules (10 Lectures)

Structure, classification, properties and function of carbohydrates, amino acids, proteins, lipids and nucleic acids.

Unit 2: Immunoglobulins and PR proteins (2 Lectures)

Structure, formation and different forms of immunoglobulins, PR proteins and their classification.

Unit 3: Plant secondary metabolites (3 Lectures)

Structure, classification and function of plant secondary metabolites.

Block 3: Metabolism – The Basics

Unit 1: Molecules aiding metabolism (2 Lectures)

Structure and biological functions of vitamins and coenzymes, enzymes: classification and mechanism of action; regulation, factors affecting enzyme action. Hormones: animal and plants.

Unit 2: Thermodynamics –principles and energetic of life (2 Lectures)

Fundamentals of thermodynamic principles applicable to biological processes, Bioenergetics.

Block 4: Catabolism and its Regulation

Unit 1: Catabolism of energy molecules (5 Lectures)

Important and basic degradative metabolic pathways of carbohydrates, lipids and proteins and their regulation.

Unit 2: ATP formation (3 Lectures)

Formation of ATP, substrate level phosphorylation, electron transport chain and oxidative phosphorylation, chemiosmotic theory and proton motive force.

Block 5: Fundamentals of Molecular Biology and Genetic Engineering

Unit 1: Molecular biology processes (4 Lectures)

Overview of replication, transcription and translation.

Unit 2: Recombinant DNA technology (3 Lectures)

Restriction enzymes, DNA cloning, applications of cloning, transgenics.

VII. Practicals

- Preparation of standard and buffer solutions
- Detection of carbohydrates, amino acids and proteins
- Extraction and estimation of sugars
- Extraction and estimation of amino acids
- Extraction and estimation of proteins

- Estimation of acid value of fat/oil
- Estimation of peroxide value of fat/oil
- Estimation of saponification value in fats and oils
- Fatty acid composition in fat/oil by GC
- Estimation of DNA and RNA by spectroscopic methods
- Estimation of Ascorbic acid
- Separation of biomolecules by TLC and Paper chromatography
- Estimation of alpha amylase activity
- Qualitative tests for secondary plant metabolites.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz

IX. Learning outcome

With this course, the students are expected to be able to understand the actual chemical concepts and fundamental processes of biology at molecular level.

X. Suggested Reading

- Nelson DL and Cox MM. 2017. *Lehninger Principles of Biochemistry*. 7th edition. W. H. Freeman & Co Ltd
- Satyanarayana U and Chakrapani U. 2017. *Biochemistry*. 5th edition, Elsevier
- Moran LA, Horton HR, Scrimgeour KG and Perry MD. 2012. *Principles of Biochemistry*. 5th edition Pearson.
- Voet D and Voet JG. 2011. *Biochemistry*. 4th edition John Wiley.
- Pratt CW and Cornely K. 2014. *Essential Biochemistry*. 3rd Edition. Wiley
- Moorthy K. 2007. *Fundamentals of Biochemical Calculations*. 2nd edition. CRC Press
- Conn EE, Stumpf PK, Bruening G and Doi RH. 2006. *Outlines of Biochemistry*. 5th edition. Wiley.

I. Course Title : Intermediary Metabolism

II. Course Code : BIOCHEM 502*

III. Credit Hours : 3+0

IV. Why this course?

To understand the interconversion of chemical compounds in the living system, the pathways taken by individual molecules, their interrelationships and the mechanisms that regulate the flow of metabolites through the pathways.

V. Aim of the course

The course is designed to give an insight into the different metabolic pathways, their interrelationship, regulation, metabolic disorders in human and pathway engineering in plants.

No.	Blocks	Units
1.	Introduction to metabolism	1. Overview of metabolism 2. Metabolic pathways
2.	Metabolism of energy nutrients	1. Carbohydrate metabolism

No.	Blocks	Units
		2. Lipid metabolism 3. Protein metabolism 4. Energy transduction and oxidative phosphorylation
3.	Sulphur and nucleotide metabolism	1. Sulphur metabolism 2. Nucleotide metabolism
4.	Metabolic regulation and defects in metabolism	1. Regulation of metabolic pathways 2. Defects in metabolism

VI. Theory

Block 1: Introduction To Metabolism

Unit 1: Overview of metabolism (4 Lectures)

The living cell - a unique chemical system, biochemical reaction types, bioenergetics, bioavailability of nutrients, transport mechanism, signal transduction.

Unit 2: Metabolic pathways (5 Lectures)

Catabolism and anabolism, compartments of metabolic pathways, experimental approaches to study metabolism, metabolic profiles of major organs.

Block 2: Metabolism of Energy Nutrients

Unit 1: Carbohydrate metabolism (5 Lectures)

Major catabolic and anabolic pathways of carbohydrate metabolism, the glyoxylate pathway.

Unit 2: Lipid metabolism (5 Lectures)

Fatty acid oxidation, ketone bodies, fatty acid biosynthesis, synthesis of triacylglycerols, cholesterol, eicosanoids.

Unit 3: Protein metabolism (3 Lectures)

General reactions of amino acid metabolism, degradative and biosynthetic pathways of amino acids, urea cycle, amino acids as metabolic precursors.

Unit 4: Energy transduction and oxidative phosphorylation (4 Lectures)

Mechanisms of energy transduction, electron transport system, oxidative phosphorylation, control of ATP production.

Block 3.sulphur and Nucleotide Metabolism

Unit 1: Sulphur metabolism (5 Lectures)

Sulphate reduction and incorporation of sulphur in to amino acids.

Unit 2: Nucleotide metabolism (3 Lectures)

Synthesis and degradation of purine and pyrimidine nucleotides.

Block 4: Metabolic Regulation and Defects in Metabolism

Unit 1: Regulation of metabolic pathways (4 Lectures)

Regulation of carbohydrate, lipid, protein, nucleotide metabolism and oxidative phosphorylation.

Unit 2: Defects in metabolism (4 Lectures)

Disorders of carbohydrates, lipids, amino acids and nucleic acid metabolism, and inborn errors of metabolism. Metabolic pathway engineering.

VII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

VIII. Learning outcome

With this course, the students are expected to learn the set of life-sustaining chemical processes that enables organisms transform the chemical energy stored in molecules into useful form and the process by which organisms respond to stimuli and metabolic disorders.

IX. Suggested Reading

- Nelson, D. L. and Cox, M. M. 2017. *Lehninger Principles of Biochemistry*. 7th edition. W. H. Freeman & Co Ltd
- Satyanarayana, U. and Chakrapani, U. 2017. *Biochemistry*. 5th edition, Elsevier
- Campbell M. K. and Farrell S.O. 2009. *Biochemistry*. 6thedition Thomson Higher Education.
- Moran L. A., Horton H. R., Scrimgeour K. G. and Perry, M. D. 2012. *Principles of Biochemistry*. 5th edition Pearson,
- Voet, D. and Voet J. G. 2011. *Biochemistry*. 4thedition . John Wiley.
- Pratt, C. W. and Cornely, K. 2014. *Essential Biochemistry*. 3rd Edition. Wiley
- Moorthy, K. 2007. *Fundamentals of Biochemical Calculations*. 2nd edition. CRC Press

I. Course Title : Enzymology

II. Course Code : BIOCHEM 503*

III. Credit Hours : 2+1

IV. Why this course?

Being highly specific and incredibly efficient biological catalysts, enzymes are responsible for bringing about almost all of the chemical reactions in living organisms. Otherwise these reactions will take place at a rate far too slow for the pace of metabolism. The course will help students in understanding the physical, chemical and kinetic properties of enzymes.

V. Aim of the course

To impart knowledge about the catalytic role of enzymes, their structure, physico-chemical, kinetic and regulatory properties and mechanism of action.

No.	Blocks	Units
1.	Introduction to enzymes	1. Structure and function of enzyme 2. Extraction and purification of enzymes
2.	Enzyme structure and function	1. Chemical nature of enzyme 2. Cofactors and coenzymes 3. Nature of active site
3.	Enzyme kinetics	1. Single substrate kinetics 2. Enzyme inhibition 3. Kinetics of allosteric enzymes

No.	Blocks	Units
		4. Regulation of enzyme activity
4.	Application of enzymology	1. Industrial application of enzymes 2. Biotechnological application of enzymes

VI. Theory

Block 1: Introduction To Enzymes

Unit 1: Structure and function of enzyme (2 Lectures)

Historic perspective, general properties of enzymes, enzyme compartmentalization in cell organelles, nomenclature and classification of enzymes, ribozymes, isozymes, abzymes.

Unit 2: Extraction and purification of enzymes (2 Lectures)

Extraction of soluble and membrane-bound enzymes, purification of enzymes, measurement of enzyme activity.

Block 2: Enzyme Structure and Function

Unit 1: Chemical nature of enzyme (3 Lectures)

Enzyme specificity, monomeric and oligomeric enzymes, catalytic mechanism, mechanism of enzyme action, pseudoenzymes, enzyme promiscuity.

Unit 2: Cofactors and coenzymes (2 Lectures)

Chemical nature and involvement of cofactors and coenzymes in enzyme catalyzed reactions, metal activated enzymes and metalloenzymes, mechanism of enzyme catalyzed reactions without cofactors.

Unit 3: Nature of active site (2 Lectures)

Active site, identification of binding sites and catalytic sites.

Block 3. Enzyme Kinetics

Unit 1: Single substrate kinetics (4 Lectures)

Relationship between initial velocity and substrate concentration, Michaelis-Menten equation, Lineweaver-Burk and Eadie-Hofstee plots, analysis of kinetic data, numerical exercises.

Unit 2: Enzyme inhibition (2 Lectures)

Reversible and irreversible enzyme inhibition, uses of enzyme inhibition.

Unit 3: Kinetics of allosteric enzymes (3 Lectures)

Nature of allosteric enzymes, sigmoidal kinetics, MWC model and allosteric regulation, KNF model and allosteric regulation.

Unit 4: Regulation of enzyme activity (3 Lectures)

Feedback regulation, regulatory enzymes, control of enzymatic activity, symmetry and sequential model, reversible covalent modification of enzymes.

Block 4: Application of Enzymology

Unit 1: Industrial application of enzymes (3 Lectures)

Industrial application of enzyme catalysis in sectors like food processing, detergents,

biofuels, paper and pulp, biosensors and clinical applications of enzymes.

Unit 2: Biotechnological application of enzymes (2 Lectures)

Large scale production and purification of enzymes, immobilization of enzymes.

VII. Practicals

- Soluble protein estimation
- Enzyme assay by taking any model enzyme
- Isolation and purification of any model enzyme
- Study of the effect of enzyme and substrate concentrations on enzyme activity
- Determination of K_m and V_{max}
- Determination of pH and temperature optima
- Effect of inhibitors on enzyme activity
- Determination of pH and temperature stability of enzyme
- Electrophoretic analysis of isozymes.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

After completion of this course students are expected to have knowledge on and insight into the chemical principles of enzyme catalysis, action of enzymes as biocatalysts and factors that influence enzyme activity and understand the kinetics of enzymatic reactions. Students will have experience with purification, handling and characterization of proteins and also get exposure of wide applications of enzymes and their future potential.

X. Suggested Reading

- Palmer T and Bonner PL. 2007. *Enzymes: Biochemistry, Biotechnology, Clinical Chemistry*. 2nd edition. Woodhead Publishing
- Okotore RO. 2015. *Essentials of Enzymology*. XLIBRIS
- Herald J. 2016. *Essentials of Enzymology*. Syrawood Publishing House
- Suzuki, H. 2015. *How Enzymes Work: From Structure to Function*. Jenny Stanford Publishing.
- Bugg TDH. 2012. *Introduction to Enzyme and Coenzyme Chemistry*, 3rd Edition. WILEY
- Guo Y. 2014. *Enzyme Engineering*. Science Press
- Bisswanger H. 2011. *Practical Enzymology*. Wiley-Blackwell

I. Course Title : Molecular Biology

II. Course Code : BIOCHEM 504

III. Credit Hours : 2+1

IV. Why this course?

Molecular biology is the study of biology at a molecular level. The concepts and techniques of molecular biology are the foundation for the studies of all aspects of biology in modern time. This course is designed to provide an intensive exposure to the theoretical concepts and experimental techniques of molecular biology and the interrelationship of DNA, RNA and protein synthesis and their regulation.

V. Aim of the course

To provide knowledge of life processes at the molecular and cellular levels, including the storage, transfer and regulation of genetic information and specialist theoretical knowledge and practical experience of gene manipulation and the analysis of nucleic acids and proteins.

No.	Blocks	Units
1.	Introduction to nucleic acids	1. History 2. Properties of nucleic acid 3. Genes and genome
2.	Synthesis of nucleic acids	1. DNA replication 2. Transcription
3.	Protein synthesis	1. Translation machinery 2. Mechanism of protein synthesis 3. Post-translational events
4.	Gene manipulation	1. DNA sequencing 2. Recombinant DNA technology 3. Techniques in molecular biology

VI. Theory

Block 1: Introduction to Nucleic Acids

Unit 1: History (1 Lecture)

Historical development of molecular biology, nucleic acids as genetic material.

Unit 2: Properties of nucleic acid (2 Lectures)

Nucleic acid structure, chemical and physical properties of nucleic acids, spectroscopic and thermal properties of nucleic acids, DNA supercoiling.

Unit 3: Genes and genome (3 Lectures)

Concept of genes and genome,genome complexity**,** genome organization in prokaryotes and eukaryotes, chromatin structure and function, repetitive and non-repetitive DNA, satellite DNA central dogma, genome editing.

Block 2: Synthesis of Nucleic Acid

Unit 1: DNA replication (3 Lectures)

Modes of replication, DNA polymerases, topoisomerases, DNA ligase, model of replisome, semi conservative replication in prokaryotes and eukaryotes, inhibitors of replication, DNA damage and repair.

Unit 2: Transcription (3 Lectures)

Basic principles of transcription, transcription initiation, elongation and termination, RNA processing, RNA interference, siRNAs, miRNAs and other ncRNAs, DNA/ RNA editing. regulation of transcription, reverse transcription.

Block 3. Protein Synthesis

Unit 1: Translation machinery (2 Lectures)

Ribosomes structure and function, organization of ribosomal proteins and RNA genes, genetic code, aminoacyl tRNA synthases.

Unit 2: Mechanism of protein synthesis (2 Lectures)

Initiation, chain elongation and termination of translation, energetics, inhibitors of translation.

Unit 3: Post-translational events (2 Lectures)

Post translational modifications of nascent polypeptide, protein targeting and turnover, regulation of gene expression in prokaryotes and eukaryotes, nucleases and restriction enzymes.

Block 4: Gene Manipulation

Unit 1: DNA sequencing (3 Lectures)

Importance, Sanger method,High-Throughput Sequencing (HTS) techniques, applications of DNA sequencing.

Unit 2: Recombinant DNA technology (4 Lectures)

Vectors, isolation of genes, recombinants vector, selection of recombinants, characterization and expression of cloned DNA, transformation, transgenesis, mutation, molecular mechanism of mutation, site directed mutagenesis, *in vitro* mutagenesis.

Unit 3: Techniques in molecular biology (3 Lectures)

Polymerase chain reaction (PCR), expression cloning, gel electrophoresis, molecular markers, macromolecule blotting and probing, arrays (DNA array and protein array) – principles and application.

