Course Title: Functional Genomics and Genes Associated with a few Physiological Processes
Course Code: PP 601
Credit Hours: 2 (2+0)

Unit 1: Gene Discovery

- Finding genes in complex plant system, Constructing gene-enriched plant genomiclibraries
- Recent advancements in genome sequencing, RNA sequencing and expression.
- In Silico prediction of plant gene function, Quantitative Trait Locus analysis as a genediscovery tool
- Gene expression analysis –micro-array and deep sequencing, small RNA andDegradome,
- Study of methylome and its significance

Unit 2: Genetic Tools for Plant Development

- Understanding the importance of mutants in unrevealing the physiological processes, genome wide insertional mutagenesis – T-DNA insertion mutants, Gain in function, Transposon mutagens, Transposition.
- Physical and Chemical mutagenesis
- Gene and Enhancer Traps for Gene Discovery
- High-Throughput TAIL-PCR as a Tool to identify DNA Flanking insertions, High- Throughput TILLING for functional Genomics.
- Genome editing approaches for functional analysis of genes

Unit 3: Gene Knock Out Approaches

- PTGS-Antisense technology
- Virus induced gene silencing (VIGS)
- Custom Knock-outs with Hairpin RNA-mediated Gene Silencing and other silencingtools
- Complementation studies

Unit 4: Chemical Genomics

- Reverse chemical genomic approaches for functional validation of genes.
- Protein structure prediction, homology modelling and virtual screening by using bio informatic approaches to identify the small molecules and their validation through phenotyping assessment.

Unit 5: Gene Over Expression Approaches

- Vector Construction for Gene Over-expression as a Tool to Elucidate Gene Function
- Transient expression, Transgenics
- Targeted and conditional expression of transgene

- Multiple gene expression by Nanostring technology
- Co-expression analysis and gene networking to identify potential genes in thepathway (informatics)
- Epigenetics

Unit 6: Synthetic Biology and Interaction Studies

- Engineering microbial pathways in plants (eg, photosynthesis)
- DNA-protein & Protein-protein interaction studies, yeast hybrid system.
- Correlating the data from genome, transcriptome, proteome, metabolome and ionome with phenome
- Multivariate analysis and identification of metabolite as biomarkers

Unit 7: Case Studies

- Functional characterization of genes associated with important cellular processes influencing crop growth and development: genes controlling photosynthesis and nutrient uptake
- Functional characterization of genes associated with important cellular processes influencing crop growth and development: genes controlling respiration and photorespiration
- Functional characterization of genes associated with important cellular processes influencing crop growth and development: fatty acid biosynthesis, seed protein quality and quantity
- Functional characterization of genes associated with important cellular processes influencing crop growth and development: genes controlling flowering

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Course Title : Signal Perception and Transduction and Regulation of Physiological Processes
Course Code: PP 602
Credit Hours: 2 (2+0)

Unit 1: Concept of Receptor and Ligands

- Signal, signal types, long (diffusible) and short (contact) range signaling and components of signaling.
- Types of receptors, nature of ligands, downstream components like primary,secondary signaling components.

Unit 2: Receptors – Signal Perception and Transfer

- Cell surface trans-membrane receptors- GPCRs, Receptor Tyrosine Kinases (RTKs), Receptors Serine Threonine kinases (RSTKs), Receptor-Like Kinases (RLKs), receptor two component systems.
- Signal transfer phosphor-relay and generation of secondary signaling components and activation of TFs or enzymes.
- Downstream components- G-proteins, second messengers-Cyclic AMP, Adenylate cyclase cascade, cyclic GMP, calcium-calmodulin-kinases; effector molecules (transcription factor).

Unit 3: Hormone Signaling

- Hormone binding receptors-Transduction process. Effector molecules and geneexpression.
- Specific signaling pathways of Auxins, Cytokinin, Gibberellins, Ethylene, ABA, Brassinosteroids, Salicylic Acid, Strigolactone, polyamines, Jasmonic acid, etc. which leads to formative effects.
- Cross talk in the signaling of different hormones-significance of studies with hormone action mutants.

Unit 4: Light Signaling

- Perception of light-pigments involved- activation of phytochrome/cryptochrome(study of mutants).
- Light signal transduction.
- Multiple signaling cascades-identification of signaling components through mutant analysis-changes in gene expression.

