GPB-311 **Crop Improvement – I (Kharif)** **2(1+1)**

Theory

Centers of origin, distribution of species, wild relatives in different cereals; pulses; oilseeds; fibres; fodders and cash crops; vegetable and horticultural crops; Plant genetic resources, its utilization and conservation Floral biology, study of genetics of qualitative and quantitative characters; Important concepts of breeding self pollinated, cross pollinated and vegetatively propagated crops; Major breeding objectives and procedures including conventional and modern innovative approaches for development of hybrids and varieties for yield, adaptability, stability, abiotic and biotic stress tolerance and quality (physical, chemical, nutritional); Seed production technology in self pollinated, cross pollinated and vegetatively propagated crops.

Cereals: Rice, maize, sorghum and bajra
Pulses: Urd, mung, cowpea, pigeonpea and moth bean
Oilseeds: Soybean, sesame and groundnut
Fibre crops: Cotton
Fodder: Bajra, sorghum, maize
Vegetables: Chilli and tomato
Cash/ other crops: Castor

Hybrid seed production technology in Maize, Rice, Sorghum, Pearl millet and Pigeonpea, etc. Ideotype concept and climate resilient crop varieties for future.

Practical

Emasculation and hybridization techniques in different crop species; viz., Rice, Maize, Sorghum, Pearl Millet, Pigeonpea, Urdbean, Mungbean, Soybean, Groundnut, Seasame , Castor, Cotton, Cowpea and Pearl millet. Maintenance breeding of different kharif crops. Handling of germplasm and segregating populations by different methods like pedigree, bulk and single seed decent methods; Study of field techniques for seed production and hybrid seeds production in *Kharif* crops; Estimation of heterosis, inbreeding depression and heritability; Layout of field experiments; Study of quality characters, donor parents for different characters; Visit to seed production plots; Visit to AICRP plots of different field crops.

Lecture Schedule: Theory

S.N.	Topic	No. of lectures
1	Crop improvement aspects in rice as mentioned in the syllabus such as Centers of origin, distribution of species Floral biology breeding objectives and procedures etc & hybrid seed production	1
2	Crop improvement aspects in maize as mentioned in the syllabus such as Centers of origin, distribution of species Floral biology breeding objectives and procedures etc & hybrid seed production	1
3	Crop improvement aspects in sorghum as mentioned in the syllabus such as Centers of origin, distribution of species Floral biology breeding objectives and procedures etc& hybrid seed production	1

4	Crop improvement aspects in bajra as mentioned in the syllabus such as	1
	Centers of origin, distribution of species Floral biology breeding objectives and procedures etc& hybrid seed production	
5	Crop improvement aspects in urd**,** mung and cowpea as mentioned in the syllabus such as Centers of origin, distribution of species Floral biology breeding objectives and procedures etc	1
6	Crop improvement aspects in pigeonpea as mentioned in the syllabus such as Centers of origin, distribution of species Floral biology breeding objectives and procedures etc& hybrid seed production	1
7	Crop improvement aspects in soybean as mentioned in the syllabus such as Centers of origin, distribution of species Floral biology breeding objectives and procedures etc.	1
8	Crop improvement aspects in sesame as mentioned in the syllabus such as Centers of origin, distribution of species Floral biology breeding objectives and procedures etc.	1
9	Crop improvement aspects in groundnut as mentioned in the syllabus such as Centers of origin, distribution of species Floral biology breeding objectives and procedures etc.	1
10	Crop improvement aspects in cotton and castor as mentioned in the syllabus such as Centers of origin, distribution of species Floral biology breeding objectives and procedures etc.	1
11	Crop improvement aspects in chilli as mentioned in the syllabus such as Centers of origin, distribution of species Floral biology breeding objectives and procedures etc.	1
12	Crop improvement aspects in tomato mentioned in the syllabus such as Centers of origin, distribution of species Floral biology breeding objectives and procedures etc.	1
13	Modern innovative approaches for development of hybrids and varieties for yield, adaptability, stability, abiotic and biotic stress tolerance and quality (physical, chemical, nutritional)	1
14	Seed production technology in self pollinated, cross pollinated and vegetatively propagated crops	1
15	Ideotype concept	1
16	Climate resilient crop varieties for future.	1

Lecture Schedule: Practical

S.N.	Topic	No. of lectures
1	Emasculation and hybridization techniques in rice, maize	1
2	Emasculation and hybridization techniques in sorghum and bajra	1
3	Emasculation and hybridization techniques in urd, mung, cowpea, pigeonpea	1
4	Emasculation and hybridization techniques in, soybean, sesame	1
5	Emasculation and hybridization techniques in and groundnut and cotton	1
6	Maintenance breeding of different kharif crops	1
7	Handling of germplasm and segregating populations by different	1

	methods like pedigree, bulk and single seed decent methods	
8	Study of field techniques for seed production and hybrid seeds production in *Kharif* crops	1
9	Estimation of heterosis, inbreeding depression and heritability	1
10	Layout of field experiments	1
11	Study of quality characters	1
12	Donor parents for different characters	1
13	Visit to seed production plots	2
14	Visit to AICRP plots of different field crops	2

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Chapter No.1

Center of origin,Distrubution of species,wild relatives in different crop

Sr. no.	Crop	Centre of origin	Distribution of species	Wild relatives
	Cereals			
1.	Rice *(Oryza Sativa)* *2n=2x=24* *2n=2x=48*	South East Asia	China, India, Japan, Korea, Pakistan, Bangladesh	*O. nivara* *O. officinalis*
2.	Maize *(Zeamays)* 2n = 20	Central America	USA, China, Russia, Canada and many south Asian countries	*Zea Mexicana* *Zea perennis*
3.	Sorghum *(Sorghum bicolor)* 2n = 2x = 20	S.E. Africa, Ethiopia	Africa, south and central India, China, Argentina, Australia and south and central plains of US.	*s. halepense,* *s. drummondii*
4.	Pearl millet *(Penisetum americanum)*	W. Africa	Africa, India, Pakistan, South East Asia, USA and Europe	*P. squamulatum* *p. purpurcum*
5.	Finger Millet *(Elusine coracana)*	Vavilov -Africa Decan dole – India	India, Africa, Pakistan	*Eleusine Indica* *Eleusine oligostachya*
	Pulses			
6.	Red gram *(Cajanus cajan)* 2n=22	Africa and India	India, Uganda, Kenya, West Indies, Burma etc.	c.*scarabacoides*, *c. serideus*
7.	SOYBEAN *(Glycine max)* 2n=40	China	USA, Brazil, China, Argentina and India	*glycin.soja*
8.	Green gram *(Vigna radiata)*	India	India, Pakistan, Bangladesh, Srilanka, Philippines, Taiwan, Thailand, Nepal and Southern Asian countries.	*V.radiata* var.*sublobata*
9.	Black gram *(Vigna mungo)*	India	India, Pakistan, Sirlanka, and South Asian countries.	*V.mungo* var. *silvestris*
10	Cowpea (Vigna unguiculate)	Africa	Nigeria, Niger, Burkina Faso, Ghana, Kenya, Uganda, Malawi, Tanzania (all in Africa) and India, Sri Lanka, Burma, Bangladesh, Philippines, Indonesia, Thailand,	*V.unguiculata* var. *spontanea*

			etc.	
	Oil seed			
11	Ground Nut *(Arachis hypogea)*	Brazil	India, China, USA, Africa, South and South East Asia.	*A. appressipila, A. giabjraia pintoi*
12	Sesame *(Sesamum indicum)* (2n=26)	India, and Ethiopia (Africa)	India, Pakistan, Africa, China, Mexico, Iran, Iraq etc	*S. alatum S. malabaricum*
13	Sunflower *(Helianthus annuus)*	North America	USSR, Romania, Canada, USA In India this crop is introduced in 1969 from USSR.	*H.hirsutus, H.rigidus*
14.	Castor (*Ricinus communis)*	Ethiopia	African countries (Egypt), China, India, middle East etc. In India Andhra Pradesh, Karnataka, Maha,	*R.communis subsp persicus ssp.chinensis*
	Fodder crops			
15.	Berseem *(Trifolium alexandrinum)*	Syria	Egypt, India, Pakistan, South Africa, USA and Australia	*Trifolium apertum T. resupinatum T. vesiculosum*
16.	*Lucerne (Medicago sativa)*	Mediterranean region	Spain, China, Sweden, North Africa. Italy, Switzerland, north America	*M.falcata, M.borealis M. romanica.*
17.	Rice bean *(Vigna umbellata)*	Indochina	Thailand, India, central China, Egypt, to the East Coast of Africa, Asia, Fiji, Australia, tropical Africa, USA, Honduras, Brazil and Mexico	*Vigna angularis*
	Cash crops			
18.	Cotton *(Gossypium sps)*	Central Africa	China, USA, India, Pakistan, Egypt. In India Rajasthan, Maharashtra, M.P. Gujarat, A.P. Karnataka and Tamil Nadu	*G. tomentosum, G. raimondii*
19.	Tobacco *(Nicotiana tabacum)*	Central America	China, Brazil, India,USA, Indonesia, Pakistan	*N. attenuata N.obtusifolia N. excelsior,*
	Vegetable crops			
20.	Ridge gourd *(Luffa acutangula)*	India	West Africa, Nigeria, Ghana, Mauritius, Madagascar	*Lufa operculata*

21.	Bottle gourd	Africa	Africa, Asia, America	
22.	Snake gourd ***(****Trichosanthes cucumerina) var. anguina*	Southeast Asia	India, Bangladesh. Nepal, Pakistan, Srilanka, Indonesia, Malaysia, Myanmar, China	*Trichosanthes cucumerina* var. *cucumerina*
23	Bitter gourd	Tropical Asia	India, Indonesia, Malaysia, China, and Africa	*Momordica muricata*
	Horticultural crops			
24.	Mango *(Mangifera indica)*	Himalayas in the areas of Burma, China and Malayan Peninsula.	It is extensively cultivated in India, Indo-China warm parts of Australia, Philippines, Pacific Islands, Himalayas.	*M. macrocarpa* *M. foetida* *M. caesia*
25.	GUAVA *(Psidium guajava)* (2n=22)	Tropical America / West Indies	America, Canada, Australia, India, Burma, Indonesia, Bangladesh etc.	*P. guineense,* *P. chinensis,* *P. cattleianum*
26.	Cashewnut (*Anacardium occidentale)*	Brazil	Vietnam, Nigeria, India, Brazil, and Indonesia	*Anacardium excelsum*
27.	Citrus	Southeast Asia	Taiwan, Japan, Australia, new guinea	*Citrus indica.*
28.	**Pomegranate** (Punica granatum)	Iran	Asia (Turkmenistan, Afghanistan, India, China, etc.), North Africa and Mediterranean Europe.	*P. protopunica*

This type of question may be ask in end theory exam
For example: write down the origin ,distribution of species ,wild relatives of the following crop
1. RICE 2.cotton 3 Red gram 4 Mango

OR

Sr.no	crop	B.name	origin	Chromosome no./distribution of species	Wild species
1.	RICE				
2.	.cotton				
3.	Red gram				
4.	Mango				

Chapter No.: 02

Plant genetic resources, its utilization and conservation

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. It is 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

- Gene pool represents the entire genetic variability or diversity available in a crop species.

- Germplasm consists of land races, modern cultivars, obsolete cultivars, breeding stocks, wild forms and wild species of cultivated crops.

- Germplasm includes both cultivated and wild species or relatives of crop plants.

- Germplasm is collected from the centres of diversity, gene banks, gene sanctuaries, farmers' fields, markets and seed companies.

- Germplasm is the basic material for launching a crop improvement programme.

- Germplasm may be indigenous (collected within country) or exotic (collected from foreign countries)

AIMS OF PGR: Prevent genetic erosion by

1. **Collection**
2. **Conservation**
3. **Study of documentation and**
4. **Utilization**

The Convention on Biological Diversity (CBD) defines genetic resources as genetic material of actual or potential value. The term ‘Genetic material’ means any material of

plant, animal, microbial or other origin containing functional units of heredity. The value of any functional units of heredity can be captured in two dimensions: which is the genetic structure per se can be utilised; or the information encapsulated in the nucleotide sequence of the genetic material can be read. FAO (1989) used the term to mean any economic, scientific or societal value of the heritable materials contained within and among plant species.

Kinds of Germplasm

The germplasm consists of various plant materials of a crop such as

1. Land races,
2. Advanced (homozygous),
3. Breeding materials,
4. Absolete cultivars,
5. Wild forms of cultivated species,
6. Modern cultivars,
7. Wild relatives,
8. 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. 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.

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 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.

3.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 -18C or -20C 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 up to 100 years.

2. Active collections:

The accessions in an active collection are stored at temperatures below 15C (often near 0C), 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 programmes. These collections are used for evaluation, multiplication and distribution of the 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 15C 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 collection.

Germplasm activities

There are six important activities related to plant genetic resources.

1. Exploration and collection
2. Conservation
3. Evaluation
4. Documentation
5. Multiplication and Distribution
6. Utilization

1.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. we get material of special interest during exploration trips.

4. 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 whenever necessary.

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

1. In situ conservation 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 center of origin of crop species concerned, preferably covering the microcenter with in the center 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 very 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,

2).it also allows evolution to continue. As a result, new alleles and new gene combinations would appear with time.

3). The risks associated 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. E.g. 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.
- Distribution of germplasm is the responsibility of the gene bank centres

- The germplasm is usually supplied to the workers who are engaged in research work of a particular crop species.
- Supplied free of cost to avoid cumbersome work of book keeping.
- The quantity of seed samples depends on the availability of seed material and demands
- Proper records are maintained about the distribution of material.
- 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.

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

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 intervention 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, airports and industrial areas also lead to genetic erosion of crop plants, because vast areas are cleaned for such activities.

ROLES OF PLANT GENETIC SOME USES AND RESOURCES

In order to grasp the importance as well as current challenges in the conservation and utilization of PGR, there is need to outline some benefits of PGR.

1) Development of new variations through genetic modification techniques.

2) Transfer of a genetic trait, such as a gene for pesticide resistance taken out of one species and put into another.

3) Production of recombinant cell lines and transgenic plants.

4) Use of in vitro nucleic acid techniques, including recombinant deoxyribonucleic acid (DNA); and direct injection of nucleic acid into cells or organelles

5) Use of fusion of cells beyond the taxonomic family.

6) Sequencing genes or genomes (e.g. identification of genes coding for useful traits; molecular systematics for understanding evolutionary relations; genotyping of plants for identification and DNA barcoding of plants for identification; environmental genomics)

7) Phenotyping of the characteristics of plants, animals and micro-organisms for ecological and other studies and purposes

8) Experimental evaluation of heritable characteristics

9) Creation of collections of reference specimens in repositories such as museums and herbaria

10) Isolation of a compound from genetic material for the purpose of characterization and evaluation.

Gene banks:

The purpose of gene banks is to collect, conserve and make genetic resources available. The maintenance of the genetic identity of the accessions is an overriding objective of gene banks. Gene banks were first established over 50 years ago to conserve threatened crop diversity in local land races that were being displaced by new improved varieties and destruction of natural habitats. Gene bank management guidelines for different crops are scanty and hard to find; most are generic. There are different kinds of gene banks including seed banks, field banks, *in vitro* banks, cryo banks, vegetative banks and DNA banks. Gene banks around the world hold collections of a broad range of plant genetic resources, with the overall aim of long-term conservation and accessibility of plant germplasm to plant breeders, researchers and other users.

Cryopreservation:

Cryopreservation is a technique that ensures safe, long-term conservation of genetic resources of plant species with recalcitrant seeds, of vegetatively propagated species and of biotechnology products such as somatic embryos, cell lines and genetically transformed material. The technique was implemented at the end of the 20th century and could be used today for routine cryostorage. Tissue culture procedures are usually required to multiply super cooled material via axillary shoots or somatic embryogenesis, and were improved for use with tree species in recent years. Three major genetic risks in *ex situ* collections are genetic drift, adaptation to cultivation and mutation accumulation.

Define germplasm or plant genetic resources .what are or enlist the kind (types or classify) of germplasm.explain the method of germplasm conservation.

Write short notes on

1) gene bank 2) Cryopreservation

Define 1.Orthodox seeds 2. Recalcitrant seeds

Chapter no.3

Floral biology

The flower is the reproductive unit in the angiosperms. It is meant for sexual reproduction. A typical flower has four different kinds of whorls arranged successively on the swollen end of the stalk or pedicel, called **thalamus or receptacle**. These are calyx, corolla, androecium and gynoecium. Calyx and corolla are accessory organs, while androecium and gynoecium are reproductive organs. In some flowers like lily, the calyx and corolla are not distinct and are termed as perianth. When a flower has both androecium and gynoecium, it is **bisexual**. A flower having either only stamens or only carpels is **unisexual.**

In symmetry, the flower may be **actinomorphic** (radial symmetry) or **zygomorphic** (bilateral symmetry). When a flower can be divided into two equal radial halves in any radial plane passing through the centre, it is said to be **actinomorphic,** e.g., mustard, *datura*, chilli. When it can be divided into two similar halves only in one particularvertical plane, it is **zygomorphic,** e.g., pea, gulmohur, bean, *Cassia*. A flower is **asymmetric** (irregular) if it cannot be divided into two similar halves by any vertical plane passing through the centre, as in canna.

A flower may be **trimerous, tetramerous** or **pentamerous** when the floral appendages are in multiple of 3, 4 or 5, respectively. Flowers with bracts -reduced leaf found at the base of the pedicel - are called **bracteate** and those without bracts, **ebracteate**.

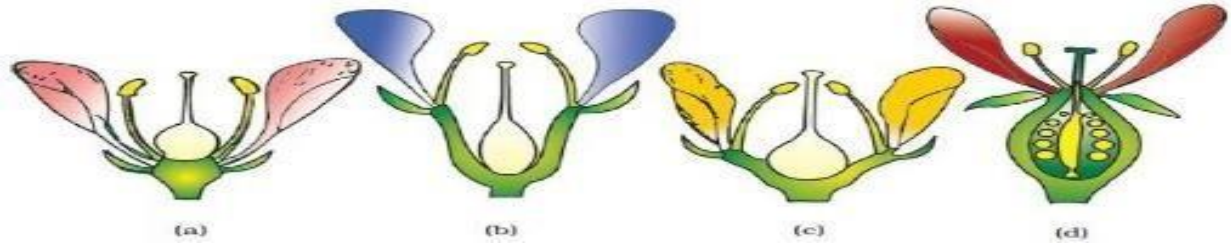


Figure: 1 Position of floral parts on thalamus: (a) Hypogynous (b) and (c) Perigynous (d) Epigynous

Based on the position of calyx, corolla and androecium in respect of the ovary on thalamus, the flowers are described as hypogynous, perigynous and

epigynous (Figure 5.13). In the **hypogynous** flower the gynoecium occupies the highest position while the other parts are situated below it. The ovary in such flowers is said to be **superior,** e.g., mustard, china rose and brinjal. If gynoecium is situated in the centre and other parts of the flower are located on the rim of the thalamus almost at the same level, it is called **perigynous.** The ovary here is said to be **half inferior,** e.g., plum, rose, peach. In **epigynous flowers,** the margin of thalamus grows upward enclosing the ovary completely and getting fused with it, the other parts of flower arise above the ovary. Hence, the ovary is said to be **inferior** as in flowers of guava and cucumber, and the ray florets of sunflower.

Parts of a Flower

Each flower normally has four floral whorls, viz., calyx, corolla, androecium and gynoecium

Calyx

The calyx is the outermost whorl of the flower and the members are called sepals. Generally, sepals are green, leaf like and protect the flower in the bud stage. The calyx may be **gamosepalous** (sepals united) or **polysepalous** (sepals free).

Corolla

Corolla is composed of petals. Petals are usually brightly coloured to attract insects for pollination. Like calyx, corolla may be also united.

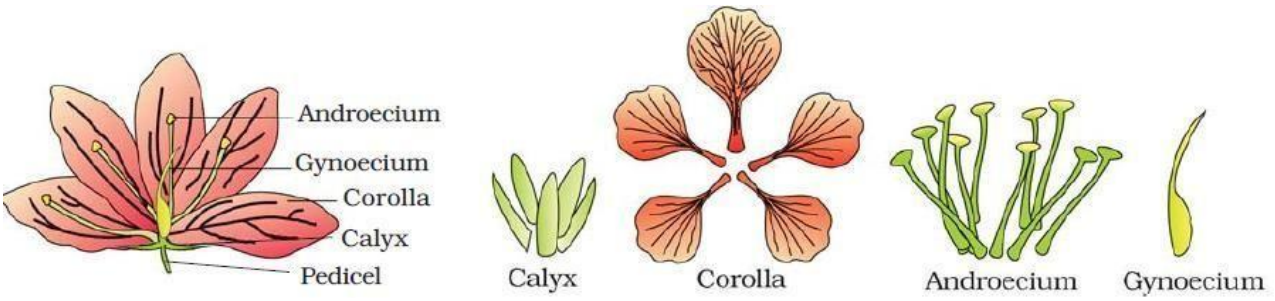


Figure 2: Parts of a flower

gamopetalous (petals united) or **polypetalous** (petals free). The shape and colour of corolla vary greatly in plants. Corolla may be tubular, bell- shaped,

funnel-shaped or wheel-shaped.

Aestivation: The mode of arrangement of sepals or petals in floral bud with respect to the other members of the same whorl is known as aestivation. The main types of aestivation are valvate, twisted, imbricate and vexillary (Figure 5.15). When sepals or petals in a whorl just touch one another at the margin, without overlapping, as in *Calotropis*, it is said to be **valvate.** If one margin of the appendage overlaps that of the next one and so on as in china rose, lady's finger and cotton, it is called **twisted**. If the margins of sepals or petals overlap one another but not in any particular direction as in *Cassia* and gulmohur, the aestivation is called **imbricate**. In pea and bean flowers, there are five petals, the largest (standard) overlaps the two lateral petals (wings) which in turn overlap the two smallest anterior petals (keel); this type of aestivation is known as **vexillary** or papilionaceous.

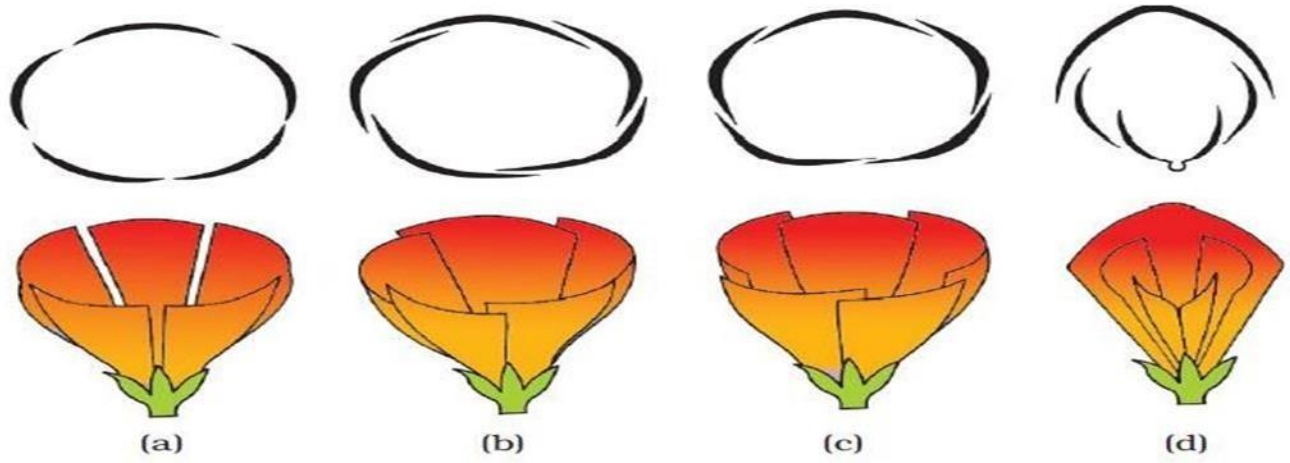


Figure 3: Types of aestivation in corolla: (a) Valvate (b) Twisted (c) Imbricate (d) Vexillary

Androecium

Androecium is composed of stamens. Each stamen which represents the male reproductive organ consists of a stalk or a filament and an anther. Each anther is usually bilobed and each lobe has two chambers, the pollen-sacs. The pollen grains are produced in pollen-sacs. A sterile stamen is called **staminode**.

Stamens of flower may be united with other members such as petals or

among themselves. When stamens are attached to the petals, they are **epipetalous** as in brinjal, or **epiphyllous** when attached to the perianth as in the flowers of lily. The stamens in a flower may either remain free (polyandrous) or may be united in varying degrees. The stamens may be united into one bunch or one bundle **(monoadelphous)** as in china rose, or two bundles **(diadelphous)** as in pea, or into more than two bundles **(polyadelphous)** as in citrus. There may be a variation in the length of filaments within a flower, as in *Salvia* and mustard.

Gynoecium

Gynoecium is the female reproductive part of the flower and is made up of one or more carpels. A carpel consists of three parts namely stigma, style and ovary. **Ovary** is the enlarged basal part, on which lies the elongated tube, the style. The style connects the ovary to the stigma. The **stigma** is usually at the tip of the **style** and is the receptive surface for pollen grains. Each ovary bears one or more ovules attached to a flattened, cushion-like **placenta**. When more than one carpel is present, they may be free (as in lotus and rose) and are called **apocarpous**. They are termed **syncarpous** when carpels are fused, as in mustard and tomato. After fertilization, the ovules develop into seeds and the ovary matures into a fruit.

Chapter No.4

Emasculation

Removal of stamens or anthers or killing the pollen of a flower without the female reproductive organ is known as emasculation. In bisexual flowers, emasculation is essential to prevent of self-pollination. In monoecious plants, male flowers are removed. (castor, coconut) or male inflorescence is removed (maize). In species with large flowers e.g. (cotton, pulses) hand emasculation is accurate and it is adequate.

Methods of Emasculation

1. Hand Emasculation

In species with large flowers, removal of anthers is possible with the help of forceps. It is done before anther dehiscence. It is generally done between 4 and 6 PM one day before anthers dehisce. It is always desirable to remove other young flowers located close to the emasculated flower to avoid confusion. The corolla of the selected flower is opened with the help of forceps and the anthers are carefully removed with the help of forceps. Sometimes corolla may be totally removed along with **epipetalous stamens** e.g. gingelly.