VII. Practicals

- Isolation and purification of DNA and RNA
- To check the purity of isolated DNA and RNA
- Restriction fragmentation of genomic DNA
- Separation of oligos by agarose gel electrophoresis
- Southern blotting experiments
- Northern blotting experiments
- Cloning of DNA fragment in vector
- Selection of recombinant
- SSR analysis of DNA
- cDNA synthesis using RT- PCR
- Basic tools in bioinformatics analysis

VIII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

IX. Learning outcome

After completion, the student should be able to explain central cell biological processes and how they are regulated and quality assured and understands how molecular cell biology forms the foundation of biotechnology.

X. Suggested Reading

- Snape A, Papachristodoulou D, Elliott, W. H. and Elliott, C. 2014. *Biochemistry and Molecular*

Biology. Oxford University Press.
- Krebs, J. E., Goldstein, E. S. and Kilpatrick, S. T. 2018. *Lewin's GENES XII*. Jones & Bartlett Learning.
- Lodish, H.,Berk, A., Kaiser, C. A., Krieger, M. And Bretscher, A. 2016. *Molecular Cell Biology*.W H Freeman & Co.
- Hoffmann, A. And Clokie, S. 2018. *Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology*. Cambridge University Press.
- Primrose SB, Twyman RM and Old RW.2002. *Principles of Gene Manipulation*: 6th Ed. Wiley
- Karp, G. 2013. *Cell and Molecular Biology*. Wiley.
- Neidle, S. 2008. *Principles of Nucleic Acid Structure*. Elsevier Inc.
- Watson J, Baker TA, Bell SP, Gann A, Levine M and Losick, R. 2014. *Molecular biology of the gene* 7th edition, Pearson.

I. Course Title : Techniques in Biochemistry

II. Course Code : BIOCHEM 505*

III. Credit Hours : 2+2

IV. Why this course?

Biochemical studies rely on the availability of appropriate analytical techniques and their applications. This course will examine modern methods and technologies that are used in biochemical analysis with emphasis on instrumentation, underlying principles, aims, strategies and current applications.

V. Aim of the course

To provide hands-on experience to different biochemical techniques commonly used in research along with the knowledge on principles and the instrumentation.

No.	Blocks	Units
1.	Separation techniques	1. Chromatography techniques 2. Electrophoretic technique 3. Hydrodynamic methods 4. Centrifugation
2.	Spectroscopic techniques	1. Spectrophotometry 2. Mass spectroscopy 3. Atomic absorption spectrophotometry
3.	Microscopy	1. Microscopic techniques
4.	Tracer, imaging, immunochemical and other techniques	1. Tracer techniques 2. Imaging techniques 3. Immunochemical techniques 4. Other techniques

VI. Theory

Block 1: Separation Techniques

Principles and applications of separation techniques.

Unit 1: Chromatography techniques (4 Lectures)

Principles and applications of paper, thin layer, gel filtration, ion-exchange, affinity, column & HPTLC, GC, HPLC and FPLC.

Unit 2: Electrophoretic technique (2 Lectures)

General principles,paper and gel electrophoresis, native and SDS-PAGE, 2D-PAGE, capillary electrophoresis.

Unit 3: Hydrodynamic methods (2 Lectures)

Hydrodyanmic methods of separation of biomolecules such as viscosity and sedimentation velocity, - their principles.

Unit 4: Centrifugation (2 Lectures)

Basic principles of sedimentation, type, care and safety aspects of centrifuge preparative and analytical centrifugation.

Block 2: Spectroscopic Techniques

Unit 1: Spectrophotometry (3 Lectures)

Principles and applications of UV-visible, Fluorescence, IR and FTIR, Raman, NMR and FTNMR, ESR and X-Ray spectroscopy.

Unit 2: Mass spectroscopy (3 Lectures)

MS/MS, LC-MS, GC-MS, MALDI-TOF, applications of mass spectrometry in biochemistry.

Unit 3: Atomic absorption spectrophotometry (2 Lectures)

Principle, function and instrumentation ofatomic absorption spectrophotometry.

Block 3. Microscopy

Unit 1: Microscopic techniques (2 Lectures)

Principles and applications, light, UV, phase contrast, fluorescence and electron microscopy, flow cytometry.

Block 4: Tracer, Imaging, Immunochemical and Other Techniques

Unit 1: Tracer technique (2 Lectures)

Tracer techniques in biology: concept of radioactivity, radioactivity counting methods with principles of different types of counters, concept of á, â and ã emitters, scintillation counters, γ-ray spectrometers, autoradiography, applications of radioactive tracers in biology.

Unit 2: Imaging techniques (2 Lectures)

Principles and applications of phosphor imager, MRI and CT scan.

Unit 3: Immunochemical technique (2 Lectures)

Production of antibodies, immunoprecipitation, immunoblotting, immunoassays, RIA and ELISA.

Unit 4: Other techniques (2 Lectures)

Cryopreservation, polymerase chain reaction (PCR), FACS.

VII. Practicals

- Expression of concentration in terms of dilution, molarity, normality, percent expression
- pH measurement and buffer preparation
- Determination of absorption maxima of biomolecules

- Estimation of biomolecules through spectrophotometry and other methods
- Separation of carbohydrates and amino acids by paper chromatography
- Separation and analysis of fatty acids/lipids by GC
- Separation/estimation of biomolecules through HPLC and FPLC
- Separation of proteins using ion exchange, gel filtration and affinity chromatography
- Electrophoretic separation of proteins and nucleic acids
- Centrifugation- differential and density gradient
- $(NH_4)_2SO_4$ precipitation and dialysis
- Use of radioisotopes in metabolic studies
- PCR
- ELISA
- Western blotting/ Dot blotting

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

At the end of the course, the student will acquire the basic knowledge of the main biochemical methods used in the separation, identification, characterization and analysis of biomolecules.

X. Suggested Reading

- Boyer R. 2011. *Biochemistry Laboratory: Modern Theory and Techniques* 2nd Edition. Pearson
- Hofmann A and Clokie S. 2010. *Wilson and Walker's Principles and Techniques of Biochemistry and Molecular Biology*. 7th edition. Cambridge University Press.
- Sawhney SK and Singh R. 2000. *Introductory Practical Biochemistry*. 2nd Ed. Narosa
- Katoch R. 2011. *Analytical Techniques in Biochemistry and Molecular Biology*. Springer
- Boyer R. 2009. *Modern Experimental Biochemistry*. Fifth impression. Pearson
- Lottspeich F and Engels JW. (Eds). 2018. *Bioanalytics: Analytical Methods and Concepts in Biochemistry and Molecular Biology*. Wiley-VCH
- Wilson K and Walker J. 2010. *Principles and Techniques of Biochemistry and Molecular Biology*, 7th Edition. Cambridge University Press

I. Course Title : Immunochemistry

II. Course Code : BIOCHEM 506

III. Credit Hours : 2+1

IV. Why this course?

This is an introduction to the field of immunology with emphasis on the biochemical aspects of the systems. This course is intended to equip the student with the knowledge and understanding of the vertebrate immune system, its component and mechanism of immune responses with specific reference to the human immune defence system and plant immunity

V. Aim of the course

To give an insight into the biochemical basis of immunity

No.	Blocks	Units
1.	Basics of Immunology	1. Introduction to immunology 2. Antibodies 3. The immune responses 4. Immunoregulation and immunological techniques

VI. Theory

Block 1: Basics of immunology

Unit 1: Introduction to immunology (7 Lectures)

History and scope of immunology, antigens, adjuvants, immune system, organs, tissues and cells, immunoglobulins, molecular organization of immunoglobulin. Haptens, ag-ab interaction, plant immunity, proteasome mediated process, plantibodies

Unit 2: Antibodies (5 Lectures)

Classes of antibodies, antibody diversity, theories of generation of antibody diversity, vaccine, monoclonal and polyclonal antibodies, hybridoma, recombinant antibodies, complement system - classical and alternate.

Unit 3: The immune responses (8 Lectures)

Cellular interactions in immune response, major histocompatibility complex, cell mediated immune response, cytokines.

Unit 4: Immunoregulation and immunological techniques (8 Lectures)

Immunoregulation, immunological tolerance, hypersensitivity, mechanisms of immunity, innate resistance and specific immunity, current immunological techniques – elisa, ria, immunoblotting, facs; basics of pcr and hybridization based methods of detection, microarray based detection, multiplexing.

VII. Practicals

- Handling, inoculation and bleeding of laboratory animals
- Preparation of antigens and antisera, natural antibodies
- Carbon clearance test
- Lymphoid organs of the mouse
- Morphology of the blood leucocytes
- Separation of lymphocytes from blood, viable lymphocyte count
- Antigen-antibody interaction,
- Precipitation and agglutination
- Direct and indirect haemagglutination
- Immunoelectrophoresis
- Complement fixation
- Quantitation of immunoglobulins by zinc sulphate turbidity and single radial immunodiffusion
- ELISA
- Western blotting
- Fluorescent Ab test
- Hybridoma technique

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

It is expected that the student should understand and explain the structure, functioning and importance of human immune system in term of health and disease.

Suggested Reading

- Punt J, Stranford S, Jones P and Owen J. 2018 . Kuby Immunology. 8th edition. W. H. Freeman
- Renshaw S. 2016. *Immunohistochemistry and Immunocytochemistry: Essential Methods*, 2nd Edition. John Wiley & Sons, Ltd.
- Abbas AK, Lichtma AH and Pillai S. 2018. *Cellular and Molecular Immunology*. 9th edition. Elsevier
- Delves PJ, Martin SJ, Burton DR and Roitt IM. 2017. *Roitt's Essential Immunology*, 13th Edition. Wiley-Blackwell

I. Course Title : Plant Biochemistry

II. Course Code : BIOCHEM 507

III. Credit Hours : 2+1

IV. Why this course?

Harnessing sunlight, plants produce a diverse array of chemical compounds to survive in challenging ecological niches. Plant-derived metabolites are major sources of human food, fibre, fuel, and medicine. This course covers topics related to plant metabolism and discusses how plants generate carbon and energy sources by photosynthesis and synthesize various compounds through complex networks of metabolic pathways.

V. Aim of the course

To provide an understanding of metabolic processes in plants and the role of different biosynthetic pathways in plant growth and development.

No.	Blocks	Units
1.	Photosynthesis	1. Photosynthetic machinery 2. Carbon reduction
2.	Conversion of photosynthates	1. Synthesis of major biomolecules 2. Nitrogen and sulphur metabolism
3.	Growth and development	1. Germination and fruit ripening 2. Phytohormones
4.	Secondary metabolites	1. Biochemistry of plant secondary metabolites

VI. Theory

Block 1: Photosynthesis

Unit 1: Photosynthetic machinery (3 Lectures)

Structure and function of plant cell and its organelles, phytochromes, chloroplast

morphology structure, structure and chemistry of photosynthetic pigments, light reaction of photosynthesis.

Unit 2: Photosynthesis – the process (4 Lectures)

Carbon reduction in C_3, C_4 and CAM plants, photorespiration, sucrose-starch interconversion.

Block 2: Conversion of Photosynthates

Unit 1: Synthesis of major biomolecules (3 Lectures)

Biosynthesis of structural carbohydrates, storage proteins and lipids.

Unit 2: Nitrogen and sulphur metabolism (5 Lectures)

Basic concepts of nitrogen and sulphur metabolism: biological nitrogen fixation, nitrate assimilation in plants, sulphur chemistry and function, reductive sulphate assimilation pathway, sulphated compounds.

Block 3: Growth and Develpoment

Unit 1: Germination and fruit ripening (4 Lectures)

Biochemistry of seed germination – stages, requirements, metabolism and mobilization of storage material; Biochemistry of fruit ripening – ripening process, cell wall degrading enzymes, role of ethylene and regulation of ethylene production.

Unit 2: Phytohormones (3 Lectures)

Different classes of phytohormones, their biosynthesis and mode of action.

Block 4: Secondary Metabolites

Unit 1: Biochemistry of plant secondary metabolites (6 Lectures)

Biochemistry and significance of plant secondary metabolites – phenolics, terpenoids, alkaloids, cyanogenic glycosides and glucosinolates, effect of biotic and abiotic factors on plant metabolism and plant defense system.

VII. Practicals

- Fractionation of cell organelles,
- Estimation of starch,
- Assay of ADPG pyrophosphorylase/starch synthase,
- Assay of PAL/SOD
- Assay of PPO/LOX,
- Estimation of individual amino acids,
- Qualitative tests of secondary metabolites (alkaloids, sterols etc.)
- Content and composition of carotenoids, anthocyanin and chlorophylls
- Determination of polyphenols/phenolics
- Fractionation of storage proteins
- Estimation of glucosinolates
- Estimation of cyanogenic compounds.

VIII. Teaching methods/activities

– Classroom lectures (oral + audio-visual)
– Assignment (Reading/Writing)
– Oral presentation by students on specified topics
– Class room quiz
– Case study

IX. Learning outcome

Successful completion of this course will provide students with fundamental knowledge of biochemistry and specific knowledge of compounds and biochemical pathways that occur in plants.

X. Suggested Reading

- Buchannan BB, Gruissem W and Jones R.L. (eds.). 2000. *Biochemistry and Molecular Biology of Plants*. 2nd edition. WILEY Blackwell
- Heldt, H-W. 2010. *Plant Biochemistry and Molecular Biology*. 4th ed. Oxford University Press
- Goodwin TW and Mercer EI. 2005. *Introduction to Plant Biochemistry*. 2nd edition. CBS
- Heldt, H-W. and Piechulla, B. 2010.*Plant Biochemistry*. 4th Edition. Elsevier
- Harinda, Makkeaand Klaus. 2007. *Plant Secondary Metabolites*. Springer
- Cseke LJ, Kirakosyan A, Kaufman PB, Warber S, Duke JA, Brielmann HL. 2006. *Natural Products from Plants*. 2ndEdition. CRC Press

I. Course Title : Animal Biochemistry

II. Course Code : BIOCHEM 508

III. Credit Hours : 3+0

IV. Why this Course?

Biochemistry is one of the few basic sciences where animal and plant kingdoms meet. It provides the knowledge base for all human and animal health studies. Knowledge of biochemistry will enable one to study, or to pursue a line of research in applied sciences.

V. Aim of the Course

To impart knowledge regarding biochemistry of various physiological processes, specialized tissues and hormone action in animal system

No.	Blocks	Units
1.	Animal biochemistry	1. Biochemistry of assimilation 2. Nutrients and their biochemistry 3. Hormones and their role 4. Immune system

VI. Theory

Block 1: Animal Biochemistry

Unit 1: Biochemistry of assimilation (7 Lectures)

Digestion and absorption of food, Detoxification, biochemistry of specialized tissues – connective tissue, skin, muscle, nervous tissue and blood and other body fluids.

Unit 2: Nutrients and their biochemistry (7 Lectures)

Water, electrolyte and acid-base balance, structure, function and mechanism of major trace elements, vitamins, energy nutrients and biochemistry of respiration, bioactive peptides and functional oligosaccharides.

Unit 3: Hormones and their role (7 Lectures)

Hormones of thyroid, hypothalamus, pituitary, pancreas, adrenals and sex hormones, Membrane receptors of hormones, signal transduction.

Unit 4: Immune system (7 Lectures)

Immune systems, immunoglobulins, monoclonal antibodies, formation of antibody, antibody diversity, complement system – classical and alternate, major histocompatibility complexes, cell mediated immune response, mechanisms of immunity.

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

Students can acquire essential foundation knowledge for further study in life sciences, agriculture, environmental science, health science, etc.

IX. Suggested Reading

- Bradley, A. 2018. Animal Physiology and Biochemistry. 1st edition. Edtech Press
- Agarwal RA, Srivastava, A.K. and Kumar, K. 2010. *Animal Physiology and Biochemistry*. Fifth revised edition S. Chand.
- Rodwell VA, Bender DA, Botham KM, Kennelly PJ and Weil PA. 2018. *Harper's Illustrated Biochemistry*, 31st edition. McGraw-Hill Education.

