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FACULTY OF AGRICULTURE SCIENCES AND ALLIED INDUSTRIES

(Crop Improvement I (Kharif))

For

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Course Instructor

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(Plant genetic resources and Qualitative and quantitative characters)

Plant Genetic Resources

The sum total of genes in a crop species is referred to as genetic resources.
or
Gene pool refers to a whole library of different alleles of a species
or
Germplasm may be defined as the sum total of hereditary material i.e., all the alleles of various genes present in a crop species and its wild relatives.
Also known as gene pool or genetic stock or germplasm or genetic resources.
Germplasm or gene pool is the basic material with which a plant breeder has to initiate his breeding programme. Important features of plant genetic resources are
1. Gene pool represents the entire genetic variability or diversity available in a crop species.
2. Germplasm consists of land races, modern cultivars, obsolete cultivars, breeding stocks, wild forms and wild species of cultivated crops.
3. Germplasm includes both cultivated and wild species or relatives of crop plants.
4. Germplasm is collected from the centres of diversity, gene banks, gene sanctuaries, farmers fields, markets and seed companies.
5. Germplasm is the basic material for launching a crop improvement programme.
6. Germplasm may be indigenous (collected with in country) or exotic (collected from foreign countries)

Kinds of Germplasm

The germplasm consists of various plant materials of a crop such as
(1) land races (4) advanced (homozygous), breeding materials,
(2) obsolete cultivars (5) wild forms of cultivated species
(3) modern cultivars (6) wild relatives
(7) mutants
These are briefly discussed below :

1. Land races

These are nothing but primitive cultivars which were selected and cultivated by the farmers for many generations without systematic plant breeding efforts.
- Land races were not deliberately bred like modern cultivars. They evolved under subsistence agriculture.
- Land races have high level of genetic diversity which provides them high degree of resistance to biotic and abiotic stresses.
- Land races have broad genetic base which again provides them wider adoptability.
- The main drawbacks of land races are that they are less uniform and low yielders.
- Land races were first collected and studied by N.I. Vavilor in rice.

2. Obsolete Cultivars

These are the varieties developed by systematic breeding effort which were popular earlier and now have been replaced by new varieties. Improved varieties of recent past are
known as obsolete cultivars.
- Obsolete varieties have several desirable characters they constitute an important part of gene pool. Example : Wheat varieties K65, K68, pb 591 were most popular traditional tall varieties before introduction of high yielding dwarf Mexican wheat varieties. Now these varieties are no more cultivated. They are good genetic resources and have been widely used in wheat breeding programmes for improvement of grain quality. Now such old varieties are found in the genepool only.

3. Modern cultivars

The currently cultivated high yielding varieties are referred to as modern cultivars. They are also known as improved cultivars or advanced cultivars.
- These varieties have high yield potential and uniformity as compared to obsolete varieties land races.
- They constitute a major part of working collections and are extensively used as parents in the breeding programmes.
- As these are good sources of genes for yield and quality, can be introduced in a new area and directly released.
- However, these have narrow genetic base and low adoptability as compared to land races

4. Advanced breeding lines

These are pre -released plants which have been developed by plant breeders in modern scientific breeding programmes. These are known as advanced lines, cultures and stocks. This group includes, nearly homozygous lines, lines derived from biotechnology programmes i.e. transgenic plants and mutant lines etc. These lines which are not yet ready for release to farmers. They often contain valuable gene combinations.

5. Wild forms of cultivated species

Wild forms of cultivated species are available in many crop plants. Such plants have generally high degree of resistance to biotic and abiotic stresses and are utilized in breeding programmes. They can easily cross with cultivated species. Wild forms of many crop species are extinct.

6. Wild Relatives

Those naturally occurring plant species which have common ancestry with crops and can cross with crop species are referred to as wild relatives or wild species. Wild relatives include all other species, which are related to the crop species by descent during their evolution. Both these groups are sources of valuable genes for biotic and abiotic stress and for quality traits and yield.

