SIXTH SEMESTER B. Sc. BOTANY DEGREE PROGRAMME

CORE COURSE-Elective paper

GENETICS AND CROP IMPROVEMENT

Code: BOT6B11T

SYLLABUS

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Module -1.

Crop genetics - General account of origin, genetic variability, floral biology, breeding techniques and achievements in: Rice, Coconut, Rubber, Arecanut, Cashew and Pepper

Module –II

1. Plant genetic resources - Definition; Classification of Plant Genetic Resources. Activities – Exploration, conservation, evaluation, documentation and utilization.

1. Agencies involved in plant genetic resources activities – NBPGR and IPGRI

2. International institutes for crop improvement – IRRI, ICRISAT, CIMMYT, IITA. Brief account on research activities and achievements of national institutes – IARI, CCMB, IISc, BARC, CPCRI, IISR, RRII, CTCRI, KFRI, JNTBGRI

Module- III

1. Methods of crop improvement: a. Plant introduction b. Selection - Principles, Selection of segregating populations, achievements c. Hybridization – Interspecific hybridization; intergeneric – achievements genetics of back crossing, Inbreeding, Inbreeding depression, Heterosis and Heterobeltiosis.

Module IV

1. Heteroploidy in crop improvement – achievements and future prospects – Significance of haploids and polyploids
2. Mutations in crop improvement – achievements and future prospects
3. Genetics of nitrogen fixation – Use of bio fertilizers in crop improvement
4. Genetics of photosynthesis

Module- V

I. Breeding for resistance to abiotic and biotic stresses – Introduction, importance of abiotic and biotic stresses and its characteristics

a. Breeding for drought resistance – Genetics of drought resistance; Breeding methods and approaches; Difficulties in breeding for drought resistance

b. Breeding for mineral stress resistance – Introduction – Salt affected soils – Management of salt affected soils: Salinity resistance – General account – Genetics of salinity resistance – Sources of salinity resistance – Breeding approaches – Problems in breeding for salinity resistance; Mineral stress resistance – General account – Resistance to mineral deficiency stress - Genetics of mineral deficiency resistance – Sources of mineral deficiency resistance c. Heat and cold resistance 1. Heat stress – General account; Heat stress resistance - Genetics of heat tolerance – Sources of heat tolerance. 2. Chilling resistance – Chilling tolerance – Genetics of chilling tolerance – Sources of chilling tolerance; Problems in breeding for freezing tolerance

B. Breeding for resistance to biotic stresses

a. Disease resistance – History of breeding for disease resistance; Genetics of pathogenicity – Vertical and horizontal resistance; Mechanism of disease resistance; Genetics of disease resistance – Oligogenic, polygenic and cytoplasmic inheritance – Sources of disease resistance – Methods of breeding for disease resistance.

b. Insect resistance – Introduction, Mechanism, Nature and genetics of insect resistance – Oligogenic, Polygenic and cytoplasmic resistance – sources of insect resistance – Breeding methods for insect resistance – Problems in breeding for insect resistance – Achievements – breeding for resistance to parasitic weeds

NOTES

Module 1

Crop genetics

- Study of genes, genetic variation and heredity in plants
- Interdisciplinary stream of study
- Prevalent after the discoveries of Mendel
- Application in crop improvement practices

Genetic variability

- The measure of how much the trait tend to vary
- Diversity is the number of actual variations
- Lead by several factors like:
    - Homologous recombination
    - Immigration, Emigration and translocation
    - Polyploidy
    - Diffuse centromeres
    - Mutations
- Factors suppressing the variability are habitat fragmentation and climate change

Floral biology

- Studies the evolutionary factors that have moulded the structures, behavior and physiological aspects involved in the flowering
- Angiosperm evolution associated with that of pollinators
- Study important as the pollinators are key factors affecting the crop yield
- Primitive plants Bisexual flower are large
- Self-pollination is reduced by dichogamy - protandry or protogyny; deeper corolla tubes for the long tongued pollinators
- Inflorescence - evolution from solitary flowers to clustered bunches to enable the pollination of several flowers in a single visit of a pollinator

- Chemotactic attraction - Production of volatile chemicals for attracting the pollinators
- Colour of the flowers- Birds attracted to large red flowers; night blooming flowers are white in colour