I. Course Title : Nutritional Biochemistry

II. Course Code : BIOCHEM 509

III. Credit Hours : 2+1

IV. Why this course?

Nutritional biochemistry deals with the structural and functional characteristics of macro and micronutrients in food consumed by humans. The course will expand understanding of the biological roles of nutrients and their metabolism using basic knowledge in physiology, biochemistry, cell biology and molecular biology. It will integrate information on the roles of nutrients in nutrition and health.

V. Aim of the course

To impart knowledge regarding the biochemical aspects of various nutrients and their interactions in foods during processing, storage and deterioration.

No.	Blocks	Units
1.	Nutritional biochemistry	1. Fundamentals of human nutrition 2. Biochemical functions of nutrients 3. Bioavailability of nutrients 4. Food sensitivity

VI. Theory

Block 1: Nutritional Biochemistry

Unit 1: Fundamentals of human nutrition (7 Lectures)

Fundamentals of human nutrition, concept of balanced diet, biochemical composition, energy and food value of various food grains (including cereals, pulses, oilseeds),

fruits and vegetables. Physico-chemical, functional and nutritional characteristics of carbohydrates, proteins and fats and their interactions (emulsions, gelation, browning etc.). Digestion and absorption, digestive secretions, their characteristic features and control, protection of microflora of the GI tract

Unit 2: Biochemical functions of nutrients (7 Lectures)

Biochemical functions of nutrients, macro- and micronutrients- carbohydrates, fats and proteins, vitamins, water soluble and fat soluble vitamins, mineral and phytonutrients, prebiotics and probiotics, enzymes and metabolic protein factors, cofactor role, electrolytic function, constituents of skeletal tissues, interrelationship in nutrient functions, mineral deficiency diseases; nutraceuticals, antinutritional factors, biochemistry of postharvest storage.

Unit 3: Bioavailability of nutrients (7 Lectures)

Factors affecting bioavailability of nutrients, biological value of proteins; effect of cooking, processing and preservation of different food products on nutrients, energy- and micronutrient malnutrition, deficiency diseases of macro and micronutrients.

Unit 4: Food sensitivity (7 Lectures)

Food sensitivity: immunologically mediated food sensitivity, nature and properties of antigens in foods, mechanism of induction of all allergic reactions, diagnostic tests for food, hypersensitivity, non-immunologically mediated food sensitivity, food sensitivity due to metabolic diseases, gastrointestinal diseases, food additives, pharmacologic agents, food toxins and poisonous and psychological factors.

VII. Practicals

- Estimation of amylose and amylopectin
- Estimation of resistant starch
- Estimation of ù3, ù6 and trans fatty acid
- Estimation of phenols in plant tissue/sample
- Estimation of carotenoids
- Estimation of amylase, trypsin and chymotrypsin inhibitor activities
- Estimation of Vitamin C in fruits
- Estimation of reducing & non reducing sugar in fruits
- Estimation of protein contents
- Estimation of dietary fibre
- Determination of limiting amino acids
- Estimation of phytate/ oxalate
- Estimation of total antioxidant activity by different methods
- Estimation of curcumin.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

On successful completion of this course students should be able to critically analyse and evaluate concepts in nutritional biochemistry that are important for an

understanding of human nutrition, provide nutritional advice based on sound scientific findings, discuss the efficacy and appropriate use of functional foods and critically evaluate nutrition information appearing in popular magazines and other forms of media.

X. Suggested Reading

- Damodaran S. and Parkin KL (ed.) 2017. *Fennema's Food Chemistry*. CRC Press
- Gibney MJ, Lanham-New SA, Cassidy, A and Voster HH (ed.) 2009. *Introduction to Human Nutrition*. Wiley-Blackwell
- Trueman, P. 2007. *Nutritional Biochemistry*. MJP Publishers
- Cox, C. 2015.*Nutritional Biochemistry: Current Topics in Nutrition Research*. Apple Academic Press Inc.
- Haugen, S. and Meijer, S. 2010. *Handbook of Nutritional Biochemistry: Genomics, Metabolomics & Food Supply*. Nova Science Publishers Inc.

I. Course Title : Nitrogen and Sulfur Metabolism

II. Course Code : BIOCHEM 510

III. Credit Hours : 2+1

IV. Why this course?

Nitrogen and sulfur compounds are continuously synthetized, degraded and converted into other forms in nature. They coexist in the biosphere as free elements or in the form of oxyanions which are to be reduced before undergoing anabolic processes to form N and S containing compounds. This course will provide the students a fundamental understanding of their reduction, assimilation and metabolism in plants.

V. Aim of the course

To impart knowledge of general nitrogen and sulfur metabolism in plants and the assimilatory pathways.

No.	Blocks	Units
1.	Nitrogen and sulfur metabolism	1. Nitrogen metabolism 2. Sulfur metabolism

VI. Theory

Block 1: Nitrogen and Sulfur Metabolism

Unit 1: Nitrogen metabolism (18 Lectures)

Nitrogen cycle, assimilation of inorganic nitrogen, nitrate uptake and transporters, enzymology of nitrate reduction - Nitrate reductase (NR) and Nitrite reductase (NiR), NR regulation, nitrate signaling.

Assimilation of inorganic nitrogen and N-transport amino acids - glutamine synthetase (GS), glutamate synthase (GOGAT), glutamate dehydrogenase (GDH), aspartate amino transferase (AspT) and asparagine synthetase (AS), interaction between carbon metabolism and amino acid synthesis, biosynthesis of amino acids. Nitrogen fixation - an overview, enzymology of nitrogen fixation - nitrogenase, *nif* genes and their regulation, symbiotic nitrogen fixation - biochemical basis of rhizobial infection, nodule development. Mechanism of creation of microaerobic

environment for nitrogen fixation. metabolic exchange between host plant and bacteroids.

Unit 2: Sulphur metabolism (10 Lectures)

Overview of sulfate assimilation, sulfur chemistry and function, sulfate uptake and transport, reductive sulfate assimilation pathway, synthesis and function of sulfur containing amino acids, glutathione and its derivatives, role of sulfated compounds in metabolism.

VII. Practicals

- Estimation of nitrite content,
- Estimation of nitrate content,
- *In vivo* assay of nitrate reductase activity,
- *In vitro* assay of nitrate reductase activity,
- *In vitro* assay of nitrite reductase activity,
- *In vitro* assay of glutamine synthetase activity,
- *In vitro* assay of glutamate synthase and glutamate dehydrogenase activity,
- Estimation of ureides and amides,
- Assay of nitrogenase activity by acetylene reduction method,
- Estimation of hydrogen evolution by legume nodules,
- Estimation of cysteine, methionine, pyruvate and glutathione,
- Assay of APS activity.

VIII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

IX. Learning outcome

Students will get an insight into the nitrogen and sulfur metabolism in plants and the coordination between nitrogen (N) and sulfur (S) assimilation

X. Suggested Reading

- Bothe, H. and Trebst, A. (eds.). 1981. *Biology of Inorganic Nitrogen and Sulfur*. Conference proceedings. Springer-Verlag
- De Kok *et al*. 2012. *Sulfur Metabolism in Plants*. Part of the Proceedings of the International Plant Sulfur Workshop book series. Springer
- Bray CM. 1983. *Nitrogen Metabolism in Plants*. Longman.
- Bidwell, R.G.S. 1983. *Plant Physiology: A Treatise*, Vol. 8: Nitrogen Metabolism. Academic Press
- Foyer. C. H. and Zhang, H. 2010. *Nitrogen Metabolism in Plants in the Post-Genomic Era.* Annual Plant Reviews, Vol.42. Wiley-Blackwell
- Buchanan B.B., Gruissem W. and James R. L. (Eds.). 2000. *Biochemistry and Molecular Biology of Plants*. American Society of Plant Physiologists.

I. Course Title : Biochemistry on Xenobiotics

II. Course Code : BIOCHEM 511

III. Credit Hours : 2+0

IV. Why this course?

Xenobiotics are compounds that are foreign to an organism that include compounds

like drugs, food additives, and environmental pollutants. Knowledge on metabolic conversion of xenobiotics, especially drugs and environmental contaminants in living system becomes pertinent in present day scenario with increased levels of pollution.

V. Aim of the course

To impart knowledge on xenobiotics and the mechanism of their metabolism and detoxification in living system.

No.	Blocks	Units
1.	Biochemistry on xenobiotics	1. Xenobiotics 2. Mode of degradation 3. Plant metabolism of xenobiotics 4. Phytoremediation

VI. Theory

Block 1: Biochemistry on Xenobiotics

Unit 1: Xenobiotics (7 Lectures)

Xenobiotics: classification and their effects on biological systems, Problems related to xenobiotics degradation, potential effects of toxic agents on immune system function, biotic metabolism of xenobiotics - biodegradation/biotransformation

Unit 2: Mode of degradation (7 Lectures)

Mode of degradation - Enzymatic and Non-enzymatic, Metabolism of toxic compounds with reference to role of detoxifying enzymes, Mechanism of xenobiotics detoxification - in animal using the enzymes of Phase I and Phase II, Role of microbes in xenobiotics degradation and co-metabolism, Biodegradation and its genetics, manipulation of xenobiotic degradative genes

Unit 3: Plant metabolism of xenobiotics (7 Lectures)

Plant metabolism of xenobiotics - transformation, conjugation and compartmentation, Metabolic responses of pesticides in plants, Impact, metabolism, and toxicity of heavy metals in plants, Regulation of xenobiotics in higher plants: signalling and detoxification.

Unit 4: Phytoremediation (7 Lectures)

Phytoremediation, Advances in development of transgenic plants for remediation of xenobiotic pollutants, safety assessment of xenobiotics

VII. Teaching methods/activities

- Classroom lectures (oral + audio-visual)
- Assignment (Reading/Writing)
- Oral presentation by students on specified topics
- Class room quiz
- Case study

VIII. Learning outcome

Students will gain the basic knowledge and perspectives of bioelimination of xenobiotic compounds.

IX. Suggested Reading

- Richardson, M. 1996. *Environmental Xenobiotics*. CRC Press
- Singh, A., Prasad, S.M. and Singh, R.P.(eds). 2016. *Plant Responses to Xenobiotics*. Springer.
- Chang, Y-C. (ed). 2019. *Microbial Biodegradation of Xenobiotic Compounds*. CRC Press
- Costas Ioannides (ed). 2002. Enzyme Systems that Metabolise Drugs and Other Xenobiotics. Wiley
- Lee, P., Aizawa, H., Gan, L., Prakash, C. And Zhong, D. 2014. *Handbook of Metabolic Pathways of Xenobiotics*. –
- Emerson, M.L. 2012. Xenobiotics*: New Research*. Nova Science
- Shamaan, N.A. 2008. *Biochemistry of xenobiotics: towards a healty lifestyle and safe environment*. PenerbitUniversiti Putra Malaysia.

Course Title with Credit Load
M.Sc. (Ag) in Plant Physiology

Course Code	Course Title	Credit Hours
PP 501*	Principles of Plant Physiology-I: Plant Water Relations and Mineral Nutrition	2+1
PP 502*	Principles of Plant Physiology-II: Metabolic Processes and Growth Regulation	2+1
PP 503*	Plant Developmental Biology: Physiological and Molecular Basis	2+1
PP 504	Physiological and Molecular Responses of Plants to Abiotic Stresses	2+1
PP 505	Hormonal Regulation of Plant Growth and Development	2+1
PP 506	Physiological and Molecular Mechanisms of Mineral Nutrient Acquisition and their Functions	2+1
PP 507	Photosynthetic Processes, Crop Growth and Productivity and Concepts of Crop Modelling	2+1
PP 508	Physiology of Field Crops	2+0
PP 509	Physiology of Horticulture Crops	2+0
PP 510*	Seed Physiology	2+1
PP 511	Phenotyping Physiological Processes	2+0
PP 512	Crop Growth Regulation and Management	2+0
PP 591	Master's Seminar	1+0
PP 599	Master's Research	30

Course Contents
M.Sc. (Ag) in Plant Physiology

I. Course Title : Principles of Plant Physiology I - Plant Water Relations and Mineral Nutrition

II. Course Code : PP 501*

III. Credit Hours : 2+1

IV. Why this Course?

Plant's growth and development and therefore, agricultural productivity depends on two major inputs like water and nutrients. In this regard, this course being a fundamental course will acquaint the students with the basic concepts of plant water relations and mineral nutrition. The course provides a basic knowledge on water and nutrient acquisition and their transport throughout the phenological stages. Further, it also provides hands on experience in assessing the plant and soil water status besides nutrient acquisition by plants.

V. Aim of the Course

The aim of this course is to impart knowledge in the field of water relations and mineral nutrition and how plants acquire water and transport it under different soil water regimes and also make use of the water in an effective way to maximize use efficiency. In addition, the other aim is to impart knowledge of how plants minimize water loss under stress conditions besides educating the students of how plants make use of nutrients in a best possible way.

The course is organized as follows:

No.	Blocks	Units
1.	Plant Water Relations	1. Soil and Plant Water Relations 2. Water Absorption and Translocation 3. Transpiration and Evaporative Cooling 4. Water Productivity and Water Use Efficiency 5. Moisture Stress and Plant Growth
2.	Mineral Nutrition	1. Nutrient Elements and their Importance 2. Nutrient Acquisition 3. Concept of Foliar Nutrition

VI. Theory

Block 1: Plant Water Relations

Unit 1: Soil and Plant Water Relations

Water and its importance; Molecular structure of water; Properties and functions of water. Concept of water potential; Plant cell and soil water potential and their components; Methods to determine cell and soil water potential; Concept of osmosis and diffusion. Soil physical properties and water availability in different soils;

Water holding capacity and approaches to improve WHC; Concept of FC and PWP; Water holding polymers and their relevance.

Unit 2: Water Absorption and Translocation

Root structure and functions; Root architecture and relevance in water mining; Mechanism of water absorption and translocation; Theories explaining water absorption and translocation; Aquaporins. Mycorrhizal association and its relevance in water mining.

Unit 3: Transpiration and Evaporative Cooling

Evaporation and transpiration; relevance of transpiration; factors regulating transpiration; Measurement of transpiration; approaches to minimize evaporation and transpiration; Concept of CCATD and its relevance. Energy balance: Solar energy input and output at crop canopy level. Stomata- its structure, functions and distribution; Molecular mechanisms of stomatal opening and closing; Concept of guard cell turgidity; role of K and other osmolytes; role of ABA in stomatal closure; Guard cells response to environmental signals; Signaling cascade associated with stomatal opening and closure. Antitranspirants and their relevance in agriculture.

Unit 4: Water Productivity and Water Use Efficiency

WUE and its relevance in water productivity; Transpiration efficiency, a measure of intrinsic WUE; Approaches to measure WUE; Stomatal and mesophyll regulation on WUE; Passioura's yield model emphasizing WUE.

Unit 5: Moisture Stress and Plant Growth

Physiology of water stress in plants; Effect of moisture stress at molecular, cellular, organ and plant level. Drought indices and drought tolerance strategies. Drought tolerance traits.

Block 2: Mineral Nutrition

Unit 1: Nutrient Elements and Their Importance

Role of mineral nutrients in plant's metabolism; Essential elements and their classification; Beneficial elements; factors influencing the nutrients availability; critical levels of nutrients. Functions of mineral elements in plants. Deficiency and toxicity symptoms in plants.