In cereals, one third of the empty glumes will be clipped off with scissors to expose anthers. In wheat and oats, the florets are retained after removing the anthers without damaging the spikelets. In all cases, gynoecium should not be injured. An efficient emasculation technique should prevent self-pollination and produce high percentage of seed set on cross pollination.

2. Suction Method

It is useful in species with small flowers. Emasculation is done in the morning immediately after the flowers open. A thin rubber or a glass tube attached to a suction hose is used to suck the anthers from the flowers. The amount of suction used is very important which should be sufficient to suck the pollen and anthers but not gynoecium. In this method considerable self-pollination, upto 10% is like to occur. Washing the stigma with a jet of water may help in reducing self-pollination, however self-pollination cannot be eliminated in this method.

3. Hot Water Treatment

Pollen grains are more sensitive than female reproductive organs to both genetic and environmental factors. In case of hot water emasculation, the temperature of water

and duration of treatment vary from crop to crop. It is determined for every species. For sorghum 42-48OC for 10 minutes is found to be suitable. In the case of rice, 10 minutes Treatments with 40-44OC is adequate. Treatment is given before the anthers dehiscence and prior to the opening of the flower. Hot water is generally carried in thermos flask and whole inflorescence is immersed in hot water.

4. Alcohol Treatment

It is not commonly used. The method consists of immersing the inflorescence in alcohol of suitable concentration for a brief period followed by rinsing with water. In Lucerne the inflorescence immersed in 57% alcohol for10 second was highly effective. It is better method of emasculation than suction method.

5. Cold Treatment

Cold treatment like hot water treatment kills the pollen grains without damaging gynoecium. In the case of rice, treatment with cold water 0.6OC kills the pollen grains without affecting the gynoecium. This is less effective than hot water treatment.

6. Genetic Emasculation

Genetic/ cytoplasmic male sterility may be used to eliminate the process of emasculation. This is useful in the commercial production of hybrids in maize, sorghum pearl millet, onion, cotton, and rice, etc., In many species of self-incompatible cases, also emasculation is not necessary, because self-fertilization will not take place. Protogyny will also facilitate crossing without emasculation (e.g.) Cumbu.

7. Use of Gametocide

Also known as chemical hybridizing agents (CHA) chemicals which selectively kills the male gamete without affecting the female gamete. e.g. Ethrel, Sodium methyl arsenate, Zinc methyl arsenate in rice, Maleic hydrazide for cotton and wheat.

Bagging:

Immediately after emasculation the flower or inflorescence enclosed with suitable bags of appropriate size to prevent random cross-pollination.

Pollination

The pollen grains collected from a desired male parent should be transferred to the emasculated flower. This is normally done in the morning hours during anthesis. The flowers are bagged immediately after artificial crossing.

Tagging

The flowers are tagged just after bagging. They are attached to the inflorescence or to the flower with the help of a thread. The following may be recorded on the tag with pencil.

1. Date of emasculation
2. Date of pollination
3. Parentage
4. No. of flowers emasculate

Chapter No.5

Mode of Pollination

Pollination refers to the transfer of pollen grain from anthers to stigmas. Pollen from an anther may fall on the stigma of the same flower leading to self-pollination or auto gamy. Sometimes pollen from an anther may fall on the stigma of another flower of different plants leading to cross pollination or allogamy. Sometimes pollen from an anther fall on the stigma of the anther flower of same plant leading to the geitonogamy.

Self-Pollination:

It is transfer of pollens from and to the stigma within the same flower, is always found in bisexual flower. In most of these species self-pollination is not complete and cross-pollination may occur up to 5%. There are various mechanism / contrivances that promote / facilitate self-pollination.

I) Bisexuality:

Male and female sexual organs present in the same flower e.g. Wheat, rice, groundnut, etc.

II) Homogamy:

Male and female sexual organs mature at the same time e.g. wheat, groundnut, etc.

III) Cleistogamy:

In this condition flowers does not open at all and ensure complete self-pollination e.g Oat, Barley, Wheat, Grasses, etc.

IV) Chasmogamy:

In some species, flower open but only after pollination has taken place. e.g Barley, Wheat, Oat, and many cereals.

V) Position of anthers

I) In crop like Tomato and Brinjal stigma are closely surrounded by anthers, hence pollination occurs after opening of flower but the position of anther in relation to stigma ensure self – pollination.

II) In crop like pea, bean, soybean, the flower open but stigma and anther are hidden by floral organ and ensures self – pollination.

III) In few species' stigmas become receptive and elongate through staminal column, ensures self-pollination.

Genetic Consequences of Self – Pollination:

I) It leads to a very rapid increase in homozygosity; therefore, self-pollinated species highly homozygous in nature.

II) Self-pollinated species do not show inbreeding depression, exhibit considerable heterosis.

Cross Pollination:

The transfer of pollen from a flower to the stigma of the other flower of different flower plant. In cross pollinated species pollination may be brought about by wind, water insect or animals. Wind (anemophily) water (hydrophily), insect (entomophily) and animal (Zoophily). In most of the cross-pollinated sp. Viz. Bajara, maize, sunflower, alfalfa, castor, cross pollination is not complete and self-pollination may occur 5-10%. There are several mechanism contrivances that facilitate cross pollination.

I) Dicliny (Unisexuality):

It is a condition in which flower is either staminate or pistilate.

a) Monoecy:

Staminate and pistilate flowers occur in the same plant either in the same inflorescence. e.g. Mango, banana, coconut or in the separate inflorescence. e.g. Maize, Cucurbit, Strawberry, etc.

b) Dioecy:

The male and female flowers are present on different plants i.e. the in such species are male or female i.e. sec is governed by a single gene. E.g. Papaya, hemp, date, palm, etc.

ii) Dichogamy:

Anther and stigma of hermaphrodite flower mature at different time, facilitating cross pollination.

a) Protogyny:

Gynoecium matures earlier than the androecium e.g. Bajara.

b) Protandry:

Androecium matures earlier than gynoecium. e.g. marigold, maize, cotton, etc.

iii) Heterostyly:

Different length of style and filaments e.g. Linseed.

iv) Herkogamy:

Presence of physical barrier or mechanical obstacles between the anther and stigma ensures cross pollination. E.g. Rui (Calotropic gigantia).

v) In Lucerne or alfalfa stigma are covered by waxy film and it does not become receptive unless this waxy film is broken by honeybees.

vi) A combination of two or more of the above mechanism may occurs in some species, e.g. Maize, – Monoecy and Protandry.

vii) Self –Incompatibility:

It refers to the failure of pollen from a flower to fertilize the same flower or other flowers on some plants. It may be saprophytic or gametophytic e.g. mustard, tobacco, sunflowers, reddish.

Viii) Male Sterility:

It refers to the absence of functional pollen grains in hermaphrodite flower.

Genetic Consequences of Cross Pollination:

1) It preserves and promotes heterozygosity in population.

2) Cross pollinated species shows inbreeding depression and considerable heterosis.

3) Usually hybrid and synthetic without reducing heterozygosity.

Often Cross Pollination:

In this type plants are self-pollinated; however, the extent of cross pollination often exceeds 5 to 50 % such species are generally known as often cross-pollinated species. E.g. Jawar, Cotton, Safflower, Arhar, etc. The genetic architecture of such crop is intermediate between self- and cross-pollinated crops and breeding methods suitable for both of them may be profitably applied.

Study of **floral biology** and afore said mechanisms is essential for determining the mode of pollination of various crop species. Moreover, if selfing has adverse effects on seed setting and general vigour, it indicates that the species is cross pollinated. If selfing does not have any adverse effect on these characters, it suggests that the species is self-pollinated.

The percentage of cross pollination can be determined by growing a seed mixture of two different varieties together. The two varieties should have marker characters say

green and pigmented plants. The seeds are harvested from the recessive (green) variety and grown next year in separate field. The proportion of pigmented plants in green variety will indicate the percentage of **outcrossing** or cross pollination.

Significance of pollination

The mode of pollination plays an important role in plant breeding. It has impact on five important aspect:

1) gene action,
2) genetic constitution,
3) adaptability,
4) genetic purity and
5) transfer of genes.

Classification of crop plants based on mode of pollination and mode of reproduction

Mode of pollination and reproduction	**Examples of crop plants**
A. Autogamous Species	
1. Seed Propagated	Rice, Wheat, Barley, Oats, Chickpea, Pea, Cowpea, Lentil, Green gram, Black gram, Soybean, Common bean, Moth bean, Linseed, Sesame, Khesari, Sunhemp, Chillies, Brinjal, Tomato, Okra, Peanut, etc.
2. Vegetatively Propagated	Potato
B. Allogamous Species	
1. Seed Propagated	Corn, Pearlmillet, Rye, Alfalfa, Radish, Cabbage, Sunflower, Sugarbeet, Castor, Red clover, White clover, Safflower, Spinach, Onion, Garlic, Turnip, Squash, Muskmelon, Watermelon, Cucumber, Pumpkin, Kenaf, Oilpalm, Carrot, Coconut, Papaya, etc.
2. Vegetatively propagated	Sugarcane, Coffee, Cocoa, Tea, Apple, Pears, Peaches, Cherries, grapes, Almond Strawberries, Pine apple, Banana, Cashew, Irish, Cassava, Taro, Rubber, etc.
C. Often Allogamous Species	Sorghum, Cotton, Triticale, Pigeon pea, Tobacco.

Chapter No.6

STUDY OF QUALITATIVE AND QUANTITATIVE CHARACTERS

The easiest characters, or traits, to deal with are those involving discontinuous, or qualitative, differences that are governed by one or a few major genes. Many such inherited differences exist, and they frequently have profound effects on plant value and utilization. Examples are starchy versus sugary kernels (characteristic of field and sweet corn, respectively) and determinant versus indeterminant habit of growth in green beans (determinant varieties are adapted to mechanical harvesting). Such differences can be seen easily and evaluated quickly, and the expression of the traits remains the same regardless of the environment in which the plant grows. Traits of this type are termed highly heritable.

A qualitative trait is expressed qualitatively, which means that the phenotype falls into different categories. These categories do not necessarily have a certain order. The pattern of inheritance for a qualitative trait is typically monogenetic, which means that the trait is only influenced by a single gene. Inherited diseases caused by single mutations are good examples of qualitative traits. Another is blood type. The environment has very little influence on the phenotype of these traits.

Expressivity

The degree of phenotypic expression of a penetrant gene is called expressivity. In other words, the ability of a gene to produce identical phenotypes in all the individuals carrying it in the appropriate genotype is known as incomplete expressivity. Many genes have incomplete expressivity, while the wild type (normal) alleles are buffered against such variations.

Penetrance

The frequency with which a gene produces a phenotypic or visible effect in the individuals, which carry it, is known as penetrance. In other words, penetrance refers to the proportion of individuals which exhibit phenotypic effect of a specific gene carried by them. In general genes express themselves in all the individuals in which they are present in the appropriate genotype is known as penetrance. It indicates the number of individuals that give the expected phenotype to any degree.

Modifying genes

These are group of genes, which enhances or reduce the phenotypic effect of a major gene. Such genes have small and cumulative effect on the expression of the major genes. As a result, continuous variation is generated in the phenotype governed by a single major gene, which converts qualitative character into a quantitative one. In rats, guinea pigs and rabbits, piebald spotting is produced by recessive genes when present in a homozygous state (ss). The degree of spotting depends upon the modifying factors, designed as S1, S2, S3 etc. which enhances or reduces the expression of this spotting gene with cumulative on spotting. Most quantitative characters of crop plants may be determined in a similar fashion. Some modifying genes affect more than one character.

Major and minor genes

In the pie bald spotting the modifying factors produce some spotting even in the absence of the spotting genes but their effect is much more pronounced in the presence of s, Obviously the spotting gene s is a major gene controlling spotting, while the modifying genes are minor genes affecting this trait.

Quantitative genetics (Inheritance of Multiple Genes)

The phenotypic traits of the different organisms may be of two kinds, viz., qualitative and quantitative. The qualitative traits are the classical Mendelian traits of kinds such as form (e.g., round or wrinkle seeds of pea); structure (e.g., horned or hornless condition in cattles); pigments (e.g., black or white coat of guinea pigs); and antigens and antibodies (e.g., blood group types of man) and so on. We have already discussed in previous chapters that each qualitative trait may be under genetic control of two or many alleles of a single gene with little or no environmental modifications to obscure the gene effects. The organisms possessing qualitative traits have distinct (separate) phenotypic classes and are said to exhibit discontinuous variations.

The quantitative traits, however, are economically important measurable phenotypic traits of degree such as height, weight, skin pigmentation, susceptibility to pathological diseases or intelligence in man; number of flowers, fruits, seeds, milk, meat or egg produced by plants or animals, etc. The quantitative traits are also called metric traits. They do not show clear cut differences between individuals and forms a spectrum of phenotypes which blend imperceptivity from one type to another to cause continuous

variations. In contrast to qualitative traits, the quantitative traits may be modified variously by the environmental conditions and are usually governed by many factors or genes (perhaps 10 or I00 or more), each contributing such a small amount of phenotype that their individual effects cannot be detected by Mendelian methods but by only statistical methods.

Such genes which are non-allelic and effect the phenotype of a single quantitative trait, are called polygenes or cumulative genes. The inheritance of poly genes or quantitative traits is called quantitative inheritance, multiple factor inheritance, multiple gene inheritance or polygenic inheritance. The genetical studies of qualitative traits are called qualitative genetics.

Certain Characteristics of Quantitative Inheritance

The quantitative inheritance have following characteristics:

1. The segregation phenomenon occurs at an indefinitely large number of gene loci.
2. If a substitution of a allele occurs in a gene locus then such allelic substitutions have trivial effects.
3. The genes for a multiple trait have different biochemical functions but similar phenotypic effects, therefore, the phenotypic effects of gene substitutions are interchangeable.
4. Blocks of genes are bound together by inversions and transmitted as units from inversion heterozygotes to their progeny, but such blocks are broken up by crossing over in insertion homozygotes.
5. The polygenes have pleiotropic effects; that is, one gene may modify or suppress more than one phenotypic trait.
6. The environmental conditions nave considerable effect the phenotypic expression of poly genes for the quantitative traits. For example, height in many plants (e.g., corn, tomato, pea, marigold) is genetically controlled quantitative trait, but some environmental factors as soil, fertility, texture, and water, the temperature, the duration and wavelength of incident light, the occurrence of parasites, etc., also affect the height. Similarly, identical twins with identical genotypes, if grow up in different kinds of environments, show different intelligence quotients

Multiple Factor Hypothesis

Laws of heredity by Mendel offer a simple and correct explanation of qualitative difference among plants and animals such as the flower colour, red or white and the seed colour, either yellow or green. But certain characters are quantitative instead of being qualitative such as weight, height, intelligence in man. Some other important characters in cultivated plants and domestic animals such as yield of seeds, fruits, eggs and amount of milk or meat produced, do not fall into clear cut classes and all gradations come between the two extremes between large and small, heavy and light etc.

Such quantitative characters show a continuous variation. Mendel's method of analysis is hard to apply in such continuously varying characters because they seem to mix or blend instead of segregating in the offspring of hybrids. The problem of the inheritance of quantitative character was taken up by the Swedish botanist. H. Nilsson-Ehle (1908) and American E.N. East (1910, 1916). These investigators showed that this apparent 'blending inheritance' can be explained by supposing that a continuously varying characters are due to the combined action of several genes, each of which has a small effect on the same character. Such genes are called the cumulative or additive or polygenes.

A cumulative gene is one which if added to another identical or similar gene affects the intensity or the degree of expression of a quantitative character. In other words, a character is governed by several genes (=polygenes) and their effects or actions are cumulative or additive in nature. This is the essence of the multiple factor hypothesis. As quantitative inheritance it is controlled by many genes. Therefore, it is also known as polygenic inheritance.

A few common examples of polygenic inheritance are described as below:

Seed colour in Wheat:

Nilsson-Ehle, crossed two varieties of wheat, red and white in colour and found that all the F_1 offspring were intermediate between red and white i.e., light red colour, showing that red is incompletely dominant over white. When the F_1 hybrids were self-fertilized the F_2 progenies or offspring's showed a ratio of 15 red to 1 white. The red progenies, however, varied in shade from pure red to pink. The ratio 15:1 clarify that this was di-hybrid cross in which two identical genes were involved for producing the red colour.

Parents · Red Wheat × White Wheat

$R_1R_1R_2R_2$ × $r_1r_1r_2r_2$

Gametes R_1R_2 ↓ r_1r_2

F_1 Medium $R_1r_1R_2r_2$

Gametes R_1R_2 R_1r_2 r_1R_2 r_1r_2

Male gametes

Female Gametes	R_1R_2	R_1r_2	r_1R_2	r_1r_2
R_1R_2	$R_1R_1R_2R_2$ Red	$R_1R_1R_2r_2$ Dark	$R_1r_1R_2R_2$ Dark	$R_1r_1R_2r_2$ Medium
R_1r_2	$R_1R_1R_2r_2$ Dark	$R_1R_1r_2r_2$ Medium	$R_1r_1R_2r_2$ Medium	$R_1r_1r_2r_2$ Light
r_1R_2	$R_1r_1R_2R_2$ Dark	$R_1r_1R_2r_2$ Medium	$r_1r_1R_2R_2$ Medium	$r_1r_1R_2r_2$ Light
r_1r_2	$R_1r_1R_2r_2$ Medium	$R_1r_1r_2r_2$ Light	$r_1r_1R_2r_2$ Light	$r_1r_1r_2r_2$ White

F_2

Summary of F_2 : 1/16 Red, 4/16 Dark, 6/16 Medium, 4/16 Light, 1/16 White.

(Member of several gene pairs which act in a cumulative way on a trait or character are known as multiple factor-Altenburg.) In some other examples, it is found that 63 out of 64 of the F_2 contains red colour and only 1 of 64 is white, suggesting that three genes are involved in this case, each producing red colour, the red parent will be represented then by the genotypes $R_1R_1R_2R_2R_3R_3$ and the white parents by $r_1r_1r_2r_2r_3r_3$. The completely white without any colour gene.

Skin colour in Man:

It was idea of Davenport (1913) that the multiple factor hypotheses explain the mode of inheritance of skin colour in man. His assumption was that the Negroes differ from the whites in having 2 pairs of colours forming genes that do not show complete dominance. He carried on his studies in Jamaica and Bermuda where intermarriages between coloured and white people were very common.

A marriage between a Negro ($P_1P_1P_2P_2$) and a white ($p_1p_1p_2p_2$) results in children having intermediate shade and have only 2 colours forming genes ($P_1p_1P_2p_2$). These are mulattoes. When 2 mulattoes marry, they may have children showing different degrees of colouration ranging from pure black to white.

In the F_2 1/16 will be as dark as the negro grandparent having 4 colour genes. The rest 14/16 will show intermediate shades depending upon the number of colour genes contained by them. But all these gradations could be seen only when a large number of children are born. In a small family the mulattoes parents will produce a completely black or white child.

F_1 hybrids will have only three colour genes $R_1r_1R_2r_2R_3r_3$ and will show light red shade. In F_2 1/64 will be completely like the red grandparent having six colour genes, 6/64 will have

5, 15/64 will have four, 20/64 will have three, 15/64 will have two, 6/64 will have one colour genes while 1/64 will be

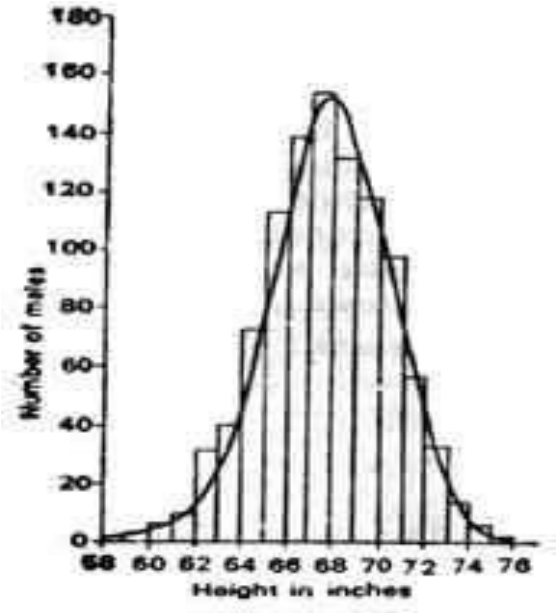
Parents	Negro	×	White
	$P_1P_1P_2P_2$	×	$p_1p_1p_2p_2$
Gametes	P_1P_2	↓	p_1p_2
F_1		Mulattoes	
		$P_1p_1P_2p_2$	

F_2	♂ gametes				
	P_1P_2	P_1p_2	p_1P_2	p_1p_2	
♀ gametes P_1P_2	$P_1P_1P_2P_2$	$P_1P_1P_2p_2$	$P_1p_1P_2P_2$	$P_1p_1P_2p_2$	Summary :
P_1p_2	$P_1P_1P_2p_2$	$P_1P_1p_2p_2$	$P_1p_1P_2p_2$	$P_1p_1p_2p_2$	15/16 Dark
p_1P_2	$P_1p_1P_2P_2$	$P_1p_1P_2p_2$	$p_1p_1P_2P_2$	$p_1p_1P_2p_2$	1/16 White
p_1p_2	$P_1p_1P_2p_2$	$P_1p_1p_2p_2$	$p_1p_1P_2p_2$	$p_1p_1p_2p_2$	

It has been proposed that the difference in the skin colour between Negros and whites is due to the presence of more than two pairs of colours forming genes bringing about a considerable variation in the skin colour. Gates has suggested for three whereas Stern's for four, five or six pairs of genes. Other geneticists have estimated the colour genes number from two to twenty pairs but the exact number involved is still unknown.

3. Height in Man

Skin colour in man is a rather simple example of polygenic inheritance because only two pairs of genes are involved. The inheritance of height in man is a more complex phenomenon involving perhaps ten or more pairs of genes. The character of tallness is



recessive to shortness, thus, an individual having the genotype of more dominant genes will have the phenotype of shortness. Because, this quantitative trait is controlled by multiple pairs of genes and is variously influenced by a variety of environmental conditions. The heights of adults range from 140 cm to 203 cm.

If one measured the height of a thousand adult men and the height of each is plotted against height in centimeters and the points connected, a bell-shaped curve is produced which is called curve of normal distribution and is characteristic of quantitative inheritance.

Quantitative inheritance is based on the following facts:

(i) Continuous variation.

(ii) A marked effect of the environment on their expression.

(iii) Governed by multiple or polygenes.

(iv) Each gene produces unit or individual effect. The effects of genes are additive or cumulative.

(v) Dominance is absent or partial. F_1 hybrids show blending in characters or in other words the F_1 hybrid is intermediate.

(vi) Segregation and independent assortment of genes in F_2 is according to Mendelian inheritance but the phenotype is in continuous range between the extreme limits of the parents. The phenotypic proportion of F_2 is modified according to the number and nature of genes.

(vii) Sometimes polygenic characters are governed by single gene too. i.e., single gene mutation may have the same effect as changes in many cumulative genes. For example, in sweet peas tallness is controlled by polygenes. Variations in the size of tall plants is partly environmental and partly polygenic but single mutation as well can result in to dwarf plants.

(viii) For statistical analysis of polygenic inheritance, we owe a great deal to Mather, Haldane & Fisher etc. Biological samples are infinite and therefore, statistical parameters are not well defined. Sampling is essential and this can lead us only near the truth but never to the truth or reality.

Transgressive segregation (= inheritance or variation):

The range of variation in F_2 progeny remains normally well within the limits of both the parents involved in a cross. But sometimes the extremes of F_2 exceed those of the

parents. This type of variation is called Transgressive variation. K. Mather firstly used the term polygene in 1941. Clearly speaking, transgressive segregants surpass the parental limits for a quantitative character and they are the result or effect of segregation. This is the reason for their name.

A classical example of transgressive variation was found in the experiments carried out by Punnett in chicken. He made a cross between a large Hamburg chicken with a small Seabright Bantam and found that the F_1 were of intermediate size. But the F_2 progeny, however, contained some birds which were larger and some which were smaller than the parental varieties. Such results are obtained if the parents do not represent the extreme genotypes.

For example, 4 pairs of genes are responsible for determining the size of the chicken and in Hamburg variety only 3 are recessive and 1 dominant. A cross between the genotypes AABBCCdd X aabbccDD will produce only one type of F_1 which will be heterozygous for all the 4 genes (AaBbCcDd) thereby determining intermediate size. In the F_2 generation the offspring with the genotype AABBCCDD will be larger or heavier than the original Hamburg parent. Likewise, those with the genotype (aabbccdd) will be smaller than the Sebright Bantam parent. However, these extreme types would be very few or limited in number. Thus, new and desirable types in plants and animals may be produced through proper crossings.