7. Mutants

Mutation breeding is used when the desired character is not found in the genetic stocks of cultivated species and their wild relatives. Mutations do occur in nature as well as can be induced through the use of physical and chemical mutagens. The extra variability which

is created through induced mutations constitutes important components of genepool. Mutant for various characters sometimes may not be released as a variety, but they are added in the genepool. The germplasm includes those carrying gene mutations, chromosomal aberrations and markers genes etc. are considered special genetic stocks. They are useful in breeding programmes.

The gene pool system of classification

The pool of a crop includes all cultivars, wild species and wild relatives containing all the genes available for breeding use.
Based on degree of relationship, the gene pool of crops can be divided into three groups (Harland and Dewet, 1971) , *viz.,*
1. Primary gene pool
2. Secondary Gene pool
3. Tertiary gene pool
These are briefly discussed below :
1. Primary gene pool (GP1) : This is also known as gene pool one (GP1). The gene pool in
which intermating is easy and leads to production of fertile hybrids is known as primary gene pool. It includes plants of the same species or of closely related species which produce completely fertile offspring on intermating. In such gene pool, genes can be exchanged between lines simply by making normal crosses. This is the material of prime breeding importance.
2. Secondary gene pool (GP2) : This type of gene pool is also known as gene pool two (GP2). The genetic material that leads to partial fertility on crossing with GP1 is referred to as secondary gene pool. It includes plants that belong to related species. Such material can be crossed with primary gene pool, but usually the hybrids are sterile and some of the progeny to some extent are fertile. Transfer of gene from such material to primary gene pool is possible but difficult.
Tertiary gene pool (GP3) : The genetic material which leads to production of sterile hybrids on crossing with primary gene pool is termed as tertiary gene pool or gene pool three (GP3). It includes material which can be crossed with GP1, but the hybrids are sterile. Transfer of genes from such material to primary gene pool is possible with the help of special techniques.
Types of seed collections
Based on the use and duration of conservation, seed collections are of three types
1. Base collections
2. Active collections
3. Working collections
1. Base collections: It is also known as principal collection. These consist of all the accessions present in the germplasm of a crop. They are stored at about
-180C or -200C with 5 + 1% moisture content; they are disturbed only for regeneration.

When the germination of an accession falls below, usually, 95% of its germination at the start of storage, the accession is regenerated. For reasons of safety, duplicates of base collections should be conserved in other germplasm banks as well. High quality orthodox seeds can maintain good viability upto 100 years.
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2. Active collections : The accessions in an active collection are stored at temperatures below 150C (often near 00C), and the seed moisture is kept at 5%. The storage is for medium duration, i.e., 10-15 years. These collections are actively utilized in breeding programme. These collections are used for evaluation, multiplication and distribution of the accessions. They are usually maintained by multiplying the seeds of their own accessions. But from time to time, base collection material should be used for regeneration of these collections. Germination test is carried out after every 5-10 years to assess the reduction in seed viability.
3. Working collections : The accessions being actively used in crop improvement programmes constitute working collection. Their seeds are stored for 3-5 years at less than 150C and they usually contain about 10% moisture. These collections are maintained
by the breeders using them.
Core collection
The concept of core collection was proposed by Franked it refers to a subset of base collection which represents the large collection. Or a limited set of accessions derived from an
existing germplasm collections.
Germplasm activities
There are six important activities related to plant genetic resources.
1. Exploration and collection 4. Documentation
2. Conservation 5. Multiplication and Distribution
3. Evaluation 6. Utilization
Exploration
Exploration refers to collection trips and collection refer to tapping of genetic diversity from various sources and assembling the same at one place.
The exploration and collection is a highly scientific process. This process takes into account six important items, *viz*, (1) sources of collection, (2) priority of collection, (3) agencies
of collection, (4) methods of collection, (5) methods of sampling and (6) sample size.
Merits and Demerits
There are several merits and demerits of exploration and collection of germplasm, some of which are as discussed below:
Merits
1. Collection helps in tapping crop genetic diversity and assembling the same at one place.
2. It reduces the loss of genetic diversity due to genetic erosion.
3. Sometimes, we get material of special interest during exploration trips.