Unit 2: Nutrient Acquisition

Mechanism of mineral uptake and translocation; Ion transporters; genes encoding for ion transporters; localization of transporters; xylem and phloem mobility; Nutrient transport to grains at maturity; Strategies to acquire and transport minerals under deficient levels. Role of mycorrhiza, root exudates and PGPRs in plant nutrient acquisition.

Unit 3: Concept of Foliar Nutrition

Foliar nutrition; significance and factors affecting total uptake of minerals; Foliar nutrient droplet size for effective entry; role of wetting agents in entry of nutrients.

VII. Practicals

- Standard solutions and preparation of different forms of solutions
- Studies on the basic properties of water
- Demonstration of surface tension of water and other solvents
- Measurement of plant water status: Relative water content and rate of water loss

- Determination of water potential through tissue volume and Chardakov's test
- Determination of water potential using pressure bomb, osmometer, psychrometer
- Determination of soil moisture content and soil water potential
- Use of soil moisture probes and soil moisture sensors
- Measurement of transpiration rate in plants; use of porometry
- Measurement of CCATD and its relevance
- Demonstration and use of anti-transpirants to reduce transpiration
- Influence of potassium and ABA on stomatal opening and closing respectively
- Deficiency and toxicity symptoms of nutrients
- Effect of water stress on plant growth and development

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

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

- comprehend the fundamental concepts of plant physiological processes associated with water relation and mineral nutrition.
- describe the physiological mechanisms of water relation and mineral nutrition.
- recognize and describe how plants respond to mineral deficiency and toxicity.

X. Suggested Reading

- Vilalta JM and Forner NG. 2017. *Water potential regulation, stomatal behaviour and hydraulic transport under drought: deconstructing the iso/anisohydricconcept Plant, Cell and Environment* 40, 962–976
- Mangrich AS, Cardoso EMC, Doumer ME, Romão LPC, Vidal M, Rigol A, Novotny EH. *Improving the Water Holding Capacity of Soils of Northeast Brazil by Biochar Augmentation*. Chapter 16, pp 339–354.
- McElrone AJ, Choat B, Gambetta GA and Brodersen CR. 2013. *Water Uptake and Transport in Vascular Plants*. *Nature Education Knowledge* 4(5): 6
- Hodson RC and J Acuff. 2006. *Water transport in plants: anatomy and physiology*. Pages 163-183, *Tested Studies for Laboratory Teaching*, Volume 27 (M.A. O'Donnell, Editor). Proceedings of the 27th Workshop/Conference of the Association for Biology Laboratory Education (ABLE), 383 pages.
- Chater CCC, Caine RS, Fleming AJ, Gray JE. 2017. *Plant Physiology*, 174 (2) 624-638; DOI: 10.1104/pp.17.00183
- Dietrich P, Sanders D, Hedrich R. 2001. *The role of ion channels in light dependent stomatal opening, Journal of Experimental Botany*, Volume 52, Issue 363, Pages 1959–1967, https://doi.org/10.1093/jexbot/52.363.1959
- Sreeman SM, Vijayaraghavareddy P, Sreevathsa R, Rajendrareddy S, Arakesh S, Bharti P, Dharmappa P, Soolanayakanahally R. 2018. *Introgression of Physiological Traits for a Comprehensive Improvement of Drought Adaptation in Crop Plants. Front. Chem*. 6, 92.
- Seyed Yahya Salehi-Lisar Hamideh Bakhshayeshan-Agdam, (2016). Drought Stress in Plants: Causes, Consequences, and Tolerance. Drought Stress Tolerance in Plants, Vol 1 pp 1-16
- Pandey R. 2015. *Mineral Nutrition of Plants*. 10.1007/978-81-322-2286-6_20.
- Barker AV and DJ Pilbeam. 2015. Handbook of Plant Nutrition, Second Edition. Books in Soils, Plants, and the Environment Series, the 2nd Edition, CRC Press.
- Vatansever R, Ozyigit II and Filiz E. 2017. *Essential and beneficial trace elements in plants, and their transport in roots: a review. Applied biochemistry and biotechnology* 181(1), 464-482..

- Tahat MM and Sijam K. 2012. *Arbuscularmycorrhizal fungi and plant root exudates bio-communications in the rhizosphere. African Journal of Microbiology Research*, 6(46), 7295-7301.
- Rajasekar MD, Nandhini DU and Suganthi S. 2017. *Supplementation of Mineral Nutrients through Foliar Spray – A Review. Int.J.Curr.Microbiol.App.Sci.* 6(3): 2504-2513.https://doi.org/10.20546/ijcmas.2017.603.283
- Tarek A and Hassan ER. 2017. *Foliar application: from plant nutrition to biofortification*. Environment, Biodiversity and Soil Security. 10.21608/jenvbs.2017.1089.1006.

General Source of Information

- Taiz T, Zeiger E and Max Mller IM, 2018, *Fundamentals of Plant Physiology*
- Taiz L and Zeiger E. 2015. *Plant Physiology and development*.6th Ed
- Salisbury FB and Ross C. 1992 (4th Ed.) *Plant Physiology*
- Epstein E and Bloom AJ. 2004. *Mineral nutrition of plants: principles and perspectives*.2nd Ed.
- Hopkins WG and Huner NPA. 2004. *Introduction to Plant Physiology*
- Kramer, P. J., *Water relations of plants*
- Kirkham, M. B., *Principles of soil and plant water relations*
- Hopkins WG, 2008, *Introduction to Plant Physiology*

I. Course Title : Principles of Plant Physiology-II: Metabolic Processes and Growth Regulation

II. Course Code : PP 502*

III. Credit Hours : 2+1

IV. Why this course?

Mechanisms associated with growth and development determine crop performance under any given condition. Metabolic and growth processes are quite sensitive to environmental factors and hence comprehensive understanding of the physiological basis of growth and development would be essential.

V. Aim of the course

This course will impart knowledge on cellular structure and function that determine of carbon and nitrogen metabolism, lipids, enzymes and secondary metabolites in plants. Relevance of metabolic processes on growth and development leading to productivity will be dealt.

The course is organized as follows:

No.	Blocks	Units
1.	Metabolic processes and growth regulation	1. Carbon Metabolism–Photochemical Processes 2. Carbon Metabolism: Biochemical Processes 3. Carbon Metabolism: Respiration 4. Product Synthesis and Translocation Leading to Crop Growth 5. Nitrogen Assimilation and Protein Synthesis 6. Lipid Metabolism and Secondary Metabolites 7. Hormonal Regulation of Plant Growth and Development 8. Synthetic Growth Promoters 9. Morphogenesis and Reproductive Phase

VI. Theory

Block 1: Metabolic Processes and Growth Regulation

Unit 1: Carbon Metabolism – Photochemical Processes

- Chloroplast ultrastructure with special mention of lamellar system
- Excitation, electron and proton transfers and their relevance in energy conservation
- Concepts of pigment systems and generation of powerful reductant and oxidant
- Water oxidation, Water-water cycle and other aspects of electron transfer

Unit 2: Carbon Metabolism: Biochemical Processes

- CO_2 diffusion mechanisms and diffusive conductances, concept of Ci determining Photosynthesis
- RuBisCO enzyme kinetics and Calvin cycle mechanisms, Regulation of Calvin cycle and metabolite fluxes
- Photorespiration: the advantages and inefficiencies of photosynthesis because of photorespiration
- Concepts of CO_2 concentrating mechanisms (CCM) and spatial and temporal differences in carboxylation
- Ecological aspects of $C_4$and CAM photosynthesis
- Product synthesis, Starch and Sucrose biosynthesis

Unit 3: Carbon Metabolism: Respiration

- Mitochondrial organization and functions
- Aspects of Glycolysis, TCA cycle and mitETC.
- Relevance of growth and maintenance respiration
- Concepts of CN resistance respiration – Alternate and SHAM sensitive ETC

Unit 4: Product Synthesis and Translocation Leading to Crop Growth

- Phloem loading and sugar transporting, concepts of bi-directional transport of sugars and other metabolites
- Source-Sink relationship and modulation of photosynthesis
- Concepts and definitions of Growth and Differentiation
- Growth and yield parameters, NAR, CGR, HI and concepts of LAI, LAD

Unit 5: Nitrogen Assimilation and Protein Synthesis

- Developments in d-nitrgen fixation
- Nitrate reduction and assimilation GS-GOGAT process for amino acid synthesis
- Inter-Dependence of carbon assimilation and nitrogen metabolisms

Unit 6: Lipid Metabolism and Secondary Metabolites

- Storage, protective and structural lipids.
- Biosynthesis of fatty-acids, diacyl and triacyl glycerol, fatty acids of storage lipids.
- Secondary metabolites and their significance in plant defense mechanisms.

Unit 7: Hormonal Regulation of Plant Growth and Development

- Growth promoting and retarding hormones: biosynthesis, transport, conjugation
- Mode of action of these hormones and their application in plant physiology

Unit 8: Synthetic Growth Promoters

- Different synthetic hormones: Salicylic acid, strigolactones etc
- Roles and biological activities of various synthetic hormones
- Commercial application of hormones to maximize growth and productivity

Unit 9: Morphogenesis and Reproductive Phase

- Photoperiodism: Phytochromes, their structure and function
- Circadian rhythms,
- Blue light receptors: Cryptochrome and morphogenesis.
- Vernalization and its relevance in germination.

VII. Practicals

- Radiant energy measurements
- Separation and quantification of chlorophylls
- Separation and quantification of carotenoids
- O_2 evolution during photosynthesis
- Anatomical identification of C_3 and C_4 plants
- Measurement of gas exchange parameters, conductance, photosynthetic rate, photorespiration
- Measurement of respiration rates
- Estimation of reducing sugars, starch
- Estimation of NO_3, free amino acids in the xylem exudates, quantification of soluble proteins
- Bioassays for different growth hormones- Auxins, Gibberellins, Cytokinins, ABA and ethylene
- Demonstration of photoperiodic response of plants in terms of flowering

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

IX. Learning outcome

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

- figure out the fundamental metabolic processes in plant
- describe the physiological mechanisms and metabolic events associated with regulation of plant growth

X. Suggested Reading

- Kirchhoff H. 2019. *Chloroplast ultrastructure in plants*, New Phytologist. Doi.org/10.1111/nph.15730
- Jafari T, Moharreri E, Amin A, Miao R, Song W and Suib S. 2016. *Photocatalytic water splitting—the untamed dream: a review of recent advances. Molecules*, *21*(7), 900.
- Jensen E, Cle´ment R, Maberly SC, Gontero B. 2017. *Regulation of the Calvin –Benson–Bassham cycle in the enigmatic diatoms: biochemical and evolutionary variations on an original theme. Phil. Trans. R. Soc. B* 372: 20160401. doi.org/10.1098/rstb.2016.0401
- Raven, J. A., and Beardall, J. 2015. *The ins and outs of CO2. Journal of experimental botany*, *67*(1), 1-13.
- Rae, B. D., Long, B. M., Förster, B., Nguyen, N. D., Velanis, C. N., Atkinson, N. .and McCormick, A.J. 2017. *Progress and challenges of engineering a biophysical CO2-concentrating mechanism into higher plants. Journal of Experimental Botany*, *68*(14), 3717-3737.
- Hagemann M, Weber AP and Eisenhut M. 2016. *Photorespiration: origins and metabolic integration in interacting compartments. Journal of experimental botany*, 67(10), 2915.
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General Text books

- *Taiz, Lincoln, Zeiger. 2007 Plant Physiology, Eduardo Original American edition Sinauer Associates, Inc., 2006; 4th ed., XXVI, ISBN: 978-3-8274-1865-4; © Springer.*
- *Plant Physiology* Frank Boyer Salisbury and Cleon Ross.
- *Introduction to Plant Physiology* (Wie)by William G. Hopkins.

I. Course Title : Plant Developmental Biology: Physiological and Molecular Basis

II. Course Code : PP 503*

III. Credit Hours : 2+1

IV. Why this Course?

From the conventional description information on plant growth and development based on morphology and anatomy, phenomenal changes and leads taken place in the last one and half decade to address these processes at physiological, biochemical

and molecular levels. This basic understanding has provided options to regulate these processes genetically using genetic and molecular tools and by interventions using chemicals and external factors. To give an example on flowering, the progress made regarding the molecular players that regulate flowering, initiation, the photoreceptors like phytochromes and their regulation by the photoperiod-short and long days has provided options to manipulate the flowering time to bring in synchrony, etc. Phenomenal progress also made in several other processes like germination, viability, root development and pollination, etc. The other major area of contribution is in tissue culture where is understanding of plant developmental biology has been put o practical use and knowledge on morphogenesis is exploited to maximum. It is very essential that the students get exposed on these aspects to complement the research programs on crop improvement.

V. Aim of the course

To explain about basic physiological and molecular processes concerning various facets of growth and development of plants. It provides knowledge on basic physiological processes governing developmental events in plants including senescence and fruit development and ripening. Development of vegetative tissue like shoot, leaf and root and morphogenetic phenomena like flower induction and development, factors associated with photoperiod and thermoperiod response. Regulation of morphogenesis would be studied at the molecular level providing information on genes involved. In addition, students will study how to apply the knowledge on plant development and morphogenesis using tissue culture.
The course is organized as follows:

No.	Blocks	Units
1.	Plant Developmental Biology	1. Evolutionary Development of Plants and Role of Environment 2. Physiological and Molecular Determinants of Seed Biology 3. Vegetative Growth and Organ Development 4. Physiological and Molecular Aspects of Reproductive Growth and Development 5. Ripening and Senescence 6. Physiological and Molecular Regulation of Plant Development Influenced by Light and Temperature
2.	Practical application of morphogenesis	1. Tissue culture and micro-propagation 2. Application of in-vitro techniques for crop improvement

VI. Theory

Block 1: Plant Developmental Biology

Unit 1: Evolutionary Development of Plants and Role of Environment

Plant development and plasticity, evolution, Biodiversity. Novel features of plant growth and development, Concept of plasticity-evolution and biodiversity, Model plants for study; Environment and development. Developmental stages and program; Cell-cycle, totipotency and regeneration.

Unit 2: Physiological and Molecular Determinants of Seed Biology

Seed development- Physiology of seed development, role of hormones in embryo development; seed development and maturation. Seed dormancy- Physiological and molecular mechanism of seed dormancy regulation. Seed germination- seed structure and Hormonal regulation of germination, Mobilization of food reserves during seed germination.

Unit 3: Vegetative Growth and Organ Development

Regeneration and totipotency- organ differentiation and development – role of hormones- developmental control genes in crop plants. Meristems in plant development. Shoot, Leaf, Trichome and stomate development and differentiation. Axillary shoot branching; Bud dormancy and growth**.** Root development; Nodule development; Tuber development- hormonal control, signaling and molecular regulation- genes involved. Vascular bundle development- xylem and phloem differentiation

Unit 4: Physiological and Molecular Aspects of Reproductive Growth and Development

Floral Induction and Development: Molecular and physiological mechanism of transition -vegetative to reproductive phase- floral organ initiation and development their controls. Development of male and female gametophyte; gametophytic mutants: pollen-stigma interaction- Pollen germination and tube growth; role of imprinting; Male sterility: and fertility restoration; Self incompatibility; Sterility and fertility restoration, Maternal gene effects, Zygotic gene effects. Sex determination in plants, mate choice in plants. Embryo and endosperm development- fertilization, role of imprinting; Parthenocarpy and apomixes

Unit 5: Ripening and Senescence

Fruit development, enlargement, maturation and ripening; climacteric and non-climacteric fruit ripening mechanism. Hormonal, biochemical & Molecular aspects of fruit ripening. Senescence and its regulation; Hormonal and environmental control of senescence; PCD in the life cycle of plants.