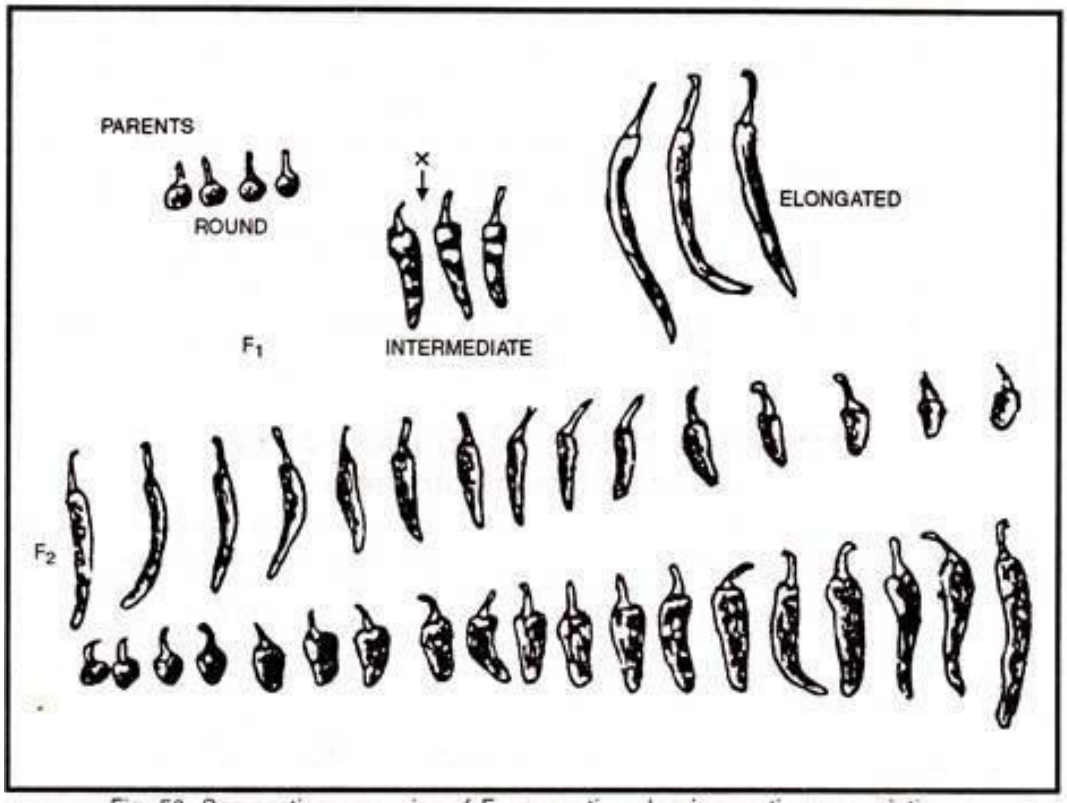


Fig. 56. Segregating progenies of F_2 generation showing continuous variation. A cross of *Capsicum annum* T-3 and T-29.

Difference between Qualitative and Quantitative characters:

Qualitative characters	**Quantitative characters:**
1.It deals with the inheritance of traits of kind, viz., form, structure, colour, etc.	1.It deals with the inheritance of traits of degree, viz., heights of length, weight, number, etc.
2.It shows discontinuous variation.	2. It shows continuous variation.
3.It may be put in to clear cut classes.	3.It may not be put up in to clear cut classes.
4.Governed by major genes.	4.Governed by minor genes.
5.Their effect is definite	5.Their effect is additive.
6.Not usually affected by environment.	6. Well affected by environment.
7.In it analysis is made by counts and ratios.	7.In it analysis is made by statistical method

Chapter No.7

PLANT INTRODUCTION

INTRODUCTION

According to Allard (1960) plant introduction is the acquisition of superior varieties by importing them from other areas. Or **plant introduction is the process of introducing plants/ genotype or group of genotypes into new environment where they were not being grown before.** Introduction may involve new varieties of a crop already grown in the area wild relatives of the crop species or totally new crop species for that area. Plant introduction may within the country between the countries or confirmed between the states or within the state.

Plant Introduction are generally classified on the basis of adaption and utilization.

Based on adaptation introduction are of two types

1) Primary introduction 2) secondary introduction.

Based on utilization again are of two types

a) direct introduction b) indirect introduction

1) Primary Introduction:

When the introduced variety is well suited to the new environment and is directly released for commercial cultivation without any change in the original genotype, known as primary introduction. Ex. Introduction of semi dwarf wheat varieties **Sonora, Lerma Rojo** and semi dwarf Rice Var. **TN-1, IR-8, IR-28, and IR-36.**

Introduction that are immediately adapted to the changed environment are known as direct introductions. The primary introduction can also be called as direct introduction.

2) Secondary Introduction:

Introduction that can be used as a variety after selection from the original genotype or used for transfer of some desirable gene to the cultivated variety is known as secondary introduction. Secondary introduction is much more common than primary introduction. **Ex. Kalyan Sona and sonalika varieties** selected from the material introduced from Mexico.

Those introductions that take some years for adaptation to the new environment are termed as indirect introduction. Thus, secondary introduction can also be called as indirect introduction.

PROCEDURE OF PLANT INTRODUCTION

Plant introduction is one of the very old and effective methods of plant breeding. It consists of following steps:

I) Procurement of Germplasm:

Any individual or scientist or institute can introduce germplasm, but the entire introduction must be routed through NBPGR, from the known source of the country or neighbouring countries. While introducing germplasm scientist has to allow two routes. In case of the first route individual make a direct request to individual or institution abroad and in the second route individual submit his requirement to the NBPGR, by giving much detail information about the requirement.

II)Quarantine:

Quarantine means to keep the materials in isolation to prevent the spread of disease, weeds etc. all the introduced material is thoroughly inspected for contamination with weed, disease and insect pests.

III) Cataloguing:

The introduced material is entered in assession register and is given on entry number. The information regarding the name of the species, crop variety, and place of origin, adoption and morphological character are reduced.

The plant materials are classified into three groups viz.

a) Exotic Collection **b)** Indigenous Collection **c)** Indigenous Wild Collection

IV) Evaluation:

The introduced material is evaluated to assess the potential of new introduction and their performance. The material resistance to disease and pest is evaluated under favourable environment conditions, and the promising one is either released as such as a variety or subjected to selection or hybridization.

V) Multiplication and Distribution:

After evaluation promising material from production may be increased by multiplication and released for general cultivation as varieties after necessary trials. Most of these are identified for desirable character and maintain for future use.

PURPOSE OF PLANT INTRODUCTION

The main purpose of plant introduction is to improve the plant wealth of the country. The chief objectives of plant introduction may be grouped as follows.

1. **To Obtain an Entirely New Crop Plant:** Plant introductions may provide an entirely new crop species. e.g., Maize, potato, tomato, Tobacco, etc., are introductions.

2. **To Serve as New Varieties:** Sometimes introductions are directly released as superior commercial varieties. The Mexican semi dwarf wheat varieties Sonora 64 and Lerma Rojo, semidrawf rice varieties TN 1, IR-8 and IR-36 are more recent examples of this type.

3. To Be Used in Crop Improvement: Pusa Ruby tomato was derived from a cross between Meeruty and Sioux, an introduction from U.S.A.

4. To Save the Crop from Diseases and Pests: Sometimes a crop is introduced into a new area to protect it from diseases and pests. Coffee was introduced in South America from Africa to prevent losses from leaf rust.

5. For Scientific Studies: N.I. Vavilov developed the concept of centres of origin and that of homologous series in variation from the study of a vast collection of plant types.

6. For Aesthetic Value: Ornamentals, shrubs and lawn grasses are introduced to satisfy the finer sensibilities of man. These plants are used for decoration and are of great value in social life.

7. Varieties Selected from Introductions. Two varieties of wheat, Kalyan Sona and Sonalika, were selected from introductions from CIMMYT, Mexico.

8. Varieties Developed through Hybridization: Semi dwarf rice varieties possess the dwarfing gene from Dee-geo-woo-gen through either TN1 or IR 8. 1) Pusa Ruby tomato obtained from a cross between Meeruti and Sioux 2) Pusa Early Dwarf Tomato derived from the cross Meeruti x Red Cloud;

ADVANTAGES OF PLANT INTRODUCTION

Merits of plant introduction method can be listed as follows

1. It provides entirely new crop plants.
2. It provides superior varieties either directly to the desired area
3. It is very quick & economical method of crop improvement
4. Plants may be introduced in new disease-free areas to protect them from damage, e.g., coffee and rubber.
5. collecting germplasm and to protect variability from genetic erosion.

DISADVANTAGES OF PLANT INTRODUCTION

Demerits of the method can be listed as follows

1. Introduction of diseases to the new area, not present earlier.
2. Introduction of insects, pests to the new area, not present earlier.
3. Introduction of noxious weeds to the new area not present earlier.

ACCLIMATIZATION

The process that leads to the adoption of a variety to a new environment is known as acclimatization. Generally, the introduced varieties perform poorly because they are often not adapted to the new environment. Sometimes the performances of that variety improve in the new environment by growing it for number of generations. Acclimatisation is brought about by a faster growing it for number of generations. Acclimatisation is brought about by a faster multiplication of those genotype that are better adopted to new environment. The population having more variability is easily acclimatised i.e. cross-pollinated crops are easily acclimatised than self-pollinated crop.

Chapter No.8

PURE LINE SELECTION

Johannsen Pure Line Theory (1903)

The concept of pure line was proposed by Danish botanist Johannsen in 1903 on the basis of his studies on Princess beans (Phaseolus vulgaris), which is highly self-pollinated species. He obtained commercial seed lot of princess variety of bean. The commercial seed lot showed variation for seed size. He selected large and small seeds and grew them separately. The progenies thus obtained differed in seed size. The progenies of larger seeds are generally larger than those obtained from smaller seeds. This clearly showed that the variation in seed size in the commercial seed lot of princess's variety of French bean had genetic basis, due to which selection for seed size was effective.

Johannsen further studied and established 19 pure line, each line was a progeny of a single seed from the original seed lot. Within each pure line has again selected large and small seeds. The progenies of the large and small seeds from a single pure line varied in weight of individual seed, but the average weight of progeny from larger seed was quite similar to the average weight of progeny from the small seed within the same pure line. Johannsen postulated that the original seed lot was a mixture of pure lines.

The variation for seed size in the original lot of Princess bean had a general basis, was heritable. Thus, each of the 19 lines had no genetic basis and is entirely due to environment and therefore non-heritable. He concludes that the population of self-fertilized species consists of several homozygous genotypes. Variation in such a population has genetic base and therefore, selection is effective. The progenies of single self-fertilized homozygous plants having identical genotypes are Pure Lines and the variation within pure lines is purely environment and thus selection within pure lines is ineffective.

Pure Line: It is the homogeneous progeny of single self-pollinated homozygous plant.

Pure Line Selection: development of new variety through identification and isolation of single best plant progeny is known as pure line selection or individual plant selection, it is also known as individual plant selection.

Characteristics of Pure Line:

1. All plant within a pure line has same genotype as the plants from which the pure lines are derived.
2. The phenotypic differences (variation) within a pure line is environmental and therefore non-heritable.
3. The pure line becomes genetically variable with time, due to mechanical mixture, mutation.

Uses of Pure Line:

1. Superior line is used as variety.
2. It is used as parent in development of new variety by hybridization.
3. Pure lines are used for studying mutations and other biological investigations such as medicine, immunology, physiology, and biochemistry.

Procedure of Pure Line Selection:

The pure line selection has three steps.

1. Selection of individual plants from a local variety or from mixed population.
2. Visual evaluation of individual plant progenies.
3. Yield Trials. 4. Release of the best pure line as a variety.

First Year:

Select phenotypically superior plants (200-1000) from old variety or land race or some other mixed population and their seeds are harvested separately. It is advisable to select plants for easily observable characteristics like flowering, maturity duration disease, resistance, presence of awns, plant height etc

Second Year:

Selected individual plants progenies are grown with proper spacing along with standard variety row. Progenies are evaluated visually and poor weak and defective segregating progenies are rejected on the basis of visual characteristics.

Third Year:

Grow the selected progenies in a replicated trail for critical evaluation. The best variety is used as a check for comparison and planted after every 20-25 progenies. If sufficient seeds are available, preliminary yield trial may be conducted.

Fourth to Seventh Year:

Replicated main yield trails are conducted using best variety as a check quality test is also conducted and used as a basis of selection. The promising strains are evaluated at several locations along with other strains in coordinated yield trials. The most promising strains are identified.

Eight Year:

The best progeny is released as a new variety and its seed is multiplied for distribution to farmers.

Merits of Pure Line Selection Method:

1. Pure line selection achieves maximum possible improvement over the original variety.
2. Variety developed by this method is uniform, more attractive, and more liked by farmers and consumers than those developed by other methods like mass selection.
3. It is easier than hybridization required less skill.
4. Used for developing inbred lines and pure lines.
5. Due to extreme uniformly, it is easily identified in seed certification.
6. This is easy and cheap method of crop improvement.

Demerits of Pure Line Selection Method:

1. It is not practised in cross pollinated crops because it is expensive, laborious.
2. The variety developed can't be easily maintained by the farmers.
3. The varieties developed by pure line selection don't have wide adaptability and stability in production.
4. The upper limit on the improvement is created by the genetic variation present in the original population.
5. It requires more time and laborious than mass selection.
6. The breeders has to devote more time to pure line selection than mass selection.

Applications of Pure Line Selection:

1. It is used for improvement of local varieties, have a considerable genetic variability, e.g. Wheat var.NP-4 and NP-52.
2. It is practised in introduced material to develop suitable varieties e.g. shining mung -1 selected from Kulu type-1, Kalyan sona from CIMMYT.
3. It is used for improvement of old pure line varieties, e.g. Chafa, from No.816 (gram)

4. It provides an opportunity for selection of new characteristics, such as disease resistance, grain, plant type, etc.

5. It provides an opportunity for selection in the segregating generation from crosses.

Achievements: A large number of improved varieties have been developed in self-pollinated crop like wheat, barley, rice, pulses, and oilseeds, cotton and many vegetables etc.

in wheat NP-4, 6,12, -28,

Mung Var, T-1, B-1,

tobacco Chatham special-9, etc.

Chapter No.9

MASS SELECTION

Mass selection is a simplest, common and oldest method of crop improvement, in which large number of plants of similar phenotype are selected and their seeds are harvested and mixed together to constitute the new variety. This method is practised in both self and cross – pollinated crops and plants are selected on the basis of their phenotype of appearance. Therefore, selection is done for easily observable characteristics such as plant height, ear/type, grain colour, grain size, etc.

The original population would have been a mixture of several pure lines and the plants selected from it would be homozygous. But the variety developed through mass selection would have a considerable genetic variation and consequently, further mass selection or pure line selection may be done in such a variety. Generally, the plants selected in mass selection are not subjected to progeny test. There are two methods of mass selection.

Main feature of mass selection

1. In self-pollinated crop, a mass selected variety is homozygous but heterogeneous, because it is mixture of several pure line.

2. Mass selected variety have wide adaptation and more stable against environmental changes due to heterogeneity which provide better buffering capacity.

3. There is heritable variation in the mass selected verities, besides environmental variation.

4. Selection is effective in case of mass selected verities of self-pollinated crops due to presence of heritable variation.

5. A variety developed by mass selection is less uniform in the quality of seed than pure line due to presence of heritable variation.

6. Mass selected varieties are less prone to the attack of new disease due to genetic diversity. They are more resistant or tolerant to new diseases.

7. Periodic removal of off type plants is essential to maintain the yield of mass selected varieties

Types of mass selection

There are two types of mass selection

1. Positive mass selection 2. negative mass selection.

1. possitive mass selection

When desirable plants are selected from a mixed population and their seeds are mixed together to grow further generation, it is referred to as positive mass selection. Land race are used as the base material for mass selection.

2. Negative mass selection

When undesirable off type of plants are removed from the field and rest are allowed to grow further, it is known as negative mass selection.

Application of Mass Selection:

In self-pollinated crops, mass selection has two major applications. i.e.

i) Improvement of local varieties

ii) Purification of existing pure line varieties.

I) Improvement of Local or Deshi Varieties:

The local varieties are mixtures of several genotypes, which may differ in flowering or maturity plant height, disease resistant etc. Many of these plants type would be inferior and low yielding, such plants will be eliminated through mass selection and local variety would be improved without adversely affecting its adaptability and stability. Because the new variety would be made up of the most of the superior plants type present in the original local variety.

II) Purification of Existing Pure Line Varieties:

Pure lines tend to become variable with time due to mechanical mixtures, natural hybridization, mutation etc. therefore, it is necessary that the purity of pure line varieties be maintained through regular mass selection. Mass selection is generally important and practised in cross-pollinated crop and has the only limited application in self-pollinated crop.

Procedure of Mass Selection:

First Year:

A large number (500-1000) of phenotypically similar plants are selected at the time of harvest on the basis of their vigour, plant type, disease resistance, maturity and other desirable characteristics. Few hundreds to several thousand plants are selected. The selected plants are harvested and seed mixed together to grow next generation.

Second Year:

The composite seed is planted in a preliminary yield trial along with standard variety as a check. Observe the phenotypic characters critically. The best performances are retained and others are discarded.

Third to Sixth Year:

The superior strains are evaluated for their performance in co-ordinated yield trails at several locations, for 3 to 4 years using standard check for comparison. Only promising one is identified for release as new variety.

Seventh and eighth Year:

Promising strain may be released for cultivation and multiplication in seventh year .in eight-year seed is ready for distribution to the farmer for general cultivation. If recommended by central variety release committee.

Advantages of Mass Selection:

1. The variety developed through mass selection is more widely adapted than pure lines.
2. It is easiest, simplest and quickest method of crop improvement.
3. Mass selection retains considerable genetic variability and hence variety can be improved after few years by another mass selection.
4. mass selected varieties are more stable in their performance than pure line.
5. mass selected varieties provide good protection against diseases.
6. The breeder can develop more time to another programme as it is less demanding method.
7. This method is applicable to both self and cross-pollinated species.

Disadvantages of Mass Selection:

1. The selection is based on the phenotypic performance
2. Progeny test is not carried out in mass selection.
3. In cross pollinated crops selected plants are pollinated by both superior and inferior pollen parents.
4. In cross pollinated crops, large numbers of plants have to be selected for bulking.
5. The verities developed by mass selection method is less uniform than pure lines.
6. The varieties developed by mass selection are more difficult to identify than pure lines in seed certification programme.

7. In the population it can’t generate new genetic variability.

8. It is not useful for improvement in quantitative characters, such as yield because phenotypic and environmental effects can’t be separated out.

9. Improvement is short lived required to be repeated every year in cross-pollinated crops.

Achievements

in India, mass selection has been useful in the development of improved verities in cross pollinated species like maize, bajra and mustard and in often cross-pollinated crops cotton and sorghum.

Chapter No.10

PEDIGREE METHOD

In pedigree method, individual plants are selected from F2 and the subsequent generation and their progenies are tested. During the entire operation, a record of the entire parent's offspring relationship is kept, is known as pedigree record. The selection of individual plant is continued till the progenies shows no segregation. At this stage, selection is done among the progenies, because there would be no genetic variation within progenies.

Procedure of Pedigree Method

Hybridization:

The selection of parents to be used in a cross is the most important step in a breeding programme based on hybridization. The selected parents are crossed to produce a simple or a complex cross.

F1 Generation:

F1 seeds are space planted so that each F1 plant produces the maximum F2 seed. Generally, 15-30 F1 plants should produce enough seed for a good F2 population size.

F2 Generation:

In F2, 2000-10000 plants are space planted to facilitate selection. About 100-500 plants are selected and their seeds are harvested separately.

F3 Generation:

Individual plant progenies are space planted; each progeny should have about 30 or more plants. Individual plants with desirable characteristics are selected from superior progeny. The number of plants selected in F3 should be preferably less than the number of F3 progenies. If the number of superior progenies is small the whole cross may be rejected.

F4 Generation:

Individual plant progenies are space planted; again, desirable plants are selected mainly from superior progenies. The no of plants selected in F4 is generally less than that of the F4 progenies.

F5 Generation:

Individual plant progenies are planted according to the recommended commercial seed rate. The number of progenies must be reduced to manage the size in preliminary yield trials which is usually 25- 100 progenies.

F6 Generation:

Individual plant progenies are planted in multi row plot and evaluated visually. Progenies are harvested in bulk. The progenies which are reasonably homozygous and have enough seed may be planted in a preliminary yield trial and inferior progenies are eliminated.

F7 Generation:

Preliminary yield trials with three or more replications are conducted to identify few superior lines. Standard commercial varieties must be included as check for comparison. Two to five outstanding lines if found superior to check would be advanced to the coordinated yield trials.

F8 – F10 Generation:

The superior lines are tested in replicated yield trials at several locations for desirable characters. During these trial lines are evaluated for yield, disease resistance, maturity, etc. a line that is superior to the best commercial variety for yield and other characteristics would be released as a new variety.

F11 Generation:

In F11 generation released var. is multiplies for distribution to the farmers. The breeder is responsible to supply the breeder seed to the N.S.C(National seed cooperation) for production of foundation seed.

Application of Pedigree Method:

1) Selection of desirable plants from the segregating population in self- pollinated crops.
2) commonly used to correct some specific weaknesses of an established variety.
3) It is also used in the selection of new superior recombinant types.
4) It is suitable for improving specific characteristics such as disease resistant, plant height, maturity etc.

Merits of Pedigree Method:

1) Maximum opportunity for breeder to use his skill and judgement for the selection of plants.
2) well suited for the improvement of characters, which can be easily identified and

simply inherited.

3) Unpromising material is rejected in earlier generation hence only superior plants are promoted.

4) Homozygous is rapidly achieved.

5) Transgressive segregation for yield and other quantitative characters may be recovered.

6) It takes less time than the bulk method to develop a new variety.

Demerits of Pedigree Method:

1) More time consuming, laborious and expensive for maintaining pedigree record.

2) Extra attention is required for selection among and within a large number of progenies.

3) The success of this method is largely depending upon the skill of the breeder.

4) Selection for yield in F2 and F3 is ineffective

Achievements of Pedigree Method:

1) Wheat: NP-52, NP120, NP125, etc.

2) Rice: Jaya, and Padma (TN-1 X T-141)

3) Cotton: Laxmi (Gadag-1 X CC2)

4) Tomato: Pusa early dwarf (Meeruti X Red cloud)

5) Chickpea: T1, T2, T3, T5, Radhey.

Chapter No.11

BULK POPULATION METHOD

Bulk population method of breeding in self –pollinated crop is also known as mass method or population method of breeding. It was first used by Nilsson Ehle in 1908. It refers to a species is grown in bulk plot (from F1 to F5) with or without selection, a part of the bulk seed is used to grow the next generation and individual plant selection is practised in F6 or later generation. In this method duration of bulking may vary from 6-7 to 30 generation.

Procedure of Bulk Population Method:

1) Hybridization:

Parents are selected according to the objective of the breeding programme and crossed.

2) F1 Generation:

The F1 generation (10 to 25 F1) is space planted and harvested in bulk.

3) F2-F6 – Generation:

F2 to F6 generations are planted at commercial seed rate and spacing. These generations are harvested in bulk. preferably 30 to 50 thousand plants should be grown in each generation.

4) F7 Generation:

30 – 50 thousand plants are space planted and out of this only 1000 to 5000 plants with superior phenotypes are selected and their seeds harvested separately.

5) F8 Generation:

Individual plant progenies are grown in single or multi row plots. homozygous progenies are harvested in bulk. 100- 300 individual plant progenies with desirable characters are selected.

6) F9 Generation:

Preliminary yield trial is conducted along with standard variety as check. The evaluation of progeny is done for important desirable characteristics.

7) F10- F12 Generation:

Replicated yield trails are conducted at several locations using standard commercial varieties as check. The lines are evaluated for important agronomic characteristics. If lines are superior to the standard check, released as new varieties.

8) F13 Generation:

Seed multiplication of the newly released variety for distribution to the farmers.

Merits of Bulk Population Method:

1) This method is simple, convenient and inexpensive.

2) Little work and attention are required in F2 and subsequent generation.

3) No pedigree record is to be kept.

4) It eliminates undesirable types and increases the frequency of desirable types.

5) It is suitable for studies on the survival of genes and genotypes in populations.

6) chances of isolation of Transgressive segregates than pedigree method.

Demerits Bulk Population Method:

1) It takes much longer to develop a new variety.

2) It provides little opportunity for the breeder to exercise his skill in selection.

3) A large number of progenies have to be selected at the end bulking period.

4) Information of inheritance of characters cannot be obtained like that of pedigree method.

Application of Bulk Population Method:

This method is suitable and most convenient for handling the segregating generation of cereals, smaller millet, grain legume and oilseeds. This may be used for three different purposes.

i) Isolation of homozygous lines.

ii) Waiting for the opportunity of selection.

iii) Opportunity for natural selection to change the composition of the population.

Achievement:

This method has between used in Barley crop for developing some varieties from the crosses (Allas X Vaughn), like Arrival, Beecher, Glacier, etc. In India only one variety “Narendra Rai” has been developed in Brown Mustard. This method has a limited application in practical plant breeding.

Chapter No.12

SINGLE SEED DESCENT METHOD

Single seed descent method is a modification of bulk method. Single seed from each F2 plants is bulked to raise the F3 generation. Similarly, F3, F4, F5 generation when the plants are homozygous plant progenies are advanced to next generation. Selection is done mainly among the progenies and number of progenies is sufficiently reduced to permit replicated trail. Individual plants may be selected from outstanding families showing segregation. So preliminary yield trial and quality tests begin in F7 to F8.

Objectives

1. Rapidly advance of generation of crosses.
2. F2 and subsequent generation are grown with a very high plant density.
3. F2 plant is represented equally in the end population.
4. Off season nursery/green house facilities are utilized.
5. Maximum possible speed.
6. Require very little space/effort/ labour.
7. Do not permit any form of selection during the segregating generation.
8. In each successive generation the population size become small due to poor generation and death of plants due to disease/pest.

Breeding Procedure:

In this method, only one seed is selected randomly from each plant in F2 and subsequent generations. The selected seed is bulked and is used to grow the new generation. This process is continuing up to F5 generation. By this time desired level of homozygosity is achieved. In F6, large number of single plants, 200-500 are selected and their progeny are grown separately. In F7 and F8, selections are practised between progeny and superior progeny and are isolated based on preliminary replicated trial. The superior progenies are then tested in multiplication trails and the best progeny is identified for release.

Merits:

1. Simple, convenient and inexpensive.
2. Due to elimination of undesirable types, isolation of desirable types is easier.
3. Natural selection increase the frequency of superior types in the population.
4. No pedigree record is to be kept which save time and labour.

5. Isolation of transgressive segregants is more.

Demerits:

1. Needs more time.
2. Little opportunity for a breeder to use selection.
3. Information on the inheritance of character cannot be obtained.
4. Natural selection act against agronomically desirable types.

Chapter No.13
BACK CROSS METHOD

A cross between F1 hybrid and one of its parents is known as a backcross. It is proposed by Harian and Pope in 1922, as a method breeding for small grains and is employed in improvement of both hybrids.

In this method two plants are selected and crossed and hybrid successively backcross to one of their parents. As a result, the grain hybrid backcross progeny becomes increasingly similar to that of the parents to which it identical with the parent used for backcrossing. In this method the desirable variety which are lacking in some characteristics known as a recurrent or recipient parent, while the undesirable variety on wild variety processing only one or two desirable characteristics known as donor parent or non-recurrent parent. The objectives of this method are to improve one or two specific defects of high yielding variety.