4. Collection also helps in saving certain genotypes from extinction.

Demerits

1. Collection of germplasm especially from other countries, sometimes leads to entry of new diseases, new insects and new weeds.
2. Collection is a tedious job.
3. Collector, sometimes has encounter with wild animals like elephants, tigers etc.
4. Transportation of huge collections also poses difficulties in the exploration and collection.

2. Germplasm conservation

Conservation refers to protection of genetic diversity of crop plants from genetic erosion. There are two important methods of germplasm conservation or preservation.

or

Germplasm conservation refers to maintain the collected germplasm in such a state that there is minimum risk for its loss and that either it can be planted directly in the field or it can be prepare for planting with relative ease when ever necessary.

There are two important methods of germplasm conservation or preservation *viz.,*

1. In situ conservation
2. 2. Ex situ conservation

1. ***In situ*** **conservation**

Conservation of germplasm under natural habitat is referred to as in situ conservation. This is achieved by protecting this area from human interference : such an area is often called as natural park, biosphere reserve or gene sanctuary. A gene sanctuary is best located within the centre of origin of crop species concerned, preferably covering the microcenter with in the centre of origin. NBPGR, New Delhi is making attempts to establish gene sanctuaries in Meghalaya for Citrus and in the North-Eastern region for *Musa, Citrus, Oryza*, *Saccharum* and *Megifera.*

This method of preservation has following main disadvantages

1) Each protected area will cover only ve ry small portion of total diversity of a crop species, hence several areas will have to be conserved for a single species.
2) The management of such areas also poses several problems.
3) This is a costly method of germplasm conservation

Merits : Gene sanctuaries offer the following two advantages.

1. A gene sanctuary not only conserves the existing genetic diversity present in the population, it also allows evolution to continue. As a result, new alleles and

new gene combinations would appear with time.
2. The risks as sociated with ex situ conservation are not operative.

2. *Ex situ* conservation

Conservation of germplasm away from its natural habitat is called ex situ germplasm conservation. This method has following three advantages.
1) It is possible to preserve entire genetic diversity of a crop species at one place.
2) Handling of germplasm is also easy
3) This is a cheap method of germplasm conservation
Preservation in the form of seed is the most common and easy method, relatively safe, requires minimum space and easy to maintain. Glass, tin or plastic containers are used for preservation and storage of seeds. The seed can be conserved under long term, medium term and
short term storage conditions.
Roberts in 1973 classified seeds on the basis of their storability, into two major groups. *viz.,*
1. Orthodox seeds
2. Recalcitrant seeds

1. Orthodox Seeds : Seeds of this type can be dried to low moisture content of 5% and stored at a low temperature without losing their viability are known as orthodox seeds. Most crop seeds belong to this category. Such seeds can be easily stored for long periods; their longevity increases in response to lower humidity and storage temperature. Eg. Wheat, Rice, Corn, Chickpea, Cotton, Sunflower

2. Recalcitrant seeds : The viability of this group of seeds drops drastically if their moisture content is reduced below 12-30%. Seeds of many forest and fruit trees, and of several tropically crops like Citrus, cocoa, coffee, rubber, oil palm, mango, jackfruit, etc. belong to this group. Such seeds present considerable difficulties in storage. They require *in situ* conservation.

3. Evaluation

Evaluation refers to screening of germplasm in respect of morphological, genetical, economic, biochemical, physiological, pathological and entomological attributes. Evaluation requires a team of specialists from the disciplines of plant breeding, physiology, biochemistry, pathology and entomology. First of all a list of descriptors (characters) for which evaluation has to be done is prepared. This task is completed by a team of experts from IPGRI, Rome, Italy. The descriptors are ready for various crops. The evaluation of germplasm is down in three different places, *viz.,* (1) in the field, (2) in green house, and (3) in the laboratory.