Unit 6: Physiological and Molecular Regulation of Plant Development Influenced by Light and Temperature

Light control of plant development: Phytochromes and cryptochromes, phototropins, their structure, biochemical properties and cellular distribution. Molecular mechanisms of light perception, signal transduction and gene regulation. Photoperiodism and its significance, vernalization and hormonal control. Circadian rhythms-biological clocks and their genetic and molecular determinants. Thermomorphogenesis- Thermoperiodism

Block 2: Application of Morphogenesis and its Practical Application

Unit 1: Tissue culture and micro-propagation

Applications of tissue culture for plant production, callus induction, somatic embryogenesis, regeneration from different explants. Micro-propogation, tip and axillary node culture of commercially important crops, hardening and ex-vitro establishment, concept of somatic hybridization and protoplast culture.

Unit 2: Application of *in-vitro* techniques for crop improvement

Development of somoclones, identification and exploitation of somoclonal variants.

Haploid production, pollen/anther, ovule/ovary culture. Production of secondary metabolites by tissue culture, concept of bio-fermenters. Plant transformation, development of transgenic plants and their characterization. Germplasm storage, cryopreservation and regulation

VII. Practicals

- Studying shoot apical meristem, floral meristem development and pollen tube development
- Phenotyping photomorphogenesis: (a) Studying effect of day length (short day and long day) in regulating floral induction/ flowering time in short day/long day/day neutral plants and (b) effect of light on seed germination in light-sensitive and -insensitive seeds.
- Studying effect of temperature on– (a) thermomorphogenesis- measuring hypocotyl elongation under different temperature conditions and (b) sex determination using cucurbits/sesame plants.
- Measure physiological paramters of fruit ripening and study the expression of key genes regulating ripening.
- Study the effect of ethylene, its inhbibitor and scruber on ripening (tomato).
- Study different sterilization techniques, prepare media stocks and plant hormones.
- Inoculate explant (seed and leaf tissue) of model plant for callus induction.
- Subculture the callus and standerdize regeneration protocol for shoot and root induction using callus and leaf explant.
- Micro-propagation using meristem tip and axillary node culture.
- Standerdize anther/ pollen culture for haploid production in model/crop/horticultural plant.
- Isolation of protoplast from Arabidopsis/tobacco and its culturing
- Study about selectable marker, reporter gene, PCR, southern and northern blotting techniques.
- Transformation of tobacco callus or leaf explant by *Agrobacterium tumefacines* and *Agrobacterium rhizogenes* for production of transgenic
- Molecular characterization of transgenic- PCR, southern blotting, gene expression.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

IX. Learning outcome

After completion of this course students are expected to have knowledge on and insight into the physiological and molecular basis of plant growth and development. The student will develop critical insight in physiological aspects of vegetative growth and reproductive development at molecular level.

X. Suggested Reading

- Niklas KJ. *Plant Evolution- An Introduction to the History of Life.*
- Bahadur *B et al*. (eds.), *Plant Biology and Biotechnology:* Volume I: Plant Diversity, Organization, Function and Improvement
- Jong MD and Leyser O. *Developmental Plasticity in Plants*. Cold Spring Harbor Symposia on Quantitative Biology. 63-73.
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- Franklin KA and Wigge PA. *Temperature and Plant Development*. Wiley Blackwell.
- Franklin KA *et al*. 2014. *Interaction of light and temperature signaling. Journal of Experimental Botany*. 65(11): 2859–2871.
- Bhojwani SS and Razdan MK. *Plant tissue culture: theory and practice, a revised edition*. Elsiver publication.
- Bhojwani SS, Dantu SS and Kumar P. *Plant Tissue Culture: An Introductory Text*.
- George EF and Hall MA. *Plant Propagation by Tissue Culture* 3rd Edition.
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General Source Information

- Eng-Chong Pua and Michael R.Davey: *Plant Developmental Biology - Biotechnological Perspectives*.
- B. Bahadur *et al*. (eds.), *Plant Biology and Biotechnology*: Volume I: Plant Diversity, Organization, Function and Improvement.
- Bewley JD *et al*., *Seeds-Physiology of Development, Germination and Dormancy*.
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I. Course Title : Physiological and Molecular Responses of Plants to Abiotic Stresses

II. Course Code : PP 504

III. Credit Hours : 2+1

IV. Why this course?

With the changing climate, plants are being more frequently exposed to abiotic stresses like, water, salinity, temperature, nutrient, radiation, etc. limiting the productivity. This will not only affect livelihoods of individual farmers but also the food security. Concerted efforts have been made to grow crops under resource limited/stressful environmental conditions and advances in physiology, molecular

biology and genetics have significantly helped in this endeavor. In recent years, our understanding of the physio-morphological, biochemical and molecular adaptation of plants to resource limited/stressful environment is phenomenal. This course will outline different abiotic stresses, their impacts on agricultural productivity, stress tolerance mechanisms, stress mitigation strategies, crop improvement approaches and traits for stress tolerance.

V. Aim of the course

This course aims to describe students the abiotic-stress physiology and their effects on plant growth and productivity. This will also help students gain insights into latest developments in stress physiology and stress tolerance mechanisms, approaches for crop improvement under stressful environment.

The course is organized as follows:

No.	Blocks	Units
1.	Abiotic Stresses	1. Introduction to Abiotic Stresses
2.	Drought Stress	1. Moisture Stress Responses in Plants 2. Stress Perception and Molecular Responses of Plants to Drought Stress 3. Plant Adaptive Mechanisms to Drought 4. Approaches to Improve Drought Tolerance
3.	Salt, Heavy Metal, Water Logging, Temperature and Light Stress	1. Salt Stress 2. Heavy Metal Stress and Water Logging 3. Temperature and Light Stress

VI. Theory

Block 1: Abiotic Stresses

Unit 1: Introduction to Abiotic Stresses

Abiotic stresses major constraints to realize potential yields of crop plants, yield losses. Drought prone areas in India- Frequency of occurrence of drought, Rainfed-kharif, Rabi, Areas affected by salinity, heavy metals, water logging, high temperature scenario due to global warming.

Block 2: Drought Stress

Unit 1: Moisture Stress Responses in Plants

Drought-characteristic features; water potential in the soil-plant-air continuum. Physiological and biochemical processes affected by drought.Oxidative stress-generation of ROS and other cytotoxic compounds, their effect on cellular process. Effect on total carbon gain- decrease in photosynthetic area and function, protein turn over and lipid characters, phenology-reproductive aspects, critical stages.

Unit 2: Stress Perception and Molecular Responses of Plants to Drought Stress

Stress perception andsignal transduction leading to expression of regulatory genes, stress specific kinases, stress specific transcription factors, functional genes associated with adaptive mechanisms.

Unit 3: Plant Adaptive Mechanisms to Drought

(a) Escape and desiccation avoidance mechanism

Concept of stress escape- exploiting genetic variability in phenology, Drought avoidance mechanisms- Maintenance of cell turgor, water mining by root characters. Moisture conservation- Regulation of transpiration- traits reducing heat load, Stomatalfactors guard cell metabolism, moisture conservation by waxes. Water use efficiency (WUE) and concept of water productivity- regulation of transpiration efficiency-stomatal conductance, mesophyll efficiency, relevance of WUE and Passioura's model.

(b) Desiccation tolerance- Concept of acquired tolerance

Decreased turgor mediated upregulation of cellular tolerance mechanisms, Osmolytes, managing cytotoxic compounds, ROS, RCC, scavenging - enzymatic and non-enzymatic, protein turnover, stability, chaperones, membrane stability, photo-protection of chlorophylls.

Unit 4: Approaches to Improve Drought Tolerance

Development of genetic resources- donor genotypes for specific traits, Genomic resources- genes, QTL's regulating adaptive mechanisms, Conventional, transgenic and molecular breeding approaches to improve relevant adaptive traits, concept of trait introgression.

Block 3: Salt, Heavy Metal, Water Logging, Temperature and Light Stress

Unit 1: Salt Stress

Soil salinity-Effect of salt stress, ionic and osmotic effects; species variation in salt tolerance; glycophytes and halophytes, Salt tolerance mechanisms - exclusion, extrusion and compartmentalization, Signaling during salt stress – SOS pathway, Approaches to improve salt tolerance.

Unit 2: Heavy Metal Stress and Water Logging

Heavy metal toxicity in plants (eg., Al, Cd), tolerance mechanisms and approaches to improve. Plant response to water logging, role of hormones- ethylene, mechanism of tolerance and approaches to improve.

Unit 3: Temperature and Light Stress

High and low temperatures; effect on plants; adaptive mechanisms, evaporation cooling, concept of cellular tolerance, protein stability, chaperones, HSPs, HSFs, membranes. High light and high ionizing radiation- photo oxidation and photo-inhibition; mechanisms of tolerance, plant adaptation to low light, concept of shade avoidance response (SAR).

VII. Practicals

- Measurement of soil and plant water status.
- Drought stress imposition and measurement of physiological and biochemical changes in plants under stress –gas exchange and fluorescence measurements.
- Determination of water use efficiency as a drought resistant trait.
- Drought Susceptibility Index (DSI) -precise field technique to identify productive genotypes under stress.
- Approaches to quantify root characters
- Determination of stomatal parameters and canopy temperature as a reflection of transpiration and root activity.
- Determination of Salinity Tolerance Index.
- Studying acclimation response - Temperature induction response.

- Heat tolerance and membrane integrity- Sullivans heat tolerance test.
- Quantification of osmolytes – proline under stress.
- Oxidative stress imposition- Quantification of oxidative stress
- Quantification of ROS under stress.
- Estimation of ABA content in leaf and root tissues under stress.
- Determination of Sodium and Potassium in plant tissue grown under salt stress.
- Estimation of antioxidant enzymes.

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

After completion of this course students are expected to have knowledge on and insight into the physiological and molecular responses of plants to abiotic stresses. The student will develop critical insight in adaptive mechanisms of plants against various abiotic stresses.

X. Suggested Reading

- *Plant Physiology Book by Eduardo Zeiger and Lincoln Taiz.*
- Plant Physiology Book by Frank B. Salisbury, Cleon W. Ross Salisbury, Frank B
- Pereira A. 2016. *Plant Abiotic Stress Challenges from the Changing Environment. Front. Plant Sci*. 7: 1123. doi: 10.3389/fpls.2016.01123
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I. Course Title : Hormonal Regulation of Plant Growth and Development

II. Course Code : PP 505

III. Credit Hours : 2+1

IV. Why this Course?

Many plant growth and developmental processes are regulated by phytohormones.

It is important to understand the hormone biosynthesis, structure, function, signal transduction and their practical application. It is also important to provide basic knowledge on manipulating growth and developmental processes using plant hormones.

V. Aim of the course

It provides knowledge on the fundamentals of hormone biosynthesis, homeostasis, transport and signaling and the role in regulating basic physiological processes governing developmental events in plants.The role of classical hormones on developmental processes from germination, shoot and root apical meristem differentiation, flowering, seed maturation and senescence. The aim of this course is to appraise the students about structure and function of plant growth regulators. The course is organized as follows:

No.	Blocks	Units
1.	Plant Growth and Development: Hormonal Regulation	1. Introduction to Plant Hormones 2. Plant Hormones - Discovery and Metabolism 3. Physiological Role of Hormones in Plant Growth and Development 4. Endogenous Growth Substances other than Hormones 5. Hormone Signaling 6. Key Genes Regulating Hormone Levels and Functions 7. Crosstalk of Hormones in Regulation of Plant Growth and Development Processes 8. Practical Utility of Growth Regulators in Agriculture and Horticulture

VI. Theory

Block 1: Plant Growth and Development: Hormonal Regulation

Unit 1: Introduction to Plant Hormones

Growth, differentiation and development regulated by plant growth substances, Definition and classification of growth regulating substances: Classical hormones, Definition and classification of growth regulating substances: Endogenous growth substances other than hormones, Synthetic chemicals.

Unit 2: Plant Hormones – Discovery and Metabolism

Discovery, biosynthetic pathways and metabolism of Auxin, Discovery, biosynthetic pathways and metabolism of Gibberellins, Discovery, biosynthetic pathways and metabolism of Cytokinins, Discovery, biosynthetic pathways and metabolism of Abscisic acid, Discovery, biosynthetic pathways and metabolism of Ethylene, Discovery, biosynthetic pathways and metabolism of Brassinosteroids, Discovery, biosynthetic pathways and metabolism of Strigolactones.

Unit 3: Physiological Role of Hormones in Plant Growth and Development

Physiological functions of Auxin and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Gibberellins and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Cytokinins and use of mutants and transgenic plants in

elucidating the physiological functions, Physiological functions of Abscisic acid and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Ethylene and use of mutants and transgenic plants in elucidating the physiological functions, Physiological functions of Brassinosteroidsand Strigolactones and use of mutants and transgenic plants in elucidating the physiological functions, Discovery, biosynthetic pathways metabolism and physiological roles of Salicylic acid and Peptide hormones.

Unit 4: Endogenous Growth Substances other than Hormones

Discovery, biosynthetic pathways metabolism and physiological role of Polyamines and Karrikins, Discovery, biosynthetic pathways metabolism and physiological roles of Jasmonates and Tricontanol, Discovery, biosynthetic pathways metabolism and physiological roles of systemins Concept of death hormone, Recent developments in elucidating responses of Salicylic acid, Peptide hormones and Polyamines at physiological and molecular level, Recent developments in elucidating responses of Jasmonates, Systemins, Karrikins and Tricontanol at physiological and molecular level.

Unit 5: Hormone Signaling

Hormone signal perception, transduction - Receptors, components and mechanism (Auxin, Gibberellin, Cytokinin, ABA and Salicylic acid), Hormone signal perception, transduction - Receptors, components and mechanism (Ethylene, Jasmonate, Brassinosteroids and strigolactones), Advances in elucidating the structure and function of receptors and signaling components of important hormones.

Unit 6: Key Genes Regulating Hormone Levels and Functions

Genomics approaches to regulate hormone metabolism and its effect on plant growth and development – case studies.

Unit 7: Crosstalk of Hormones in Regulation of Plant Growth and Development Processes

Crosstalk of Hormones in Regulation of Plant Growth and Development Processes: Floral transition, reproductive development, Shoot and root apical meristem development

Unit 8: Practical Utility of Growth Regulators in Agriculture and Horticulture

Practical Utility of Growth Regulators in Agriculture and Horticulture: Rooting of cuttings, Vine and brewing industry, Promotion of gynoecious flowers, hybrid rice production, induction of flowering in pine apple, cucurbits, Practical Utility of Growth Regulators in Agriculture and Horticulture: Delaying of senescence and ripening, Production of dwarf plants for ornamental purpose, As herbicides, Reduction in flower and fruit drop.

VII. Practicals

- Extraction of Auxins from plant tissue
- Separation and detection of Auxins by GC / GC-MS / HPLC / Immunological technique
- Bioassay of auxin- effect on rooting of cuttings
- Extraction of abscisic acid (ABA) from plant tissue
- Separation and detection of ABA by HPLC/Immunological technique
- ABA bioassays- effect on stomatal movement

- Preparation of samples for ethylene estimation in plant tissue
- Estimation of ethylene in plant tissues using gas chromatography
- Ethylene bioassays, estimation using physico-chemical techniques- effect on breaking dormancy in sunflower and groundnut
- Extraction of Gibberellins from plant tissue- GC / GC-MS / HPLC
- Separation and detection of GA by GC / GC-MS / HPLC/Immunological technique
- GA bioassays- effect on germination of dormant seeds
- Cytokinin- extraction from plant tissue
- Separation and detection of cytokinin by GC / GC-MS / HPLC
- Cytokinin bioassays- effect on apical dominance and senescence / stay green

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

After successful completion of this course, the students are expected to be able to:
– acquire basic knowledge about plant hormones and plant growth regulators.
– understand the physiological roles and mechanisms of actions of plant hormone.
– obtain practical knowledge about application of plant growth regulators in agricultural and horticulture.

