

# **09. PLANT PHYSIOLOGY**

## **Unit 1: Cell Organelles and Water Relations**

Cell organelles and their physiological functions Structure and physiological functions of cell wall, cell inclusions. Cell membrane structure and functions. Water and its role in plants, properties and functions of water in the cell, water relations, water potential of plant cells. Mechanism of water uptake by roots transport in roots, movement of water in plants, water loss from plants, energy balance, solar energy, input energy dissipation at crop canopy level. Evapotranspiration, plant factors influencing transpiration rate. Stomata, structure function - Mechanism of stomatal movement, antitranspirants. Physiology of water high temperature and salinity stress in plants. Influence of water stresses at cell, organ, plant and canopy levels. Indices for assessment of drought resistance.

## **Unit 2: Metabolic Processes and growth Regulation**

Energy and work, free energy and chemical potential, redox reactions and electrochemical potential. Enzyme classification and mechanism of action, factors affecting enzyme action. Gene expression and protein turnover. Photosynthesis, translocation and respiration as key processes regulating carbon metabolism and plant growth. Photosynthesis and bioproductivity. Photochemical process- Chloroplast, its structure, CAM plants and their significance. Rubisco structure and regulations, Photorespiration and its significance, CO<sub>2</sub> fixation as a diffusive process, effect of environmental factors on photosynthetic rates. Synthesis of sucrose, starch, oligo and polysaccharides. Translocations of photosynthates and its importance in sink growth. Mitochondrial respiration, growth and maintenance respiration, cyanide resistant respiration and its significance. Nitrogen metabolism. Inorganic nitrogen species (N<sub>2</sub>, NO<sub>3</sub>, NH<sub>3</sub>) and their reduction, protein synthesis, nucleic acids. Sulphate uptake and reduction. Lipid metabolism- storage, protective and structural lipids. Secondary metabolites and their significance in plant defence mechanism. Growth and differentiation, hormonal concept of growth and differentiation, plant growth hormones (auxins, gibberellins, cytokinins, ABA, ethylene etc.), biosynthesis of growth hormones and their metabolism, synthetic growth regulators, growth retardant, apical dominance, senescence, fruit growth, abscission, photomorphogenesis, photo-receptors, phytochrome, physiology of flowering, photoperiodism and vernalisation.

## **Unit 3: Crop Productivity and Modeling**

Role of crop physiology in agriculture, crop growth and productivity, crop growth models describing yield (Duncan/Passioura), phenology-crop productivity, growth

factors related to biomass - concept of growth rates- canopy photosynthesis (leaf area and net assimilation rates as determining factors). Light interception as a major function of leaf area-index, LAD canopy architecture- Light extinction coefficient relative growth rate. Net assimilation rate. Biomass and yield relations. Assimilate partitioning, yield and yield structure analysis. Concept of source and sink, factors influencing source and sink size and productivity. Environmental factors determining crop growth. Light, temperature and VPD, effect of photoperiod and thermoperiod on duration of growth stages. Ideotype concept-selection- indices for improving crop productivity.

#### **Unit 4: Abiotic Stress Responses in Plants**

Abiotic stresses affecting plant productivity. Basic principles of a crop improvement programme under stress, interactions between biotic and abiotic stresses. Drought characteristic features, water potential in the soil-plant-air continuum. Development of water deficits, energy balance concept, transpiration and its regulation – stomatal functions/VPD. Physiological process affected by drought. Drought resistance mechanisms: Escape, dehydration postponement (Drought avoidance), Dehydration tolerance, and characteristics of resurrection plants. Osmotic adjustment Osmoprotectants, stress proteins. Water use efficiency as a drought resistance trait. Molecular responses to water deficit stress perception, expression of regulatory and function genes and significance of gene products. Stress and hormones-ABA as a signaling molecule – Cytokinin as negative signal. Oxidative stress: reactive oxygen species (ROS) – role of scavenging systems (SOD, catalase etc.). High temperature stress: tolerance mechanisms- role of membrane lipids in high temperature tolerance. Functions of HSPs chilling stress; effects on physiological processes. Crucial role of membrane lipids. Salinity: species variation in salt tolerance. Salinity effects at cellular and whole plant level, tolerance mechanisms. Breeding for salt resistance. Heavy metal stress: aluminum and cadmium toxicity in acid soils. Role of phytochelatins (heavy, metal binding proteins).