Breeding techniques in rice

- *Oryza sativa* - Poaceae
- Rice - the staple food of many countries including India
- Cordial temperature for production - 30 to 32 0C
- Jaya - miracle rice of India
- Jagannath- first mutant variety of India
- Flowers - In panicle, each complete flower with bifid feathery stigma, unilocular ovary and versatile anthers, buds closed in the protective structures called palea and lemma
- Improvement by hybridization - First step is emasculation- Stamens are removed in the bud stage, dusted with the pollen of desired variety.
- Objectives of breeding techniques - Maintain and improve cooking quality, increase grain length, minimize chalkiness, increased nutraceutical value, higher yield and milling stability
- Qualities improved - stress resistance, early maturation, water conservation
- Methods: Pedigree selection, Back crossing and forward crossing, induced mutation, bulk selection, mass selection
- Breeding programs - short, intermediate and long term goals
- Time required to release a new variety - 12 to 20 years
- Ideotype - The model plant selected in the basis of superior quality by morphological traits

Breeding techniques in Coconut

- *Cocos nucifera* - Arecaceae
- Perennial tree crop cultivated in the tropics for its nuts
- Some varieties released in India - Kerachandra, Chandrakalpa, kalparaksha, Kalpaprathibha by CPCRI, VPM-3, ALR-1 by TNAU

- Floral: Monoecious, spike inflorescence, wind pollinated, endosperm edible fruit
- Breeding methods: Introduction, selection, hybridization, biotechnological methods
- Breeding for the 1st time stated in the world at Neeleswaram

  1. Introduction: new varieties imported from Ceylon, Thailand, Philippines etc
  2. Selection: Mass selection for the improvement; based on the quality of the breeder; noted for the yield, age of the plant, nature and disposition of the leaf, size and shape of the nut
  3. Hybridisation
  4. Embryo culture, tissue culture, mol. Bio. Tech., QTL and linkage

Breeding techniques of Arecanut

- *Areca catechu* - Arecaceae
- Production dominant in the coastal region
- Commonly used for mastication
- Floral: Monoecious, Spadix inflorescence, Single seeded berry, insect pollinated or by air
- Largest producer and consumer - India
- Selection, Hybridisation and clonal selection

Breeding techniques in Cashew

- *Anacardium occidentale* - Anacardiaceae
- India accounts for 65% of the global cashew production
- Culinary uses: health benefits, resins and oils
- Evergreen tree, panicle inflorescence, fleshy peduncle, cross pollinated
- Varieties from Kerala - Sulabha, Mridula, Priyanka, Amrutha, Anagha
- Breeding for - high yield with bold nuts, increased fruit setting, dwarf and compact canopy, short flowering phase, high sex ratio, breeding for resistance
- Developed by selection and hybridization

Breeding techniques in Pepper

- *Piper nigrum* - Piperaceae

- Originated in India - WG
- Floral - Spike, Dioecious flowers, no perianth, berry fruit with pungent taste, exhibits protogyny
- Breeding - for higher yield, quality, higher levels of essential oils, resistance for diseases, drought and shade tolerance
- Methods: Selection (clonal, open pollinated progeny selection, germplasm), Hybridisation, Polyploid breeding, Mutation
- Achievements: Panniyur 4, 6, Sreekara, Subhakara, Panchami, Pournami

Module 2 - Plant Genetic Resources

Chapter 1

- Plant genetic resources - **Def.** the entire generative and vegetative reproductive material of species with economical and/or social value, especially for the agriculture of the present and the future, with special emphasis on nutritional plants.

  PGR- activities
- **Exploration:** Searching for something with specific aim and to utilize it. 1. Plant exploration and germ plasm collection is the first and foremost activity in PGR management. 2. This activity is executed through planning, co-ordinating and conducting collaborative explorations for collection of germplasm of different agrihorticultural crops and their crop wild relatives from various diversity rich regions.
- Procedure 1. Planning, 2. Making contacts with local research organization, 3. Gathering equipment and preparation, 4. Meeting with local researchers in area to be surveyed, 5. Sorting out of collected samples, 6. Reporting to the Headquarters, 7. Preparation & publication of reports, and 8. Distribution/ conservation of collected samples
- **Conservation: In-situ & Ex-situ**: In-situ is the conservation of the organisms in its own habitat. Ex-situ: in gene banks or field collections as seed or tissue samples.
- **Evaluation:** necessary to identify the appropriate germplasm with a target trait for their further utilization. A number of techniques are available for characterization and evaluation depending upon the need, type and nature of the plant/material available.

Amongst these, a) agro-morphological traits b) Biochemical traits, and c) molecular or DNA based markers are the prominent techniques for characterization and evaluation of PGR. The techniques of field-testing for agro-morphological parameters cannot be avoided even though these are highly influenced by the environment. The DNA based markers or molecular markers are also gaining importance because of the lack of environmental influence on these molecular makers.