For the successful development of a new variety, following requirements must be fulfilled.

1) A suitable recurrent parent must be available which lack in one or two characters.
2) A suitable donor parent must be available which passes the characters be transfer in highly intense form.
3) The character to be transferred much have high heritability.
4) A sufficient number of backcrossed should be made so that the genotype of the recurrent parent is recovered in full.

Application of the Backcross Method:

This method is commonly used for the transfer of disease resistant from one variety to another. But is also suitable for the transfer of quantitative characters and is applied is both self and cross-pollinated crops.

1) Intervarietal transfer of simply inherit characters such as disease resistance, seed colour, plant height etc.

2) Intervarietal transfer or quantitative characters. Such as earliness, seed size, seed shape may be transferred from one variety to other belongings to same species.

3) Interspecific transfer of simply inherited characters i.e. disease resistance from related species to cultivated species

4) Transfer of cytoplasm from one variety or species to another and is desirable in case of cytoplasmic male sterility.

5) Transgressive segregation – Backcross method may be modified to produce Transgressive segregants.

6) Production of isogenic line.

Genetic Consequences of Back Crossing:

1) It results in rapid increase in homozygosity and frequency of homozygote.

2) The repeated backcrossing results in increase in frequency of desirable genotype thus the genotype of progeny become increasingly similar to recurrent parent.

3) The gene under transfer must be maintained by selection in the back-cross generation. Therefore, there would be opportunity in each backcross generation for crossing over to occur between the gene being transferred and tightly linked genes.

Procedure of Back Cross Method of Breeding in Self Pollinated Crops

The plan of back cross method depends upon whether the gene being transferred is recessive or dominant. The plan for transfer of a dominant gene is quite simple than for recessive gene.

Transfer of Dominant Gene:

Let us suppose that a high yielding and widely adopted variety ‘A’ is susceptible to stem rust (rr) and another variety ‘B’ is poor yielding but resistant to stem rust (RR) i.e. dominant to susceptibility. In this back-cross programme rust resistance trait is transfer from donor parent into a recurrent parent.

1) Hybridization:

Variety ‘A’ is crossed with variety ‘B’ in which variety ‘A’ is used as female parent which is recurrent and variety ‘B’ is used as donor parent.

2) F1 Generation:

During the second year F1 plants are backcrossed to variety ‘A’ since all the F1 plants will be heterozygous for rust resistance. Selection for rust resistance is not necessary.

3) First Back Cross Generation:

In the third-year half of the plant would be resistant and remaining half would be susceptible to stem rust, rust resistant plants are selected and backcross to variety ‘A’.

4) BC2 –BC6 Generation:

In each backcross generation, segregation would occur for rust resistance. Rust resistant plant are selected and backcrossed to the variety ‘A’ selection for plant type of variety ‘A’ may be practised particularly in BC2 and BC3 generation.

5) BC6 Generation:

On an average the plant will have 98.50 genes from variety A rust resistant plants are selected and selfed, their seeds are harvested separately.

6) BC6 F2 Generation:

Individual plant progenies are grown from the selected plants. Rust resistance once plant, which are similar to variety ‘A’ are selected and selected plants are harvested separately.

7) BC5 F3 Generation:

Individual plant progenies are grown homozygous progenies resistant to rust and similar to plant type of variety ‘A’ harvested in bulk. Several similar progenies are mixed to constitute the new variety.

8) Yield Test:

The new variety is tested in R.Y.T i.e. replicated yield trials along with the variety ‘A’ as a check. Plant type, dates of flowering, date of maturity, quality, etc are critically evaluated. The new variety would be identical to variety ‘A’ in performance. Therefore, detail yield test is not required, and the variety may be directly released for cultivation.

Transfer of Recessive Gene:

When rust resistant is due to a recessive gene, all the backcross cannot make one after other. After the first backcross and after every two backcrosses F2 must be grown to identity the rust resistant plants. The F1 and the back-cross progenies are not

inoculated with rust because they would be susceptible to rust. Only F2 is tested for rust resistant.

1) Hybridization: The recurrent parent is crossed with rust resistant donor parent. The recurrent parent is generally used as female. i.e. (rr X RR).

2) F1 Generation:

F1 plants are backcrossed to the recurrent parent.

3) BC1 Generation:

If rust resistance is recessive all the plant will be rust susceptible. Therefore, there is no test for rust resistance. All the plants are self- pollinated.

4) BC1 (F2) Generation:

Rust resistance plants are selected and backcrossed with recurrent parent. i.e variety 'A'. Selection is made for the plant type and other characteristics of the variety 'A'.

5) BC2 Generation:

No rust resistance test, plants are selected, which is identical to the recurrent parent (A) and backcrossed with the recurrent parent.

6) BC3 Generation:

No disease resistance test. The plants are self – pollinated to raise F2. selection is made for the plant type identical to variety 'A'.

7) BC3 F2 Generation:

Plants are inoculated with stem rust. Rust resistant plant, similar to 'A' are selected and backcrossed to variety 'A'.

8) BC4 Generation: No rust resistance test plants are backcrossed to variety 'A'.

9) BC5 Generation: No rust resistance test plants are self-pollinated to raise F2 generation.

10) BC5 (F2) Generation:

Plants are subjected to rust epidemic, resistance plant for rust and having similar characteristic of variety. 'A' is selected and self-seed are harvested separately.

11) BC5 (F3):

Individual plant progenies are grown and subjected to rust epiphytotic selection is done for rust resistance and for characteristics of variety 'A' seeds from several similar rust resistant homozygous progenies are mixed to constitute new variety.

12) Yield Test: Same as in case of transfer of dominant gene.

Merits of Backcross Methods:

1) The genotype of new variety is nearly identical with that of the recurrent parents.

2) It is not necessary to test the variety developed by this method, because the performance of recurrent parent is known.

3) It is not depending upon environment.

4) It is useful for developing disease resistance var generally interspecific gene transfer.

5) It is rapid, predicted and repeatable.

6) It is useful for removing some defects such as abnormality, disease resistant etc.

Demerits of Backcross:

1) New variety cannot be superior to the recurrent parent except for the character transfer from donor parents.

2) Undesirable genes may also transfer to the new variety.

3) Hybridization has to be done for each backcross so time required is more.

4) Does not permit combination of genes from more than two parents.

Achievement:

Backcross method has been widely used for the development of disease resistant varieties in both self and cross-pollinated crops.

Cotton: Gossypium herbaceum var. V-797, Digvijay, Vilalpa and Kalyan.

Wheat- Kharchia 65, NP-853, NI-5439 etc.

Chapter No.14

Somatic Hybridization

Sexual hybridization in higher plant is a valuable tool for the conventional plant breeding to improve cultivated crops. However, many desirable combinations of characters cannot be transmitted through conventional methods of genetic manipulation. Secondly, conventional hybridization is limited to only very closely related species and was total failure for distantly related species as well as in sexually incompatible species. However, by using a protoplast fusion technology, it possible to fuse two genotypically different by protoplast to obtain para sexual hybrid protoplast.

Definition of Somatic Hybridization:

It is fusion between isolated somatic protoplasts under in vitro conditions and subsequent development of their product to a hybrid plant is known as somatic hybridization.

Cybrid:

Plasmid and mitochondrial genomes are inherited maternally in sexual crossings. Through the fusion process the nucleus and cytoplasm of both parents are mixed in the hybrid cell. This results in various nucleo- cytoplasmic combination. Sometimes interaction in the plastome and genome contribute to the formation of cybrid. Cybrids in contrast to conventional hybrids, possesses a nucleus genome from only one parent but cytoplasmic gene

Cybridization:

The process of protoplast fusion resulting in the development of cybrid is called as Cybridization. In Cybridization heterozygosity of extra-chromosomal material can be obtained, which has direct application in plant breeding. Studies during last decade have revealed that the process of protoplast fusion may be a useful tool for the induction of genetic variability and combination of traits which do not exist in nature.

Isolation of Protoplast:

Methods of Protoplasts isolation can be classified into three main groups.

a) Mechanical:

Mechanical isolation is done by cutting plasmolysis tissue with a sharp-edged knife and releasing the protoplasts by deplasmolysis. The protoplasts isolated are few in

number. Generally, protoplasts were isolated from highly vacuolated cells of storage tissues (Onion, bulbs, scales, radish root, mesocarp of cucumber and beet root).

b) Sequential Enzymatic (two step):

Takebe et al. (1968) employed sequential or two step procedure for isolating mesophyll protoplasts using commercial preparation of enzymes. The sequential approach involves initial incubation of macerated plant tissues with pectinase which, in turn, are then converted into protoplasts by cellulose treatment.

c) Mixed Enzymatic Procedure:

Cocking (1968) mixed two enzymes together and isolated protoplasts in one –step. In this mixed enzymatic approach plant tissues are plasmolysis in the presence of a mixture of pectinases and cellulases, thus inducing concomitant separation of cells and degradation of their walls to release the protoplasts directly.

Source of Protoplasts:

i) Leaves:

The leaf is the most convenient and popular source of plant protoplast because it allows isolation of a large number of relatively uniform cells. Protoplasts isolation from leaves involve five basic stages: a) Sterilization of leaves, b) removal of epidermal cell layer c) Pre-enzyme treatment d) incubation in enzyme and e) isolation by filtration and centrifugation.

ii) Callus Culture:

Young actively growing callus is subcultured and used after two weeks for protoplasts isolation.

iii) Cell Suspension Culture:

A high –density cell suspension is centrifuged. After removing the supernant, cell is incubated in enzyme mixture (cellulose + pectinase) in a culture flask placed on a platform shaker for 6 hrs to overnight depending on to the concentration of enzymes. A lower concentration of enzymes helps to prevent the formation of aggregates in the cell suspension in order to obtain better yield.

iv) Preconditioned Plant Materials:

Mesophyll protoplast of some crop plants have a low morphogenetic response. This is because of the fact that the physiological state of growth of a donor plant under natural condition largely affect the regeneration potential of protoplasts in this system. on

the contrary, tissue cultured regenerated plants are maintained under uniform physiological conditions and therefore provides materials preconditioned for protoplasts isolation, and regeneration. This approach is particularly essential for regeneration of potato protoplasts.

Test for Viability of Protoplast:

Cell wall formation, cell division, callus formation, etc. depends upon the viability of protoplast. The most frequently used staining methods for assessing protoplast viability are fluorescens diactate (FDA), phenosafranine. FDA dissolved in 5.0 mg/ml acetone is added to the protoplast culture at 0.01% final concentration. The chlorophyll from broken protoplasts fluoresces red. Therefore, the percentage of viable protoplast in a preparation can be easily calculated. Phenosafranin, also used at final concentration of 0.01% is specific for dead protoplast. As soon as the strain is mixed with protoplast preparation, the inviable protoplasts strain red and viable protoplasts remain unstained.

Protoplast Regeneration:

Formation of Cell Wall:

The process of cell-wall formation may be completed in two to several days although protoplast in culture generally starts regenerating a cell wall within a few hours after isolation. The regeneration of cell wall can be detected by using Calcofluor White (CFW) florescence strain. The freshly formed cell wall is composed of loosely arranged microfibrils, the process requiring an exogeneous supply of a readily metabolised carbon source in the nutrient medium.

Development of Callus or Whole Plant:

Soon after the formation of wall around the protoplasts, the reconstituted cells show considerable increase in size and first division generally occurs within a week. Subsequent division give rise to cell colonies. After 2-3 weeks macroscopic colonies are formed which can be transferred to an osmotic free medium to develop a callus. The callus may be induced to undergo organogenic differentiation or whole plant regeneration following a appropriate procedure.

Applications of Somatic Hybridization:

Somatic hybridization has opened new possibilities for the in vitro genetic manipulation of plants to improve the crops.

1. Disease resistance:

Several interspecific and inter-generic hybrids with disease resistance have been created. For example, resistance has been introduced in tomato against diseases such as TMV, spotted wilt virus and insect pests.

2. Environmental tolerance:

The genes responsible for the tolerance of cold, frost and salt could be successfully introduced through somatic hybridization, e.g., introduction of cold tolerance gene in tomato.

3. Quality characters:

Somatic hybrids for the production of high nicotine content, and low erucic acid have been developed. A modification of hybridization in the form of cybridization has made it possible to transfer cytoplasmic male sterility.

4. Somatic hybridization has helped to study the cytoplasmic genes and their functions.

5. Protoplast fusion will help in the combination of mitochondria and chloroplasts to result in a unique nuclear-cytoplasmic genetic combination.

6. Somatic hybridization can be done in plants that are still in juvenile phase.

7. Protoplast transformation (with traits like nitrogen fixation by incorporating exogenous DNA) followed by somatic hybridization will yield innovative plants.

Limitations of Somatic Hybridization:

Although somatic hybridization is a novel approach in plant biotechnology, there are several problems and limitations.

The success of the technique largely depends on overcoming these limitations, some of which are listed below:

1. Somatic, hybridization does not always produce plants that give fertile and visible seeds.

2. Regenerated plants obtained from somatic hybridization are often variable due to soma clonal variations, chromosomal elimination, organelle segregation etc.

3. Protoplast culture is frequently associated with genetic instability.

4. Protoplast fusion between different species/genus is easy, but the production of viable somatic hybrids is not possible in all instances.

5. Some of the somatic hybrids, particularly when produced by the fusion of taxonomically different partners, are unbalanced and not viable.

6. There are limitations in the selection methods of hybrids, as many of them are not efficient.

7. There is no certainty as regards the expression of any specific character in somatic hybridization.

8. Somatic hybridization between two diploids results in the formation of an amphidiploid which is not favourable. For this reason, haploid protoplasts are recommended in somatic hybridization.

Chapter No.15

Transgenic Breeding

Transgenic

Genetically engineered organisms are called transgenics. In other words, a genotype developed by the process of genetic engineering is called transgenic (plural transgenics). It may be a plant, an animal or microbes such as fungi, viruses and bacteria.

- The term transgenic was first used in 1981 by Gordon and Ruddle.
- The first transgenic plant was developed in tobacco in USA by Fraley et al in 1983.
- Transgenic plants are developed by the techniques of genetic engineering. The sexual process is bypassed in developing transgenic plants.

Transgene

Transgene refers to foreign gene or modified gene of the same species which is used for development of transgenic organisms. Transgene may be from the same species (in modified form), related wild species, unrelated species and microbes such as fungi, bacteria and viruses.

- The main sources of transgenes are same species, related wild species, unrelated species, micro-organism and animals.
- The process of transfer, integration and expression of transgene in an organism is called genetic transformation.

The main features of transgenic plants are given below:

(i) Transgenic plants contain transgene.

(ii) They are developed by the process of genetic engineering.

(iii) The sexual process is bypassed in developing transgenic plants.

(iv) The frequency of transgenic plants is extremely low (0.001%).

(v) Transgenic plants are developed to solve specific problem which cannot be tackled by conventional methods.

Transgenic breeding

Genetic improvement of crop plants, domestic animals and useful micro-organisms, through genetic engineering, in relation to their economic use for mankind is referred to as transgenic breeding.

Transgenic plant breeding

Transgenic plant breeding refers to genetic improvement of crop plants in relation to various economic characters useful for human beings, through genetic engineering.

Advantages of transgenic crop breeding

(i) It is a rapid method of crop improvement.

(ii) It overcomes barriers of cross incompatibility.

(iii) It is useful in solving those problems which cannot be solved by conventional methods.

(iv) It permits gene transfer from any source including animals.

Method of Gene transfer

A. Indirect Gene transfer method

1.Transformation (Agrobacterium spp**)**

B. Direct Gene transfer method

i. Transfer via Electroporation

ii. Transfer via Polyethylene Glycol (PEG):

iii. Transfer via Biolistics:(Particle bombardment method)

iv. Transfer via Microinjection:

v. Liposome Mediated Gene Transfer:

1. Indirect Method:

Transfer via Agrobacterium:

The transformation of a plant can be carried out directly by using Agrobacterium spp. which is a common bacterium causing crown gall tumour in legumes. This bacterium carries a plasmid with T-DNA which is capable of being integrated into the host chromosome.

If a foreign gene is introduced in the plasmid of the bacteria and a plant tissue or cell suspension is grown in culture along with the bacteria, then ultimately the foreign gene can be transferred into the nucleus of the plant or more precisely, in the functional position of the host genome (Figs. 18.20 and 18.21). The two enzymes, restriction enzyme and ligase, play the most significant role in the process of trans-genesis.

iii. Basic Steps for Agrobacterium Mediated Transformation:

The steps involved are:

(a) Selection of plant tissue or explant

(b) Co-cultivation with Agrobacterium

(c) Inhibition of Agrobacterium growth

(d) Selection of transformed tissue

(e) Regeneration from selected tissue (transgenic plant)

(f) Confirmation of transgenic plant

(a) Selection of plant tissue or explant:

Suitable plant tissue, to be used as a source of explants (which has good regeneration ability), is removed from the donor plant and sterilized (if the plant is not grown in sterile condition). The explants may be decapitated seedlings, cells, protoplasts or leaf tissue, callus, etc.

(b) Co-cultivation with Agrobacterium:

The tissue or explant is cut into small pieces and placed into a culture of Agrobacterium (which contains the suitable vector containing foreign gene) for about 30 min., a process known as co- cultivation. During this period, the bacteria attach to the plant tissue, and the excess culture is blotted off and placed on medium for co-cultivation.

(c) Inhibition of Agrobacterium growth:

The incubation of the explants with Agrobacterium is allowed to continue for 2-3 days to permit the transfer of T-DNA to the plant cells. Then the explants are removed from the medium and washed in an antibiotic solution and further transferred onto antibiotic (bacteriostatic) containing medium to inhibit the growth of Agrobacterium.

(d) Selection of transformed plant cells:

The explants are then transferred onto the selective media containing proper selective agent to encourage the growth of transformed tissue.

(e) Regeneration from the transformed tissue:

The selected tissue part (putatively transformed), grown or selective media, are then transferred onto the regeneration media for shoot regeneration either by organogenesis or by embryogenesis in presence of proper selective agent. The shoot apices come out, those are then transferred in rooting media to get the whole plant.

(f) Confirmation of the putatively transformed plant:

The transgene expression is examined either through foreign protein expression or any phenotypic character expression. The presence of foreign DNA can be examined either through PGR or Dot Blot or Southern Blot experiment. The confirmed transgenic plants then are transferred to soil to get the next generation plant. The whole process has been depicted in Fig. 18.24.

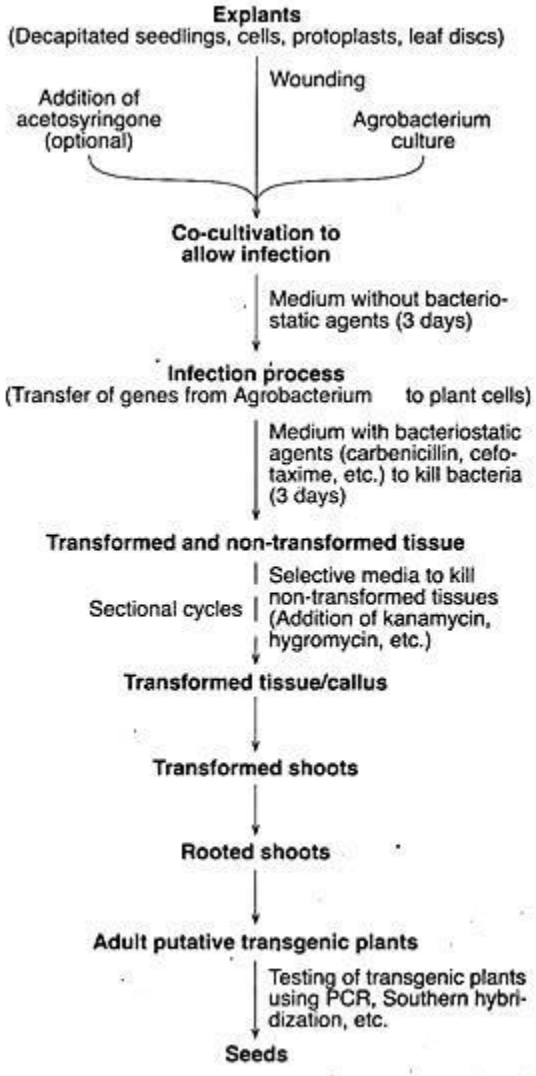


Fig. 18.24: A general scheme of Agrobacerium-mediated transformation of explant (from Chawla)

2. Direct Method:

i. Transfer via Electroporation:

Electric field membrane permeabilization is based on the fact that the electric pulses can open the cell membrane and allow penetration of alien DNA. Heat shock, in combination with electroporation has been used resulting in a higher efficiency of the transformation.

The method requires protoplasts, because electroporation is only efficient on cell membranes. These protoplasts, harbouring the alien DNA, have to be developed into callus and regenerated into a plant.

ii. Transfer via Polyethylene Glycol (PEG):

The chemical compound polyethylene glycol (PEG) changes the pore size of the cell membranes which enhances the probability of an alien DNA molecule penetrating into the cell. Heat shock may enhance the uptake of DNA. The method is mainly applied to protoplasts. The transfer of DNA via polyethylene glycol has been used for monocots as well as dicots.

iii. Transfer via Biolistics:

The principle of transfer via micro projectile bombardment is to shoot particles coated with DNA into selected tissues or cells by particle gun. The gun may be driven by either air-pressure or electric discharge. The particles may consist of either tungsten or gold carrying the DNA. Any growing plant tissue may be used for this method, but the plant material has to be regenerated via callus formation.

iv. Transfer via Microinjection:

The method involves transfer of a very small solution of DNA into a selected cell by injection with a capillary tube or a micropipette. The procedure has to be performed under a microscope. Often the specially designed micromanipulator is used for microinjecting the DNA.

v. Liposome Mediated Gene Transfer:

Liposomes are small lipid bags, in which a large number of plasmids can be enclosed. Those can be fused with the protoplasts using PEG.

TABLE 23.1 Comparison of Transgenic and Conventional Breeding methods

Particulars	Transgenic breeding	Conventional breeding (hybridization)
1. Sexual process	Bypassed	Involved
2. Methods involved	Tissue culture and genetic engineering	Hybridization between two genotypes
3. Transfer of genes from microbes and animals	Possible	Not possible
4. Frequency of desirable plants	Very low	Adequate
5. Technical skill required	Very high	Moderate
6. Expenditure involved	Very high	Low
7. Time required for release of new variety	3-4 years	10-15 years
8. Equipments required	Sophisticated	Simple or not required
9. Improvement of polygenic traits	Not possible	Possible
10. Facilities required	Well equipped lab	Mainly field facilities

TABLE 23.2. Comparison of three methods of foreign gene (DNA) transfer

Particulars	Plasmid method	Particle bombardment method	Micro-injection method
1. Basic requirement	Regenerable cells or protoplasts.	Regenerable tissues or organs or cells.	Regenerable cells or protoplasts.
2. Host specificity	Exhibits severe host specificity.	Does not exhibit host specificity.	Does not exhibit host specificity.
3. Effectiveness	More effective with dicots than monocots.	Equally effective with dicots and monocots.	Equally effective with dicots and monocots.
4. Recovery of transgenic plants	Low to moderate.	Low to moderate.	Extremely low.
5. Expenditure involved	Lesser than particle bombardment method.	Higher than plasmid and micro-injection methods.	Lesser than particle bombardment method.
6. Procedure	Difficult.	Simple.	Difficult.

Chapter No. 16

Meaning of Marker Assisted Selection (MAS)

Marker Assisted Selection [MAS] refers to indirect selection for a desired plant phenotype based on the banding pattern of linked molecular (DNA) markers. MAS is based on the concept that it is possible to infer the presence of a gene from the presence of a marker which is tightly linked to the gene of interest. If the marker and the gene are located far apart then the possibility of their transmission together to the progeny individuals will be reduced due to double crossover recombination events.

i. Other Terms Used:

Marker assisted selection (MAS) is also termed as marker aided selection and marker assisted breeding (MAB). It differs from gene assisted selection (GAS) which refers to the selection which is based on QTLs (quantitative trait locus or loci).

ii. Pre-Requisites:

There are two pre-requisites for marker assisted selection. These are: (i) a tight linkage between molecular marker and gene of interest, and (ii) high heritability of the gene of interest.

Features of Marker Assisted Selection (MAS)

i. Application:

MAS is applicable for genetic improvement of plants as well as animals. In plants, it is equally applicable in both self-pollinated and cross-pollinated species.

ii. Markers Used:

MAS makes use of various types of molecular markers. The most commonly used molecular markers include Amplified fragment length polymorphisms (AFLP), restriction fragment length polymorphisms (RFLP), random amplified polymorphic DNA (RAPD), simple sequence repeats (SSR) or micro satellites, single nucleotide polymorphisms (SNP), etc. The use of molecular markers differs from species to species also.

iii. Efficiency:

MAS is useful when the heritability of the trait is low. Moreover, MAS is more efficient than purely phenotypic selection in quite large populations.

iv. Accuracy:

Molecular markers have very high accuracy. They are not affected by environmental conditions. MAS is a new breeding tool which is available to make more

accurate and useful selections in breeding populations. MAS allows heritable traits to be linked to the DNA which is responsible for controlling that trait.

v. Speed of Progress:

MAS permits identification of recessive alleles even in heterozygous condition and thus speeds up the progress of crop improvement work. MAS is a rapid method of crop improvement. For example, in conventional breeding when we transfer a recessive character through backcross, one selfing is required after every backcross for identification of recessive character.

vi. Traits Improved:

MAS can be used for improvement of both oligogenic and polygenic traits. In the past, MAS has been mostly used for the genetic improvement of oligogenic traits and little progress has been made with polygenic traits.

vii. Material Developed:

MAS leads to development of non-transgenic genotypes or cultivars. In other words, MAS is used for development of non-transgenic cultivars. The transgenic cultivars face public resistance. On the other hand, cultivars developed by MAS are acceptable by consumers.

viii. Cost:

MAS is very costly as compared to phenotypic selection. In MAS, the costly items include equipment's, consumables, infrastructure, labour and DNA extraction process. MAS requires sophisticated and well-equipped laboratory.

3. Steps in Marker Assisted Selection (MAS):

In the marker aided selection, RFLP markers are widely used for genetic improvement of crop plants for various economic characters.