4. Documentation

It refers to compilation, analysis, classification storage and dissemination of information. In plant genetic resources, documentation means dissemination of information about various activities such as collection, evaluation, conservation, storage and retrieval of data. Now the term documentation is more appropriately known as information system. Documentation is one of the important activities of genetic resources. Large number of

accessions are available in maize, rice, wheat, sorghum, potato and other major crops. About 7.3 million germplasm accessions are available in 200 crops species. Handling of such huge germplasm information is only possible through electronic computers.

5. Distribution

The specific germplasm lines are supplied to the users on demand for utilization in the crop improvement programmes.

1. Distribution of germplasm is the responsibility of the gene bank centres
2. The germplasm is usually supplied to the workers who are engaged in research work of a particular crop species.
3. Supplied free of cost to avoid cumbersome work of book keeping.
4. The quantity of seed samples depends on the availability of seed material and demands
5. Proper records are maintained about the distribution of material.
6. It helps in acclimatization and purification of the material.

6. Utilization

It refers to use of germplasm in crop improvement programmes. The germplasm can be utilized in various ways. The uses of cultivated and wild species of germplasm are briefly discussed below:

a) Cultivated Germplasm

It can be used in three main ways: (1) as a variety, (2) as a parent in the hybridization, and (3) as a variant in the gene pool.

b) Wild Germplasm

it is used to transfer resistance to biotic and abiotic stresses, wider adaptability and sometimes quality such as fibre strength in cotton.

Organizations associated with germplasm

IPGRI – International Plant Genetic Resources Institute

NBPGR – National Bureau of Plant Genetic Resources

CENTRES OF DIVERSITY AND GENE BANKS

Gene Sanctuaries

The genetic diversity is sometimes conserved under natural habitat. The areas of great genetic diversity are protected from human interference. These protected areas in natural habitat are referred to as gene sanctuaries. Gene sanctuary is also known as natural park or biosphere reserve. Gene sanctuary is generally established in the centre of diversity or microcenter. India has setup its first gene sanctuary in the Garo Hills of Assam for wild relatives of citrus. Efforts are also being made to setup gene sanctuaries for Banana, Sugarcane, Rice and Mango. In Ethiopia gene sanctuary for conservation of wild relatives of coffee was setup in 1984.

Gene sanctuaries have two main advantages.

1. It protects the loss of genetic diversity caused by human intervention.
2. It allows natural selection and evolution to operate.
3. The risks associated with *ex situ* conservation are not operative

There are two main drawbacks of gene sanctuary.

1. Entire variability of a crop species can not be conserved.
2. Its maintenance and establishment is a difficult task.

3. It is a very good method of *in situ* conservation.

Genetic Erosion

Genetic erosion refers to loss of genetic diversity between and within populations of the same species over a period of time.

or

Gradual reduction in genetic diversity in the populations of a species, due to elimination of various genotypes, is called genetic erosion.

Thus genetic erosion leads to reduction of the genetic base of a species due to human intervension and environmental changes.

There are five main reasons of genetic erosion

1. Replacement of land races with improved cultivars : The main features of modern cultivars are high yield, uniformity, narrow genetic base and narrow adaptability. On the other hand land races and primitive cultivars have more genetic diversity, broad genetic base, wider adaptability and low yield potential. Thus replacement of land races with modern cultivars has resulted in reduction in genetic diversity because land races are disappearing.

2. Modernization of agriculture : Clean and modern agriculture, Improved crop management practices has resulted in the elimination of wild and weedy forms of many crops. These weedy forms enhance the genetic diversity through introgression of genes from crop to weedy forms and weedy forms to crop plants.

3. Extension of farming into wild habitats : It has resulted in destruction of wild relatives of various crops resulting in reduction of their genetic diversity.

4. Grazing into wild habitats : Grazing of animals in the wild habitat also reduces genetic diversity by destroying the wild and weedy forms of crop plants.