- **Documentation and utilization:** Information systems, data standards, data exchange and distributed data network are required
- The proper documentation of plant genetic resources is required to properly conserve, manage and use biodiversity. For information important are documentation resources, types of documentation and information systems. In documentation system
- Institute of Plant Genetic Resources are included:

   Standards, protocols, rules and descriptor list

   Passport data

   Characterization data

   Evaluation data

   monitoring gene flow data

   Gene bank management software

   Information systems

Module 3 - Methods of Crop Improvement

a. Plant Introduction:

- Introducing the plants from their environment to a new environment
- Involve new varieties and wild varieties of a new crop species
- 2 types: 1. Primary introduction- when the introduced variety is well suited to new environment without any alteration of genotype. Eg. Wheat - Sonora-64, Dwarf rice variety - Taichung Native 1
- Secondary Introduction - When introduced variety is subjected to selection, the local varieties are improved with certain characters. Eg. Kalyan sona and sonalika varieties of wheat have been improved due the introduction from CIMMYT, Mexico

- Purpose: Introduction for new varieties of crops for agricultural development, forestry and industrial development - Ornamental plants are introduced for aesthetic purpose, for the conservation of germplasm (the spread of high yielding varieties causes danger to old varieties to get lost from an area)- for studying the origin and distribution of crop plants plus their evolution
- **Procedure**: **1**.Plant procurement,
  2. Packing and dispatch,
  3. Entry and plant quarantine,
  4. Cataloguing,
  5. Evaluation,
  6. Multiplication and distribution
- Agencies involved: NBPGR (HQ - Delhi) - Shimla, Jodhpur, Amravati, Kanyakumari, Shillong. - Others: FRI, BSI
- Merits: New crop, Superior varieties, Germplasm collection and maintenance, most quick and economical method, protection of some crops in newer areas.
- Demerits: Weeds like Argemone, Eichhornia, Lantana was introduced along with the crops; Fungal disease like late blight of potato, flat smut of wheat, coffee rust, bunchy top of banana; Insect pests like potato tuber moth, woolly aphids of apple, fluted scale of citrus
- Achievements: New crops - Potato, Maize, Groundnut, Coffee, Grape, ornamentals like Salvia, Gulmohar etc.; New crop varieties: 1. Direct multiplication - Sonora 64 wheat, IR 8 rice; 2. Selection of desirable varieties - Sonalika, 3. Introduced varieties as donors in hybridization programmes - Sugarcane; 4. Mutation breeding - If introduced material is agronomically superior but lacking a few characters may be treated with mutagen to rectify the defect. Eg. Sonora-64 introduced with red colour was not accepted by farmers the new mutagenic product sharbati Sonora was produced by MS Swaminathan by gamma ray treatment

b. Selection: Natural: Survival of the fittest

- Artificial: 4methods

- Mass selection: phenotypically superior plants selected in a huge number - most vigorous ones from the mixed population is selected - no scientific knowledge needed - demerits- importance given only to the phenotypic characters, no control over pollination, not applicable for the cross pollinated crops
- Progeny selection: used in cross pollinated crops- selected on the basis of the performance of the progenies - simplest method is ear-to-row method. Merits: simple, convenient, inbreeding may be avoided. Demerits: no control over pollination, some methods are complicated, large area required.
- Pure line selection: isolating an individual with desired characters and breeding with the same without contamination- 10 to 12 years needed for a pure line variety release. Merits: improvement of local varieties, easier than hybridization, applicable to both self and cross pollinated crops. Demerits - lengthy and laborious
- Clonal selection: selection and propagation of the desirable variations between the clones as well as within a clone. Stem cutting, grafts and buds, tuber, sucker, bulbs, runners, rhizomes, corms etc. merit: only method to improve the clonal crops, helps to eliminate the unproductive and undesirable types. Demerits: no new genetic variability, applicable only to vegetatively propagated plants
- Achievements: Potato varieties like Kufri red and Kufri safed; Pedda Neelam in Mango; High gate in banana etc.
- **Hybridization:** formation of a hybrid by means of crossing two genetically different parents
- Produces new combinations of genes
- Procedure: 1. Selection of parents, 2. Selfing of parents or artificial self-pollination, 3. Emasculation, 4. Bagging, 5. Tagging, 6. Crossing, 7. Harvesting and storing of F1seeds, 8. Raising the F1 generation.
- Interspecific hybridization- crossing between different species of the same genus - allows the exploitation of useful genes from wild Eg.
- Intergeneric hybridization: An intergeneric hybrid is a cross between plants in two different genera in the same family. They are closely related enough that pollination will produce a hybrid, though the seeds of this hybrid are usually sterile.