The marker aided selection consists of five important steps, viz:

(i) Selection of parents,

(ii) Development of breeding population,

(iii) Isolation of DNA from each plant,

(iv) Scoring RFLPs, and

(v) Correlation with morphological traits.

i. Selection of Parents:

Selection of suitable parents is an important step in marker aided selection. parents with contrasting characters or divergent origin should be chosen. This will help in identification of DNA of both the parents and also their segments in F_2 generation in various recombination's. For selection of parents, we have to screen germplasm and select parents with distinct DNA. The parents that are used for MAS should be pure (homozygous). In self- pollinated species, plants are usually homozygous. In cross-pollinated species, inbred lines are used as parents.

ii. Development of Breeding Populations:

This is the second important step for application of marker aided selection. The selected parents are crossed to obtain F_1 plants. F_1 plants between two pure-lines or inbred lines are homogeneous (alike phenotypically) but are heterozygous for all the RFLPs of two parents involved in the F_1. The F_2 progeny is required for the study of segregation pattern of RFLPs. Generally, 50-100 F_2 plants are sufficient for the study of segregation of RFLP markers.

iii. Isolation of DNA:

The third important step is isolation of DNA from breeding population. The main advantage of MAS is that DNA can be isolated even from the seedlings and we need not to wait for flowering or seed development stage. The DNA is isolated from each plant of F_2 population. Standard procedures are available for DNA isolation. The isolated DNA is digested with specific restriction enzyme to obtain fragments of DNA. The DNA fragments of different sizes are separated by subjecting the digested DNA to agarose gel electrophoresis. The gel is stained with ethidium bromide and the variation in DNA fragments can be viewed in the ultraviolet light.

iv. Scoring RFLPs:

The polymorphism in RFLPs between the parents and their involvement in the recombinants in F_2 population is determined by using DNA probes. The labelled probes are used to find out the fragments having similarity. The probe will hybridize only with those segments which are complementary in nature. Generally, ^{32}P is used for radioactive labelling of DNA probe. Now non-radioactive probe labelling techniques are also available. In this way RFLPs are determined.

v. Correlation with Morphological Traits:

The DNA marker (say RFLPs) are correlated with morphological markers and the indirect selection through molecular markers is confirmed. Once the correlation of molecular markers is established with morphological markers, MAS can be effectively used for genetic improvement of various economic traits.

4. Applications of Marker Assisted Selection (MAS):

Important applications of MAS in plant breeding are briefly presented below:

a) MAS is very effective, efficient and rapid method of transferring resistance to biotic and abiotic stresses in crop plants.
b) It is useful in gene pyramiding for disease and insect resistance.
c) It is being used for transfer of male sterility and photo period insensitivity into cultivated genotypes from different sources.
d) MAS is being used for improvement of quality characters in different crops such as for protein quality in maize, fatty acid (linolenic acid) content in soybean and storage quality in vegetables and fruit crops.
e) MAS can be successfully used for transferring desirable transgene (such as Bt gene) from one cultivar to another.
f) MAS is very effective in introgression of desirable genes from wild into cultivated genotypes.
g) MAS is equally effective in genetic improvement of plants and animals.
h) MAS is useful in genetic improvement of tree species where fruiting takes very long time (say 20 years) because for application of phenotypic selection we have to wait for such a long time.
i) MAS has wide application for genetic improvement of oligogenic traits as compared to polygenic traits.

5. Achievements of Marker Assisted Selection (MAS):

MAS has been used for genetic improvement of different field crops such as maize, barley, rice, wheat, sorghum, soybean, chickpea, pea, sunflower, tomato, potato and some fruit crops for various economic characters. MAS has been mainly used for developing disease resistant cultivars in different crops.

Some notable examples of the use of MAS are given below:

i. Rice:

In rice MAS has been successfully used for developing cultivars resistant to bacterial blight and blast. For bacterial blight resistance four genes (Xa_4, Xa_5, Xa_{13} and Xa_{21}) have been pyramided using STS (sequence tagged site) markers.

ii. Maize:

In maize, normal lines have been converted into quality protein maize (QPM) lines through MAS using opaque 2 recessive allele. The MAS used for conversion of normal maize lines into QPM is simple, rapid and accurate.

iii. Soybean:

In soybean cyst nematodes pose serious problem and most of the varieties are susceptible to this parasite. The resistant gene (rhg 1) is available. In soybean, nematode resistant lines have been developed through MAS using SSR marker (Sat 309).

iv. It has also been used for transfer of various characters such as male sterility, photoperiod insensitivity, earliness, and improvement of protein contents in some crop plants

v.In fruit crops MAS is being used for higher fruit production, better keeping quality for storage and disease resistance.

vi. In vegetable crops MAS is being used in tomato and potato based on RFLP, RAPD and AFLP markers mainly for disease resistance.

vii. MAS has been found useful for genetic improvement of tree crops such as coconut and rubber.

6. Advantages of Marker Assisted Selection (MAS):

MAS has several advantages over phenotypic selection and other breeding techniques.

Some important advantages of MAS are briefly discussed below:

i. Accuracy:

The accuracy of MAS, is very high because molecular markers are not affected by environmental conditions. It is very effective even with the characters having low heritability.

ii. Rapid Method:

MAS is a rapid method of crop improvement. It takes 3-5 years for developing a new cultivar against 10-15 years taken by the conventional method of breeding.

iii. Non-transgenic Product:

MAS leads to development of non-transgenic cultivars which are acceptable to everybody. In other words, it does not involve transgene. Hence there is no question of gene silencing.

iv. Identification of Recessive Alleles:

MAS permits identification of recessive alleles even in heterozygous condition and thus speeds up the progress of crop improvement programmes. In other words, it is equally effective for the genetic improvement of recessive characters.

v. Early Detection of Traits:

MAS permits early detection of traits that are expressed late in the life of plant. For example, characters such as grain or fruit quality, flower colour, male sterility, photoperiod sensitivity that express late in the life of a plant can be screened in the seedling stage.

vi. Screening of Difficult Traits:

MAS permits screening traits that are extremely difficult expressive and time consuming to score phenotypically. For example, screening for traits such as root morphology and resistance to biotic (insects and diseases) and abiotic stresses (drought, salinity, heat, frost etc.) is very easy through MAS.

vii. Gene Pyramiding:

MAS is very effective method in accumulating multiple genes for resistance to specific pathogens and pests within the same cultivar. This process is called gene pyramiding. Maker assisted backcrossing is routinely applied in breeding programmes for gene introgression. MAS can provide an effective and efficient breeding tool for detecting, tracking, retaining, combining and pyramiding genes for disease resistance.

viii. Small Sample for Testing:

MAS requires only a small amount of plant tissue for DNA testing. In other words, MAS can be carried out with small breeding populations. Moreover, MAS can be applied at any stage of plant growth.

ix. Permits QTL Mapping:

MAS permits mapping or tagging of quantitative trait loci (QTL) which is not possible by conventional method.

x. Highly Reproducible:

The MAS is based on DNA fingerprinting technique and the results of DNA fingerprinting pattern are highly reliable and reproducible.

Limitations of Marker Assisted Selection (MAS):

a) MAS is a costly method. It requires well equipped laboratory viz. expensive equipment's, glassware and chemicals.
b) MAS requires well trained manpower for handling of sophisticated equipment's, isolation of DNA molecule and study of DNA markers.
c) The detection of various linked DNA markers (AFLP, RFLP, RAPD, SSR, SNP etc.) is a difficult, laborious and time-consuming task.
d) MAS sometimes involves use of radioactive isotopes in labelling of DNA, which may lead to serious health hazards. This is a major disadvantage of RFLP based markers. The PCR, markers are safe in this regard.
e) It has been reported that MAS may become less efficient than phenotypic selection in the long term.
f) The use of MAS is more difficult for QTL because they have minor cumulative effects and are greatly influenced by environmental conditions and genetic background.

Chapter No.17

BREEDING FOR BIOTIC STRESS RESISTANCE DISEASE RESISTANCE

Stress: Constraining influence, force, pressure or adverse conditions for crop growth caused by biological or environmental factors.

Biotic (living): Adverse effects due to pests and diseases abiotic stresses

Abiotic (nonliving): Adverse effects on host due to environmental factors eg: Drought, water logging, heat, cold, salinity, alkalinity and air pollution etc.

Host: Plant effected by a disease or which can accommodate pathogen.

Pathogen: An organism that produces the disease

Disease: an abnormal condition in the plant caused by an organism (pathogen)

GENETIC RESISTANCE

Genetic resistance refers to those heritable features of a host plant that suppress or retard development of a pathogen or insect. In other words, genetic resistance is the ability of some genotypes to give higher yields of good quality than other varieties at the same initial level of pest infestation under similar environmental conditions, thus resistance is defined in relation to susceptible varieties.

MAIN FEATURES OF GENETIC RESISTANCES ARE GIVEN BELOW:

1. Genetic resistance is governed by nuclear genes or cytoplasmic genes or both in other words; genetic resistance is an inbuilt mechanism or inherent property.

2. Genetic resistance is measured in relation to susceptible varieties or genotypes.

3. Breeding of resistant cultivars takes into account the genetic variability of both pest and host plant.

4. The resistant variety may become susceptible after few years due to formation of new races of pathogen or new biotypes of an insect.

5. Breeding for disease and insect resistance differs from breeding for higher yield. There is triangular interaction is between genotype and environment only.

TYPES OF GENETIC RESISTANCE:

A).Vertical or Specific Resistance:

Specific resistance of a host to the particular race of a pathogen is known as vertical resistance. This type of resistance is governed by one or few genes and, therefore, is

referred as oligogenic resistance. When the resistance is controlled by single gene, it is called monogenic resistance. Since vertical resistance controls only one race of a pathogen, it is also termed as specific resistance. Because of its simple inheritance, it is known as major gene resistance. As the controlling genes have distinct effect, it is also known as major gene resistance. The host with vertical resistance controls only one race; therefore, it is also known as non-uniform resistance.

Main features of vertical resistance are given below:

1. Vertical resistance displays discontinuous variation among genotypes and classification of genotypes into resistances and susceptible classes is possible.

2. Transfer of oligogenic resistance from one host genotype to another is simple.

Oligogenic resistance is usually short lived or less durable. The resistance can easily break down when new race of a pathogen is formed.

3. Vertical resistance provides protection only from one race of a pathogen.

It has high heritability and can be easily identified in the breeding programmes.

4. Vertical resistance applies to host pathogen gene for gene relationships.

B). Horizontal or General Resistance:

The resistance of a host to all the races of a pathogen is called horizontal resistance.

This type of resistance is called by various names as per reasons given below:

1. General Resistance:

The host plant provides protection from all the prevailing races of a pathogen.

2. Polygenic Resistance:

The resistance is controlled by a number of genes, also called quantitative resistance.

3. Minor Gene Resistance:

Each gene involved in the resistance has small effect which is not visible.

4. Non-specific Resistance:

The host resistance is not for a specific race of a pathogen. The resistance is similar to all the races of a pathogen; hence also resistance is similar to all the races of a pathogen, hence also referred as uniform resistance.

Main features of horizontal resistance are given below:

a). Horizontal resistance exhibits continuous variation among genotype into different distinct classes is not possible.

b). It has low heritability and, therefore, identification of resistant types is difficult.

c). It provides protection from several races of a pest.

d). The resistance cannot be easily overcome by new races of a pathogen due to polygenic control.

e). It is difficult to transfer polygene resistance from one genotype to another, because individual allele in a parent cannot be identified.

f) General resistance is not applicable to gene for gene relationships.

g) It is difficult to transfer polygene resistance from one genotype to another, because individual allele in a parent cannot be identified.

h). General resistance is not applicable to gene for gene relationships.

MECHANISMS OF DISEASE RESISTANCE: There are different ways of disease resistance viz., disease escape, disease endurance or tolerance disease resistance and immunity

1. **Disease escape:**

The ability of susceptible host plants to avoid attack of disease due to environmental conditions factors, early varieties, change in the date of plating, change in the site of planting; balanced application of NPK etc. e.g. Early varieties s of groundnut and potato may escape 'Tikka' and 'Late blight' diseases respectively since they mature before the disease epidemic occurs. **Changing planting season in sugarcane from June to October has successfully escaped leaf-rust.**

2. **Disease endurance or tolerance**:

The ability of the plants to tolerate the attack of the pathogen without showing much damage. This endurance is brought about by the influence of external characters. To estimate tolerance the loss in yield and some other trait of several host varieties having the same amount of disease. e.g. Wheat varieties when fertilized with potash and phosphorus are more tolerant to the rust and mildew infection. The Rice crop fertilized with silicate is resistant to blast infection in Japan.

3. **Disease Resistance**:

The ability of plants to withstand, oppose or overcome the attack of pathogens. Resistance is a relative term and it generally refers to any retardation in the development of the attacking pathogen. Resistance is largely controlled by inherited characters i) may be controlled by single dominant gene e.g. **in wheat all rusts NP 809**

4. Immunity:

When the host does not show the symptoms of disease it is known as immune reaction. Immunity may result from prevention of the pathogen to reach the appropriate parts of the hoste exclusion of spores of ovary infecting fungi by closed flowering habit of wheat and barley. In immune reaction the rate of reproduction in zero i.e. r = 0

5.Hypersensitivity:

Immediately after the infection several host cells surrounding the point of infection are so sensitive that they will die. This leads to the death of the pathogen because the rust mycelium cannot grow through the dead cells.

6.Nutritional factors:

Reduction in growth and in spore production is generally supposed to be due to unfavorable physiological conditions within the host. Most likely a resistant host does not fulfill the nutritional requirements of the pathogen and thereby limits its growth and reproduction.

SOURCES OF DISEASE RESISTANCE

Resistance to diseases may be obtained from four different sources:

1.A known variety

2.Germplasm collection

3.Related species

4.Through mutations

1). A known variety:

Cultivated varieties are the best source of disease resistance e.g in cotton varieties MCU5VT tolerant to verticillium wilt was isolated from the commercial variety of MCU 5 of Gossypium hirsutum.

2). Germplasm collection:

When resistance to a new disease or a new pathotype of a disease is not known in a cultivated variety germplasm collection should be screened. Several instances disease resistance was found from the germplasm collections. e.g. resistance to neck blotch in barley, resistance to wilt in watermelon

3). Wild species

Related wild species are also potential sources of disease resistance. wild related species are only used as source of resistance when the desired resistance is not found

within the cultivated species. Often the resistance to a disease may be found in wild species and transferred through interspecific hybridization.eg. Resistance to stem, leaf & stripe rusts of wheat

4). Mutation:

Resistance to diseases may be obtained through mutation arising spontaneously or induced through mutagenic treatments. Resistance to Victoria blight in oats, was induced by irradiation with x-rays or thermal neutrons / also produced spontaneously**,** Resistance to stripe rust in wheat.

METHODS OF BREEDING FOR DISEASE RESISTANCE

1. Introduction
2. Selection
3. Hybridization
4. Budding & Grafting
5. Mutation Breeding
6. Biotechnological methods.

1. Introduction:

Resistant varieties may be introduced for cultivation in a new area. E.g.a) Early varieties of groundnut introduced from USA have been resistant to leaf spot (Tikka) b) Kalyanasona and Sonalika wheat varieties originated from segregating material introduced from CIMMYT, Mexico, were rust resistant.

2. Selection:

Selection of resistant plants from commercial varieties is easiest method.e.g. a) Kufri Red potato is selection from Darjeeling Red round. b) Pusa Sawani behind (yellow mosaic) selection from a collection obtained from Bihar

3. Hybridization:

Transferring disease resistance from one variety or species to the other. a. Pedigree method is quite suitable for horizontal r e s i s t a n c e . Artificial disease epiphytotic are produced to help in selection for disease resistance. E.g. a)In wheat Kalyana Sona, Sonalika, Malvika 12 b)Laxmi in Cotton (Gadag 1 x CO2) for leaf blight resistance

4. Budding & Grafting:

The disease resistance in vegetative propagated material is transferred by adopting either by budding or grafting. By grafting or budding the resistant material, the resistance can be transferred.

5. Mutation Breeding:

When adequate resistance is not available in the germplasm; Mutation breeding is resorted to induce resistance. This is also us ed to break the linkages between desirable resistant genes and other desirable genes.

Chapter No.18

BREEDING FOR BIOTIC STRESS RESISTANCE 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:

The ability of a plant to withstand, oppose or overcome the attack of an insect in known as insect resistance. It is the property of a variety or 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 host.

MECHANISMS OF INSECT RESISTANCE:

There are four mechanisms of insect resistance, viz 1) no preference, 2) antibiotics, 3) tolerance, and 4) avoidance or escape.

1. Non – preference:

Non-preference refers to various features of host plant that make the host undesirable for unattractive to insects for food, shelter, or reproduction. This type of insect resistance is also known as non-acceptance and antixenosis. Non-acceptance appears to be more accurate term, because in most known examples of this type of resistance, insects will not accept a resistant host plant even if there is no alternative source of food. Various plant character which are associated with non-preference include colour, light penetration, hairiness, leaf angle, odour and taste**. For example, in cotton red plant body, smooth leaves, thickness and hardness of boll rind and long pedicel are examples of non-preference to bollworms**, and hairiness of leaf and stem is non-preference for jassids.

2. Antibiosis:

Antibiosis refers to the adverse effect of host plant on the development and reproduction of insect pests which feed on resistant plant. Resistant plants retard the growth and rate of reproduction of insect pest. In some cases, antibiotics may lead even to death of an insect. An antibiotic is considered as the true form of resistance to insect pests. In cotton, antibiotics is related with high level of gossypol, resistance to cotton bollworm tannins and in rice high silica contents resistance to rice stem borer. antibiotics may involve morphological, physiological and biochemical features of the host plant.

3. Tolerance:

Tolerance refers to the ability of a variety to produce greater yield than susceptible variety at the same level of insect attack. In other words, a tolerant variety will give higher yield than susceptible one despite the insect attack. The tolerance is measured in terms of rejuvenation potential, healthy leaf growth, flowering compensation potential and superior plant vigour. Hybrid cottons, by virtue of their very high potential, show tolerance to insect pest. Tolerant cultivars have greater recovery of damaged parts than susceptible ones.

4. Avoidance:

Refers to escape of a variety from insect attack either due to earliness or its cultivation in the season where insect population is very low e.g. Early maturing cotton varieties escape pink boll worm infestation, which occurs late in the season.

SOURCE OF INSECT RESISTANCE IN PLANT BREEDING

There are five different source of insect resistance in crop plants, viz.

1) Cultivated varieties,
2) Germplasm collections,
3) Wild species,
4) Mutations, and
5) Microorganism.

This are briefly discussed below:

1. Cultivated Varieties:

In some crops, genes for insect resistance may be found in cultivated varieties. For example, cotton varieties SRT1, Khandwa2, DHY286, PKV081, and B 1007 are good source of Jassid resistance. The insect reactions of cultivated varieties are known in

almost all the crops. The desirable source of resistance can be selected from the cultivated varieties. Cultivated varieties are the best source of resistance because they have good agronomic characters, besides resistance.

2. Germplasm Collections:

Germplasm or genetic resources are good source of insect resistance. Resistant lines are identified by screening of germplasm for specific insect. In apple, 14 lines resistant to rosy aphid and 3 lines immune to green apple aphid were identified through screening of 2000 apple germplasm lines. Many such examples of insect resistance can be cited from other crops.

3. Wild Species:

In several crop resistant genes for insect are found in the wild species or wild relative of crop plants. Wild species are good source of insect resistance, for example, wild species Gossypium tomentosum, G. anomalum and G. armourianum are good source of Jassid resistance in cotton. In tobacco, resistance to root knot nematode is obtained from wild species.

4. Induced Mutation:

Sometimes, insect resistance is obtained through induced mutations. Insect resistance has been obtained in many crops by this method.

5. Micro Organisms:

Now microorganisms are being used as source of resistance to insect pests. In USA, Monsanto Company has transferred a gene from *Bascillus thuringiensis* (Bt) into the system of cotton plant through genetic engineering. The bt. Gene is believed to provide effective resistance against bollworms. When the bollworm larva punctures the boll, a toxin is secreted by the plant which leads to death of the larvae by a slow process.

Breeding Methods for Insect Resistance

1. **Introduction:** e.g. Phylloxera vertifoliae resistance grape root-stocks from U.S.A. into France.
2. **Selection**: e.g. Resistance to potato leaf hopper, Resistance to spotted alfalfa aphid
3. **Hybridization**: 1) Pedigree for oligogenic characters,
   2) Back cross for Polygenic characters
4. **Genetic engineering**: Bascillus thurengiensis (cry gene) resistance in maize, soybean, cotton etc

Chapter No.19

Plant Breeding for Drought Resistance

Introduction:

There are several environmental factors that have adverse effects on normal growth and development of crop plants. Such factors include deficiency or toxicity of minerals, moisture deficit and low temperature, soil salinity and alkalinity. Soil acidity and environmental pollutants. These factors are known as abiotic or no biotic factors. *The stress or adverse condition caused by such factors for growth and development of crop plants are referred to as abiotic stress or environmental stress.* Crop plants often suffer from abiotic stresses resulting significant reduction in both yield and quality. In some areas, the soil and weather conditions are so much unfavourable that cultivation of certain crops becomes very difficult and non-profitable. Under such situation, it is essential either to develop stress resistant cultivars or to modify the environment is the most practical way of solving such problems. This chapter deals with breeding for drought and salt tolerance.

Drought Resistance:

In India, problems of drought, salinity and alkalinity are of major concern among environmental stresses. **Drought refers to the condition of soil moisture deficiency or water scarcity.** Soil drought is more common in the arid and semi-arid tropics and in the areas of steep slope. Thus, desert areas are more prone to drought conditions. **The ability of crop plants to grow, develop and reproduce normally under moisture deficit conditions is referred to as drought resistance.** Improvement in the drought tolerance ability of a plant is known as drought hardening. Main features of drought are given below:

1. Drought is characterized with soil moisture deficit or low soil moisture.
2. Arid and semi-arid areas are more prone to drought than humid zones. About 36% of the land area constitute arid and semi-arid zones.
3. Drought leads to reduction in both yield and quality of economic product in crop plants. It has adverse effects on plant growth and development.
4. Drought damages chloroplasts and lowers output of the photosynthetic apparatus.
5. There is an increase in proline level in the leaves of plants which are subjected to drought, Proline level can be used as an indicator of water stress, but not as a measure of drought resistance.

6. The occurrence of drought depends on the amount and distribution pattern of rainfall. If the rainfall is adequate and well distributed over the crop season, there are less chance of drought. On the other hand, when rainfall is erratic there are more chances of drought. Soil type and topography also affect drought.

7. Drought resistance is a genetically controlled physiological property of plant species. Resistance to drought is associated with various morphological and physiological features of the plant.

8. Xerophytic plants are more resistant to drought than mesophytes.

9. There is an increase in abscisic acid content in leaves of barley, and in ethylene level in cotton and wheat under drought conditions.

Mechanisms of Drought Resistance:

There are four different mechanisms which help in survival of plants under moisture deficit conditions. There are:

1) Drought escape,

2) Drought avoidance,

3) Drought tolerance, and

4) Drought resistance. The last one refers to true drought resistance. These are briefly described below:

1. Drought Escape:

The simplest way of survival under drought conditions is to escape drought. Generally, drought occurs either in the mid or late-crop season. For Example, yields of early varieties of wheat, sorghum, maize, and rice are less affected by severe drought than late maturing ones. All these crops have determinate growth habit. In spring wheat, late maturing varieties give higher yield than early types especially when drought occurs early in the season and is over before anthesis.

2. Drought Avoidance:

Drought avoidance refers to ability of the plant to maintain a favourable internal water balance under moisture stress. In other words, plants which avoid drought retain high water contents in their tissues. Drought avoidance can permit a longer growth period in the crop through reduced water use or increased water uptake. However, drought avoidance leads to reduction in photosynthesis and thereby reduction in the growth of aerial parts. It leads to increase in root development and therefore, is more

important than drought tolerance. In cereals, drought avoidance operates during vegetative phase, while tolerance operates during reproductive phase. Drought avoidance mechanisms are of two types. First those which reduce water loss through transpiration. Such features include stomatal characteristics and shape, size and orientation of leaves. The second, those which maintain water uptake during drought period.

3. Drought Tolerance:

The ability of crop plants to withstand low tissue water content is referred to as drought tolerance. Drought tolerance is more desirable because the crop can produce more yield at lower water potential. In cereals, drought tolerance generally operates during reproductive phase. Tolerant cultivars exhibit better germination, seedling growth and photosynthesis. In Sorghum, a drought resistant line exhibited higher photosynthetic rate at leaf water potential than a less drought resistant line. Drought tolerance differs from drought avoidance in several aspects.

4. Drought Resistance:

Drought resistance is the sum of drought avoidance and drought tolerance. In other words, **drought resistance refers to the ability of crop plants to give good yield under moisture deficit conditions.** Drought resistance is measured in terms of various mechanisms associated with drought tolerance and yield under soil moisture deficit. In winter wheat, both avoidance and tolerance features are important for drought resistance.

Source of Drought Resistance in Plant Breeding

There are three main sources of drought resistance in crop plants:

1) Cultivated varieties,
2) Germplasm collections, and
3) Wild relatives and wild species.

Transfer of drought resistance is easy from cultivated variety and germplasm of cultivated species, because such material can be easily used in the breeding programmes. Moreover, there is no problem of cross incompatibility. When the source of drought resistance is a wild species, the transfer of resistance poses several problems such as cross incompatibility, hybrid inviability, hybrid sterility and linkage of several undesirable genes with desirable ones. Wild sources of drought resistance have been reported in wheat, sugarcane, tomato, and several other crops.

Wild Sources of Resistance to Drought and Salinity in Some Crop Plants:

Name of Crop	Name of Wild Species	Resistant Available for
Wheat	Aegliops kotsehyi	Drought
	Ae.variabills	Drought
Sugarcane	Saccharum spontaneum	Drought and Salinity
Tomato	Lycopersicon cheesmanii	Salinity

Basis of Drought Resistance

Drought resistance is associated with various morphological and physiological features or factors of crop plants. Morphological characters which are associated with drought resistance included earliness, shape, size and structure of stomata, size, number and orientation of leaves; presence of cuticle; Waxiness on leaf lamina and stem, rooting pattern, growth habit etc. Various physiological characters which are related to drought resistance are photosynthetic rate, transpiration rate, osmotic concentration etc. These factors are briefly discussed below:

Morphological Characters:

1. Earliness:

Earliness is a desirable character which leads to drought escape in many crops. For example, in wheat, sorghum, maize, and rice yield of early maturing varieties is less affected by severe drought than late maturing varieties.