5. Developmental activities like Hydroelectric projects, growth of towns, cities, roads, air ports and industrial areas also lead to genetic erosion of crop plants, because vast areas are cleaned for such activities.

Extinction

Extinction refers to permanent loss of a crop species due to various reasons.

Introgression

Transfer of few genes from one species into the full diploid chromosome complement of another species.

Gene banks

Gene bank refers to a place or organization where germplasm can be conserved in living state. Gene banks are also known as germplasm banks. The germplasm is stored in the form of seeds, pollen or *in vitro* cultures, or in the case of a field gene banks, as plants growing in the field. Gene banks are mainly of two types, viz.,

1. Seed gene banks
2. Plant or field gene banks
3. Meristem gene banks
4. Cell and organ gene banks and
5. DNA gene banks

These are briefly discussed below :

1. Seed gene banks :

A place where germplasm is conserved in the form of seeds is called seed gene banks. Seeds are very convenient for storage because they occupy smaller space than whole plants.

However, seeds of all crops can not be stored at low temperature in the seed banks. The germplasm of only orthodox species (whose seed can be dried to low moisture content without losing variability) can be conserved in the seed banks. In the seed banks, there are three types of conservation, viz., (1) short term, (2) medium term, and (3) long term. Base collections are conserved for long term (50 years or more) at – 18 or – 200C. Active collections are stores for medium term (10-15 years) at zero degree Celsius and working collection are stored for short term (3-5 years) at 5-100C. The main advantages of gene banks are as follows.

1) Large number of germplasm samples or entire variability can be conserved in a very small space.

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2) In seed banks, handling of germplasm is easy

3) Germplasm is conserved under pathogen and insect free environment

There are some disadvantages of germplasm conservation in the seed banks.

1) Seed of recalcitrant species can not be stored in seed banks

2) Failure of power supply may lead to loss of viability and there by loss of germplasm

3) It requires periodical evaluation of seed viability. After some time multiplication is essential to get new or fresh seeds for storage.

2. Field Gene banks

Field gene banks also called plant gene banks are areas of land in which germplasm collections of growing plants are assembled. This is also *ex situ* conservation of germplasm.

Those plant species that have recalcitrant seeds or do not produce seeds readily are conserved in Field gene banks. In field gene banks, germplasm is maintained in the form of plants as a permanent living collection. Field gene banks are often established to maintain working collections of living plants for experimental purposes. Field gene banks have been established in many countries for different crops.

Field gene banks in some countries

Name of country Crop species for which field gene bank is established

Malaysia Oil palm has been conserved on 500 hectares

Indonesia Earmarked 1000 hectare area for coconut and other perennial crops

Philippines South East Asia germplasm of banana has been conserved

India Global collection of coconut has been conserved in Andman & Nicobar

Field gene banks have some advantages and disadvantages.

Advantages

1. It provides opportunities for continuous evaluation for various economic characters.
2. It can be directly utilized in the breeding programme

Disadvantages

1. Field gene banks can not cover the entire genetic diversity of a species. It can cover only a fraction of the full range of diversity of a species.
2. The germplasm in field gene banks is exposed to pathogens and insects and sometimes is damaged by natural disasters such as bushfires, cyclones, floods, etc.
3. Maintenance of germplasm in the field gene banks is costly affair

Meristem gene banks

Germplasm of asexually propagated species can be conserved in the form of meristems. This method is widely used for conservation and propagation of horticultural species. *In vitro* method can be used in two ways. First for storage of tissues under slow growth conditions. Second, for long term conservation of germplasm by cryopreservation. In cryopreservation, the tissues are stored at a very low temperature i.e. at -1960C in liquid nitrogen. At this temperature, all biological processes virtually come to a stop.

Shoot Tip Gene Banks

In such gene banks, germplasm is conserved as slow growth cultures of shoot-tips and nodal segments. Their regeneration consists of sub-culturing the cultures, which may be done every 6 months to 3 years. The chief merits for the conservation of germplasm of vegetatively propagated crops and tree species.