X. Suggested Reading

- Davies P.J. 2004, *Plant Hormones: Biosynthesis, Signal Transduction and Action,* 2nd Edition. Kluwer Academic Publishers, Dordrecht, The Netherlands.
- Hedden, P. and Thomas, S.J. 2006. *Plant Hormone Signalling*, Blackwell Publishing Ltd., Oxford, UK.
- Osborne, D.J. and McManus, M.T. 2005. *Hormones, Signals and Target Cells in Plant Development*. Cambridge University Press, New York, USA.
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- Buchanan B B, Gruissem W and Jones R L. *Biochemistry and Molecular biology of Plants*, 2nd Edition
- Lincoln Taiz and Eduardo Zeiger. *Plant Physiology and Development*, 6th Edition.
- *Teaching Tools in Plant Biology*, The American Society of Plant Biologists
- *The Arabidopsis* Book(http://www.arabidopsisbook.org/)

I. Course Title : Physiological and Molecular Mechanisms of Mineral Nutrient Acquisition and their Functions

II. Course Code : PP 506

III. Credit Hours : 2+1

IV. Why this course?

In both basic and applied plant sciences, an understanding of the mineral nutrition of plants is of fundamental importance. Nutrient element forms the skeleton of any organic molecule in the organism vis-à-vis plant. Apart from the conventional information on criteria of essentiality, nutrient uptake pathways, function of essential elements and their deficiency and toxicity symptoms, remarkable advances have been made at physiological and molecular level. Exploration of the physiological mechanisms adopted by plants to tolerate the deficiency of specific nutrient element

provides an opportunity alter the plants' ability to cope with the low nutrient condition. Identification and functional validation of various transporters involved in nutrient uptake and distribution, deciphering the sensing and signaling of nutrient starvation response and their regulatory network provides options to develop nutrient uptake and utilization efficient crops. In the era of Omics, 'ionomics' provides the total elemental composition of the plant and is a powerful approach to the functional analysis of its genes and the gene networks. Besides, it is also essential to expose the students to various conventional and high-throughput phenotyping techniques to identify the nutrient efficient 'donors', traits and QTLs/ candidate genes to complement the research program on crop improvement.

V. Aim of the course

It provides knowledge on basic physiological processes governing nutrient uptake, physiological role of elements, factors influencing uptake, internal remobilization of nutrient element during starvation and adaptation strategies. Regulation of nutrient uptake and translocation would be studied at the molecular level providing information on genes and other signaling factors involved. The aim of this course is to make the students understand the physiological and molecular basis of nutrient uptake, translocation and utilization and to apply this knowledge in genetic improvement of crop plants.

The course is organized as follows:

No.	Blocks	Units
1.	Mineral Nutrient: Classification, Function, Availability, Deficiency and Toxicity	1. Mineral Elements: Classification, Function, Deficiency and Toxicity 2. Nutrient Availability at Rhizosphere
2.	Nutrient Uptake, Translocation and Acquisition	1. Ion Uptake Mechanisms 2. Ion Transport to Shoot and Grains 3. Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Macronutrients 4. Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Micro and Beneficial Nutrients 5. Microbes, Fungal Association for Nutrient Acquisition 6. Nutrient Delivery
3.	Nutrient Efficiency of Crop	1. Improving Nutrient Acquisition and Efficiency of Crops

VI. Theory

Block 1: Mineral Nutrient: Classification, Function, Availability, Deficiency and Toxicity

Unit 1: Mineral Elements: Classification, Function, Deficiency and Toxicity

Classification based on mobility and characteristic features; physiological role in regulating plant growth, metabolism, development and human health- Regulatory Dietary Allowance (RDA), Deficiency and toxicity of macro, micro and beneficial elements, Tolerance of plants to nutrient toxicity, hyper-accumulators of nutrients: Concept of phytoremediation.

Unit 2: Nutrient Availability at Rhizosphere

Biological and chemical reactions influencing nutrient availability near the root system, interaction between ions in the rhizosphere, Rhizosphere chemistry in relation to plant nutrition- chemical reactions, root exudates to mobilize nutrients.

Block 2: Nutrient Uptake, Translocation and Acquisition

Unit 1: Ion Uptake Mechanisms

Mineral salt absorption- chemical potential of solute- Nernst equation- passive uptake- diffusion, ion exchange-Donnan Equilibrium, mass flow of ions, Mediated transport- Facilitated diffusion-ionophores; membrane transport proteins- active transport-ion channels, Primary and secondary transport- carriers and pumps.

Unit 2: Ion Transport to Shoot and Grains

Long distance transport in plants - Mechanism of xylem and phloem transport, Radial movement of ions across the root, Mechanism of phloem transport, remobilization of mineral nutrients - phloem loading, phloem unloading.

Unit 3: Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Macronutrients

Molecular structures of LAT and HAT, their localization and regulation by various external factors, Nitrate transporters and their functional regulation - Nitrate transporters (NRT1, NRT2, dual-affinity nitrate transporter NRT1.1/CHL1), Phosphate transporters and their functional regulation - PT1/PHT1, PHT2, PHT3, PHT4, Potassium transporters and their functional regulation - KT/HAK/KUP family Ion transporters involved in transport of multiple elements, for example, sulphate transporter for Selenate transport, phosphate transporter for Arsenate transport, etc.

Unit 4: Physiological and Molecular Mechanism of Nutrient Acquisition and Transport: Micro and Beneficial Nutrients

Plant Strategies: Different Strategies I & II adopted by plants for uptake of Fe under Fe deficient condition, Transporters and genes regulating uptake and transport of micronutrients, genes encoding transport/channel proteins, Examples of genes encoding mineral ion transporters for Zn, Fe, Mn, Cu, B, Mo, Ni, Cl, Na, Si, Se, Beneficial nutrients and their role in plant growth and development – Sodium, Silicon, and Cobalt.

Unit 5: Microbes, Fungal Association for Nutrient Acquisition

Microbes to improve nutrient availability – Bio-inoculation technology- P solubilizers and Zinc solubilizers in nutrient absorption, Microbial systems for biological nitrogen fixation – process of nodulation, biochemistry of N2-fixation, Endophytes to improve nutrient availability, Mycorrhiza- Mycorrhizal symbiosis on nutrient uptake by root. Role of AMF on nitrogen, phosphorus and zinc uptake.

Unit 6: Nutrient Delivery

Foliar application of nutrients, absorption and their compartmentation, Concept of slow release fertilizers and chelates (organic and inorganic), Soil less cultures-aeroponics, hydroponics, fertigation.

Block 3: Nutrient Efficiency of Crop

Unit 1: Improving Nutrient Acquisition and Efficiency of Crops

Concept of nutrient uptake and use efficiency- Genotypic differences- physiology and molecular mechanisms, Nutrient use efficiency in selected crops, Root system architecture (RSA), root characters associated with nutrient acquisition, Genes and QTLs to improve nutrient acquisition and efficiency for important nutrients in few crop species, Transgenic and molecular breeding approaches to improve traits associated with acquisition and efficiency – Case studies, Biofortification strategies – for micronutrients, agronomic approaches, Influence of nutrition status on plant response to biotic and abiotic stresses.

VII. Practicals

- Techniques to develop the deficiency symptoms of nutrients –Hydroponics/ Aeroponics- diagnosis of deficiency symptoms in agriculturally important crop plants
- Physiological and biochemical markers to identify nutrient deficiency levels
- Biochemical markers for essential elements: Assay of nitrate reductase activity for N
- Estimation of chlorophyll concentration in leaves of N deficient and N sufficient plants
- Collection of acid phosphatase from root exudates and enzyme assay for P
- Measuring anthocyanin and chlorophyll pigments concentration in leaves for P
- Collection of organic acid in root exudates, characterization and quantification for P
- Assay of carbonic anhydrase activity for Zn
- Assay of SOD Activity for Cu, Zn and Mn
- Estimation of nitrogen concentration in plant tissue - Kjeldhal and Dumas method
- Estimation of phosphorus concentration in plant tissue – colorimetric method
- Estimation of potassium, magnesium and sodium concentration in plant tissue – flame photometer
- Estimation of micronutrients (Zn, Cu, Fe, Mn, Co etc) concentration in plant tissue – atomic absorption spectrometer/ ICP-OES
- Measurement of simple root traits such as root length, angle, volume, surface area, etc. (using conventional methods or root scanner and WinRhizo)
- 'Shovelomics' in the field grown crops (for measuring root architecture) and using 'ImageJ' for analysis
- Non-invasive techniques to quantify nutrients – XRF (X-Ray Fluorescence) and hyper spectral reflectance.

VIII. Teaching methods/ activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

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

– comprehend the fundamental concepts of mineral nutrition of plant.
– describe the physiological and molecular mechanisms of acquisition and translocation of nutrient.
– describe the basis of differential nutrient efficiency.

X. Suggested Reading

- *Recommended Dietary Allowances*: 10th Edition (https://www.ncbi.nlm.nih.gov/books/NBK234932/pdf/Bookshelf_NBK234932.pdf)
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- Sarma, H., 2011. *Metal hyperaccumulation in plants: a review focusing on phytoremediation technology. Journal of Environmental Science and Technology*, 4(2), pp.118-138.
- Marschner H. *Mineral Nutrition of Higher Plants* 3rdEdn
- Zeiger and Taiz L. *Plant Physiology*
- *Mineral Nutrition of Plants*, *In: Plant Biology and Biotechnology*. B. Bahadur *et al*. (eds.), Volume I: *Plant Diversity, Organization, Function and Improvement*, DOI: 10.1007/978-81-322-2286-6_20, Springer India, Pp. 499-538.
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- Mitra GN. *Regulation of Nutrient Uptake by Plants: A Biochemical and Molecular Approach*
- Uraguchi, S., Kamiya, T., Sakamoto, T., Kasai, K., Sato, Y., Nagamura, Y., Yoshida, A., Kyozuka, J., Ishikawa, S. and Fujiwara, T., 2011. *Low-affinity cation transporter (OsLCT1) regulates cadmium transport into rice grains. Proceedings of the National Academy of Sciences*, 108(52), pp.20959-20964.
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I. Course Title : Photosynthetic Processes, Crop Growth and Productivity and Concepts of Crop Modelling

II. Course Code : PP 507

III. Credit Hours : 2+1

IV. Why this Course?

Agronomic inputs and environmental factors enhance crop growth by improving photosynthetic processes and photosynthate partitioning. Carbon metabolism is the most important physiological process that has a direct influence on crop growth and productivity which is quite sensitive to biotic and abiotic constraints. Hence a comprehensive understanding canopy photosynthetic process is crucial. This is an important component in crop improvement program, especially in the scenario of plateauing yields. These photosynthetic processes and their response to environmental factors form the basis for developing growth and yield predicting models.

V. Aim of the Course

The course provides a comprehensive theoretical and hands on experience and expertise to students on various aspects of photosynthesis including biophysical, biochemical and molecular regulations. While canopy photosynthesis drives crop growth rates, factors associated with sink activity and partitioning determine

productivity. Hence, adequate emphasis would be given to canopy photosynthesis, translocation and its feedback regulation, Crop growth and yield structure analysis and their responses to environmental factors. Growth and yield prediction models and their relevance will be adequately discussed.

The course is organized as follows:

No.	Blocks	Units
1.	Photosynthetic Processes	1. Canopy Architecture and Energy Utilization 2. Photochemical Processes 3. Biochemical Processes 4. Product Synthesis and Translocation 5. Growth and Yield forming Mechanisms
2.	Yield Improvement and Modelling	1. Molecular Options to Improve Photosynthesis, Growth and Productivity 2. Fundamentals of Dynamic Simulation Models 3. Description of Well-established Yield Models 4. Examples of Robust Models Extensively Used

VI. Theory

Block 1: Photosynthetic Processes

Unit 1: Canopy Architecture and Energy Utilization

Parameters associated with canopy architecture that determine radiation interception and absorption, Energy absorption by primary and accessory pigments and energy utilization efficiency, Light distribution inside the canopy and concepts of light extinction coefficient.

Unit 2: Photochemical Processes

Ultrastructure of chloroplast: structure and composition of lamellar system, Components of electron transport, Water oxidation system and energy conservation processes, Pigment systems and the generation of a powerful oxidant and a powerful reductant, Chlorophyll fluorescence and fluorescence quenching: qN, qP, NPQ.

Unit 3: Biochemical Processes

CO_2 diffusion and resistances (g_s and g_m). Concept of Ci determining CO_2 diffusion. RuBisCO activation state, kinetics and catalytic properties, Carboxylation processes in C_3, C_4 and CAM plants and their relevance, CO_2 concentrating mechanisms and their importance in improving carbon assimilation, Ecological significance of C_4 and CAM photosynthesis, Photorespiration and Mitochondrial respiration and net carbon gain, Carbon isotope discrimination and its importance as a surrogate of Ci.

Unit 4: Product Synthesis and Translocation

Triose phosphate utilization and regulation of Calvin cycle mechanisms, Product synthesis and partitioning between starch and sucrose, Concepts of end-product inhibition or Pi-regeneration limitation, Phloem transport and factors that regulate phloem loading and un-loading.

Unit 5: Growth and Yield forming Mechanisms

Carbon gain and the concepts of Canopy photosynthesis. Relevance of LAI and LAD in determining total carbon gain and crop growth rates, Source: Sink relationship and its relevance in governing differences in crop growth rates and

productivity. Concepts of HI and partitioning coefficient and remobilization of carbon from vegetative organs to reproductive structures, Growth analysis and parameters that explain growth rates: NAR, CGR, HI and their inter-dependence.

Block 2: Yield Improvement and Modelling

Unit 1: Molecular Options to Improve Photosynthesis, Growth and Productivity

Characteristic features of the Chloroplast genome: its structure and genes associated with various photosynthetic mechanisms, coordinated expression of chloroplast and nuclear genome for maintaining photosynthetic activities. Genomic and genetic resources such as specific genes and QTL associated with photosynthetic processes Transgenic options to enhance photosynthetic performance such as transferring genes to mitigate oxidative stress damage (SOD, APX, AKR etc), Theoretical concepts of crop improvement through inducing CCM in C_3 plants and reducing photorespiration.

Unit 2: Fundamentals of Dynamic Simulation Models

Collection of crop specific genetic coefficient, Crop, soil and historic weather data

Unit 3: Description of Well-established Yield Models

Application and limitations of modeling, Yield prediction models such as APSYM, PeanutGrowetc, Machine learning approaches and IoT for making informed on-farm decisions.

Unit 4: Examples of Robust Models Extensively Used

Duncan'syield prediction model, Passioura'smodelfor growth maximising.