- Interspecific hybridization is the crossing of two species from the same genus. This allows the exploitation of useful genes from wild, unimproved species for the benefit of the cultivated species.
- crossing of a hybrid with one of its parents
- Advantages: If the recurrent parent is an elite genotype, at the end of the backcrossing programme an elite genotype is recovered. As there is no "new" recombination, the elite combination is not lost.
- Disadvantages: Works poorly for quantitative traits; Is more restricted for recessive traits; In practice, sections of genome from the non-recurrent parents are often still present and can have unwanted traits associated with them; For very wide crosses, limited recombination may maintain thousands of 'alien' genes within the elite cultivar; Many backcrosses are required to produce a new cultivar which can take many years
- **Inbreeding:** Inbreeding is the mating of organisms closely related by ancestry. It goes against the biological aim of mating, which is the shuffling of DNA.
- Occurs naturally in the form of self-pollination; results in homozygosity, which can increase the chances of offspring being affected by deleterious or recessive traits.
- **Inbreeding depression:** Inbreeding depression is the reduced biological fitness in a given population as a result of inbreeding. Inbreeding depression is often the result of a population bottleneck. Factors affecting: purging selection, polyploidy, selection for heterozygosity
- **Heterosis,** hybrid vigor, or outbreeding enhancement is the improved or increased function of any biological quality in a hybrid offspring. An offspring is heterotic if its traits are enhanced as a result of mixing the genetic contributions of its parents
- **Heterobeltiosis:** The magnitude of hybrid vigor is normally presented in terms of heterosis (H = superiority of the F1 hybrid over its parental mean) and heterobeltiosis (Hb = superiority of the F1 hybrid over its better parent).

Heteroploidy in crop improvement

- Ploidy is the number of sets of chromosomes in a cell. It shows the number of sets of chromosomes in an organism
- Heteroploidy is the condition where there the number of chromosome sets is different from the normal set

- Hetroploidy is basically of two types: Euploidy (includes Monoploidy, Diploidy, Polyploidy) and aneuploidy (Hyperploidy and Hypoploidy)

Achievements and future prospects

- Alloploidy sometimes helps in creation of new species as Triticale is the best example which is an alloploid between *Triticum aestivum* and *Secale cereale*. Triticale varieties are mainly cultivated in Polland, Germany and France.
- Raphanobrassica, the triploid (AAC), was also a promising creation of new variety, which was of no use as the desired traits was not been obtained from the cross.

Significance of haploids

- They carry only one allele of each gene. Thus any recessive mutation or characteristic are apparent.
- Plants with lethal genes are eliminated from the gene pool
- One can produce homozygous diploid or polyploid plants that may be valuable in plant breeding
- Production of haploids shortens the time for inbreeding for superior hybrid genotypes.

Significance of polyploids

- Some of the most important consequences of polyploidy for plant breeding are the increment in plant organs ("gigas" effect)
- buffering of deleterious mutations
- increased heterozygosity
- Increased hybrid vigour

Mutation in crop improvement

- The process of exposing seeds to chemicals or radiation in order to generate mutants with desirable traits to be bred with other cultivars.
- Mutation breeding uses a plant's own genetic resources mimicking the process of spontaneous mutations, that's under way in nature all the time, the basis of evolution
- Mutation breeding steps: Fixing an objective - Selection of the crop - selection of the mutagen - selection of the part of the plant to be treated - calculating the dose of the mutagen- giving optimum dose of the mutagen into the desired plant varieties - raising the M1 progenies - Selfing and clonal propagation of the progenies for several generations - M2, M3, M4, M5 - Field trails and release of new variety.

Genetics of Nitrogen fixation

- Nitrogen forms the major component of the proteins, nucleic acids and energy molecules in the living system and it has to be fixed in the available form to the living organisms
- This is biologically enabled by nitrogen fixing bacteria - either the free living soil bacteria or the symbiotic ones
- Nif genes - seen in the free-living nitrogen bacteria and in symbiotic bacteria.
- Nif genes are involved in the synthesis of Nitrogenase enzyme which in turn helps in the conversion of nitrogen to nitrite and ultimately to nitrate.
- Nod genes are seen in the bacteria and nodulation gene is seen in the plants and a combined action of them leads to the formation of nodules
- Ultimately the atmospheric nitrogen is converted into nitrate that is assimilated in to the plant cells
- Genes in the bacteria and the plant cells have a combined action and this is the reason for the specificity of the symbiotic relationship.

Bio-fertilizers in crop Improvement

- A living microbial colony applied on to the roots, stems or other parts of the plants where it develops into a rhizobia and promotes the growth of the plant is called a biofertilizer
- Actions performed - nitrogen fixation, phosphorus solubilizing, stimulate the production of plant growth promoters
- Biofertilizer is recommended for improving the soil fertilityand thus enhancing the productivity
- Types: Bacterial, fungal, algal, aquatic ferns, earthworms etc. are used as biofertilizers

Genetics of photosynthesis

- Photosynthetic complexes includes the enzymatic as well as structural components involved in the major function of photosynthesis

- The photosynthetic complexes are composed of several sub-units - some of them are coded by the nuclear genes while the others are coded by the chloroplast genes
- Chloroplast DNA or cpDNA also known as Plastid DNA or ptDNA is the circular double stranded DNA molecule with multiple copies of genome per organelle
- Codes for several proteins, rRNAs and tRNAs - also codes for polypeptide components of the photosystems, subunits of RuBP carboxylase
- Very much useful in the systematic studies - like rbcL, matK, trnL-trnF etc.