1. Genotypes of the accessions can be conserved indefin itely free from diseases and pests.
2. They can be used for such crops, which either do into produce seeds or produce recalcitrant seeds.
3. Subculture becomes necessary only after relatively long periods (every 6-36 months).
4. Regeneration i.e., subculturing, requires a comparatively very short time.

In addition, cuttings, bulbs and tubers can be maintained under controlled humidity and temperature conditions; however, this approach is practical for the short and medium term storage, and it should be used in conjunction with a field gene bank.

Cell and Organ Gene Banks

A germplasm collection based on cryopreserved (at -1960C in liquid nitrogen) embryogenic cell cultures, shoot-tips and or somatic/zygotic embryos may be called cell and organ bank. The techniques for cryopreservation of plant cells and tissues are being rapidly refined, and some such banks have been established, e.g., for potato in Germany.

DNA Gene Banks

In these banks, DNA segments from the genomes of germplasm accessions are maintained as cosmid clones, phage lysates or pure DNA (the last one being for relatively short periods). These DNA segments can be evaluated and the desired ones may be used to produce transgenic plants. This approach is applicable to the conservation of genetic materials of already extinct species since DNA extracted from well preserved herbarium specimens can often be cloned. However, it is very expensive and highly sophisticated. A world -wide network of DNA banks for threatened / endangered species has been established.

Qualitative and Quantitative characters :

Some characters are little affected by other genes, i.e. the genetic back ground, or the environment. Such characters are generally governed by one or few genes with large,

easily detectable effects, such genes are known as **oligogenes**. The characters produced by oligogenes show distinct classes and are known as **qualitative characters** or **olygogenic traits**. On the other hand, the development of many characters is very much affected by the genetic background and, more particularly, by the environment. These characters are governed by several genes with small individual effects; these genes one known as **polygenes**. The characters produced by polygenes are referred to as **quantitative characters**, because they do not show clear -cut classes and have to be studied by measurement. They are also called **Polygenic traits** since they are governed by polygenes. The inheritance of both qualitative and quantitative characters follows the laws of Mendel. But the effects of individual genes in the two cases are totally different in magnitude consequently, the techniques used to study the two types of characters are also different

INSECT RESISTANCE

Global average loss due to insect pests is 14%. Estimated losses in individual crops vary from 5% in wheat to 26.7% in rice and still more in crops like cotton & sugarcane.

Insect Resistance :

1. The ability of a plant to withstand, oppose or overcome the attack of an insect in known as insect resistance.
2. It is the property of a variety or a host crop due to whic h it is attacked by an insect pest to a significantly lower degree than are other varieties of the same host.

Biotypes : Strains of a species of an insect pest, differing in their ability to attack different varieties of the same host species (syn: Physiological races)

Host Habitation :

1. Polyphagy 3. Seasonal Oligophagy
2. Oligophagy 4. Monophagy

1. Polyphagy : Insects feed on a vide range of hosts avoiding few plant species. Eg. Scales & moths.
2. Oligophagy : Live on one taxonomic unit only. Eg. Hessianfly on wheat
3. Seasonal oligophagy : Insects may live on many species in one part of the year and on few in another part of the year. Eg : Aphids.
4. Monophagy : Avoid all hosts except one particular species or variety Eg. Boll weevil on cotton.

Mechanism of Insect Resistance :

Insect resistance is grouped into four categories :

1. Non preference
2. Antibiosis
3. Tolerance
4. Avoidance

1. **Non preference** : Host Varieties exhibiting this type of resistance are unattractive or unsuitable for colonization, oviposition or both by an insect pest. This type of resistance in also termed as non-acceptance and anti-xenosis. Non preference involves various morphological and biochemical features of host plants such as – color, hairness, leaf angle, taste etc.