VII. Practicals

- Plant sampling for leaf area and biomass estimation; analysis of growth and yield parameters – LAD, NAR. CGR, LAI, LAR, SLA portioning efficiency, HI.
- Measurement of light interception, light extinction coefficient, energy utilization efficiency based energy intercepted, and realized.
- Gas exchange: principles and uses to assess variations in CO_2 and water vapour transfer, determination of A/gs and intrinsic WUE
- Quantification of chlorophyll content by various methods: colorimetric and SPAD meter. The concept of SLN
- Chlorophyll fluorescence and quenching coefficients
- Theoretical aspects of carbon isotope fractional and its use in determining WUE
- Quantification of RuBisCO content by ELISA (if possible)
- Determination of RuBisCO activity and activation state using radioactive CO_2
- CO_2 and light response curves and computation of carboxylation efficiency, quantum efficiency, relative limitations of photosynthesis at single leaf level.
- Adoption of crop models: Growth and yield prediction by Duncan's and Passioura's models

VIII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation
– Practicals

IX. Learning outcome

After completion of this course students are expected to have in depth knowledge on Photosynthetic processes associated with product synthesis and yield development. Students will also obtain current knowledge on various crop models.

X. Suggested Reading

- Goyne, P.J., Milroy, S.P., Lilley, J.M., and Hare, J.M. (1993). Radiation interception, radiation use efficiency and growth of barley cultivars. *Australian Journal of Agricultural Research*, 44(6), 1351-1366.
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- https://www.mdpi.com/1424-8220/18/8/2674/pdf
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- https://www.mdpi.com/1424-8220/18/8/2674/pdf
- Splinter, W.E. (1974). Modelling of plant growth for yield prediction. *Agricultural Meteorology*, 14(1-2), 243-253.

General Source Information

- Blankenship RE. 2014. *Molecular mechanisms of Photosynthesis* 2nd Edition
- *Canopy Photosynthesis: From Basics to Applications*. 2016 Ed Hikosaka, Kouki, Niinemets, Ülo, Anten, Niels P.R.

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I. Course Title : Physiology of Field Crops

II. Course Code : PP 508

III. Credit Hours : 2+0

IV. Why this course?

In recent years, phenomenal progress has been made in understanding plant processes which are crop specific. Genetic gain in productivity can be achieved only by improving plant physiological traits/adaptive mechanisms. Even crop management should be based on sound physiological principles. For example, crop's response to the increase in global warming has to be looked from thermo morphogenesis concept in terms of GDD and its effect on phenological processes in some of the important field crops exposure on crop specific physiological processes is necessary and has particular significance.

V. Aim of the course

This course provides a broad exposure on the physiological aspects of field crops. The objective is to impart comprehensive information on physiological processes and physiological basis of growth, development and productivity of field crop plants. Besides, the emphasis is on unique crop specific features.

Broad categories of crops that can be selected for this course are as follows.

1. Cereals– Rice, Wheat, Maize etc.
2. Millets– Finger millet, Sorghum etc.
3. Pulse crops– Green gram, Black gram, Lentil, Pigeon pea, Chickpeas, Cowpea, Beans etc.
4. Oilseed crops– Groundnut, Rapeseed Mustard, Soybean etc.
5. Sugarcane
6. Fibre crops– Cotton, Jute, Ramie, Hemp etc.

The course is organized as follows:

No.	Blocks	Units
1.	Physiology of Field Crops	1. Introduction 2. Crop Establishment, Crop Growth and Development 3. Reproductive Growth 4. Seed Nutrient Quality 5. Plant Nutrition 6. Abiotic Stress Response 7. Crop Specific Physiological Processes and Importance

VI. Learning outcome

After completion of this course, students will accrue comprehensive knowledge on various physiological processes of variety of field crops.

VII. Theory

Block 1: Physiology of Field Crops

Unit 1: Introduction

Origin- Variability in physiology of crop plants between wild species and cultivated. Adaptability to growing environments (ecosystems), Importance in food grain contribution.

Unit 2: Crop Establishment, Crop Growth and Development

Seed characteristic features, dormancy, viability, concept of seed priming seedling establishment and crop stand. Different crop growth stages, concept of source establishment and optimum LAI, Canopy architecture, light interception/radiation use efficiency, thermal time, heat units, GDD, determining growth duration.

Unit 3: Reproductive Growth

Photo and thermo-periodic response for flowering, sink development, sink source relationship, partitioning efficiency, improvement in HI, yield determining factors, genetic gain in yield over years, structuring of ideal plant type, limitations to improve source to sink size, options to improve yield potential.

Unit 4: Seed Nutrient Quality

Seed quality, seed as a source of nutrients, seed constituents and their improvement, concept of pathway engineering to improve seed quality.

Unit 5: Plant Nutrition

Nutrient requirement, genetic variability in nutrient acquisition under constraint conditions, specific nutrient disorders.

Unit 6: Abiotic Stress Response

Response to different abiotic stresses, plant traits/mechanics to improve adaptation to realize potential yields. Global warming responses, thermomorphogenesis, approaches to overcome the constraints.

Unit 7: Crop Specific Physiological Processes and Importance

Choosing location specific crop species exposure will be given on physiological process as described above. Besides, emphasis is on providing information on crop specific features/productivity constraints.

Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

Suggested Reading

- *Grain Legumes*: Ed De Ron, Antonio M. (Ed.) 2015. Springer
- *Legumes under Environmental Stress: Yield, Improvement and Adaptations*. Eds MM Azooz P Ahmad and Hoboken, NJ: John Wiley and Sons, Ltd., 328 pages. ISBN: 978-1-118-91708-4
- *Pulse Crops: Biotechnological Strategies to Enhance Abiotic Stress Tolerance*. Ganeshan S, Gaur PM, Chibbar RN, Tuteja N, Gill SS, Tuteja R. chapter 17
- *Climate Change and Management of Cool Season Grain* Legume *Crops*. Eds Yadav GS, McNeil DL, Redden R, Patil SA. Springer
- *Nature's pulse power: legumes, food security and climate change.* Considine MJ, Siddique

KHM and Foyer CH, 2017 *J Exp Bot*. 68(8): 1815–1818. Published online 2017 May 11. doi: 10.1093/jxb/erx099

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- Fahad S, Bajwa AA, Nazir U, Anjum SA, Farooq A, Zohaib A, Sadia S, Nasim W, Adkins S, Saud S and Ihsan MZ. 2017. *Crop production under drought and heat stress: plant responses and management options. Frontiers in Plant Science* 8(1147): 1-16.
- Pandey V and Shukla A. 2015. *Acclimation and Tolerance Strategies of Rice under Drought Stress. Rice Science* 22(4): 147-161.
- Kole C. 2006. *Cereals and millets. Genome Mapping and Molecular Breeding in Plants. Springer*.
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- Rinki, Mamrutha HM, Sareen S, Tiwari V, Singh GP. 2018. *Dissecting the physiological and anatomical basis for high yield potential in HD 2967. Vegetos*. 31: 121-124.
- Kumar R, Kaur A, Ankita P, Mamrutha HM, Singh GP 2019. *CRISPR based genome editing in wheat: A comprehensive review and future prospects. Molecular Biology Reports* 10.1007/s11033-019-04761-3
- Tiwari R and Mamrutha HM. 2014. *Precision Phenotyping for Mapping of Traits for Abiotic Stress Tolerance in Crops. Biotechnology: Prospects and Applications*. Ed. Salar RK, Gahlawat SK, Siwach P and Duhan JS. Pp79-85. Publisher: Springer.
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- Reynolds *M. Wheat Physiological Breeding volume I and II (CIMMYT): Wheat Physiological Breeding: A Field Guide to Wheat Phenotyping*.
- Mamrutha HM *et al*. 2019. *Physiological and Molecular Basis of Abiotic Stress Tolerance in Wheat*. In: Rajpal V., Sehgal D., Kumar A., Raina S. (eds) *Genetic Enhancement of Crops for Tolerance to Abiotic Stress: Mechanisms and Approaches*, Vol. I. Sustainable Development

and Biodiversity, vol 20. Springer, Cham
- Tiwari V. *et al.* 2017. *Managing Abiotic Stresses in Wheat.* In: Minhas P., Rane J., Pasala R. (eds) *Abiotic Stress Management for Resilient Agriculture*. Springer, Singapore

I. Course Title : Physiology of Horticulture Crops

II. Course Code : PP 509

III. Credit Hours : 2+0

IV. Why this Course?

Improving physiological processes forms the basis to enhance the productivity or to improve a specific growth processes. Several interventions based on principals of physiological processes provide options to enhance crop productivity. Basic insight on photoperiodic response is crucial for determining planting dates. Understanding the mechanisms of rooting for vegetative propagation has lead in developing rooting hormones etc., In view of this, a comprehensive exposure on growth and development of horticulture crops and providing insights on major production constraints and physiological approaches to overcome is highly essential.

V. Aim of the Course

This course should provide a broad exposure on the physiological aspects of horticulture crops. The objective is to impart comprehensive information on physiological processes and physiological basis of growth, development and productivity of horticultural crop plants. To describe basic and applied physiology behind the production and productivity of horticultural crops and their pre and postharvest management, ideal storage conditions, quality retention, processing and value addition.

Broad categories of crops that can be selected for this course are as follows.

1. Fruit crops: Mango, Grapes, Apple, Banana, Citrus etc.
2. Vegetable crops: Tomato, Onion, Brinjal, Cauliflower, Okra etc.
3. Tuberous crops: Potato, Cassava, Sweet potato, Yam etc.
4. Plantation crops: Coconut, Oil palm, Cashew, Tea, Coffee, Rubber, Areca nut, Cocoa etc.
5. Floriculture crops: Rose, Marigold, Carnation, Chrysanthemum, Gladiolus, Orchids, Tuberose etc.
6. Other groups: Medicinal crops, Aromatic crops, Spices crops.

The course is organized as follows:

No.	Blocks	Units
1	Physiology of Horticultural Crops	1. Introduction 2. Crop growth and Development 3. Reproductive Growth 4. Pre and Post-harvest Physiology 5. Plant Nutrition and Abiotic Stress Responses 6. Specific Aspects and Unique Crop Features

VI. Learning outcome

After completion of this course, students will accrue comprehensive knowledge on various physiological processes of variety of horticultural crops.

VII. Theory

Block 1: Physiology of Horticultural Crops

Unit 1: Introduction

Origin, distribution and adaptability of crops to different agro-climatic conditions

Unit 2: Crop growth and Development

Internal factors (hormone, etc.) influencing various physiological processes linked to vegetative growth or growth of specific organ, correlative and algometric growth External factors (water, nutrition, temperature, etc.) influencing various physiological processes linked to vegetative growth or growth of specific organ, correlative and algometric growth, Propagation methods, grafting, cutting, budding, air layering. Physiology of pruning, dwarfing, branch bending, canopy management etc., Physiological and biochemical aspects of scion and root stock interaction and compatibility.

Unit 3: Reproductive Growth

Physiology of flowering, photo- and thermo-periodism and response to vernalization, Factors influencing reproductive growth, fruit and seed set/retention, physiology of flower sex ratio, Physiological processes governing source-sink relationship and productivity.

Unit 4: Pre and Post Harvest Physiology

Preharvest factors influencing postharvest physiology, Physiological and molecular mechanisms of ripening, Physiological and molecular mechanisms of senescence, Hormonal and chemical control of postharvest deterioration of fruits/vegetable/ flowers. Regulation of ripening at physiological and molecular levels, Regulation of senescence at physiological and molecular levels, Approaches to improve shelf life and storability. Approaches to improve postharvest management, Approaches to improve processing and value addition.

Unit 5: Plant Nutrition and Abiotic Stress Responses

Nutrient acquisition and requirement, plant phenology and nutrient requirement; Role of rootstocks in nutrient acquisition and in abiotic stress tolerance, Adaptive mechanisms and approaches to improve performances under drought and high temperature, Adaptive mechanisms and approaches to improve performances under frost, chilling and nutrient deficient conditions, Root physiology in abiotic stress tolerance.

Unit 6: Specific Aspects and Unique Crop Features

Specific aspects

Polyhouse cultivation, Hormones/PGRs for improving crop performance, Major and micronutrients for improving crop performance, Light interception, shade regulation, dwarfing root stocks, Chilling requirement for flowering, photoperiodic response, pollen viability, stigma receptivity, Flower (blossom) and fruit drop.

Unique crop features

Maturity and maturity indices, Source-sink relations, Vegetative propagation, Physiology of tuberization and rhizome initiation and formation, Virus free planting material, Bulbs/tubers dormancy, bud break, Physiological disorders, Storage, Packaging, Quality.

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation

IX. Suggested Reading

- Sethuraj MR and Raghavendra AS. 2012. *Tree Crop Physiology*. ISBN-13: 978-0444428417, ISBN-10: 0444428410, Elsevier Science Publishers.
- Bhatnagar P. *Physiology of Growth and Development of Horticultural Crops*, ISBN-10: 817754666X, ISBN-13: 978-8177546668
- Singh A. *Fruit Physiology and Production*, ISBN-10: 8127211788, ISBN-13: 978-8127211783, Kalyani Publishers; 5th edition (March 28, 2003).
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Brinjal

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I. Course Title : Seed Physiology

II. Course Code : PP 510*

III. Credit Hours : 2+1

IV. Why this course?

Seeds are considered as propagule and as a major source of nutrition for humans and other animals. Therefore, all information concerning their nutritive value, chemical composition; storability, retention of viability are very important. Looking into the importance of seeds, emphasis has been given to produce high quality seeds with excellent genetic potential to improve seed germination and to produce vigorous seedlings. In fact, recently techniques are employed to raise healthy and vigorous seeds to obtain vigorous seedlings. Several hormones and chemicals are used to improve the oil, protein, and other economic attributes of seeds. Therefore, to give more insight into the development of quality seeds and also protecting them without losing much of nutritive value, this course has been proposed.

V. Aim of the course

This course will approach the subjects from two perspectives –physiology of seed development and seed germination. It aims to describe students the physiological processes involved in regulation and mechanism of seed development, dormancy and germination. Further, to provide an insight into physiological processes governing seed quality and its survival. Accordingly.

The course is organized as follows:

No.	Blocks	Units
1.	Physiology of Seed Development	1. Introduction to Seed Physiology 2. Seed Development 3. Seed Maturation 4. Metabolism in Developing Seed
2.	Physiology of Seed Germination and Dormancy	1. Seed Germination 2. Seed Dormancy and Viability

VI. Theory

Block 1: Physiology of Seed Development

Unit 1: Introduction to Seed Physiology

Importance of seed as a propagule, seed structure and functions; chemical composition of seeds. Embryogenesis: pollination and fertilization, pollen and pistil interaction, signal for interaction; pollen load hypothesis; genetical and environmental influence on seed development. Source-Sink relationship affecting seed yield and quality. Concept of seed viability and seedling vigour and their relevance; approaches to improve the storability of seeds. Physiological and molecular mechanisms of seed germination; approaches to improve seed germination; seed size and its influence on seed germination.

Unit 2: Seed Development

Physiology and molecular mechanisms of embryo, endosperm and seed coat development; cellularization during endosperm development; morphological and cellular changes during seed coat development, anatomy and function of seed coat, programmed cell death (PCD) in seed coat, Deposition of seed storage reserves during development.

Unit 3: Seed Maturation

Seed maturation and maturation indices; physiological and anatomical changes during seed maturation; Seed drying and acquisition of desiccation tolerance in seeds; mechanisms of desiccation tolerance; role of ABA LEA's, HSP's, dehydrins and other stress proteins during seed maturation and drying, Seed abortion and approaches to reduce it.

Unit 4: Metabolism in Developing Seed

Chemical composition of seeds (carbohydrates, proteins, fats etc.), source of assimilates for seed development, pathways of movement of assimilates to developing seed, approaches to increase the chemical composition of seeds. Seed respiration and mitochondrial activity; seed respiration rate and storability of seeds. Seed ageing, Mobilization of stored resource in seeds; Chemistry of oxidation of starch, proteins and fats; Utilization of breakdown products by embryonic axis.