Unit 5: Abiotic Stress Signaling and Nutrient Signaling

- Sensing of environmental factors (Temperature-Osmotic-Ionic stress)
- Activation of specific molecules and secondary messengers, activation of downstream components-leading to stress gene expression.
- Case studies with different abiotic stresses.
- Retrograde signaling.
- Nitrogen fixation, nitrogen and phosphorus uptake, nutrient translocation.

Unit 6: Signaling Cascade during Developmental Events

- Leaf senescence/fruit development and ripening.
- Tuberization.
- Sugar signaling.
- Signaling during seed germination.

Unit 7: Signal Perception and Transduction in Plant Defense Responses

- General mechanisms to pathogen response.
- Role of salicylic acid and active oxygen species.
- Cross Talk Signaling- Stress matrix under field conditions, cross talk between abiotic-abiotic stress, biotic-abiotic stress signaling networks.

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Title: Molecular Approaches for Iproving Physiological Mechanism through trait Introgression
Credit: 2+1
Course Code: PP 603

BLOCK 1: TRAIT INTROGRESSION THROUGH MOLECULAR BREEDING

Unit 1: Physiological Traits Relevant for Crop Improvement and their Phenotyping

- Physiological traits with relevance to growth, development, biotic/abiotic stress tolerance, nutrient acquisition
- Concept of complex, multi-gene control of physiological traits
- Concepts of trait introgression to augment crop productivity and/or stress adaptation.

Unit 2: Identification of QTL by Bi-parental Mapping Approach

- Concepts of developing trait-specific mapping population and identification ofcontrasting parental lines through phenotyping
- Mapping populations and their developments – F2, RIL, doubled haploid populations
- Accurate phenotyping of bi-parental mapping populations
- Conventional Genotyping strategies using SNP and SSR markers, other rapid approacheslike GBS, RADseq, QTLseq etc.,
- Composite interval mapping and other approaches for QTL discovery

Unit 3: Identification of QTLs by Association Mapping Approach

- Concepts of assembling a "Panel" of germplasm amenable for association mapping basedon molecular and phenotypic diversity.
- Concepts of linkage disequilibrium, LD decay and population structure
- Concepts QTL discovery in structured populations
- Phenotyping of the association mapping populations
- Concepts of Genome wide association studies (GWAS)

Unit 4: Trait Introgression by Molecular Breeding Approaches

- Strategies for QTL introgression and Marker Assisted Selection (MAS).
- Various breeding methods for trait introgression: Marker assisted backcross breeding(MABC),
- Marker assisted recurrent selection (MARS),
- Marker assisted phenotypic selection (MAPS) etc.

BLOCK 2: TRAIT INTROGRESSION THROUGH TRANSGENIC TECHNOLOGY

Unit 1: Gene Discovery and Gene Constructs for Relevant Plant Traits/Adaptive Mechanisms

- Map-based cloning to identify novel genes and their allelic variants
- Identification of differentially expressed genes through transcriptome, metabolome andproteome analysis in contrasting genotypes.

- Gene identification through forward (inducing mutations with radiation, chemicals, orinsertional mutagenesis)and reverse genetic approaches (site-directed mutagenesis, geneknockout or knockdown)
- Cloning full-length candidate genes, inducible promoters
- Concepts of "codon optimization" to make constructs for specific crops

Unit 2: Trait Improvement or Pyramiding through Transgenic Technology

- Introduction to GMOs and its application in crop improvement
- Gene stacking strategies for trait improvement
- Agrobacterium and other methods of plant transformation including gene gun, in planta,etc

Unit 3: Genome Editing, a Potential Option for Gene Regulation by Transgenic Approach

- Genome editing techniques: CRISPR/Cas9, Zinc finger nucleases etc
- CRISPR as tool to generate loss-of-function and gain-of-function transgenics

Unit 4: Characterization of Transformed Plants and Event Selection Strategies

- Molecular analysis bySouthern, qRT-PCR/Northern analysis, and immunoassays
- Concepts of copy number and desirable number of independent events
- Evaluation of transgenics based on empirical/physiological/biochemical processes under specific conditions – containment and confined field trials
- Generation of T1 populations, event characterization
- Molecular data as per regulatory requirements
- Biosafety and Regulatory aspects of GMO

BLOCK 3: OTHER APPROACHES FOR TRAIT INTROGRESSION

Unit 1: Trait Introgression through Tissue Grafting and Asexual Propagation

- Concept of identifying root stocks with superior traits, grafting, scion root stockinteraction, compatibility, concept of chimeric grafting in transgenic technologyinvolving a non-transgenic shoot to a transgenic root.