2. Stomatal Features:

Sunken, small size and a smaller number of stomata are associated with drought resistance. Control of stomatal aperture is important in drought resistance. The rapid closing of stomata during development of drought helps in maintaining higher water potential in the tissues by reducing transpiration rate and thus resulting in drought avoidance. The stomatal aperture is measured with the help of porometers. Drought resistant genotypes have rapid closing habit of stomata. Leaves with closed stomata will exhibit higher temperature than those with open stomata. Leaves with open stomata have cooling effect due to water loss through transpiration.

3. Leaf Characters:

Cuticular thickness and Waxiness of leaf surface help in reducing transpiration. These characters are genetically controlled. Leaf rolling is an indicator of stress. It can also serve as drought avoidance mechanisms. In cotton, small and thick leaves are

associated with drought resistance. Leaf hairiness lowers the leaf temperature and thus reduces transpiration. The genotypes which reflect more light have more cooling effect resulting in reduction of transpiration.

4. Rooting Patterns:

Increase in depth, width and branching of root systems leads to decrease in plant water stress. Generally, deep rooted plants exhibit greater drought avoidance than shallow rooted ones. The new varieties combine deep root system, good grain quality and high yield. seedling root growth is an indication of root growth at maturity.

5. Growth Habit:

In upland cotton, indeterminate genotypes yielded more than determinate genotypes in a semiarid environment. Indeterminate plants produce flowers throughout the growing seasons whenever sufficient moisture is availability. This is not possible in case of determinate genotype.

6. Awns:

In wheat and barley, presence of awns appears to be associated with high yield under drought conditions. The increase in yield from awns results due to increase in seed size. Awns play important role in growth and development of seeds through increase in photosynthetic surface of spike.

Physiological Factors:

Resistant genotypes maintain high photosynthesis under moisture stress conditions by restricting transpiration water loss. Hence photosynthesis is a reliable parameter to select drought resistant genotype in segregating materials in breeding programmes. In spring wheat, dehydration hardiness is associated with small cell size, high concentration of cell sap, increased protoplasmic permeability and high viscosity of cytoplasm.

Plant Breeding Methods for Drought Resistance

Breeding methods for drought resistance are the same as for yield and other economic characters. Breeding for drought resistance refers to breeding for yield under soil moisture stress condition. In other words, it refers to yield improvement in environment represented b water deficit. Four breeding methods, viz.

1) Introduction,

2) Selection,

3) Hybridization,

4) Mutations are commonly used for development of drought resistant crop cultivars.

In self-pollinated crops, introduction, pure line selection, mass selection, hybridization (Pedigree method and backcrossing) and mutation breeding are used. When drought resistance is available in an exotic variety, such variety can be introduced and after through testing, if found suitable, can be released in the new area. When the drought resistant genotypes are available in the land races or mixed populations, either pure line selection or mass selection is adopted. When the resistant genes are available in the germplasm or wild species, the breeder has to resort to hybridization.

Mutation is used when the desired genes are not available in the germplasm. Sufficiently large segregating populations have to be grown to select for drought resistance. In maize, drought tolerance is controlled by no less than genes pairs. Simple screening was effective in selection of drought resistant characters in one genotype, screening of material under drought conditions, use of large population in yield test and testing at several locations will help in selection of superior lines.

In cross pollinated crops, the most commonly used methods are mass selection, backcross, hybridization of inbreds to develop hybrid cultivars, recurrent selection and formation of synthetic cultivars. Mass selection is partially effective because there is no control of pollination. The backcross method is equally successful in self- and cross-pollinated species. Heterosis is used in both species. However, hybrid vigour is more successful in cross pollinated species than in self-pollinated ones.

Chapter No.20

Plant Breeding for Salt Resistance

Salt tolerance refers to the ability of plants to prevent reduce or overcome the injurious effect of soluble salts present in their root zone. The problem of salinity is of global significance because saline and alkaline soils are found in almost all countries of the world. In India, more than seven million hectares land is estimated to be salt affected. Higher concentration of salt in the soil adversely affect the growth and development of plants by disturbing various physiological processes.

There are two ways to overcome the problem of salinity.

1). One is reclaiming the salt affected soil and the other

is2). To develop salt tolerant genotypes/ cultivars.

The first method is very costly, time consuming and short method, on the other hand, is long lasting, more effective and less costly. Genetic differences exist among cultivars for their salt tolerance capacity, moreover, plants adapt themselves to adverse environments for their survival. High salt tolerant plants in crop are found in the salt affected areas.

Breeding Approaches:

In India, breeding work for salt resistance is carried out at Central Soil Salinity Research Institute (CSSRI), kernel and its various regional centres. In India, two types of approaches are followed for salt tolerance breeding.

The two approaches are:

1) Improving yield level of salt tolerant cultivars, and 2) Transfer of salt tolerant genes to high yielding cultivars. In the first traditional cultivars of salt affected areas are improved for their productivity without affecting their salt tolerance ability. In the second approach, salt tolerances gene from locally adapted (Salt tolerant) cultivars are transferred to high yielding cultivars through hybridization and selections.

Screening Techniques:

Various methods are used for screening segregating material for salt resistance. The commonly used methods are:

1) Lysimeter micro plots,

2) Sand culture, and

3) Solution culture tanks.

The Lysimeter micro plots of 6 m X 3 m X 1 I size are used at CSSRI, Karnal. Several levels of salinity are used and replicated experiments are conducted to screen for salt resistance. Some workers prefer to use sand culture technique using nutrient solution. Solutions of various salinity levels are applied in the sand. Another technique is use of solution culture tanks with several levels of salinity. Replicated experiments are conducted over seasons to get more reliable result. Genotypes which survive under salinity conditions are considered as tolerant and screened further.

The salt tolerance capacity differs from species to species. For example, crops like barley, cotton, sugarcane, oilseeds and grasses are known to be more salt tolerant than other crops. The salt tolerance capacity also differs within a crop based on ploidy level. For instance, in wheat, hexaploid bread wheat is more tolerant to salt than durum (tetraploid) and einkorn (diploid) wheat. In Brassica, tetraploid species are more tolerant than diploids. In rice, late maturing, tall and coarse grain varieties exhibit maximum tolerance to salinity conditions. In crested wheat grass, selection for tolerance under artificial salinity conditions improved the salt tolerance level of selected lines. In sugarcane, vast differences for salt tolerance are observed among strains. In Hawaii, salt shock treatment is used for improving salinity tolerance. In sugarcane, moreover, land races are more tolerant to salinity than high yielding cultivars.

Breeders require close cooperation of geneticist, physiologist, biochemist, and soil scientist in developing salinity resistant varieties. The new approaches such as tissue culture and genetic engineering may be rewarding in developing more salt tolerant genotypes.

The main limitations in the breeding for salt tolerance are:

1) Lack of efficient selection criteria,
2) Lack of inter disciplinary cooperation, and
3) paucity of funds, etc.

Chapter No.21

BREEDING FOR QUALITY

Quality

“The suitability or fitness of an economic plant product in relation to its end use.” “Breeding for special traits deals with genetic improvement in some special aspect e.g. protein, oil, vitamins, amino acids and removal of anti-nutritional substances.”

Quality trait of selected crops

Wheat

white or amber grain colour, medium to bold size, hard vitreous texture, & lustrous appearance are important features for good market quality. High lysine content & good baking quality are essential for use in biscuit & bread manufacturing.

Rice

White coloured fine & long slender grains, taste & fragrance, less breakage in milling, more hulling recovery, better cooking quality, high protein & lysine contents.

Maize

Bold flint grains with attractive colour, high lysine, oil & sugar contents. The seed colour should be yellow or white.

Sorghum

Bold, thin pericarp, white grains of attractive shape & size, high protein & lysine content

Pearl millet

Bold lustrous & pearly amber colour grains with high iron contents

Barley

In malting barley, low protein content & high extract of soluble oligosaccharides after malting are desirable characters. Low protein produces less haze in beer & high oligosaccharides are suitable for fermentation.

Pulses

Attractive shape, size & colour of grains, high protein contents; high methionine & tryptophan; & less flatulence

Oil seeds

Attractive shape, size & colour of seeds, high oil content free from antinutritional

factors & more proportion of unsaturated fatty acids

Cotton

Fibre length, strength, fineness, maturity, uniformity & colour

Tobacco

- Short & thin leaves with less branched veins are preferred for cigar.
- Thin leaves are also preferred for pipe smoking.
- Thick leaves are suitable for cigarettes.
- High nicotin content for bidi, hookah & chewing & low for cigarettes are preferred.
- High sugar content is also preferred.

Sugarcane

Moderate hardness, long internode, optimum (low) fibre for milling; sucrose ratio, high sucrose content & good quality of juice.

Potato

Attractive shape, size & colour of tubers, taste, cooking quality, thin skin, keeping quality & high starch content.

Vegetables

High vitamin & mineral contents, good taste, keeping quality & cooking quality.

Forage crops

Greater nutritive value, more palatability & freedom from toxic substances.

Medicinal plants

High content of active substance.

Four major goals for breeding for improved nutritional quality.

These are breeding for

1). High Content & Quality of Protein,

2). High Content & Quality of Oil,

3). High Vitamin Contents, &

4). Low Toxic Substances Which Are Harmful for Human Health.

NUTRITION & NUTRIENTS

- The scientific study of food in relation to health is referred to as nutrition.
- Various chemical components of food which provide nourishment to the body are called nutrients.
- These are carbohydrates, fats, proteins, vitamins, minerals & water.

- Good nutrition refers to adequate intake of well-balanced diet, which supplies all essential nutrients required by the body.
- Malnutrition may result from deficiency, excess or imbalance of nutrients.
- Hence all the nutrients should be taken in adequate quality.

Protein content & Quality

Proteins are an essential component of the diet. Protein are organic macromolecules consisting of a long chain of amino acids linked with each other by peptide bonds formed by carboxyl(-COOH) group of one amino acid with amino group(-NH2) of other amino acid. The nutritional properties of proteins are determined by their amino acid composition. There are 21 amino acids which are important in human nutrition. These can be classified into two groups, viz. (1) essential amino acids & (2) non-essential amino acids.

EAA can't be synthesized in human body & their requirement has to be met through dietary intake. There are ten EAA (methionine, isoleucine, leucine, lysine, threonine, tryptophan, valine, phenylalanine, histidine, & arginine). Out of these arginine & histidine are considered non-essential for the adult. The non EAA can be synthesized in human body & they need not be supplied through diet. These are cystine, cysteine, proline, glycine, serine, alanine, aspartic acid, hydoxyproline, glutamic acid, norleucine & tyrosine. The quality of protein is determined by the content of essential amino acids. The sulphure containing amino acids (Tryptophan, Threonine, Isoleucine, Lysine, Valine & Methionine) are referred to as limiting amino acids.

EAA deficient in some vegetarian foods:

Food	Limiting amino acids
Cereals	lysine, threonine, sometimes tryptophan
Pulses	Methionine, tryptophan
Nuts & oilseeds	Lysine
Green leafy vegetable Leaves & grasses	Methionine

Vitamins

A vital substance which is required in very small quantity & is essential for proper growth & good health is called **vitamin.** Vitamins are essential for body growth,

maintenance & reproduction. Based on their solubility, vitamins are of two types. *Viz*. **(1) fat soluble (A, D, E & K) & (2) water soluble: (B group vitamins & vitamin C).** Vitamin D & folic acid can be partly synthesized in the body. Rest of the vitamins has to be supplied through diet. Vitamin D is found in fats other vitamins are found in fleshy fruits & green vegetables.

NUTRITIONAL QUALITY OF CEREALS & PULSES

Cereals are important sources of carbohydrates. The contribution of cereals is 70% to the total calories in human diet. They contribute 50% to the global protein requirement, while grain legumes contribute only 20 %. Remaining 30% comes from animal products. The average protein content in the cereal's ranges from 10 to 13%. However, the cereal protein is deficient in lysine, tryptophan & threonine.

Cereal Protein Quality

In cereals, four types of protein, viz.

1. Albumins (water soluble)
2. Globulins (soluble in saline solutions)
3. Prolamins (soluble in strong alcohol)
4. Glutamine (soluble in dilute alkaline solutions)

Cereals contains about 70% Prolamins + Glutamine and 30% Albumins +Globulins.

Major protein fraction of cereal proteins

Protein fraction	**Soluble in**	**Amino acid profile**	**Remarks**
Albumins	Water	Balanced - Balanced	
Globulins	Saline	Balanced - Balanced	
Prolamines	Strong Alcohol	Deficient in Lys, Tsp; rich in Pro, Gln	Major fraction in wheat, barley maize & sorghum
Glutelins	Dilute alkali		

In all cereals, Prolamines are relatively rich in proline & glutamine but low in basic amino acids including lysine. Therefore, they have poor nutritional value. Generally, prolamin content in cereals is negatively associated with total protein content. Cereals contain about 70% prolamine & glutelin and 30% albumin & globulin. Several mutants with improved protein quality have been identified in cereals like maize, jowar & barley.

Legume Protein Improvement

Legumes contain protein from 18 to 28% which is almost double of cereals (exception, soybean:43%).in pulses, two types of proteins, viz. albumin & globulin are found. The major storage protein in grain legumes is globulin which constitutes about 80% of the total seed protein. In chickpea, globulin is of three types, viz. alpha, beta & gamma. The alpha globulin accounts for more than 80% of the total protein. In faba & pea, globulin is of two types, viz. legumin & vicilin. Legumin is less soluble in salt solution than vicilin. Moreover, legumin does not coagulate at high temperature (950C) while vicilin coagulates.

Proteins legumes are deficient in methionine & tryptophan. Moreover, they contain several toxic substances such as protease inhibitors, haemagglutinins, lathyrogens, glucocides, goitrogens, cyanogens, metal binding factors & antivitamin factors. However, many of these toxic compounds are destroyed during cooking. Some of these toxins have to be eliminated through breeding. The mixture of cereals & pulses in 3: 1 ratio provides nutritionally balanced diet.

In Pulse, two types of protein, viz.

1. Albumins (water soluble)
2. Globulins (soluble in saline solutions)

- Pulses contains about 20% Albumins and 80% Globulins.
- High methionine and tryptophan.

GENETICS OF NUTRITIONAL TRAITS

The quality traits may be governed by

(1) Oligogenic Inheritance,

(2) Polygenic Inheritance, &

(3) Maternal Effects

Oligogenic inheritance

Inheritance is governed by one or few major genes. Each gene has large & easily detectable effect on the expression of nutritional quality character. The differences between characters of high & low value is clear cut. In *Sorghum*, high lysine content is controlled by single gene with incomplete dominanace.

In barley, high lysine content is governed by one major gene plus several minor genes. In safflower, fatty acid composition is governed by one major gene with three major

alleles. In tomato, high beta carotene content is conditioned by two major genes plus modifires.

Polygenic inheritance

Inheritance is governed by several genes each with small additive effect In such inheritance, the variation for a character is continuous from one extreme to another. Classification of plants into clear cut classes is not possible.

The protein content in cereals & pulses & seed oil content in oilseed crops are governed by polygenes. Characters which are governed by polygenes are sensitive to environmental changes & generally have low heritability. In carrot, high carotenoid content exhibits complex inheritance pattern.

Maternal Effects:

Important/present in case of some quality traits. Usually, such traits are concerned with grain characteristics, e.g., seed size (quite common), protein content, etc. For ex., reported for protein content in chickpea, fatty acid composition in maize, soybean & rapeseed is influenced by genotype of maternal parent.

Maternal effects have same effect on genetic advance under selection as other environmental factors, i.e., they confuse correspondence between genotype & phenotype &, thereby, reduce the progress under selection. Therefore, selection schemes must make allowances for maternal effects if & where present.

Table 4: Genetics of nutritional quality characters in some crop plants

Crop species	Quality character	Inheritance controlled by
Sorghum	High lysine	Single partially dominant gene
Barley	High lysine	One major gene & several minor genes
Oats	Protein content	Complex, low content is dominant over high
Maize, Sunflower,	Seed oil content	Additive genes
Sesame	Seed oil content	Additive genes with partial dominance for
Rape seed	Erucic acid & eicosanoid	Two genes with multiple alleles
Turnip rape	Erucic acid & eicosanoid	Single genes with multiple alleles
Safflower	Fatty acid composition	Three major alleles at one locus Tomato
Safflower	Fatty acid composition	Three major alleles at one

		locus Tomato
Carrot	Carotenoid content	The inheritance is complex

BREEDING METHODS

Breeding methods used for improvement of quality do not differ from breeding methods used for any other character.

Breeding methods that are extensively used for improvement of quality traits include **backcross, pedigree method, single seed descent, recurrent selection, progeny selection & mutation breeding.**

- In common bean (*Phaseolus vulgaris*), pedigree, single seed descent & recurrent selection methods have been used for improvement of protein content. Two cycles of recurrent selection increased seed protein from 21.9% to 24.6%.
- In soybean, five cycles of recurrent selection increased seed protein from 42.8 to 46.1 per cent.
- In *Sorghum*, pedigree breeding procedure was used for developing high lysine lines. In barley, backcross method was used for development of high lysine lines. In barley, high lysine line had small seed size & low grain yield
- In sunflower, seed oil content was increased from 30% to almost 50% by Russian breeders in 50 years using modified recurrent selection. In safflower, oil content was increased from 37% to 50% through reduction in hull content.
- In maize, seed oil content increased from 4.7 to 17% & protein from 10.9 to 23.5 after 70 cycles of recurrent selection in USA. But there was a drastic reduction in grain yield.
- Mutation breeding has been used for development of high lysine lines in *Sorghum*, barley & maize. I-ethyl-sulphonate (DES) has been used in *Sorghum* & EMS & EI in barley forinduction of high lysine mutants.

SCREENING TECHNIQUES

- Breeding for enhanced nutritional quality involves lot of chemical analysis.
- The breeding material has to be screened for protein content, amino acid composition, seed oil content, fatty acid composition, vitamin contents & antinutritional factors.
- This requires close cooperation of biochemist.
- The selection of plants with better nutritional quality is done based on chemical

analysis should be simple, cheap & rapid.

- Now rapid chemical analysis methods are available for protein estimation, seed oil estimation, fatty acids & amino acid analysis.

Seed Oil Analysis

- The seed oil analysis is done with the help of Nuclear Magnetic Resonance (NMR) or Nuclear Infrared Analyser (NIR).
- This is the non-destructive method of oil analysis. After oil analysis the seeds can be used for sowing purpose.
- Several single plants in segregating populations can be analyzed.
- This method is quite simple, highly accurate & very fast. By this method, 300- 400 samples can be easily analyzed per day.

Protein Analysis

- Now analysis of grain protein is done with the help of **protein analyser.**
- The analysis is based on the principle of infra-red reflectance measurement.
- The seed is grouped into flour which is used for the analysis.
- This method is very fast. By this method 200-300 samples can be easily analyses per day.
- Individual amino acids can be estimated by colorimetric method or microbiological method.
- Analysis of antinutritional factors is carried out by chemical method.
- The old methods of protein estimation (Kjeldahl method) & oil analysis (Soxhlet method) were very much time consuming though more accurate.
- Now fast methods have been developed.

BREEDING FOR LOW TOXIC SUBSTANCES

- In some grain legumes, oilseeds. Vegetables, fruits & forage crops toxic substances are found.
- These toxic substances have adverse effects on human & animal health.
- Feeding of forage with toxic substance will adversely affect the health of animal.
- it is essential to develop varieties of forage & food crops with low level of toxic substance so that it should not have adverse effect when consumed by animals.
- Considerable progress has been made in the development of varieties with low toxin content in above crops.

- Breeding for reduction in toxic substances requires lot of chemical analysis.
- Hence development of simple, cheap, rapid & reliable methods of chemical analysis is essential.

Toxic substances found in different food & fodder crops

Crop species	Toxic substance	Crop species	Toxic substance
Food crops			***Fodder crops***
Khesari	Neurotoxin	sorghum	Tannin and cyanogenic glucocides
Pigeon pea and cowpea	Tripsin inhibitors	Sorghum	Tannins & cyanogenic Glucocides
French bean	Haemagglutinine Tripsin & amylase inhibitors	Sudan grass	Cynogenic glucocides
Soybean	Tripsine inhibitor & goitrogens	White clover	Cynogenic glucocides
Rapeseed &	Rapeseed &	Alfalfa	Saponins and plant estrogens.
Mustard	Eicosenoic acid		
Cotton seed	Gossypol		
Safflower	Polyphenolics		
Potato	Steroidal alkaloids		
Cucurbits	Cucurbitacines	Sweet clover	Coumarin
Brinjal	Bitter principle		
Cassava	CN glucocides	Lespedeza	Tannins
Yarn	Alkaloids		
Mango	Resigns		
Field pea	Anti-vitamin E factor		

PRACTICAL ACHIEVEMENTS

- Varieties with improved nutritional quality have been developed in several food crops in many countries.
- In common bean, seed protein has been increased from 21.9 to 24.6, & in soybean seed from 42.8 to 46.1%.
- In sunflower, seed oil content has been increased from 32% to almost 50% in USSR, & in safflower from 37 to 50%.
- In maize, seed oil content has been increased from 4.7 to 17% & protein content from 10.9 to 23.5%.
- In wheat, Atlas-66 is an important source of high protein which is being used in breeding programmes for improvement of protein content.

Limitations

- Most are polygenic
- Difficult to estimate & evaluate, hence more finance required
- Low heritability & affected by environment
- There is negative association of seed protein with grain yield in both cereals & pulses.
- In some cases, improvement in quality leads to reduction in grain size and yield.
- For example, in barley selection for high lysine content causes
- reduction in grain size and grain yield.
- Sometimes, the quality character is found in wild relatives or species
- The analysis requires close cooperation of biochemist which sometimes becomes limiting factor in the progress.
- Biotechnological tools have not been used widely in all crops.

Varieties with improved quality released in some crop plants in India

Crop species	Quality character	Varieties released
Maize	High lysine content	Protina, Shakti & Rattan
Sugarcane	High sucrose content	Co 671, Co 6806, Co 7314,Co 7704 & Co 62174
Barley	Malting quality	Karan 15, Karan 92 & Karan 280
Lathyrus	Low neurotoxin	Pusa 24
Soybean	High protein & high oil content	Lee (Protein 43-45% & oil 23-25%)
Rapeseed	High oil content	K 88 (48.8% oil)

SOURCES OF QUALITY TRAITS:

(1) a cultivated variety,
(2) a germplasm line,
3) a spontaneous or induced mutant,
(4) a somaclonal variant,
(5) a wild relative and
(6) a transgene

1). A cultivated Variety

For wheat most, preferred source *e.*g. **Atlas 66 (USA)** & **Naphal (INDIA)** have been used as sources of high Lysine and protein content

2). A Germplasm Line

e.g. High lysine (3% of total protein) lines of sorghum, viz., **IS 11167** & **IS 11758,** were identified from Ethiopian collections. These lines also have (15%) protein but their seeds are shriveled & red in colour. They have been extensively used in breeding programmes.

3). A mutant

Many quality traits have been contributed by spontaneous/induced mutants. There are also examples of isolation of desirable mutants from mutant lines for quality traits.eg. P-721 opaque mutant of sorghum has opaque endosperm, which is not liked by consumers.

A vitreous endosperm DES-induced mutant was isolated from P-271 opaque line; this mutant has high lysine content.

4). A Soma clonal Variant

Soma clonal variants may sometimes show an improvement in a quality trait. e.g., a soma clonal variant of sweet potato had deeper & more stable root colour, which is preferred by consumers; this variant was released as a new variety called **'Scarlet'**

5). A wild Relative

There are several instances where genes for improved quality were contributed by a wild relative**.** In many cases, the quality trait is not expressed as such in the wild species, but it is detected only in the segregants recovered from its cross with the cultivated relative; such traits are called **latent traits.**

e.g., *L. hirsutum,* a wild relative of tomato, produces small green fruits. Yet some of the lines extracted from a cross between tomato & *L. hirsutum* showed enhanced red colour, while some others showed considerably higher carotene content.

Chapter No.22

SEED PRODUCTION TECHNOLOGY IN SELF POLLINATED CROPS

SEED PRODUCTION IN RICE

Isolation requirements

Rice is self-pollinated crop but sometimes cross-pollination is also reported, however the extent of cross-pollination ranges between 0.1- 4.0%. The isolation distance for foundation and certified seed should be fixed by minimum distance of 3 m from plots of other varieties of rice.

Varietal purity

The maximum permissible limit of off type plants in foundation seed plots is 0.05% and in certified seed plots of 0.2% at final inspection. The objectionable weed plants (wild rice) should not exceed 0.05% in foundation seed plots and 0.1% in certified seed plots at maturity of seed.

Seed borne disease

The foundation seed plots should not have more than 0.2% plants affected by neck blast and in certified seed plots should not exceed 0.5% at any inspection between ear emergence and harvesting.

Roguing

Roguing is necessary to maintain varietal purity standards. During pre-flowering stage, rouging should be done on the basis of early or late maturing varieties. All off type and objectionable weed plants should be removed before final inspection, which is normally conducted at full maturity and prior to harvesting of seed crop.

3. Cultural Practices

The crop can be grown by direct seeding or by transplanting methods. For seed production, it is desirable to grow puddle and transplanting system as described below.

Land selection for nursery

The land should not have been used in the previous year as nursery or general crop of the other varieties to avoid varietal admixture due to the growth of volunteer plants.

Time of sowing:

The seed sowing time is third week of May to 1st week of June for long duration varieties and 2nd week of June to 4th week of June for short duration varieties. In case of early rice, third week of Feb. to 2nd week of March is the time of nursery raising.

Preparation of nursery bed

The soil of the bed should be pulverized by repeated ploughing. Raised bed of 6m x 1.5m x 0.15 m and 50 cm gap between plots should be maintained. That gap or channel between plots may help to drain the excess water. The total of 50-60 such beds are sufficient to transplant one ha of land.