2. **Antibiosis** : Antibiosis refers to an adverse effect of feeding on a resistant host plant on the development and/or reproduction of the insect pest. In severe cases, it may even lead to the death of the insect pest. Antibiosis may involve morphological, physiological or biochemical features of the host plant; some cases of insect resistance involve a combination of features. Eg. Resistance to BPT is due to antibiosis & non preference.

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 produces a higher yield than a susceptible variety. Ability of the host plant to withstand the insect population to a certain extent which might have damaged a more susceptible host.

Tolerance is mainly a host character and it may be because of greater recovery from pest damage. Eg. Rice varieties tolerant to stem borer/gall midge produce additional tillers to compensate yield losses (as in stem borer in sorghum) or due to the ability of host to suffer less damage by the pest eg. aphid tolerance in Sugarbeet & Brassica sps. And green bugs tolerance in cereals. Inheritance of tolerance is complex in many cases and is supposed to be governed by polygenes.

4. **Avoidance** : Pest avoidance is the same as disease escape , and as such it is not a case of true resistance Mostly insect avoidance result from the host plants being at a much less susceptible developmental stage when the pest population is at its peak. Eg. 1. Early maturing cotton varieties escape pinkboll worm infestation, which occurs late in the season.

Nature of Insect Resistance / Factors for insect -resistance

Insect resistance may involve :

1. Morphological
2. Physiological (or)
3. Biochemical features of the host plant

1. **Morphological features** : Morphological factors like, hairiness, colour, thickness and toughness of tissues etc. are known to confer insect resistance.

a) Hairiness of leaves is associated with resistance to many insect pests leaf beetle in cereals, in cotton to Jassids , in turnip to turnip aphid.

b) Colour of plant : Color may contribute to non preference in some cases. For example : Red cabbage, Red leaved brussel's sprouts are less favored than green varieties by butterflies and certain Lepidoptera for oviposit ion. Boll worms prefer green cotton plants to red ones.

c) Thickness and Toughness of plant – Tissues prevent mechanical obstruction to feeding and oviposition and thereby lead to non-preference as well as antibiosis.

Eg.

1. Thick leaf lamina in cotton contributes to Jassid resistance
2. Solid stem in wheat confers resistance to wheat stem sawfly
3. Thick and tough rind of cotton bolls makes it difficult for the boll worm larve to bore holes and enter the bolls.

Other characters : also contribute to insect resistance.

Eg. 1. *Gossypium arboretum* varieties with narrow lobed and leathery leaves are more resistant to Jassids than are those with broad lobed and succulent leaves.

2. Cotton varieties with longer pedicels are more resistant to boll worms.

2. **Physiological Factors :** Osmotic concentration of cell sap, various exudates etc; may be associated with insect resistance.

Eg.

1) Leaf hairs of some *solanum sps*. secrete gummy exudates. Aphids and coloradobeetles get trapped in these exudates.

2) Exudates from secondary trichomes of *Medicago disciformis* leaves have antibiotic effects on alfalfa weevil.
3) Cotton- High osmotic concentration of cell sap is associated with Jassid resistance.

3. **Biochemical Factors**: Several biochemical factors are associated with insect resistance in many crops. It is believed that biochemical factors are more important than morphological and physiological factors in conferring non-preference and antibiosis.
Eg.
1) High concentrations of gossypol is associated with resistance in several insect pests in cotton.
2) In rice – high silica content in shoots gives resistance to shoot borer

Genetics of Insect Resistance

Insect resistance is governed by -
1. Oligogenes
2. Polygenes
3. Cytoplasmic genes

1. **Oligogenic Resistance** : Insect resistance is governed by one or few major genes or oligogenes, each gene having a large and identifiable individual effect on resistance. Oligogenic resistance may be conditioned by the dominant or the recessive allele of the concerned gene. The differences between resistant and susceptible plants are generally large and clear-cut. In several cases, resistance is governed by a single gene (monogenic resistance)
Eg. In wheat to green bugs In cotton to Jassids In apple to woolly aphis In rice to plant & leaf hopper.
2. **Polygenic Resistance** : It is governed by several genes, each gene producing a small and usually cumulative effect. Such cases of resistance.
1) Involve more than one feature of the host plant
2) Are much more durable than the cases of oligogenic resistance.
3) Difference between resistance & susceptible plants are not clear cut
4) Transfer of resistance is much more difficult

Examples for polygenic resistance
1) In wheat to cereal leaf beetle
2) In alfalfa to spotted aphid
3) In rice to stem borer
4) In maize to ear worm and leaf aphid Evolution of resistance breaking biotypes is almost rare.