Unit 2: Doubled haploids for Trait Introgression

- Concept of crossing trait donor lines and developing doubled haploids from the F1 anthers.
- Screening and identifying trait introgressed doubled haploids.

PRACTICALS

Phenotyping approaches for the different physiological traits. Development of SSR, SNP and SCAR markers, resolution of polymorphism on agarose gels and PAGE, genotyping options for SSR markers using capillary and chip based fragment analysis systems. scoring of gels and assessment of polymorphism

Statistical approaches to assess genetic variability, heritability and other parameters. Phylogenetic analysis and principle component analysis and construction of

dendrograms.Construction of Linkage map, QTL maps, population structure, LD decayetc leading to identification of QTLs.

Bioinformatics – sequence analysis, structure analysis, designing primers for SSR regions, SNP2CAPS approaches of genotyping.

Molecular biology - genomic/plasmid DNA isolation, RNA isolation.Full-length gene cloning, vector construction with specific promoter, gene stacking and transient assays.Transformation in model system

Crop transformation - Agrobacterium mediated transformation (in-planta and invitro), particle-gun transformation.

Evaluation of transgenics – semiquantitative and quantitative RT-PCR, southern blot, northern blot, western blot and ELISA, biochemical/physiological assay based on the function of gene and testing LOD.
Improvement of traits based on grafting options.
Techniques in developing doubled haploids and characterization.

Course Title : Plant Phenomics – Next Generation Phenomics Platforms
Course Code: PP 604
Credit Hours: 2 (2+0)

BLOCK 1: CONCEPTS OF HIGH THROUGHPUT PHENOTYPING AND ITS REQUIREMENT

Unit 1: Concepts of Phenotyping

- The concepts of "phene and trait" analogous to gene and allele. Genome-phenome relationship, definition of phenotyping, GxE interaction on phenome.

Unit 2: Physio-Morphological Traits Associated with Crop Performance

- Overview of phenotyping needs to complement genomic resources, specific traits associated with yield potential, stress adaptation (both biotic and abiotic stresses).
- Need for high throughput precision phenotyping approaches for basic studies and togenerate genetic and genomic resources.

Unit 3: Features of Phenomic Platforms

- Precision growth conditions, maintenance of light, temperature/VPD and RH to realize the potential crop growth response.
- Controlled environmental facilities for simulating challenging climatic conditions to phenotype diverse plant traits.
- Concept of sensors, diverse sensors and their utility in precise quantification of environmental variables, soil moisture sensors.
- Imaging to capture plant traits, image acquisition. Automated big data access,processing etc.

Unit 4: Trends in Phenomics

- Types of phenomic platforms- Laboratory, Greenhouse and the field-based platforms.
- Platforms designed for specific needs i.e., root phenotyping, drought studies etc., Crop specific phenotyping, mobile and stationary platforms.
- Global trends in establishing major phenomics platforms, and their characteristicfeatures and impact.

Unit 5: Non-invasive Phenotyping Approaches

- **The concept of non-invasive capturing of plant growth and health**
    - Imaging technologies - image acquisition, segmentation and data analysis.
    - Critical aspects of Visual, IR Thermal, Fluorescence, NIR, Hyperspectral imaging.

- Development and validation of models for deriving relevant physiological traits from image phenome.

- **Concepts of Plants to sensors and sensors to plants.**
  - Stationary and ground based tractor mounted sensors/imaging tools.
  - Unmanned aerial vehicle (UAV) sensors.
  - Machine learning and its integration to analyze ground and aerial basedimages.

BLOCK 2: APPLICATIONS OF THE PHENOMICS PLATFORMS

Unit 1: Basic Studies to Assess the Crop Response

- Functional validation of genes, chemicals and other interventions.
- Characterize the growth and stress response in contrasts to identify the relevance ofadaptive trait

Unit 2: Applied Studies Focused on Crop Improvement Programs

Unit 1: Basic Studies to Assess the Crop Response

- Functional validation of genes, chemicals and other interventions.
- Characterize the growth and stress response in contrasts to identify the relevance of adaptive trait

Unit 2: Applied Studies Focused on Crop Improvement Programs

- Characterizing the pre-released promising lines for productivity under defined environmental variables. Phenotyping germplasm accessions, mapping populations for specific traits for mapping.
- Concept of Phenome Wide Association Studies (PWAS).
- Genomic selection, gene-based crop models to predict complex traits.
- Impact of phenomics platform, progress made, case studies.