Manuring of nursery beds

Apply well-decomposed manure or compost plus 450 gm of super phosphate for 9 m2 area at the time of final bed preparation and mix them thoroughly with the soil. In area where Khaira disease is prevalent, spray ZnSO4 @ 5 kg plus lime 2.5 kg dissolved in 1000 lit of water/ha of nursery areas at 10 days after seeding and second at 20 days after seeding.

Seed rate and seed treatment

Seed is to be sown 500-600 gm/bed (9m2) i.e. 30-35 kg/ha for coarse and 25-30kg/ha (400-500 gm/bed) for fine rice varieties. Seed should be treated with Agrosan G.N. @ 2.5g/kg of seed.

Method of sowing:

Dry or pre-sprouted seed can be broadcasted at the time of seeding. For sprouting, the seeds are allowed to sprout by loosely packing in gunny bag and soaking them in water for 16-20 hours and then drying out excess water completely. The seed bags are kept in damp by covering with wet gunnies till sowing to maintain optimum condition for germination.

After care

Nursery should be protected for 3-4 days from bird's damage. Bed should be wet and if excess water is accumulated from any source, it should be drained out and should be kept free of weeds also.

Transplanting

After 3-4 weeks of sowing, the seedlings are ready for transplanting. Seedlings should be uprooted gently. Weak, diseased or variant seedlings should be discarded.

Land preparation for transplanting

Land is ploughed 3-4 times to obtain fine tilth and a soft soil. It also creates impervious sub soil condition, due to which the seedlings can establish quickly and plant

nutrients are not washed down. If possible, the field should be flooded for 7-10 days before transplanting.

Fertilizer application

Fertilizer should be applied according to soil test result. In general, 100-120:50-60:50-60 NPK kg/ha should be applied just before the final puddling, where N is applied in 3 split doses. Half dose of N as basal, 1/4th at mid-tillering and 1/4th at panicle initiation stage. If deficiency of N is observed in the field, 2% urea can be sprayed. In zinc deficient conditions apply 15 kg ZnSO4 + 2.5 kg lime in 1000 L of water /ha.

Method of transplanting

Transplant 2-3 seedlings per hill in 2-3 cm depth. The seedlings should not be under or over aged. The spacing is followed as under. a) Shy tillering variety - 20cm x 10 cm to 20cm x 15 cm b) More tillering variety- 20 cm x 15 cm to 20 cm x 20 cm.

Water management

Water at 3-5 cm depth should be maintained throughout the growth phase of the crop. Irrigation should be given whenever necessary.

Intercultural operation

The plot should be kept free from weeds by weeding 2-3 times before heading. If herbicides are used, following schedule should be followed. a) Use 2, 4-D or MCPA 1kg a.i. in 150-250 L of water/ha at 20-25 DAT to kill broadleaved weeds. b) To control grasses, use butachlor or benthiocarb @ 1.5 kg a.i./ha at 5-7 DAT in 600-700 L of water/ha

Plant protection

The rice crop may be infested by different diseases and insects. The major diseases of rice are blast, blight, brown spot, false smut, khaira disease, etc. Seed treatment with Streptocylcine (3 g in 11 L of water) after soaking for 8 hr in Ceresin (0.1%) will control most of the diseases. Blast can be control by spraying Blasticidin at 20 ppm or Rabicide 20% solution at 1.5 kg/ha. Foliar spray with 5 kg ZnSO4 + 2.5 kg slaked lime in 1000 L of water per ha is effective in controlling khaira disease. The common insects of the rice are paddy stem borer, rice gundhi bug, case worm, rice hispa, gall fly army worm, brown hopper, etc. They can be controlled by dusting 10% BHC or spraying 0.05% Carbaryl or Diazinon or Endosulfan.

4. Field inspection

A minimum of 2 inspections should be conducted.

1). The 1st inspection is conducted at flowering to verify source of seed used for seed production and to check isolation requirements.

2). The final inspection is allowed with the request of seed grower, if the number of off types and objectionable weed plants exceed prescribed permissible limit. During final inspection at maturity of seed crop, actual counts are taken from separate places distributed at random in such a way that whole area of the seed plot is covered. Thousand (1000) ear heads should be included in each count and examined carefully for off types and objectionable weed plants. An inspection and a copy of the report should be handed over to the seed grower.

5. Harvesting and threshing

The crop should be harvested just after physiological maturity by hand with sickles. Seeds are threshed, winnowed to remove chaff, dust, and empty husks and light grains. The clean seeds are dried around 11-12% moisture content for storage.

6. Seed yield:

The expected seed yield is 5-8 tons/ha.

7. Storage:

The seed should be store after proper drying at dry places. The rice bags should be stacked on a wooden pallet in a dry and cool place. Mark the bags with the name of cultivar and other information to avoid mechanical mixing. Do not store different varieties in the same room without stack identification.

SEED PRODUCTION IN WHEAT (Triticum aestivum L.)

1. Land selection

As in the case of rice or other crops, the plot should be free from volunteer plants, devoid of noxious weeds and well drained. The soil should be fertile with neutral in soil pH (6-6.5). Avoid too acidic or too alkaline soils. If karnal bunt disease is prevalent growing wheat in successive year should be avoided. Longer intervals between two wheat crops are desirable to reduce the contamination of seed from diseases like karnal bunt.

2. Field standards

Isolation requirements

Wheat being self-pollinated crop lime rice has very little chance for cross pollination, though cross pollination to the extent of 1-4% has been reported. Both foundation and certified seed fields should be isolated by a minimum distance of 3m from fields of other varieties. A minimum isolation of 150 m should also be provided from fields of wheat, rye and triticale with infection of loose smut in excess of 0.1% for foundation seed fields and 0.5% for certified seed fields.

Varietal purity

The maximum permissible limit of off type and inseparable other crop plants (barley, oats, triticale and chick pea) is 0.05% and 0.05% respectively in foundation seed fields and 0.1% and 0.3% respectively in certified seed fields at the time of final inspection.

Seed borne disease

The foundation seed fields should not have more than 0.1% plants affected by loose smut and in certified seed fields such plants should not exceed 0.5% at any inspection between ear emergence and harvesting.

Roguing

Timely rouging is necessary for maintaining varietal purity and seed health standards. Plants affected by loose smut should be removed as soon as spotted from ear emergence to harvesting of seed crops. Off type plants should be rogued out on the basis of plant height, tillering habit, ear size and density, awn length & colour and glume colour before final inspection. Plants of barley, oats, triticale, and chickpea should also be removed before final inspection.

3. Cultural Practices

3.1 Land preparation

Land should be prepared by deep ploughing with a soil turning plough followed by harrowing after pre-sowing irrigation. Taking 2-3 times of ploughing and disking should pulverize seedbed. The field should also be leveled. Organic manure plus soil applying insecticides like BHC or Malathion dust 10% @ 25 kg/ha applied just before the last harrowing or ploughing.

Time of sowing

It depends upon the climatic condition of any location. In general 15th November is the best time for terai and inner terai region and Oct last to Nov 1st week for hilly areas.

Seed selection and treatment

Purchased the seed from authorized seed agency. It must be of appropriate class and certified by certifying agency. The seed should be treated with Vitavax @ 2.5 gm/kg of seed is recommended to control loose smut disease.

Seed rate:

Eighty to hundred (80-100) kg per ha seed is recommended.

Method of sowing

The seed is sown in rows by using seed drill, behind the local plough or by using broadcasting method. The depth of seeding should be 5-7 cm. If we use seed drill, it should be clean to avoid mechanical mixture with another cultivars.

Spacing

If seed is sown in line, the spacing between rows should be maintained as 20-22cm and between plants it should be 3-5cm.

Fertilizer management

The fertilizer application depends upon the soil test result. In general provide 80-120: 50-60:40kg NPK/ha respectively. Apply N in 3 split doses of 60:30:30 kg/ha at basal, tillering and panicle initiation stage, respectively. If Zinc deficiency is noticed in the soil, ZnSO4 @ 15-20kg/ha as basal dose should be applied.

Water management

Irrigation number is depends upon the types of soil, residual moisture of proceeding season, variety etc. Depending upon the soil 4-6 irrigation may be sufficient. If sufficient irrigation is available it should be applied at CRI, tillering, jointing, flowering, milking and dough stages.

4.9. Weed management:

Periodic hoeing and weeding kept the field free of weeds. Manual weeding is generally practiced. It manual weeding is not possible different herbicides can be used. For control of broad leaf weeds 2,4-D @ 0.5 kg a.i./ha in 750 lit of water after 25-30 DAS and to control grasses like Ragatejhar (Phalaris minor) or Wild oat (Avena fatua) apply Pendamethalin 1 kg/ha in 750 lit of water after 35 DAS or Isoproturon 1 kg a. i. /ha in 750 lit of water after 35 DAS.

3.9. Plant Protection:

Termite, stem borer, army worm, wire worm, etc. may infest fields. They can be control by mixing 5% Aldrin or dusting with 5% BHC dust or spraying 0.07% Diazinon, etc. The rust, karnal bunt, etc may be a problem of disease. So apply seed treatment with Benlate 3%, Vitavax 3% or Ceresin 2% @ 2ml/kg of seed or spray Carboxin 1%.

4.Field inspection

The first inspection is conducted

1). at emergence to verify source of seed and to check isolation requirements.

2). The second is at heading stage.

3). The third and final inspection is conducted at full maturity to record off types, and inseparable other crop plants. During any inspection between ear emergence and harvesting, actual counts should be taken from separate places distributed at random in such a way that whole area of seed field is covered. Thousand (1000) ear heads should be included in each count and examined carefully for off types, number of objectionable weeds and loose smut affected plants. An inspection report should be prepared on completion of each inspection and copy of the report should be given to the seed growers.

5. Harvesting and Threshing

Handle the produce carefully during harvesting and threshing. Harvest the crop soon after maturity to avoid shattering and loses due to unfavourable weather condition (sprouting). Check the cleanliness of threshing floor and threshing equipment's properly. Threshing can be done with stationary thresher or by bullocks trampling. The crop can also be harvested by using combine harvester directly in the field when seed moisture is below 16%.

6. Drying, cleaning, bagging and storage

The moisture percent of the seed should be 11-12%, which can be maintained by drying. The seed should be cleaned, treated and bagged immediately after threshing or stored in a dry, insect and rodent proof warehouse.

7. Seed yield:

Estimated seed yield may be 4-5 tons/ha.

SEED PRODUCTION TECHNOLOGY IN CROSS POLLINATED CROPS

SEED PRODUCTION OF MAIZE

Land requirements

The selected field of maize should be free from volunteer maize plants and it should be well drained and aerated also.

Isolation requirements

Maize is generally cross-pollinated crop and pollinating agent is normally wind. It should be prevent from foreign pollen contamination. The foundation seed plot should be isolated by a minimum distance of 400 m and certified seed plot by 200 m from plots of other varieties.

No of Field inspections:

A minimum of two field inspections shall be made in such a way that one is conducted before flowering and the other during flowering stage so as to check for isolation distance, off types, designated diseases and other relevant factors.

Rouging:

Rouging for off types such as very tall or dwarf should be completed before pollen shedding. Remove malformed and diseased plants affected by stalk rot from time to time. At harvest sorting should be done remove off-colored and off -textured ears. Proper rouging should be done before flowering of seed crop to avoid contamination due to out-crossing. Roguing of off type plants should be continued throughout flowering period.

Varietal purity

The maximum permissible limit of off type plants that have shed or shedding pollen is 1.0% in foundation and 2.0% in certified seed production plot at any inspection during flowering when 5.0% or more of the plants have receptive silks.

Cultural Practices

Land preparation

Prepare the land by giving one deep ploughing followed by 2-3 harrowing and levelling to prepare desired tilth. If necessary one pre-sowing irrigation should be given before 1st ploughing.

Time of sowing

The time of sowing maize is differing from place to place. Maize can be sown two weeks before the onset of monsoon where irrigation facility exists. It is generally sown

from 3rd week of March (in khet land in mid hill) to 1st week of April in case of rainy season maize (in bare land). Seed production of maize is successful in terai in winter due to low isolation problem and less incidence of disease and pest. Maize can be sown in Oct-Nov in terai.

Seed selection

Seed should be selected from the authorized agency with kinds and source approved by seed certification agency.

Method of sowing

Maize can be sown with the help of maize planted by maintaining 75cm x 25cm row to row and plant to-plant. The depth of seeding should be 5-6cm.

Seed rate

Seed rate of 16-20kg/ha is sufficient. A population of 55-60 thousand plants per ha at harvest would be needed to attain maximum seed yield.

Fertilizer management:

Fertilizer recommendation is based on soil analysis value from soil testing lab. Add 10-15 tons of well-rotted organic matter as FYM or compost. For good crop, total requirement of maize crop for one ha is 120-150 kg N, 50-60 kg P2O5 and 40-50 kg K2O/ha. Mostly maize crop suffer from Zn deficiency, so it can be solved by using ZnSO4 20-25 kg/ha in basal dose. One third N plus full P and K as basal dose and remaining 1/3rd at knee high stage and another 1/3rd before tasselling.

Water management:

Maize is very sensitive to excess water and drought conditions. Both irrigation and drainage are equally important. So, irrigate the field frequently and do not let the water stand in field more than few hours by opening bunds or drainage channel.

Intercultural operations:

Timely weeding of maize is very important so 2-3 hoeing is done including earthing up of the crop. Inter cultivation should not be more than 3-5 cm deep so that roots are not damaged. If weed problem is very high, we can the herbicides as under: Simazine (50%) or atrazine (50%) 1.5 kg a.i./ha in 1000 lit of water as pre-emergence soil application is recommended. After application do not disturb the soil for 4-5 weeks.

Plant Protection:

Major insects are stem borer, pink borer, shoot fly, hairy caterpillars, army worms, maize beetles, hoppers, etc and major diseases are downy mildew, brown stripe, bacterial stalk rot, Pythium stalk rot, leaf rust, head smut, several types of kernel and ear rot, leaf blight (Helminthosporium), leaf rust, etc. Apply the appropriate control measures as 0.05% Endosulfan, 0.1% Carbaryl or 0.05% Lindane to control insects and treat the seeds by using Bavistin or Thiram or Captam @2-3gm/kg of seed or spray Mancozeb 75 WP@1.5kg + 0.25kg zinc sulphate in 500 L of water per ha to control diseases.

Harvesting

Maize comes under physiological maturity stage at about 30-35% moisture content. If it can be drying efficiently, we can harvest at physiological maturity stage when the husk turned yellow and grains are hard enough. In the absence of drying facility, harvesting is delayed until the grain moisture drops down to 15% level. Remove the husk from the cobs and then dry in sun for 7-8 days.

Shelling and cleaning

The seed-certifying agency requires an inspection of maize cobs before shelling. After drying, all off type and diseased cobs should be removed before shelling. After approval from seed certifying authority the cobs should be shelled and cleaned or processed.

Seed yield:

Under average situation the seed yield varies from 2.5-3.0 tons/ha.

SEED PRODUCTION IN SORGHUM

Land requirement: Land should be free from volunteer plants, Johnson grass, Sudan grass and other forage types. The same crop should not be grown on the same piece of land in the previous one season unless it is the same variety and certified by certification agency for its purity.

Isolation Distance

Sorghum is an often crops pollinated crop having 50% cross pollination. Isolation distance should be maintained so as to avoid varietal contamination of seed. Isolation distance is the distance by which the seed crop is separated from any other variety of the same crop.

Contaminants Isolation Distance (M)

	Foundation seed	Certified seed
Other varieties	200	100
Sudan grass	400	400
Fodder sorghum	400	400

Seed sowing

For seed production, sowing may be done during June – July and October – November seasons. Of these, October November is more conductive for quality seed production.

Seed Treatment

Seeds are soaked in 2% potassium dehydrogenase phosphate solution for 10 hours and then dried back to original moisture. One kg of seeds is to be soaked in 600 ml of leaf extract for 16 hours. Hardened seeds will have the ability to withstand drought during germination and plant growth.

Brief Cultural Practices:

Obtain appropriate class of the seed from the source approved by seed certification agency. The seed rate required is 12-15 kg/ha and the spacing adopted is 45cm between the rows and 15cm between the plants. Other cultural practices are similar to raising a commercial crop. Necessary prophylactic measures should be taken so as to raise a good crop.

Rouging of off-types in quality seed production

Growth	**Off types**
Before flowering	Self-sown crop plants with different leaf colour, shape and stem colour
During flowering	Early or late flowering plants and plants with deviant panicle shape
Before harvest	Panicle affects by ergot, fungi and smut and plants with deviating panicle features

Number of field Inspections: A minimum of three field inspection should be done. First inspection should be done during vegetative stage to determine isolation, volunteer plants and designated diseases etc. Second inspection shall be made during flowering to check

isolation, off types and other relevant factors. Third inspection shall be made at maturity prior to harvest to verify designated diseases true nature of plants, head and seed.

	Foundation class	certified class
Off types	0.05 %	0.10 %
Diseases plants	0.05 %	0.10 %

Field preparation seed sowing

- After the application of 12.5 tonnes of FYM, plough the field 1 to 2 times by harrowing 2 to 3 times levelling.
- Then apply 2 kg of Azospirillum uniformly.
- After the basal application of above fertilizers, ridges of six metre length are formed at 45 cm distance.
- Seeds are sown with a spacing of 15 cm on one side of the ridge

Fertilizer Application:

	N (kg/ha)	P (kg/ha)	(kg/ha)
Basal application	50	50	50
25 days after sowing	25 _ _		
45 days after sowing	25 _		

Micronutrient

For zinc deficient and iron deficient soils, 25 kg of ZnSO4 and 50 kg of FeSO4 have to be applied respectively.

Irrigation Management

According to the soil condition, irrigation is given once in 7 days or once in 10 days. The following are the important stages in which drought should be avoided.

1.Panicle emergence stage

2.Flowering stage

3.Seed maturation stage

Harvesting and threshing:

The seed crop must be harvested when it is fully ripe. The harvested heads should be sorted out to remove the diseased or otherwise undesirable. The heads should be dried on the threshing floor or tarpaulin for a couple of days before threshing. Threshing can be done by threshers or manually. The seed should be thoroughly cleaned and dried to 10 % moisture before storage.

Seed Yield: Depending up on the potentiality of the variety and the management practices adopted, seed yield may be in the range of 35-40 q/ha.

Drying

Seed are dried in sunshine heat. Harvested Seeds are to be dried to a moisture content of 10-12 per can

Seed Processing

Seed processing is an operation by which all immature, wrinkled, broken and small seeds as well as all physical impurities such as sand, stones, dust, other crop sees and week seeds are removed. For processing sorghum seeds, sieve of 9/64" diameter can be used so as to get uniform size seeds.

SEED PRODUCTION TECHNOLOGY IN VEGETATIVELY PRAPOGATED CROPS

Seed production of Sugarcane (Saccharum Spp.)

Land Requirements:

The seed plot should be selected in such area that where sugarcane crop was not grown in the previous year. To avoid and reduce the disease (red rot, wilt etc) and insects (termites, shoot borer, mealy bugs, scales etc) long duration crop rotation should be adopted. Field should be well drained.

Field standards

Isolation

In any case the seed plot must be isolated at least by 5m all around from other sugarcane fields.

Rouging

Rogue out clumps affected by smut, grassy shoot disease, red rot and wilt from time to time. Reject the off-type cane stalk differing from the typical characteristics and remove the plants infested by borers also.

Cultural Practices

Land preparation

One to two deep ploughing followed by disc harrowing or repeated ploughing by desi plough followed by levelling to get good tilth is necessary.

Time of planting

Mainly Oct planting and spring planting is generally followed. The seed crop should be adjusted in such a way that the seed crop is harvested 8-10 months age in tropical and at 10-12 months age in sub-tropical regions of the country.

Source of seed

Collect the seeds of appropriate generation of seed (nucleus/breeder's/foundation) certified by seed certifying agency.

Seed set treatment:

Generally, two methods are followed which are:

a) Heat treatment: By using hot water (50oC for 2 hours) or by using hot air (54oC) coupled with 95% RH for 4 hours.

b) Chemical treatment: The seed setts should be dipped in agallol or aretan 0.1% solution for 10 minutes before planting.

Method of planting

There are different methods of sugarcane planting which are

a) Flatbed method b) Furrow bed method c) Space transplanting method d) Ring method etc. Any one method can be used for seed multiplication programme.

Fertilization

120-150:60:40 kg NPK per ha and FYM or Compost @ 10-15 t/ha. The fertilizer can be applied as:

Basal: Full dose of P_2O_5 as furrow bottom.

At 30 DAP: ⅓N + ⅓K as band placement close to rows and partially earthed up.

At 60 DAP: ⅓N + ⅓K applied to base and slightly earthed up.

At 90 DAP: ⅓N + ⅓K applied to base and fully earthed up.

Pre-fertilization: 6-8 weeks prior to harvest @50:25:25 kg N, P_2O_5 and K_2O, respectively.

Irrigation and Drainage

In the absence of rain irrigation should be given at an interval of 10-12 days during its growing period. All excess water must be drained out from the field.

Intercultural Operation

After 3-4 weeks of planting, 1st hoeing and weeding should be done. If weeds infestation is maximum at initial stage of planting one blind hoeing should be given within one to two weeks after planting. Two to three more hoeing with earthing up and weeding are required during the first 3 months after planting.

Earthing and tying Earth up

The crop before monsoon rains. It is also desirable to tie up the canes to prevent from lodging.

Plant protection

Red rot, smut, wilt, etc are the major diseases of sugarcane. They can be controlled by sett treating with 0.25% solution of Agallol or Aretan for five minutes.

The insects like root borer, shoot borer, pyrilla, white fly etc. infest the crop. They can be controlled by applying 30 kg Carbofuran 3% or spraying with 1.5 L Endosulfan 35 EC or Monocrotophos 36 EC in 1000 L of water.

Field inspection

Minimum 2 field inspections should be done by the seed inspector. First inspection is after 2 months of planting and second 2 months before harvest the seed crop. During inspection off types, diseased and pest infected stalks should be rejected.

Harvesting and after care

Harvesting is done when the seed cane is about 8-10 months of age in tropical and 10-12 months in sub-tropical regions. A good irrigation should be given before cutting the crop. Damage of stalk should be avoided during handling. The harvested cane should not be allowed to dry up and if there are any delays in planting water sprinklings should be done on the canes for checking drying of the canes.

Seed yield: 40-60 tons/ha.

Seed Production of Potato (Solanum tuberosum)

Land requirements

The land should be free from infested disease like wart, cyst forming nematodes, or non-cyst forming nematodes within the three years and common scab. Two to three year's crop rotation should be followed. Two to three year's crop rotation should be followed. The field should be well-drained, well aerated, deep and having a pH range of 5.2-6.4.

Field standards

Isolation requirements

A minimum of 5m isolation distance should be maintained all around the seed field, with other varieties.

Roguing

A minimum of 3 times rouging should be done at different stages of crop

1) First rouging should be done at 25DAS to remove virus affected plants and other varieties which can be identified from foliage.

2) Second rouging should be done at fully growing stage (50-60DAS). At this stage virus affected plant as well as off type plants should be removed.

3) Third and final rouging should be done just before cutting the foliage. All virus affected and off type plants should be removed

Cultural Practices

Time of sowing:

Sept-Oct 5.2 Seed rate: 2.5-3t/ha (4-6cm diameter of seed tuber)

Source of seed:

Seed should be obtained from authorized organization and the generation of seed (type) should be cleared.

Fertilization:

100:80:80-100 kg NPK/ha plus 15-20 tons of FYM or compost should be applied. Half N + P and K should be applied at the time of sowing and remaining half N at 30-35DAS.

Method of sowing:

It can be planted by using furrow bed method of raised bed method or flat bed or pit method or behind the local plough. Care must be taken that each piece to be used for planting has 2-3 emerging eyes and weight at least 40gm. Plant the tubers 3-4cm deep in moist soil. Seed tubers should not come in contact with fertilizer, and placed below the seed potato.

Spacing:

60cm RR and 20 cm PP is recommended spacing.

Irrigation:

Irrigation should be given at frequent intervals (10 -15days) from emergence to 10-15 days before cutting the haulms. It depends upon the soil type, season and stage of crop also. The submerging of whole plot should be restricted.

Intercultural operation

Keep the field free from weeds. At least one earthing up is necessary at vegetative growth stage or when the plant attains 15 cm height. Exposed tubers should be covered with soil during subsequent earthing up.

Haulm cutting

It is a practice of removing uppermost portion (foliage) of the plant to avoid the chances of viral diseases transmission through the vectors like aphids. It should be done at the end of December or when the aphid population reaches the critical stage (20 aphids per 100 compound leaves). No re-growth should be allowed.

Important insects and diseases Insects:

Aphids, Jassids, Potato cut worms, Potato tuber moth, red ant etc. They can be controlled by applying 0.2% Carbaryl@1000 L of water or Chlorpyriphos 20Ec @2.5ml/L of water or Metasystox 25EC or Rogor 30EC @600 ml in 1000L of water per ha.

Diseases:

Early blight, late blight, black scurf, potato scab etc. They can be controlled by applying Ridomil MZ or Matco or Krilaxyl @2g/L of water or soil treatment with Brassicol @25-30kg/ha.

Harvesting

a) Time of harvest: 10-15 days after haulm cutting or when the skin of tuber has hardened. The moisture of soil should be optimum for obtaining clean tuber.

b) Method of harvest: Precaution should be taken during harvesting of potatoes to avoid cuts and bruises etc. After harvesting, tubers should not be open to hot sun not more than an hour. It can be store in an airy shed and kept in piles for 7-10 days for further hardening.

Grading

Grading should be done after curing the potatoes. Size should be about 4-5 cm diameter and about 4050cm weight should be maintained. While grading the shape, colour, depth of eyes of tubers should be carefully examined and off type discarded. Cut, bruises, cracks and mechanically damaged, containing scab, black scurf disease should be removed.

Packaging

Soon after grading, the potatoes should be put in clean Hessian bags (50kg size) and levelled with information.