MODULE V

I. Breeding for resistance to abiotic stresses:

Introduction & Importance

- The factor that interferes with the expression of the complete genotypic potential is called a stress
- This affects the growth and yield of the plants
- It could be either abiotic - nonliving or biotic - living factors
- Water logging, heat stress, cold stress, salinity of the soil and drought are the abiotic factors often causing stress in plants
- Each of the factors adversely affects the plants in various manner and thus has to be tackled by appropriate methods

1. Breeding for drought resistance

- Reduced water availability or lower water potential forms the major cause of the drought condition
- Leads to various physiological adversities like decreased photosynthesis, generation of ROS and thereby oxidative stress, membrane damages, loss of turbidity and disruption of cell expansion, inhibition of mitosis etc.
- Water logging is the excess of water in the soil is also a stress condition that causes the condition of hypoxia or anoxia, i.e., the deficiency of oxygen

Genetics

- Genetic variation for drought resistance has been explained in crops like wheat, rice, barley, maize, sorghum, etc.
- Oligogenic to polygenic characters are observed. Waxy coat on leaves, glabrous coating, etc are oligogenic while ABA accumulation, proline accumulation and pod formation are polygenic traits
- The identification of various quantitative traits can be carried out using Linkage mapping or QTL analyses.

Methods and approaches

- Adaptation to a specific environment - selection and evaluation carried out under moisture stress conditions; needs high skill and precision while selection
- Adaptation to a variable environment - Attempt to combine high yield potential with drought resistance; selection is based on yield; evaluated under stress and non-stress conditions
- Marker assisted back crossing- transfer of QTLs associated with drought resistance into elite genotypes Eg. Maize, pearl millet, rice
- Genomics based integrated approach - Evaluation of germplasm is done followed by selection of a trait - three level screening approach - expression of the genes are analyzed - superior ones are isolated and transformed into separate lines to study the gene expression
- Common method:
    - Line A (High yielding) × Line B (Drought resistant) - at optimum environment
    - F1, F2, F3 propagated - F3 harvested separately and F4 developed
    - F4 - evaluated under range of environments - High yielding ones selected
    - Selected ones grown under optimum environment
    - Repeated up to F7
    - F8 - Preliminary field trial
    - F9-F11 - Multi-location trial
    - F12 - Seed multiplication and released as a new tolerant variety

Difficulties

- A new variety developed has to be tested for which year to year and location to location variations is difficult
- Selection has to be done under moisture stress condition and this is often difficult
- Drought resistance is often the result of multiple characters and thus selection based on a single character is difficult
- Measurement is difficult
- Use of wild varieties for improvement is often problematic
- Use of transgenes is also questionable

2. Breeding for mineral stress resistance

Salt affected soils

- Soil with excess accumulation of soluble salts in the root zone leading to detrimental effects on plant growth and development
- Two types: 1. Saline, 2. Alkaline soil
- Soils differ in the types of salts present, physical properties, geographical distribution and the biological effects generated by them.
- Approaches for their management and utilization differs markedly

Management of salt affected soils

- Reclamation: removal of soluble salts or excess exchangeable sodium from the root zone
- Common methods - leaching of soluble salts, Application of soluble calcium amendments to remove excess exchangeable sodium, suitable drainage of soil water
- Use of salt tolerant varieties of the crops

Salinity resistance

- May arise due to various reasons : 1. Resistance to water stress or osmotic effects of salinity, 2. Resistance to salinity induced ionic toxicity or toxic effects of salinity, 3. A combination of both

- 1. Resistance to salinity induced water stress - this is enabled by salinity stress - allows the maintenance of turgor and avoids leaf desiccation - Proline is the important mechanism to counter the osmotic effects of salinity - osmoregulation is also achieved by sugars, organic acids, glycine-betaine, myoinositol and K+ ions
- Osmoregulation may protect enzymes and cellular membranes from damage due to stress
- Other factors - leaf attributes, characteristics of root system etc also relieves salinity induced stress
- 2. Resistance to salinity induced ion toxicity - achieved by two methods - one by ion exclusion and other by cellular compartmentation or salt excretion
- Ion exclusion: The condition when the species/genotypes take up smaller quantities of the injurious ions than the other similar species/ genotypes is called ion exclusion - often occurs at the root level - this might be due to the absorption of salt by specialized xylem parenchyma.
- Salt tolerance: differential responses of the genotypes to the same amount of salt in their tissues. This might depend on the age of the plant and the process of hardening.