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Course Title : Experimental Techniques to Characterize Plant Processes for Crop Improvement
Course Code: PP 605
Credit Hours: 2 (0+2)

Unit 1: Stress Responses

- Thermal (reflectance) characters as a measure of water status and root characteristics.
- Oxidative stress induction and assessing the response on lipid peroxidation and quantification of ROS, RCC's, RNS
- Fluorescence to assess the stress response.
- Water use efficiency quantification at leaf, plant level, surrogates for WUE
- Tissue localization of ROS, RNS by qualitative staining and fluorescence-basedmethods

Unit 2: Photosynthetic processes

- Concept and approaches to assess of radiation utilization efficiency (RUE)
- Quantification of mesophyll and other diffusive resistances regulating photosynthesis
- Carboxylation efficiency (light and CO_2 response curves)
- RuBiSCO activation status

Unit 3: Hormonal Response on Specific Plant Growth Processes and Quantification

- Bioassays to assess the biological process regulated by hormones – new in-vivoassays
- Promoter assays for hormone response- GUS/YFP/GFP based assays- expression of hormone responsive genes
- Recent analytical tools and techniques to quantify hormones – GC-MS, LC-MS, Capillary electrophoresis

Unit 4: Nutrient Response Acquisition and Quantification

- Recent advances in soil less cultures to study the nutrient response- Hydroponics/Aeroponics/Fogoponics.
- Noninvasive techniques to quantify nutrients – XRD (X-Ray Diffraction analysis)and hyper spectral reflectance.

Unit 5: Photo and Thermo Morphogenesis

- Photo receptors, light and temperature regulation of plant growth and flowering.
- Thermal time, heat units, GDD.
- Concept and approaches for speed breeding.

Unit 6: Recent Approaches for Functional Genomics

- In silico prediction of gene function.
- Flanking sequence identification in insertional (T-DNA/transposon) mutants.
- Concept of insertional mutagenesis and mutant experiments
- Utilization of genetic resources for functional genomics – mutants and tilling, eco tilling
- VIGS, RNAi, miRNA
- Genome editing –CRISPR
- Concept of chemical genomics for functional validation
- Relevant molecular tools to assess gene expression or (to regulate the process and assign a function to gene).
- Multiple gene expression by Nano String technology
- Cap analysis gene expression (CAGE) – to identify start point of transcription
- Yeast hybrid interaction.
- Immunoprecipitation
- Chip-PCR.

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Course Title : Globa Climate Change and Crop Response
Course Code: PP 606
Credit Hours: 2 (2+0)

Unit 1: Fundamentals of Climate Change

Definition of climate change, history and evidences of climate change and its implications. Natural and anthropogenic climate change. Sources of Greenhouse Gas (GHG) emission, Global Warming Potential of GHGs, accumulation of GHGs in the atmosphere and science behind climate change, industrial revolution and GHG build-up in the atmosphere, Energy- Emission-Economy Interactions, carbon intensity of economy, carbon equity/justice.

Unit 2: Manifestations of Climate Change

Impact on monsoons, occurrence of extreme weather events, hydrological cycle and water availability, effect on crop growing period in tropics, subtropics and temperate regions, shifts in distribution of flora and fauna, effects on biodiversity and migration of tropical plant species to higher latitudes and altitudes.

Unit 3: Major GHGs (CO_2, Methane, NO_2 etc.), their Production Rates, Monitoring and their Influence on Climate Change

GHGs: An Overview, - role of CO_2, methane and major uncertainties. Mechanism of their production and emission from various, source and sinks of GHGs; and contribution of GHGs to global warming. Techniques used in monitoring GHGs.

Unit 4: Agricultural Practices on GHG Production

Carbon footprint analysis of agriculture and various agricultural practices contribute to climate change. Impacts of natural factors and farming practices on greenhouse gas emissions. Sources of agricultural GHG emission- Agricultural Soil Management, enteric fermentation, manure management, other sources. Opportunities to reduce GHG emission from Agriculture.