#### **Unit 5: Plant Growth Regulators and Plant Development**

Plant growth regulators – Hormones, endogenous growth substances and synthetic chemicals. Endogenous growth regulating substances other than hormones. Brassinosteroids, triacontanol, phenols polyamines, jasmonates, concept of death hormone. Classification, site of synthesis, biosynthetic pathways and metabolism and influence on plant growth and development by auxins, gibberellins, cytokinins, abscisic acid and ethylene. Concept of hormone action - hormone receptors and signal transduction Hormone mutants. Hormonal regulation of gene expressions at various developmental stages of plant-flowering, seed maturity, seed dormancy. Action of hormones on cellular functions: Auxins- cell elongation, retardation of abscission of

plant parts, gibberellins – stem elongation, germination of dormant seeds, cytokinins-cell division, retardation of senescence. Abscisic acid- stomatal closure and induction of drought resistance, ethylene- fruit ripening, acceleration of senescence of leaves. Interaction of hormones in regulation of plant growth and development processes. Synthetic growth regulators, growth retardants, apical dominance, senescence, fruit growth, abscission. Growth and differentiation, hormonal concept of growth and differentiations. Rooting of cuttings- flowering physiological and molecular aspects of control of reproductive growth. Apical dominance, senescence and abscission. Fruit growth and development, physiological and molecular aspects of ripening processes and improving post harvest life of fruits. Induction and breaking dormancy in seeds and buds. Synthetic growth regulators. Practical utility in agriculture and horticulture. Herbicides, classification and their mode of action.

### **Unit 6: Mineral Nutrition**

Importance of mineral nutrition in plant growth. Classification and essentiality criteria. General mechanisms - concept of apparent free space and nature of biomembranes. Dual mechanism and other concepts of ion uptake. Short distance transport-pathway from external solution (Apoplast) to sieve across the root cortical cells-factors contributing to xylem loading. Long distance transport in xylem and phloem, xylem unloading in leaf cells. Uptake and release of mineral nutrients by foliage. Rhizosphere and root biology, root growth, influence of micro-organism in nutrient acquisition, release and uptake by plant roots. Yield and mineral nutrition concept of nutrient use efficiency, Mineral nutrition under adverse soil situations drought, salinity, acidity etc. Heavy metal toxicity and concept of phytoremediation. Interaction of phytohormones and nutrients. Molecular aspects- uptake and transport, role of transporter genes, genetics of nutrient uptake, identification and transfer of genes for tolerance to nutrient deficiencies, etc.

### **Unit 7: Climate and Climate Change**

Climate- Analytical methods to determine long term changes in environment- Tree ring, cellulose, stable carbon isotope discrimination, stable  $^{18}\text{O}$  discrimination for hydrological changes. Likely changes in climate in future and its impact on crop and ecosystems. The greenhouse gases and global warming.  $\text{CO}_2$  as an important greenhouse gas, global carbon deposits, fluxes in the sinks and sources. Approaches to contain atmospheric  $\text{CO}_2$  level. Effect of elevated  $\text{CO}_2$  on plant growth and development. Methane as a greenhouse gas. Prediction on global warming, GCM models, effects on climate and biota. High temperature and  $\text{CO}_2$  interaction on plant growth and productivity, ionising radiation UV-B chlorofluoro carbon (CFC)– their impact on ozone layer- ozone hole and alteration in UV-B radiation. Effects of UV-B radiation on plant ecosystem, repair and acclimation to UV-B damage. Carotenoids

and their role in membrane stabilization. Air pollution, SO<sub>2</sub>, NO, methane, ozone, peroxy acetyl nitrate and their effect on ecosystem. Industrial and domestic effluent their effect, on aquatic ecosystem, plant growth and development.