3. **Cytoplasmic Resistance :** governed by plasmagenes
Eg. 1. Resistance to European corn borer in maize
2. Resistance to root aphid in lettuce

Sources of Insect Resistance

1. A cultivated variety 3. A related wild species
2. Germplasm collections. 4. An unrelated organisms

1. Cultivated variety : Resistance to many insect pests may be found among the cultivated varieties of the concerned crop. Varieties SRT 1, Khand waz ; DNJ 286 and B 1007 of *G. hirsuturn* are good sources of resistance to Jassids.
2. Germplasm collection :
Eg.
1) In apples for rosy apple aphid, green apple, apple maker and apple saw-fly.
2) In cotton, several strains resistant to Jassids.
3. Related wild species :
Eg.
1) Resistance to both the species of potato nematodes has been transferred fro *Solanum vernei* to potato
2) Jassid resistances is known in wild relatives of cotton *G. tomentosum; G.anomalum* and *G.armourianum*
4. An unrelated organism : It is done through recombinant DNA technology
a) T he 'Cry' gene of *Bacillus thuringiensis* is the most successful example.

Other genes of importance are the
b) Protease inhibitor encoding genes found in many plants eg. the cowpea pea, trypsin inhibitor (cp TI) gene.

Breeding Methods for Insect Resistance
1. Introduction 2. Selection
3. Hybridization 4. Genetic Engineering

1. Introduction :
Eg. *Phylloxera vertifoliae* resistance grape root-stocks from U.S.A. into france.

2. Selection :
Eg.
1) Resistance to potato leaf hopper
2) Resistance to spotted alfalfa aphid
3. Hybridization : Pedigree oligogenic characters Back cross Polygenic characters
4. Genetic Engineering : *B.theningiensis* (cry gene) resistance in maize, soybean, cotton etc.

Screening Techniques for determining resistance
The most crucial and, perhaps , the most difficult task in breeding for insect resistance is the identification of insect resistant plant during segregation generations. There are two types of screenings.
1. Field Screening
2. Glass house screening

Field Screening :

The techniques designed to promote uniform infestation by an insect pest in the field are

1. Inter planting a row of known susceptible variety between two rows of testing material.
2. Screening in highly prone areas
3. in case Soil insect pests to be tested in sick plots only
4. Testing in a particular season when the infestation is very high. Eg. Rice stem borer in off season.
5. Transferring manually equal number of eggs or larvae to each test plant.

Glass house screening

Result from glass house tests are much more reliable than those from field tests since both the environment and the initial level of infestations are more or less uniform for all the plants being tested.

Problems in Breeding for Insect Resistance :

1. Breeding for resistance to are insect pest may leads to the susceptibility to another pest. Eg. Glabrous strains of cotton are resistant to bollworms but susceptible to Jassids.
2. Reduction is quality or make unfit for consumption.
3. Linkage between desirable & undesirable genes. Inter specific varieties are generally low yielding and their produce is often of inferior quality.
4. Screening for resistance is the most critical and difficult step is a breeding programme it necessitates a close co-ordination among scientists belonging to different disciplines.
5. It is a long term programme.

Achievements

INDIA

1. India – cotton varieties – G 27, MCU 7, LRK 516 – resistant to boll worms.
2. Rice – variety vijaya – resistant to leaf hopper

Rice – TKM 6, Ratna – Stemborer

Rice –Vajram, chaitanya, Pratibha – BPH