Unit 5: Direct and Indirect Effects of Climate Change on Plant Processes

Problems and Prospects of Crops with changing temperature: Growth and Development of Crop plants, Thermo-morphogenesis, phenology, Physiological processes such as photosynthesis, Net carbon assimilation, C_3 and C_4 plants adaptation,Respiration, Nutrient acquisition and metabolisms, Plant water relations and Heat shock proteins, Grain/seed development: Grain Quality parameters and yield.

Unit 6: Climate Change Scenario and Impact on Crops

Different scenarios for temperature, rainfall in different agro-climatic zones of India and their impact on crop growth and productivity. Major climate change (temperature, CO_2, and rainfall)

impact quantification using field or controlled environment experiments, meta- analysis and simulation models. Some examples of crop simulation models calibration and their application in short-term and long-term predictions.

Unit 7: Ozone Depletion leading to Increased Ionizing Radiations and its Implications on Crop Growth

Role of CFCs in ozone depletion, penetration of ionizing UV radiations and its implications on crop growth.

Unit 8: Long-term and Short-term Projections of Climate Change : Effects on Natural Vegetation and Ecosystems

Response of natural ecosystems to increasingatmospheric CO_2 concentration and climate warming, effect of climate change on quality of feed i.e leaf and stored grains/seeds, its implications on pollinators and pests

Unit 9: Technologies for Climate Change Mitigation in Agriculture

a. Agricultural biotechnology to produce crop varieties with enhanced carbon uptake.
b. Nutrient management: Management of nitrogenous fertilizers;
c. Tillage/residue management: 1.Conservation tillage CO_2 mitigation technology; 2. Biochar: A potentialtechnique for carbon sequestration.
d. Methane mitigation using reduced tillage technology, change in methanogenic bacterial activity using electron acceptors.
e. Carbon sequestration potential, concept and measurement.

Unit 10: Climate-resilient Agriculture

Conventional and biotechnological approaches to improve the crop adaptation to climate change. Relevance of "Genome wide mutants" to identify genes/processes for improved adaptation to changing environments.

Unit 11: Climate Change: Technologies for Crop response studies

Temperature Gradient Chambers, Temperature Gradient Greenhouses, Soil plant atmosphere research system (SPAR), Infra-red warming Technology, Free Air temperature enrichment technology, Soil Warming system etc.

Unit 12: Politics of Climate Change Negotiations

IPCC, Major International conventions/treaties, Kyoto Protocol, Paris Agreement, Global initiatives on Carbon sequestration, carbon trading.

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Course Title : Physiological and Molecular Aspects of Source-Sink Capacity for Enhancing Yield

Course Code: PP 607

Credit Hours: 3 (3+0)

BLOCK 1: SOURCE SIZE AND FUNCTION- BASIC CONCEPTS, PHYSIOLOGICAL AND MOLECULAR MECHANISMS, GENOMIC RESOURCES TO REGULATE SOURCE CHARACTERS

Unit 1: Source Establishment

- Maximize energy capture by improved light interception, light distribution and its utilization efficiency, concepts of shade avoidance response (SAR) and option to increase.
- Increase canopy size by vertical expansion – concept of increasing optimum LAI levels.
- Concepts of semi-tall varieties with resistance to lodging: traits associated with lodging resistance.
- Sustain net carbon gain with age – the relevance of stay green character, photon capture and achieve high CO_2 reduction to photon ratio under low light.
- Options for increasing canopy photosynthesis.
- Relevance of maintaining cell turgor and nutrient status.

Unit 2: Source Function- Photochemical Reactions

- Maximize conversion efficiency of intercepted radiation by improving net carbon gain - Emerging solutions to increase carbon fixation rate.
- Improve efficiency of photochemical reaction by - Engineering the pigments to expand PAR spectrum into IR range; reduce antenna size, optimize energy dissipation mechanisms; optimize components of ETC and downstream acceptors; accelerate adaptation for shifting light intensities.

Unit 3: Source Function- CO_2 Diffusion and Concentration

- Enhance stomatal conductance (g_s) and mesophyll conductance (g_m) – guard cell metabolism; concepts of leaf mesophyll tissue thickness (SLW).
- Concepts of VPD responses of g_s to enhance duration of photosynthesis during the day.
- Bicarbonate transports and aquaporins; achieve higher CCM - Engineering C4 cycle,CAM, cyanobacteria, carboxysomes, algal pyrenoids.

