Revised and Restructured Syllabi for PG Courses from Department of Crop Physiology

CODE	COURSE TITLE	CREDITS
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 510	Seed Physiology	2+1

COURSE CONTENTS

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. Objectives:

•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.

•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.

V. Syllabus:

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.

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

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

II. Course Code : PP 502

III. Credit Hours : 2+1

IV. Objectives:

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.

V. Syllabus:

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 C4and 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 ofsugars 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.

Practicals

• Radiant energy measurements

• Separation and quantification of chlorophylls
• Separation and quantification of carotenoids
• O2 evolution during photosynthesis
• Anatomical identification of C3 and C4 plants
• Measurement of gas exchange parameters, conductance, photosynthetic rate, photorespiration
• Measurement of respiration rates
• Estimation of reducing sugars, starch
• Estimation of NO3, 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

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

II. Course Code : PP 503

III. Credit Hours : 2+1

IV. Objectives:

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.

V. Syllabus:

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 somaclones, identification and exploitation of somaclonal 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

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 parameters of fruit ripening and study the expression of key genes regulating ripening.

• Study the effect of ethylene, its inhibitor 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 standardize regeneration protocol for shoot and root induction using callus and leaf explant.

• Micro-propagation using meristem tip and axillary node culture.

• Standardize 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 tumefaciens and Agrobacterium rhizogenes for production of transgenic

• Molecular characterization of transgenic- PCR, southern blotting, gene expression.

I. Course Title : Physiological and Molecular Responses of Plants to Abiotic Stresses

II. Course Code : PP 504

III. Credit Hours : 2+1

IV. Objectives:

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:

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 and signal 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, Stomatal factors 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, photoprotection 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 photoinhibition; mechanisms of tolerance, plant adaptation to low light, concept of shade avoidance response (SAR).

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.

I. Course Title : Hormonal Regulation of Plant Growth and Development

II. Course Code : PP 505

III. Credit Hours : 2+1

IV. Objectives:

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.

V. Syllabus:

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 Brassinosteroids and 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.

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

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. Objectives:

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.

V. Syllabus:

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.

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.

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. Objectives:

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.

V. Syllabus:

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 (gs and gm). Concept of Ci determining CO_2 diffusion.

RuBisCO activation state, kinetics and catalytic properties, Carboxylation processes in C3, C4 and CAM plants and their relevance, CO_2 concentrating mechanisms and their importance in improving

carbon assimilation, Ecological significance of C4 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 C3 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’s yield prediction model, Passioura’s model for growth maximising.

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 CO2 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 CO2
- CO2 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'smodels

I. Course Title : Seed Physiology

II. Course Code : PP 510

III. Credit Hours : 2+1

IV. Objectives

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.

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.

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 of seed vigour index
- Dormancy breaking treatments

- Seed priming techniques
- Effect of environmental stresses on seed germination and seedling growth
- Effect of hormones on seed germination