Genetics of salinity resistance

- Genetic variation exists both among and within species
- For a successful breeding programme it is necessary for a reliable estimation of magnitude of this variability
- Interspecific variation - SY100 or the threshold salinity describes the maximum salinity level at which there is no yield loss - Allopolyploids are generally more tolerant to saline/alkaline soils than their putative diploid progenitors. Eg. Wheat.
- Intraspecific variation - Highest level of tolerance is found in the adapted indigenous varieties; In rice -Tall, photosensitive, coarse grained and late maturing varieties are tolerant; in wheat - bread wheat is tolerant than durum wheats.
- Gene action and inheritance of salinity resistance is not well known. Available information suggests that monogenic control occurs

Sources of resistance

- Cultivate varieties - Eg. Muskmelon

- Germplasm collection - Eg. Kharchia wheat adapted to salt affected areas of Rajasthan
- Related species - Eg. Lycopersicum cheesmanii a relative of tomato is resistant to salinity
- Somaclones - from micropropagated cultures
- Transgenes - genes for osmoregulation is incorporated to the desired crop varieties

Breeding approaches

- Use of root stocks of the salinity resistant varieties of the crops
- Selection of the resistant lines
- Hybridization - Intervarietal one is preferred or the interspecific ones
- Cell selection - Somaclones selected from the micropropagated cultures
- Genetic engineering - by means of transferring the appropriate genes

Problems

- Tedious, costly and beyond the reach of many breeders in terms of creating a reliable controlled salinity environment
- Difficult to score the selection method
- Genetically complex and difficult to identify the specific genes
- Basis for the salinity resistance is poorly understood. Hence, breeding is difficult

Mineral stress resistance

- When plant performance is adversely affected by an excess of minerals or deficiency of an essential nutrient in soil, it is called the mineral stress.
- Plants respond to mineral stress by enhancing their root growth relative of that shoot ad by increasing the permeability of their membranes.
- Plant roots secrete organic acids to increase the availability of P, Zn, and Mn particularly in deficient soils.

Mineral deficiency stress resistance

- The genotypes that show markedly lower detrimental effects of mineral deficiency than other genotypes of the same species are called mineral efficient genotypes.

- They can absorb or transport more quantities of deficient mineral than the other genotypes.
- Thus avoids the mineral deficiency by mineral redistribution, efficient mineral uptake, increased mineral transport, increased root/shoot ratio, and increased root hair density.

Genetics

- P efficiency in several crops is polygenic with low to high heritability
- Boron inefficiency is tomato and celery is controlled by a single recessive gene
- In tomato, *btl* allele is believed to interfere with boron translocation from roots
- Fe efficiency in soyabean and maize is determined by single gene

Sources of mineral stress resistance

- Cultivated varieties
- Land races or desi or local varieties
- Mutants
- Related species

3. Heat and Cold Stress

- Temperature forms one of the basic factors required for the growth and development of the plants
- Optimum temperature requirements differ with each crop
- High temperature causes heat stress; low temperature causes either chilling stress or freezing stress.

Heat stress and resistance

- Heat stress affects the growth and development, cell and tissue survival as well as the physiological activities of the plants including respiration, photosynthesis, photosynthate translocation, protein denaturation, membrane composition and stability along with the production of heat shock proteins.
- Ability of some genotypes to perform better than the other during the seat stress condition is called the heat stress resistance.

- This is accomplished by two strategies - 1. Heat avoidance and 2. Heat tolerance
- 1. Heat avoidance : The ability of a genotype to dissipate the radiation energy and avoid a rise in temperature related stress
- Primary strategy adopted is transpiration followed by reflective properties of leaves, protection of organs by bark.
- 2. Heat tolerance: Ability of the genotypes to withstand high temperatures than the relates genotypes
- Made possible by heat hardening mechanisms that includes membrane stability, reduced heat sensitivity of PS II, photosynthate translocation, stem-reserve mobilization and osmoregulation

Genetics of heat tolerance

- Genetic variation is known for germination, growth during heat stress, growth recovery after heat stress etc.
- Traits for heat resistance is polygenic in control
- The only oligogenic controlled trait is the number of pods in snap bean

Sources of heat tolerance

- Within the breeding germplasm - material should be properly evaluated for the concerned traits
- Transgenic plants with increased heat tolerance by transgene technology
- Selection of the tolerant varieties from normal field environment, programmed environment and *in vitro* environments

Chilling tolerance and resistance

- Ability of the genotypes to survive or perform better under chilling stress rather that the other genotypes is called chilling tolerance.
- Chilling stress at plant level results in the reduced germination, reduced seedling growth, decline in root growth, ABA accumulation and formation of abnormal flowers/fruits and failure of seed and fruit set.