Unit 4: Source Function- Metabolic Engineering of CO_2 Fixation

- RuBisCO carbon fixation activity - Increase and optimize kinetics of RuBisCO withenhanced specificity to CO_2.
- Engineer RuBisCO to minimize feedback regulation by metabolite inhibitors.

- Increased activation state by improving stability and function of RuBisCOactivase; optimize RuBp regeneration – modulate specific enzyme levels.
- New concepts on photorespiratory synthetic bypass.

Unit 5: Case Studies to Improve Source Capacity

- Genetic and genomic resources, genes/QTLs associated with specific yield potential traits and/or photosynthetic mechanisms.
- Genetic resources to improve source traits- case studies.

BLOCK 2: IMPROVING SINK SIZE AND CAPACITY

Unit 1: **Sink Establishment**

- Optimise duration of phenological stages related to sink establishment, genetic and environmental factors, GDD and phenology.

Unit 2: Increase the Sink Size by Enhancing the Relevant Constituent Traits

- Role of hormones in regulating molecular mechanisms of yield structure development.
- Genomic and genetic resources developed for regulation/improvement of such traits.
    - Sink Size: Tillering associated traits, branching patterns/fruiting points, spikelet number, pod number, fruit number.
    - Sink development: Basic concepts and molecular mechanisms associated with pollination, fertilization, ovary development in determining the spikelet fertility/sterility components and strategies for engineering seed/fruit size in crop plants.

Unit 3: Genetic and Genomic Resources, Genes/QTLs, Genetic Resources to ImproveSink Traits- Case Studies

- Progress and status in developing genomic and genetic resources of validated genes/QTLsto improve sink traits- Specific case studies.

Unit 4: Source to Support the Sink Capacity

- Canopy architecture to support sink requirements in cereals: plant height, tillering, leaf area, shading or senescence of lower canopy leaves, canopy photosynthesis.
- Canopy architecture to support sink requirements in Pulses: Leaf senescence, abscission, mobilization of N and other nutrients.
- Symbiotic N fixation to support sink size and capacity in pulses.

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Course Title : Seed and Fruit growth and their Quality Improvement
Course Code: PP 608
Credit Hours: 2 (2+0)

BLOCK 1: PHYSIOLOGICAL AND MOLECULAR ASPECTS OF SEED ANDFRUIT GROWTH: QUALITY IMPROVEMENT

Unit 1: Physiology of Seed Growth and Development

- Mechanism of seed development and different developmental stages; synthesis, mobilization and accumulation of stored reserves;
- Forms of stored reserves and their localization
- Sink drawing ability (SDA) and its relevance in seed growth and development;
- Role of plant hormones in seed growth and development and SDA

Unit 2: Seed as a Propagule

- Seed as a propagation material; seed size and seed chemical composition and their relevance in seed germination.
- Physiological, biochemical and molecular mechanisms and approaches to regulate seed germination, seedling emergence and establishment and seedling vigour.
- Physiological, biochemical and molecular mechanisms and approaches to regulate seed priming and crop establishment: seed dormancy, precocious germination and controlling pre-harvest sprouting in crops.
- Physiological, biochemical and molecular mechanisms and approaches to regulate seed viability, improving the viability and storability of seeds.

Unit 3: Seed as a Source of Nutrition

- Seed as a source of nutrition to humans: approaches to improve the quality of seeds through synthesis of seed storage reserves and other constituents.
- Genes/QTL's regulating these processes and concept of pathway engineering to improve the quantity and quality of seed constituents.
- Carbohydrates- Amylose and amylopectin ratios for glycemic index, resistant and digestable starch, improving dietary fibre, alter gelatinisation.
- Protein content, modified proteins, essential amino acids.
- Oil content, fatty acid composition, Omega 3 fatty acids. Carotenoids and vitamins
- Biofortification strategies to enhance the grain zinc, iron, other minerals and other essential compounds.
- Engineering for low protease inhibitors, phytic acid, tannins, phenolic substances, lectins, oxalates as anti-nutritional factors.
- Case studies of improving seed nutrition components by molecular breeding and

transgenic approaches.