Block 2: Physiology of Seed Germination and Dormancy

Unit 1: Seed germination

Seed germination, types of germination, imbibition kinetics of germinating seed; Physiological events during germination: seed respiration, mitochondrial activity, mobilization of food reserve; energy utilization by the germinating seed.

Environmental regulation of germination: hydro-time, thermal time and hydrothermal time models; Influence of environmental factors on germination; Role of plant hormones/PGR's during seed germination.

Unit 2: Seed Dormancy and Viability

Physiological and molecular basis of seed dormancy, hormonal regulation of dormancy, After ripening, dormancy breaking treatments; Ecological perspective of seed dormancy. Seed viability: concept and physiology of seed viability, theories of seed ageing, seed storage and regulation of storage life of seeds; methods to prolong seed viability; Conservation of orthodox and recalcitrant seeds. Seed vigour: concept, importance, measurement; Physiological, biochemical and molecular basis of seed vigour.

VII. Practicals

- Determination of seed reserves: carbohydrates, proteins and lipids
- Study of different seed structures
- Kinetics of seed imbibition; Seed germination test, enzymatic activities and respiration during germination and vigour testing methods etc.
- Accelerated ageing test to know the seed vigour and storability
- Measurement of seed moisture content
- Determination of amylase activity in germinating seeds
- Measurement of electrical conductivity in seed leachate
- Measurement of seed viability using tetrazolium chloride
- Determination of dehydrogenase activity
- Seed germination study- Determination of Germination Index and seedling growth
- Measurement ofseed vigour index
- Dormancy breaking treatments
- Seed priming techniques
- Effect of environmental stresses on seed germination and seedling growth
- Effect of hormones on seed germination

VIII. Teaching methods/activities

- Lecture
- Assignment (Reading/Writing)
- Student presentation
- Practicals

IX. Learning outcome

At the end of the course the students are expected to be able to understand the physiology of seed development and seed germination. The students will be able to identify the physiological processes involved in regulation of seed development, dormancy and germination.

IX. Suggested Reading

- Bewley, JD, Bradford K, Hilhorst H, Nonogaki H. (2013). *Seeds: Physiology of Development, Germination and Dormancy*, Springer-Verlag.
- Larkins BA and Vasil IK (Ed), *Cellular and Molecular Biology of Plant Seed Development*, 2010, Springer.
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- http://sbc.ucdavis.edu/Research_pages/Seed_physiology_and_technology/.
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I. Course Title : Phenotyping Physiological Processes

II. Course Code : PP 511

III. Credit Hours : 2+0

IV. Why this course?

One of the main mandates of SAU and crop specific institutes is crop improvement. Seed industry and academic institutes need contribution from physiologists on these aspects. Conceptual changes in breeding approaches in terms of breeding for specific physiological traits necessitates that the students develop conceptual approaches for phenotyping in different physiological processes. Characterizing the parents, germplasm accessions, segregating populations for specific physiological traits like flowering response, variation in root system architecture, etc is crucial for genetic enhancement of these traits. This student ready Course can contribute richly to research and development of the seed sectors and crop specific institutions where the major emphasis in recent years is genetic enhancement of traits.

V. Aim of the course

The major emphasis in this course is to phenotype well characterized physiological processes/plant traits associated with plant growth, development and productivity, besides, comprehensive approach to precise imposition of various abiotic stresses and capture genetic variability in adaptive traits. The aim is to employ these techniques for crop improvement programs.

The course is organized as follows:

No.	Blocks	Units
1.	Phenotyping Physiological Processes	1. Concept of Phenotyping 2. Phenotyping for Traits for Crop Establishment 3. Concept and Approaches to Identify Genotypes with Superior Growth Rate 4. Identifying Photo-insensitive Genotypes-options and Approaches 5. Identifying Thermo-insensitive Genotypes-options and Approaches 6. Yield Structure Analysis- Relevant Yield Attributes 7. Source-sink Relationship- Assessment of Limitation

No.	Blocks	Units
		8. Identify Genetic resources for Abiotic Stress Constraints

VI. Theory

Block 1: Phenotyping Physiological Processes

Unit 1: Concept of Phenotyping

Phenotyping technologies are essential component for assessing plant responses, identify superior trait donors, mitigation responses, trait introgression and trait based breeding.

Unit 2: Phenotyping for Traits for Crop Establishment

Seed viability, seed dormancy, seed hydration rates, seed density and weight, Seedling vigour in normal and adverse conditions.

Unit 3: Concept and Approaches to Identify Genotypes with Superior Growth Rate

Phenotyping for leaf expansion, leaf area index, light interception and crop extinction coefficient. Pigment quantification for nitrogen and chlorophyll status - SPAD, anthocyanin and flavonoids – Duolex. Growth rates by non-invasive techniques like NDVI, Concept of Net assimilation rate and DM/LAD; surrogates for photosynthetic traits; stomatal characteristic.

Unit 4: Identifying Photo-insensitive Genotypes-options and Approaches

Exposing to longer and shorter photoperiod by staggered sowing; extending the day length- light interception by red light; days to heading/ anthesis, approaches for synchronization of flowering.

Unit 5: Identifying Thermo-insensitive Genotypes-options and Approaches

Altering total degree days- staggered sowing at lower latitudes or by growth chambers; quantifying heading, anthesis, maturity and grain filling days, grain number and weight, grain filling rate.

Unit 6: Yield Structure Analysis- Relevant Yield Attributes

Pollen biology, stigma receptivity, spikelet sterility (cereals), floral abscission (other crops), fruiting points / productive tillers, number of grains/ fruits per panicle/ inflorescence and grain characteristic. Phenotyping for lodging- culm traits, intermodal length, lignification, Phenylalanine ammonia lyase (PAL) and Tyrosine ammonia lyase(TAL). Approaches to identify genetic resources with traits to improve yield potential.

Unit 7: Source-sink Relationship- Assessment of Limitation

Phenotyping for source-sink size, Concept of sink-source limitation- defloration and defoliation. Remobilization of stored metabolites and concept of stay green; estimation of water soluble carbohydrates; partitioning coefficient and harvest index.

Unit 8: Identify Genetic Resources for Abiotic Stress Constraints

Approaches for precise stress imposition to diverse stresses, Identify trait donor lines for different stresses: approaches by Stress Susceptibility Index (SSI), Stress Induction Response (SIR), Capturing variability for adaptive traits: root traits,

stomatal factors/wax, osmolyte, surrogate approach for acquired tolerant traits, Flowering response, Spikelet fertility, Abscission and Senescence, Screening high density response-based on SSI – root adaptation and Shade Avoidance Response (SAR).

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation

VIII. Learning outcome

After completion of this course students are expected to develop clear concept and insight into phenotyping technologies associated with plant growth, development and productivity.

IX. Suggested Reading

- Kumar J, Pratap A and Kumar S. 2015. *Plant Phenomics: An Overview*. 10.1007/978-81-322-2226-2_1.
- Pratap A, Gupta S, Nair RM, Gupta SK, Schafleitner R, Basu PS, Singh CM, Prajapati U, Gupta AK, Nayyar H, Mishra AK, Baek KH. 2019. *Using Plant Phenomics to Exploit the Gains of Genomics. Agronomy* 9, 126.
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- Ouzounis, T., Rosenqvist, E., and Ottosen, C., 2015. *Spectral Effects of Artificial Light on Plant Physiology and Secondary Metabolism: A Review American Society Horticulture Science.* 50(8); 1128–1135 doi.org/10.21273/HORTSCI.50.8.1128
- *The Flowering Response of the Rice Plant to Photoperiod: A Review of The Literature* Fourth Edition.
- Sehgal A, Sita K, Siddique KH, Kumar R, Bhogireddy S, Varshney RK and Nayyar H. 2018. *Drought or/and Heat-Stress Effects on Seed Filling in Food Crops: Impacts on Functional Biochemistry, Seed Yields, and Nutritional Quality. Frontiers in Plant Science*, 9.
- Prasad, P. V., Bheemanahalli, R., andJagadish, S. K. 2017. *Field crops and the fear of heat stress—Opportunities, challenges and future directions. Field Crops Research* 200, 114-121.
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  Hirano K, Ordonio RL and Matsuoka M. 2017. *Engineering the lodging resistance mechanism of post-Green Revolution rice to meet future demands. Proceedings of the Japan Academy, Series B*, 93(4), 220-233.

  White, A. C., Rogers, a., Rees, M and Osborne, C.P., 2016. *How can we make plants grow faster? A source–sink perspective on growth rate Journal of Experimental Botany*, 67(1): 31–45.

  Ragheba, A., El-Shimyb, H and Raghebb, G. 2016. *Green architecture: a concept of sustainability, Procedia - Social and Behavioral Sciences* 216: 778 – 787.

- Wang H, Wu G, Zhao B, Wang B, Lang Z, Zhang C and Wang H. 2016. *Regulatory modules controlling early shade avoidance response in maize seedlings*, *BMC Genomics***17**: 269, https://doi.org/10.1186/s12864-016-2593-6.
- Carriedo, L., Maloof, J and Brady, S. 2016. *Molecular control of crop shade avoidance. Current Opinion in Plant Biology*. 30. 151-158. 10.1016/j.pbi.2016.03.005.

I. Course Title : Crop Growth Regulation and Management

II. Course Code : PP 512

III. Credit Hours : 2+0

IV. Why this Course?

Besides crop improvement, the approach to regulate physiological processes for improving crop production made very good leads in recent years. The focus is to employ the basic knowledge of several physiological processes to manipulate the plant growth and specific processes like ripening, flowering to achieve higher economic yields. This dynamic course will address many of these technologies that are being developed for crop production based on principles of plant physiological processes. Training the students in this student ready coursewill provide the required practical knowledge which will be of immense relevance to contribute private agricultural sectors and for agri-based industries.

V. Aim of the Course

A comprehensive information needs to be provided in this course like light regulation in polyhouse cultivation, photoperiod responses by red/far red light for synchronizing flowering, techniques for soil less culture like aeroponics, pollen biology and hybrid production, chemical regulation of plant growth processes like flower initiation, flower sex, flower drop, fruit maturity, ripening and shelf-life, etc.
The course is organized as follows:

No	Blocks	Units
1	Propagation - Crop Establishment	1. Seed as a Propogule 2. Vegetative Propogule
2	Regulation of Plant Growth Processes	1. Regulation of Plant Growth and Flowering 2. Fruit Ripening and its Regulation 3. Concept of Senescence and its Retardation
3	Protective Cultivation–Stress Mitigation	1. Protective Cultivation Interventions to Alter Physiological Processes and Growth 2. Drought Mitigation Options and Approaches 3. Specific Plant Processes Regulated by Chemicals and Growth Hormones

VI. Theory

Block 1: Propagation - Crop Establishment

Unit 1: Seed as a Propogule

Concept of improving seed characteristics for crop establishment. Mechanisms of regulating seed dormancy, precocious germination, ways to control pre-harvest sprouting in crop plants. Seed viability and its regulation, factors to minimize loss of viability and improve seedling vigour. Concept of seed priming, techniques of

priming, seed priming to induce tolerance to stresses. Role of media, nutrition and PGPR's on seedling vigour and subsequent crop establishment.

Unit 2: Vegetative Propogule

Chemical and hormonal regulation of vegetative propagation. Regulation of rooting, bud sprouting, Bulb/tuber dormancy. Chemical regulation of graft union. Concept of *in vitro* micropropogation.

Block 2: Regulation of Plant Growth Processes

Unit 1: Regulation of Plant Growth and Flowering

Chemical and hormonal regulation of plant architecture, tillering, branching, bud breaking, Regulation of flowering by photo and thermoperiod, nutrients, chemicals and hormones, concept of speed breeding, Flowering synchrony in hybrid seed production, Sex ratio alteration, flower and fruit thinning, Pollen viability in relation to environment, harvesting, storage and transportation, Prevention of abscission, flower and fruit drop, seed and fruit growth regulation- role of hormones.

Unit 2: Fruit Ripening and its Regulation

Approaches to improve shelf life – storage environment, water loss, respiration, Modified atmosphere, gaseous environment for storage, storage disorders, chilling injury.

Unit 3: Concept of Senescence and its Retardation

Physiology of senescence and options to regulate, Chemical regulation of senescence, maintenance of chlorophyll during storage, role of hormones/micronutrients in reducing senescence, Concept of stay green, advantages and limitations. Relevance of stay green traits in plant breeding for crop improvement.

Block 3: Protective Cultivation–Stress Mitigation

Unit 1: Protective Cultivation Interventions to Alter Physiological Processes and Growth

Spectral characteristics of light in polyhouse, light regulation to optimize plant photosynthetic and photomorphogenic processes and plant growth, LED sources of monochromatic light to regulate growth, etiolating and flowering, High temperature induced thermomorphogenic processes, Artificial growing media, soilless cultures, aeroponics, fogoponics, Concept of CO_2 fertilization. Effect of humidity on leaf expansion and growth.

Unit 2: Drought Mitigation Options and Approaches

Moisture conservation options at soil and plant level, Concept of increasing water holding capacity, role of Hydrogels – water and mineral nutrients release pattern. Approaches to improve transpiration over evapo-transpiration, stomatal and non-stomatal regulation of water loss, antitranspirants, Osmoprotectants, ROS scavengers, plant nutrients, Root stocks in improving tolerance, Chemical regulation of flower drop due to temperature, Chemicals to improve pollen viability during abiotic stress.

Unit 3: Specific Plant Processes Regulated by Chemicals and Growth Hormones

Rooting of cuttings, Wine brewing industry, Promotion of gynoecious flower, Hybrid rice production, Induction of flowering in pine apple, cucurbits, Delaying of

senescence and ripening, Production of dwarf plant for ornamental purpose, Reduction in flower and fruit drop, Increase in berry size in grapes.

VII. Teaching methods/activities

– Lecture
– Assignment (Reading/Writing)
– Student presentation

VIII. Suggested Reading

- Wu X, Ning F, Hu X and Wang W. 2017. *Genetic Modification for Improving Seed Vigor Is Transitioning from Model Plantsto Crop Plants. Front. Plant Sci*. 8: 8. doi: 10.3389/ fpls.2017.00008
- William E. Finch-Savage and Steven Footitt. 2017. *Seed dormancy cycling and the regulation of dormancy mechanisms to time germination in variable field environments Journal of Experimental Botany*, 68, (4), 843 856, https://doi.org/10.1093/jxb/ erw477
- Afzal I, Ur Rehman H, Naveed M and ShahzadMaqsood, Basra A. 2016. *Recent Advances in Seed Enhancements* Intech.
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- Sandarani, MDJC, Dasanayaka DCMCK and Jayasinghe CVL. 2018. *Strategies Used to Prolong the Shelf Life of Fresh Commodities. J AgriSci Food Res* 9: 206.
- Falagán, N and Terry LA. 2018. *Recent advances in controlled and modified atmosphere of fresh produce. Johnson Matthey Technology Review* 62(1), 107-117.
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- Bian, Z., Jiang, N., Grundy, S. and Lu, C., 2017. *Uncovering LED light effects on plant growth: new angles and perspectives-LED light for improving plant growth, nutrition and energy-use efficiency*. In *International Symposium on New Technologies for Environment Control, Energy-Saving and Crop Production in Greenhouse and Plant* 1227. 491-498.
- Barrett, G.E., Alexander, P.D., Robinson, J.S. and Bragg, N.C., 2016. *Achieving environmentally sustainable growing media for soilless plant cultivation systems–A review. Scientia horticulturae*, 212: 220-234.
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