- Chilling stress at sub-cellular level is indicated by the membrane damage, conformational changes in the proteins, interference in the production of chlorophyll, accumulation of photosynthates,
- Chilling stress at sub-cellular level is indicated by the membrane damage, conformational changes in the proteins, interference in the production of chlorophyll, accumulation of photosynthates and induction of toxicity injuries.

Sources

- Well adapted breeding population
- Germplasm collection
- Cold tolerant mutants
- Somaclonal variants
- Related wild species
- Genetic engineering

Problems in breeding

- This is a complex trait and involves several components which cannot be readily measured
- Breeding work carried out under the field environment is subjected to variations of other conditions too
- Tedious effort of breeding in the fields
- Laboratory conditions is not applicable for large breeding populations

II. Breeding for resistance to biotic stress

1. Disease resistance

- An abnormal condition in an organism produced by an organism or an environmental factor
- The affected plant is called the host while the causative organism is called the pathogen

History

- Theophrastus noted that cultivated varieties differed in their ability to avoid diseases in third century BC
- Prevost showed that wheat bunt was produced by a fungus and concluded that diseases are produced by pathogens
- 1905 - Biffen demonstrated that resistance to yellow rust in wheat was governed by a recessive gene segregating in the ratio 3:1
- Breeding for disease resistance have started with Orton in1990 who selected lines of cotton resistant to *Fusarium* wilt.
- 1894 - Erikson - Pathogens differ in their ability to attack different related host species
- 1951 - Flor - gene for gene relationship between host and pathogen
- Information available till now reveals that pathogenicity is not the function of the host alone but also the pathogen action.

Genetics of pathogenicity

- Pathogenicity is the ability of a pathogen to attack a host
- The inheritance of virulence can be studied inly when a host has a resistance gene
- Often controlled by more than one gene with two alleles on each locus
- In addition to the major genes of pathogenicity, there are evidences for polygenic control also.
- In the *Ustilago* fungal infection of barley, aggressiveness showed a polygenic control but the polygenic system was only a part of the total genetic system of the pathogen

Vertical resistance

- Also known as race specific or pathogen specific resistance
- This is generally determined by major genes
- The host carrying a gene for vertical resistance is attacked by only that pathotype which is virulent towards that resistance gene.

- Immune response in this case depends on the presence of virulent pathotype. When virulent pathotype becomes frequent, epidemics are common in the case of vertical resistance

Horizontal resistance

- Also known as race-nonspecific or pathotype nonspecific
- Generally controlled by polygenes and its pathotype-nonspecific
- The reproduction rate of the pathogen is never zero but is less than one
- This does not prevent the symptoms of the disease but it slows down the spread of the disease in the host population
- Polygenic governing horizontal resistance operate on gene-for-gene basis

Mechanism of disease resistance

1. Mechanical: Anatomical features of the host may prevent infection. Eg. Closed flowering habit of wheat and barley prevents the pore infection of the ovaries

2. Hypersensitivity: this is the property of the host found in the case of biotropic organisms or obligate parasites. Immediately after the infection, the surrounding cells die thereby preventing the spore production

3. Nutritional: Reduction in growth and in spore production might be due to unfavourable physiological conditions within the host. A resistant host does not fulfill the nutritional requirements of the pathogen and thus limits its growth and reproduction.

Genetics- Oligogenic

- Oligogenic resistance is the vertical resistance where the resistance is governed by one or few major genes and resistance is dominant to the susceptible reaction.
- Oligogenes generally produce immune reaction - a resistance gene is effective against some specific pathotype, while it is ineffective against the others.
- Gene-for-gene relationship: this is between a host and its pathogen - postulated by Flor in 1951 - For every resistance gene present in the host the pathogen has a gene for virulence. There are two types:

- Incompatible relationship: Found in biotropic pathogens. The alleles for resistance in the host and those for avirulence in the pathogen produce molecules which specifically recognize each other and when these molecules interact, they produce resistant response in the host
- Compatible reaction: The alleles for susceptibility in the host and those for virulence in the pathogen produce specific molecules which interact with each other to produce the susceptible response.