Unit 4: Quality Deterioration during Storage

- Changes in chemical composition during storage; factors influencing the deterioration of nutritional quality of seeds during storage; approaches to minimize nutritional quality deterioration
- Effect of quality deterioration on human and animal health

Unit 5: Fruit Growth and Development

- Flower and fruit development; concept of parthenocarpy
- Physiological and biochemical changes during fruit development and chemical composition
- Molecular approaches to regulate flower and fruit drop/ abscission; Role of hormones

Unit 6: Fruit as a Source of Phytochemicals : Nutraceuticals

- Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Antioxidants, Flavanoids, anthocyanins
- Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Vitamins- Vitamin C, Tocopherol, Carotenoids
- Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Alkaloids, Mangiferin, tomatins
- Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of DigestableFiber lycopene, stillbeans
- Biosynthetic pathways and the quantification and options to improve by hormonal and molecular pathway engineering approaches of Aroma, monoterpenoids and Fatty acid esters.

Unit 7: Fruit Ripening, Post Harvest Deterioration and Shelf life

- Physiological and molecular mechanisms of fruit ripening.
- Postharvest deterioration of fruits; factors regulating fruit deterioration; hormonal and environmental aspects of reducing post harvest deterioration of fruits
- Physiological and Molecular approaches to regulate fruit ripening and shelf life: Role of Ethylene and Ethylene response factors regulating specific processes of fruit ripening; Approaches to regulate specific shelf life characters.
- Improving fruit ripening and shelf life by molecular approaches-Case studies.

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Course Title : Plant Microbe Interaction
Course Code: PP 609
Credit Hours: 3 (2+1)

BLOCK 1: PLANT PATHOGEN INTERACTION

Unit 1: Introduction to Plant Pathogen Interaction

- Introduction to plant microbe interaction and importance, the concepts of holobiome and hologenome
- Differences between endophytes/ rhizosphere/phylloplane microbes and phytopathogens
- Types of endophytes/rhizosphere/phylloplane microbes, and their classifications

Unit 2: Genetic Basis of Host Pathogen Interaction

- Genetics of immune response, Signal perception, Host-pathogen interaction (bacteria, fungus and virus).
- Nature of resistance to diseases-pathogenecity genes (pat) in plant pathogens-disease specific genes (dsp), avirulence genes (avr), avr gene – coded proteins-structure of avr genes.
- Transmission of the alarm signal to host defense producers: signal transduction, pathogen elicitors, protein kinases, calcium ions, phosphorylases, phospholipases, ATPases.
- Accumulation of Phytoalexins as a Resistance mechanism-Biosynthesis and metabolism of Phytoalexins, Modes of action of Phytoalexins,
- Pathogenesis-Related proteins (PR) and Disease Resistance- intro-Characterizationand biological functions of PR proteins, Biosynthesis of PR proteins.

Unit 3: Growth Regulators of Plant Defense and Susceptibility

- Regulation of hormones countering the pathogen infection and toxins modulating the plant physiology
- ABA-SA cross talk and role of JA during plant interaction biotrophic andnecrotrophic pathogens respectively

Unit 4: Bioenergetics in Plant Pathogen Interaction

- An overview of energy-capture and energy-utilization processes in higher plant,Energy-capture and utilization process as affected by pathogenic infection.
- Molecular basis of pathogenesis and the process of interaction**-** classical examples of pathogens causing necrosis, wilts, tumours and soft rots
- Role of primary metabolism in plant-pathogen interaction

BLOCK 2: PLANT- ENDOPHYTES / RHIZOSPHERE / PHYLLOPLANEMICROBES INTERACTION

Unit 1: Interaction of Endophytes/ Rhizosphere/ Phylloplane Microbes with Plants

- Approaches to study endophytic/ rhizosphere /phylloplane microbes bacteria andfungi, Intracellular bacteria 'Cytobacts'
- Possible mechanisms of host plant genotype influence in recruitment of endophytic microbes vertical / seed transmission;
- Inter-kingdom signaling regulating endophyte/ rhizosphere/phylloplane microbes development
- Adaptation with respect to colonization of endophytes/ rhizosphere/phylloplanemicrobes

Unit 2: Role of Endophyte / Rhizospheric / Phylloplane Microbiota in Plant Physiological Processes

- Phytohormones role in beneficial endophyte/rhizospheric/phylloplanerecruitment; Hormonal regulation of assimilate partitioning in plant-microbe interactions.
- Plant-Fungus-Bacteria, the three fold interaction for improved plant nutrition

Unit 3: Endophyte / Rhizospheric / Phylloplane Microbes in Improving Biotic and Abiotic Stress Tolerance

- Importance in imparting stress (biotic and abiotic) adaptations, in the regulation of bioactive compound (alkamide) accumulation; acclimatization of root-interacting fungi for improved plant nutrition and stress tolerance;
- Cultivable versus uncultivable endophytes with respect to their extent of tissue colonization and diversity
- Genetic engineering of endophytes for production of industrially important bioactive compounds, endophyte-enrichment technologies in crops for traits manipulation.
- Role of existing microbiome on introduced endophyte, symbiotic microbes and their interaction
- Modern techniques for examining plant-microbe-insect interactions.