### **Unit 8: Seed Physiology**

Structure of seeds and their storage. Seed development patterns and source of assimilates for seed development. Pathway of movement of assimilates in developing grains of monocots and dicots. Chemical composition of seeds. Storage of carbohydrates, proteins and fats in seeds. Hydration of seeds. Physiological processes. Seed respiration, mitochondrial activity Mobilization of stored resource in seeds. Chemistry of oxidation of starch, proteins and fats. Utilization of breakdown products by embryonic axis. Control processes in mobilization of stored reserves. Role of embryonic axes. Gibberellin and  $\alpha$ -amylase and other hydrolytic activity. Seed maturation phase and desiccation damage, role of LEA proteins. Seed viability. Seed dormancy. Means to overcome seed dormancy.

### **Unit 9: Physiology of Flowering and Reproduction**

Evolutionary history of flowering plants (angiosperms). Semelparous and iteroparous reproduction, monocarpic and perennial life etc. Flowering phenomenon, effect of plant age, juvenility- transition to flowering. Flowering nature and classification of plants. Photoperiodic responses and the mechanisms in short and long day plants. Theories related to flowering. Endogenous substances and flowering. Gene expression in flowering. Control of flowering. Thermoperiodism - photo and thermo-period interactions. Vernalization-mechanism. Photomorphogenesis, photoreceptors, phytochrome, cryptochrome, physiology of flowering, photoperiodism and vernalization. Optimization in flowering response-to environmental features (light, temperature, stress) etc. plant reproductive physiology. Mating strategy in plants, molecular techniques to understand mating patterns, self-incompatibility responses, physiological processes mediating fertilization (pollen-stigma interactions), seed and fruit development, seed and fruit abortion and means to overcome it. Molecular biology of seed development, physiological basis of cytoplasmic male sterility and fertility restoration. Physiology of heterosis.

### **Unit 10: Physiology of Horticultural and Plantation Crop species**

Growth and development of horticultural and plantation crop species. Juvenility, shoot growth, types of shoots, patterns of shoot growth, cambial growth and its regulation. Physiological aspects of pruning and dwarfing. Growth measurements. Water relations of tree species. Water uptake and transport. Concepts of transpiration rate and water use efficiency. Sexual and asexual propagation. Rootstock and scion

interactions. Physiology of flowering in perennial species, photoperiodism and thermoperiodism. Physiological aspects of fruit crops: mango, banana, grapes, citrus, papaya and pineapple etc. Physiological aspects of plantation crops: tea, coffee, cardamom, coconut, and blackpepper.

### **Unit 11: Post-Harvest Physiology**

Senescence and ageing in plants. Ethylene – the senescence hormone, leaf senescence. Monocarpic plant senescence. Biochemistry and molecular biology of flower senescence. Gene expression during senescence. Concept of physiological maturity of seeds - post harvest changes in biochemical constituents in field crops - loss of viability, loss of nutritive value, environmental factors influencing post-harvest deterioration of seeds. Physiological and biochemical changes during fruit ripening and storage. Senescence and post harvest life of cut flowers. Physical, physiological and chemical control of post - harvest deterioration of fruits, vegetables and cut flowers and its significance during storage and transport. Molecular approach in regulation of fruit ripening. Transgenic technology for improvement of shelf-life. Edible vaccine

### **Unit 12: Morphogenesis, Tissue Culture and Plant Transformation**

Morphogenesis; the cellular basis of growth and morphogenesis; polarity in tip growing cells and diffusive growing cells. Control of cell division and differentiation, phyto-chromes, different forms, physiological effects and gene regulation, and cellular totipotency, physiology and biochemistry of differentiation, in organ cell, tissue and cultures, micropropagation strategies, application of tissue culture in agriculture, horticulture, forestry and industry: plant transformation; transformation vectors, concept of selectable and scorable markers. *Agrobacterium* mediated transformation, binary vectors, biolistics. Electroporation, selection of putative transgenic plants, genetic analysis. PCR, Southern analysis evaluation of transgenic plants.