Polygenic

- Disease resistance is governed by many genes with small effects and a continuous variation for disease reaction is produced ranging from no resistance to good resistance
- Measurement of polygenic inheritance can be done using the following methods:
  1. Number of pathogens scored by the percentage of tissue covered with the pathogen
  2. Hemibiotropic and necrobiotropic fungi, the symptoms are visible as discoloration
  3. Systemic expression of disease symptoms like stunting, leaf rolling, mottling etc are caused by viruses

Cytoplasmic inheritance

- In some cases, resistance is determined by the cytoplasmic genes or plasmagenes
- Eg. Maize strains having the T male sterile cytoplasm (cms-T) are extremely susceptible to southern leaf blight while those having normal or non-T cytoplasm are resistant to the disease
- A rare phenomenon
- Yellow leaf blight is also an example that confers male sterility

Sources of resistance

- A known variety
- Germplasm collection
- Related species
- Mutations
- Somaclonal variations

- Transgenes

Breeding methods

- Selection - Eg. Cotton variety MCU1 was selected from Coimbatore 4 for resistance to black-arm
- Introduction - Early varieties of groundnut introduced from USA were resistant to Tikka disease
- Mutation - By mutagenesis
- Hybridization - Methods involve pedigree method, backcross method, and breeding for partial resistance.
- Somaclonal variation
- Genetic engineering

2. Insect resistance

Introduction & Mechanisms

- Insect resistance is the property of a variety of a host crop due to which it is attacked by an insect pest to a significantly lower degree than are other varieties of the same crop
- This dates back to 1792 for the wheat variety resistant to hessian fly
- Loss due to insect attack includes damages to leaf, stem, and other aerial parts, premature defoliation and even wilting of plants
- AN insect biotype capable of adaptation to the resistance mechanisms of a host strain so that it is able to infest and survive on the resistant host strain is called virulent
- Mechanism: Allomones and kairomones are plant biochemicals having adverse and favourable effects, respectively
- Insect resistance is grouped into 4 categories:
- 1. Nonpreferance - hosts are unsustainable for colonization, oviposition or both by an insect pest

  2. Antibiosis - leads to an adverse effect of feeding on a resistant host plant on the development and reproduction of the insect pest

3. Tolerance - an insect tolerant variety is attacked by the insect pest to the same degree as a susceptible variety but at the same level of infestation, a tolerant variety produses a larger yield
4. Ecological - results from temporary shifts in the environmental conditions that enable a susceptible host to suffer less damage or escape infestation.

Genetics - Oligogenic

- Governed by one or few genes or oligogenes, each gene having a large and identifiable individual effect on resistance
- May be conditioned by either the dominant or the recessive allele of concerned gene
- Monogenic - trait governed by a single gene- is simply inherited as 3:1 ratio in F2
- Durable monogenic resistance may be due to one or more reasons like cultivation of resistant varieties over a relatively small area or time, a lack of biotype differentiation in the pest species and the involvement of morphological features of the host in resistance

Polygenic

- Governed by several genes, each producing a small and usually cumulative effect
- This involves - 1. Involves more than one feature of the host plant; 2. Are much more durable than the cases of Oligogenic resistance; 3. The difference between resistance and susceptible plants are not clear-cut due to continuous variation, 4. Transfer of resistance is much more difficult than oligogenic

Cytoplasmic inheritance

- There are atleast 4 known cases of insect resistance that are governed by plasma genes
- Resistances to European corn borer in maize and to root aphid in lettuce show cytoplasmic inheritance in addition to the nuclear genetic control.
- Resistance to boll weevil and tobacco budworm show cytoplasmic inheritance

Sources

- Cultivated variety - SRT1 of cotton -resistance to jassids
- Germplasm collection - slightly difficult approach

- Related wild species - *G. tomemtosum*, *G. anomalum* are the wild varieties of *Gossipium* for the resistance against diseases
- An unrelated organism - by transgene and transgenic technology

Breeding methods

- Introduction
- Selection
- Hybridization
- Genetic engineering

Problems

- Susceptibility of the crops to multiple pests
- Breeding methods reduces the quality of produce
- Sometimes, the genes for resistance are only available in the wild varieties
- Screening for this resistance is most critical and difficult
- This is a long-term programme
- Efficient breeding requires experts
- Biotype differentiation is intertwined with resistance breeding

Achievements

- Till 1990, more than 200 varieties with resistance to 50 insect species were released and were in commercial cultivation
- Eg. Introduction of Phylloxera resistant grape variety from USA to France
- In USA, 23 Hessian fly resistant wheat varieties have been developed
- Wheat variety ‘Rescue’ has solid stem which is resistant to sawfly
- Barley variety ‘Will’ developed in USA is resistant to green bugs
- Cotton - B1007, SRT1, Khandwa 2 evolved in India - resistant to jassids
- Maize variety - B59 - resistant to European corn borer

Breeding for resistance to parasitic weeds

- Weeds like *Striga* intrudes the crops and reduces the growth and yield of the crops
- Cheaper way to reduce the losses in crop yields due to such parasitic weeds is to develop resistant or tolerant varieties
- *Striga* resistant sorghum, SAR-1 has been developed from ICRISAT, Hyderabad
- Four peal millet lines developed from ICRISAT resistant to *Striga*
- Significant in the areas where considerable economic loss happens due to the weeds.