Unit 4: Bioethics, Biosafety, Intellectual property rights and implications in plant-microbe research

- DBT biosafety regulations on working with microbial organisms associated withplants
- Standard operating procedure (SOP)
- Committees dealing with biosafety and safe release of microorganisms

BLOCK 3: MICROBIAL INTERACTION WITH PLANTS IN THE PRESENCE OF ABIOTIC FACTORS

Unit 1: Disease Triangle and the Contribution of the Environmental Factors in Influencing the Plant-microbe Interaction

- Disease triangle involving plant-pathogen-environment and the importance of environmental stresses (drought, heat, humidity and soil factors) in influencing the resistance or susceptibility
- Role of environmental factors in influencing establishment and sustenance of introduced beneficial microbes

Unit 2: Physiological and Molecular Basis for Predisposition or Endurance of Plantduring Abiotic-biotic Stress Interaction

- Plant-water relations and changes in physiology in deciding the microbe interaction with plants
- Metabolites in deciding the microbe interaction with plants
- Hormonal cross talk, signal transduction, role of R-genes and other defense pathways during the simultaneous exposure to abiotic stress

PRACTICALS

- *In-planta* bacterial/fungal multiplication in plant under drought stress
- Detection of plant pathogens using molecular tools
- Stomatal conductance in plants under drought stress and pathogen stress
- Apoplast isolation from plants subjected to bacterial infection
- Virus induced gene silencing in plants
- Acetylene reduction assays to check nitrogen fixation in plant (The effect of beneficial microbes in plant)
- Biochemical analyses of beneficial and pathogen-effector proteins
- Plant colonization and disease or growth promotion scoring
- In-vivo detection of plant immune responses and their inhibition by effectors
- Estimation of phytoalexins, PR proteins, ACC deaminase and growth hormones in pathogen challenged plants
- Effect of plant microbe interaction on plant physiological processes viz., photosynthesis, chlroroplast, transpiration etc.

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Course Title : Weed Biology and Physiology of Herbocide Action
Course Code: PP 610
Credit Hours: 2 (2+0)

BLOCK 1: WEED BIOLOGY

Unit 1: Weed Biology and its Importance in Weed Management

Introduction to weeds, Classification of weeds, Yield losses caused by weeds, Environmental impacts of invasive weed species, Aspects of Weed biology, Germination, Dormancy and growth behaviour of weed species, Effect of environmental factors on weeds, Adaptation of weeds to different ecologies

Unit 2: Life Cycle and Population Dynamics of Weeds

Growth duration and reproductive potential of weed species, Population dynamics, Weed Shift due to weed management, weed Seed Bank,

Unit 3: Crop Weed Competition

Understanding the nature of crop-weed competition, critical stages of crop weed competition, growth stages of weeds for improved control by herbicides

BLOCK 2: PHYSIOLOGY OF HERBICIDE ACTION

Unit1: Introduction to Herbicides

Introduction, Chemistry and classification of herbicides by mechanism of action, HRAC Classification, Site of Actions, Application techniques, doses, active ingredients, formulations, Absorption and translocation of soil and foliar applied herbicides, Methods to increase the efficiency of soil and foliar applied herbicide – role of membranes, adjuvants, surfactants, synergists,

Unit 2 : Mechanism of Action of Herbicides

Physiological and biochemical effects of herbicides: Effects on membrane structure and functions, cell division and cell development, Effects on chloroplast, photosynthesis, respiration, protein synthesis, synthesis of lipids, Molecular mechanism of action, Molecular mechanisms of herbicide resistance in relation to chloroplast gene expression,

Unit 3. Herbicide Resistance and its Management

Herbicide resistance-Definition, history, magnitude; Mechanisms of resistance: Target site and non-target site, cross and multiple resistances, Role of management practices on resitance development, Resistance management: Strategies; HR crops, Super weeds.

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