Storage

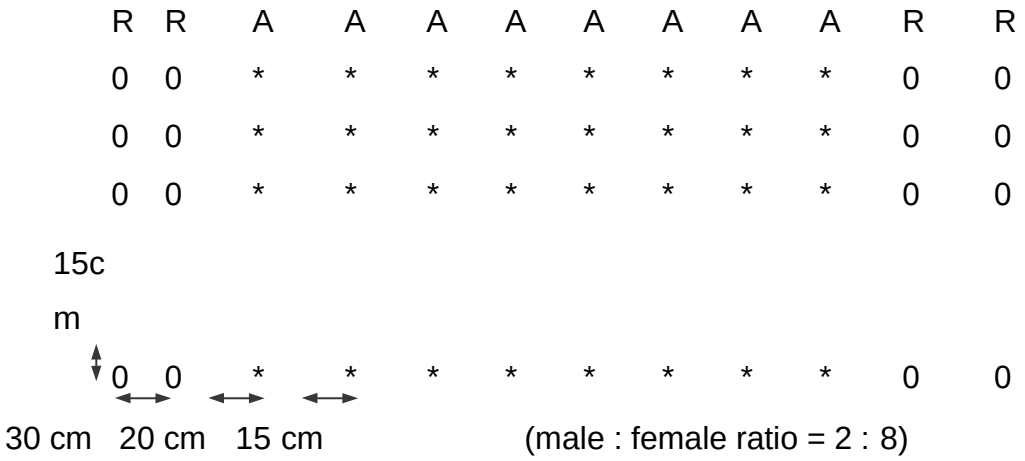
After packaging, the seed tubers can be store in rustic store in ambient temperature in high hill areas (more than 1500m altitude from mean sea level) where the temperature is below 18-20oC. In plane or terai areas where ambient temperature is above 32oC, the potatoes can be stored in cold storage at temperatures from 2.2-3.3oC and 75-80% RH. Periodic inspection of seed stocks in cold storage is necessary to ensure that stocks are keeping good.

Chapter No.23

Hybrid seed production in Rice

Hybrid rice seeds were produced using (cytoplasmic genic male sterility) three-line system. The two genes Rf_1 and Rf_2 are the genes for fertility restoration.

The process of hybrid rice production involves continuous supply of agronomically improved cytoplasmic male sterile line (A), maintainer line (B) and fertility restorer (R) line in system. Maintainer and restorer lines are maintained by selfing, while CMS line and F_1 seeds are produced with efforts to enhance cross pollination in field. F and S refer to fertile and sterile cytoplasm. Rf and rf are fertility restoring and non-restoring gene respectively. Row ratio and spacing of A and R lines in the main field



Technique of hybrid rice seed production

The following points are to be taken in to account for a successful hybrid rice production.

1.Choice of field: Fertile soil, protected irrigation and drainage system, sufficient sunshine. No serious disease and insect problem.

2.Isolation: To ensure purity of hybrid seed and avoid pollination by unwanted pollen isolation is a must.

a. Space isolation: No other rice varieties should be grown except pollen parent with a range of 100m distance.

bTime isolation: a time of over 20 days is practiced (The heading stage of other variety over a 100m range should be 20 days earlier or later over the MS line).

c.Barrier isolators: Topographic features like wood lot, tall crops to a distance of 30m/artificial obstacles of (plastic sheet) above 2m height.

3. Optimum time for heading and flowering

Favorable climatic condition for normal flowering are

1.Mean temperature 24-28°C

2.Relative humidity 70-80%

3.Day and night temperature difference 8-10°C. (iv)Sufficient sun

4.Sufficient breeze.

4. Synchronization of flowering

As the seed set on MS line depends on cross pollination it is most important to synchronize the heading date of the male and female parents. In addition, in order to extend the pollen supply time, the male parent is usually seeded twice or thrice at an interval of 5-7 days.

5. Row ratio, row direction and planting pattern

Row ratio refers to the ratio of number of rows of the male parent to that of the female parent in the hybrid seed production field. The layout of row ratio depends on

1. The growth duration of the R line
2. Growth vigor of the R line
3. Amount of pollen shed and
4. Plant height of the R line.

The principles include

* R line should have enough pollen to provide
* the row direction should be nearly perpendicular to the direction of winds prevailing at heading stage to facilitate cross pollination.

Practically, a row ratio of 2:8 is currently widely used in Indica hybrid seed production. Generally, the R line is transplanted with two to three seedlings per hill and separated by a spacing of 15cm from plant to plant, 30cm from one row of restorer to another and 20cm from CMS line. The MS line is transplanted with one to two seedlings per hill with a spacing of 15x15 cm.

A good population structure to get more seed yield is given below:

a) Seedling/hill	b) Hills/sq.m	c) effective tillers/sq.m A
line = 1-2	A line = 30	A line = 300
R line = 2-3	R line = 5	R line = 120

6. Prediction and adjustment of heading date

Even if the seeding interval between both parents is accurately determined, the synchronization of their flowering might not still be attained because of variation in temperature and difference in field management. Hence it is necessary to predict their heading date in order to take measures as early as possible to make necessary adjustments by examining the primordial initiation of panicle.

Adjustment of flowering date can be made by applying quick releasing nitrogen fertilizer on the earlier developing parent and the later developing parent should be sprayed with 2% solution DAP. By this measure a difference of 4 to 5 days may be adjusted.

7. Leaf clipping, gibberellin application and supplementary pollination

These techniques are very effective for increasing the outcrossing rate.

a) Leaf clipping: The leaves taller than the panicles are the main obstacles to cross pollination and, therefore, should be cut back. Generally, leaf clipping is undertaken 1-2 days before the initial heading stage, and more than 2/3 rd of the blades of flag leaves are cut back from the top.

b) Application of gibberellin: (GA_3) GA_3 can adjust physiological and biochemical metabolism of rice plant and helps in hybrid seed production by stimulating the elongation of young cells. In most of the CMS lines, about 20-30% of spikelets of a panicle are inside the flag leaf sheath (exertion is only 70%). GA_3 affects exertion of panicle completely out of flag leaf sheath. In India recommended dose of GA_3 is 50g/ha using knapsack sprayer and 25g/ha with ultra-low volume sprayer.

Advantage of GA_3 application

* enhances panicle and stigma exertion
* speed up growth of late tillers and increase effective tillers
* flag leaf angle is increased

* reduces unfilled grains
* enhances seed setting and seed yield

Spraying stage: 5% of panicle emergence Spraying time: 8-10AM is the best time.

c) Supplementary pollination:

Shaking the R lines panicles by rope-pulling or rod driving during anthesis can enhance the crossing rate. This is carried out during peak anthesis (10-12 AM).

8) Rogueing

To get 98% purity of CMS lines and R lines, in addition to strict isolation, a thorough rogueing is also necessary.

9. Harvesting, threshing & drying

- Turning of 90% green seeds to straw yellow colour is the stage of physiological maturity
- Moisture content will be 17-20%.
- Male parent should be harvested first
- Care should be taken to avoid admixture of male line with female line while harvesting.
- The female parent should be threshed at 16-17% moisture content separately in a well cleaned threshing floor.
- The threshed seed should be winnowed and dried to reduce the seed moisture content to 12%
- The seed should not be dried under direct sun between 12 to 3.00 p.m. during hot sunny days.

10. Seed treatment

Seeds are treated with thiram / captan @ 4 g/kg. or with 5 gm halogen mixture. The halogen mixture is prepared by mixing $CaOCl_2$ + $CaCO_3$ for 1 week in airtight container.

11. Storage

- Fort short term storage use gunny bag or cloth bag.
- For long term storage use polythene bag of > 700 gauge and dry the seeds to 8% moisture content.
- When compared with varieties, the hybrids and parental lines A & B lines are poor in storability.
- The order of the storage potential is R > F1 > B > A.

12. Seed Yield :Hybrid yield (F1) : 800-1200 kg ha-1

HYBRID SEED PRODUCTION IN PIGEON -PEA

For hybrid seed production, a ratio of 4:1 of male sterile pollen parent is adopted. Sufficient isolation distance i.e., more than 200 metres for the hybrid seed production plot is needed. There should not be any pigeon pea crop within a radius of 200 metres from the seed production plot. Since the male sterility is maintained in heterozygous state following the test cross principle, there would be fertile and sterile plants in the ratio 1:1 in the male sterile population. It is therefore imperative to remove the male fertile plants in the male sterile population before flower opening. The rogueing should be done thoroughly to avoid contamination by the pollen from any left out fertile plants.

Steps involved in hybrid seed production

1. **Selection of site**
    1. Fertile field with an irrigation source
    2. Previous crop should not be pigeon pea
    3. Isolation distance of 200m from any other variety of pigeon pea.
2. **Fertilizer**
    1. Farm yard manure @ 20 cart loads per hectare
    2. 25 Kg N + 50 Kg of P as basal application
3. **Sowing**
    1. The female and male parents are sown in the ratio of 4:1 with two border rows of pollinator parent.
    2. The pollen parent (ICPL 87109) should be sown one week after sowing the female parent (MS T.21).
    3. Row spacing of 45 cm.
    4. Plant to plant spacing should be 15 cm.
    5. Dibble 2-3 seeds per hill for the female parent
    6. Seed rate (per hectare) for 4:1 ratio 12-15 Kg of female parent, 5 kg of male parent.
    7. Sowing should be done during **first fortnight of June or first fortnight of December.**
    8. The whole plot should be bordered with sunflower to increase the bee activity to effect cross pollination.

4. Irrigation

1. First irrigation after sowing and a life irrigation 2-3 days after sowing.
2. irrigate the plot at 7-10 days interval depending upon the moisture in the field

5. Rogueing

1. Male sterile line or female parent:
2. Remove the off-type plants
3. Remove the male fertile plants by examining the colour of the anthers (yellow) at the time of first flower formation, one-day before flower opening.
4. Rogueing should be completed in 7-10 days' time
5. Remove the late flowering plants also.
6. Male fertile line or pollen parent:
7. Rogue out off types.
8. Remove the immature pods set in the plants from time to time to induce continuous flowering and to ensure pollen availability for a longer period.

6. Harvesting

Collect the pods from the female parent i.e., male sterile parent. This will give the hybrid seeds.

7. Production and maintenance of male sterile line

Genetic male sterility is utilized in hybrid seed production. In case of pigeon pea, the male sterile line will segregate in 1:1 ratio of fertile to sterile. For the maintenance of the male sterile population (to be raised under isolation), the male sterile plants have to be identified and tagged and the fertile plants have to be retained without tagging.

The male sterile lines will be pollinated naturally by the pollen from the male fertile plants in the population through insect pollinators. After maturity, the seeds from the tagged male sterile plants are collected and will be used for producing male sterile lines again or for producing hybrid seeds.The main difference between the hybrid seed production and the male sterile line maintenance is, during hybrid seed production the male fertile plants from the male sterile population are to be rogued off, while they are retained during male sterile line maintenance.

HYBRID SEED PRODUCTION IN MAIZE

Crossing technique : Manual emasculation by detasseling

Detasseling : Removal of male inflorescence from t he monoecious crop

Time for detasseling : The time taken for shedding of pollen from the tassel in 1-2 days after emergence. Hence the tassel should be removed before the shedding of pollen.

Detasseling

Detasseling is the removal of tassel from female parent. Detasseling is done when the tassel emerged out of the boot leaf, but before anthesis have shed pollen. Anthers take 2-4 days to dehisce after complete emergence. Only in few cases, the anthers start dehisce before its complete emergence. In such case detasseling should be done earlier. Detasseling is done every day from the emergence of tassel up to 14 days.

Method

- Hold the stem below the boot leaf in left hand and the base of the basal in right hand and pull it out in a single pull.
- Grasp entire tassel so that all the pollen parts are fully removed.
- Do not break or remove leaves as removal will reduce yields and will result in lower quality of seed.

Precautions to be adopted during detasseling

No part should be left on the plant as it causes contamination.

- It should be uniform process done daily in the morning in a particular direction.
- Donot break the top leaves as the field may be reduced due to the earning of source material to accumulate in sink [seed] as removal of 1 leaf course 1.5% loss 2 leaves 5.9% loss and 3 leaves 14% loss in yield.
- Detassel only after the entire tassel has come out and immature detasseling may lead to reduced yield and contamination.
- Mark the male rows with marker to avoid mistake in detasseling
- Look out for shedders [shedding tassel] in female rows as the may cause contamination.
- After pulling out the tassel drop it there itself and bury in soil. Otherwise late emerging pollen from detasseled tassel may cause contamination.
- Do not carry the tassel through the field as any fall of pollen may lead to contamination.
- Donot practice, improper, immature and incomplete detasseling.
- **Improper detasseling**: A portion of the tassel is remaining in the plant while detasseling.
- **Immature detasseling:** Carrying out detasseling work when the tassel is within the leaves.
- **Incomplete detasseling**: The tassel is remaining in lower or unseen or unaccounted in within the whole of leaves.
- There should not be any shedding tassel.
- **Shedding tassel**: Either full or part of tassel remain in female line after detasseling and shedding pollen which may contaminate the genetic purity of the crop.

System of Hybrid seed production

- Detasseling (Manual creation of male sterility)

Types of
hybrids Single
cross hybrid

It is a cross between 2 inbreds. A x B. A genotype will be detasseled and crossed with B genotypes.

- ✓ COH 1- UMI 29 x UMI 51
- ✓ COH 2- UMI 810 x UMI 90
- ✓ CoH(M) 5-UMI 285 X UMI 61

Double cross

- ✓ It is a cross between two single crosses.
- ✓ It is a cross between 2 hybrids (A x B) x (C x D) (A x B) single cross hybrid will be produced by detasseling A and by crossing with B (C x D) hybrid will be produced by detasseling C and crossing with D.
- ✓ Then (A x B) will be detasseled and crossed with (C x D) hybrid.

Example

Ganga 2 : (CM 109 x CM 110) x (CM 202 x CM 111)

Ganga 101 : (CM 103 x CM 104) x (CM 201 x CM 206)

COH3 : (UMI 101 x UMI 130) x (UMI 90 x UMI 285)

Three way cross

- ✓ It is a cross between a single cross and an inbred.
- ✓ It is first generation resulting from the crossing of on approved inbred line and a certified open pollinated variety A x variety)
- ✓ A will be detasseled and allowed for crossing in the variety.

Example Ganga -5 (CM 202 x CM 111) x CM 500.
COH (M) 4: (UMI 90 x UMI 285) x UMI 112

Double top crosses : The first generation resulting from the controlled crossing of a certified single cross and a certified open pollinated variety.

: (A x B) x variety

: (Ax B) will be detasseled and crossed with a variety

Seed production technology

Season - November- December, Mid July, Jan. Feb and Sep. Oct

Isolation distance

	Foundation seed (m)	Certified seed (m)
1. Inbreds	400	-
2. Single cross hybrid	400	-

Field standards for isolation (modification based on situation) For (foundation single crosses and hybrid of certified class)

	Foundation stage	**Certified stage**
• Same kernal color	400	200
• Different kernal colour	600	300
• Field of single cross / inbreds not confirming to varietal purity	400	200
• Single cross with same male parent confirming to varietal purity	5	5
• Single cross with other male parent not confirming to varietal purity	400	200

- Differential blooming dates are permitted for modifying isolation distance provided 5.0% or more of the plants in the seed parent do not have receptive silk when more than 0.20% of the plants in the adjacent field within the prescribed isolation distance are having shedding pollen.
- In hybrid seed production (certified seed stage) alone the isolation distance (less than 200 meter) can be modified by increasing the border rows of male parent, if the kernal colour and texture of the contaminant are the same as that of the seed parent.

The number of border rows to be planted all around the seed field to modify isolation distance less than 200 m shell also be determined by the size of the field and its distance from the contaminant as shown below.

Seed production stages and production of parental lines / hybrids

Stage of seed	Single cross	Double cross	Three way cross	Double top cross	Top cross
Breeder seed	A, B	A, B, C, D	A, B, C	A, B, variety	A, variety
Foundation seed	A, B	(AxB) (CxD)	(AxB), C	(AxB) variety	A, variety
Certified seed	A X B	(AxB) x (CxD)	(AxB) x variety	(AxB) x variety	Ax variety

Spacing

Seeds are sown in ridges and furrows

Hybrids : 60x 25 cm

Seed rate : Female : 7 -10 kg ha^{-1}

: Male : 3 -4 kg ha^{-1}

Spacing : Female : 60 x 20 to 75 x 30 depending on the area.

Male :45 x 30 cm

Planting ratio

Single cross	4:2
Double cross	6:2
3 way cross	6:2
Border rows	a. Inbreds & single cross - 4 rows
b. Others	- 3 rows

Fertilizer

NPK kg / ha	:	200 : 100 : 100
Basal	:	100 : 100 : 50
1st Top	:	50 : 0 : 0 (20th days -vegetative phase)
2nd Top	:	50 : 0 : 50 (Boot leaf stage at 45 days)
Foliar	:	DAP 2% at 50% flowering
In Zn deficient soil	:	$ZnSO_4$ @ 25 kg ha^{-1}

Fertilizer

NPK kg / ha	:	200 : 100 : 100
Basal	:	100 : 100 : 50
1st Top	:	50 : 0 : 0 (20th days -vegetative phase)
2nd Top	:	50 : 0 : 50 (Boot leaf stage at 45 days)
Foliar	:	DAP 2% at 50% flowering
In Zn deficient soil	:	$ZnSO_4$ @ 25 kg ha^{-1}

Roguing

Should be done periodically based on position of cob, colour of silk, arrangements of seeds in cob, leaves etc. Shedding tassels are to be removed in roguing . It refers to the tassels in female parents rows, shedding pollen or that has shed pollen in hybrid maize plots. During field inspection a tassel whose main spike or any side branch or both have shed pollen or shedding pollen in more than 5 cm of branch length is counted as a shedding tassel during inspection the shedding tassels are taken into count for acceptance or rejection of production plot.

Field standard (%)

	FS	CS
Off types	0.2	0.5
Shedding tassel	0.5	1.0 (when receptive silk is 5% or more)

Inseparable other crop : Nil (both stage) Objectionable weed : Nil (both stage) Designated diseases : Nil (both stage)

Field standards –specific

Specific factors	**Certified stage**
Off types shedding pollen when 5 % or more of seed parent in receptive silk	0 .50 %
Seed parent shedding pollen when 5 % of the seed parent is having receptive silk	1.0 %
Total of pollen shedding tassel including tassel that had shed pollen for all 3 inspections conducted during flowering on different dates	2 .0 %
Off types in seed parent at final inspection	0 .5 %

Number of inspection : Four

(Seed certification officers) : One : Before flowering

: Three : During flowering

Harvest

- ✓ Harvest when the moisture content falls to 20-25%
- ✓ Harvest male first and remove from the field and then harvest female

Threshing

a. **Dehusking** - The husks are removed manually.

b. **Cob sorting** - Remove ill filled, diseased cobs and cobs having kernel colour variation.

Shelling

Cob sorting should be the first operation it is a post harvest, evaluation for genetic purity. The sheath is removed and check for kernel colour, shank colour, diseased cobs, kernel arrangement. The cobs are shelled either mechanically or manually at 15-18% moisture content. Improper shelling leads to48% damage to kenel Growth of storage fungal Pericarp damage. Crack on pericarp can be identified by $FeCl_3$ or Tz test. Shelling is done mechanically using cob sheller and manually by rubbing with stones.

Drying

Seeds are dried to 12% moisture content.

Grading

Grade the seeds using 18/64" (7.28 mm) sieve.

Seed treatment

Slurry treat the seeds with 8% moisture content either with captan or thiram 75% W.P. @ 70 g/100 kg with 0.5 litre of water. Treated seeds can be stored for 1 year in cloth bag.

Others: As in varietal seed production

Seed yield : 2.5 - 3.6t/h

HYBRID SEED PRODUCTION IN BAJRA

Breeding Technique for hybrid seed production : Cytoplasmic genetic male sterility system (CGMS)

History of bajra hybrid

Seed production : The first report on CGMS line was made by Burton and his co workers at Tifton Georgia USA. The line is Tift 23A.

Popular hybrid

Hybrid	Female	Male
KM 1	MS 5141 A	J 104
KM 2	MS 5141 A	K 560 -D-230
X4	MS 5141 A	PT 1921
X5	PB 111A	PT 1921
X6	732 A	PT 3095
X7	111A	PT 1890
H B1	Tift 23A(USA)	BIL -3B
HB 3	Tift 23A(USA)	J 104
HB 5	Tift 23A(USA)	K 559
UCH 11	732 A	PT 3075 (TNAU)
COH(cu) 8	732 A	PT 4450

Commercial Hybrid Seed Production

Isolation m	:	Foundation seed: 1000 Certified seed: 200 m
Season	:	Irrigated : March – April, January – February
Rainfed :		June-july October – November
Seed rate	:	A line : 6 kg/ha B line : 2 kg/ha
Main field preparation	:	Ridges and furrows
Planting ratio	:	Foundation Seed : 4 : 2 Certified Seed : 6 : 2 Pusa 23 - 8 : 2
Border rows	:	Foundation Seed : 8 (B line) Certified Seed : 4 (R line)
Spacing	:	A line : 45 x 20 cm B line : 45 x solid row.
Nursery bed	:	Seedling can also be raised in raised nursery and can transplante to the main field at 20-25 days of aging.

Manures & Fertilizers

Nursery	:	750 kg / 7.5 cents for transplanting in one ha.
Mainfield	:	Compost : 12.t ton/ha NPK 100:50:50 kg ha^{-1}
Basal		: 50:50:50 kg ha^{-1}
Top		: 50:0:0 kg ha^{-1} (At tillering phase
Foliar spray	:	DAP 1% at peak flowering to enhance flowering and seed set.

Steps for synchronization of flowering

- Withholding irrigation
- Application DAP 1%
- Staggered sowing
- Jerking

jerking

It is done 20-25 days after transplanting or 30-40 days after direct sowing. The early formed earheads of the first tillers are pulled out or removed which will result in uniform flowering of all the tillers.

Specialty with bajra in synchronization

The synchronization problem is less in bajra due to

- Tillering habit
- Supply of continuous pollen
- Lesser pollen weight
- Flight capacity of pollen
- Pollen viability & stigma receptivity are longer.

Roguing : Done in both lines

- A line :seek for offtypes pollen shedder and partials
- R line :Seek for early flowering plants,rouges and diseased plants.

Character of offtypes : Variation in leaf colour, leaf waviness, grain colour earhead, shape, size, etc.

No. of field inspection : Three

- Seedling stage
- Tillering stage
- Grain formation stage.

Field standards

Standards	**Maximum permitted (%)**	
	FS	**CS**
Offtypes	0.05	0.10
Pollen shedders	0.05	0.10
Downy mildew diseased plants	0.05	0.10
Earheads affected by ergot	0.02	0.04

Harvesting Technique :• Due to tillering habit, harvest the panicle / earhead in 2 picking (to avoid delayed harvest)

Select 5-7 tillers for seed purpose.

Processing :• Grade with 4/64” round perforated metal sieve as middle screen

Use OSAW cleaner cum grader

Seed Treatment :Thiram / Bavistin @3g kg^{-1} seed

Seed storage: • Cloth bag for short term storage (12months) 700 gauge polyethylene bag – long term storage (> 24 months)

Mid storage correction **:**HDH with Na_2PO_4 10^{-4}m for 4h.

Seed standards

Standards	**Permitted (%)**	
	FS	**CS**
Physical purity (Maximum)	98	98
Inert matter (Maximum)	2	2
Other crop seed (Maximum)	10 / kg	10 / kg
Weed seed (Maximum)	10 / kg	10 / kg
Ergot effected seeds (Maximum) by number	0.020 %	0.040%
Germination	75	75
Moisture content **-** Moisture pervious Moisture impervious	12 5	12 5

Seed yield : 3200 - 3250 kg / ha

HYBRID SEED PRODUCTION IN SORGHUM

Breeding technique for Commercial production

Cytoplasmic genetic male sterility (CGMS)

Seeds produced in different stages

Nucleus seed stage seed to row progenies.	:	Maintenance of basic source by
Breeder Stage	:	A (AxB), B and R line are multiplied
Foundation Stage	:	A (AxB) and R line are
multiplied Breeder and foundation seed stage or	:	Multiplication of male sterile line maintenance of A and B line
Certified seed stage	:	A x R – F1 hybrid produced.
Certified seed stage	:	Production of hybrid seed

Stages of Seed Production

Breeder seed ---> A x B - B- R

Foundation seed ---> A x B - B - R

Certified seed ---> A x R

Popular hybrids of their parents: The first hybrid (CSH 1) was released in 1964. In 1969, the Coordinated Sorghum Improvement Project was established. Now there are more than 30 hybrids. Some popular are

CSH1	CK 60 A x IS 84
CSH5	2077A x CS3541
CSH 9	MS 296 A x CS 3541
COH2	2219A x IS3541(Kovilpatti Tall)
COH3	2077A x CO21
COH4	296A x TNS30
CSH 13 R	296 A x RS 29
CSH 14	AKMS 14A x AKR 150
CSH 16	27 A x C 43
CSH 15 (R)	104 A x R 585
CSH 17	AKMS 14A x RS 673

Stages of seed multiplication :Breeder seed – foundation seed – certified seed.

Foundation seed production :A and B line are raised in 4:2 ratio with 4 rows of B line as border row and allowed for cross pollination. The seeds from A line will be collected as A line seeds (multiplied).

Certified seed production : Hybrid seed production

Commercial in Hybrid seed production techniques

	Isolation distance	
	FS	CS
Normal	200	100
On presence of Johnson grass	400	400
On presence of forage sorghum	400	200
Hybrids	300	200

Johnson grass

Forage sorghum

Seeds and sowing

Seed rate	:	A line : 8 kg ha^{-} R line : 4 kg ha^{-}
Spacing	:	A line : 45 x 30cm R line : 45 x solid row spacing.
Planting ratio	:	Foundation seed stage: 4:2(A: B) Certified seed stage : 5.2 (A:R)
Border rows	:	4 rows of male (either B or R line) to, supply adequate pollen.
Live markers	:	• Live plants used for identification of male line live markers are used. It should have distinguishable morphological characters. Live markers can be sunflower, daincha etc.

Manures and Fertilizers

Compost	:	12.5 t / ha
NPK	:	100:50:50 kg ha^{-1}
Basal	:	50:50:5 kg ha^{-1}
Top dressing	:	25kg N after last ploughing
		25kg N after boot leaf stage (45 days)

Synchronization technique

1. Staggered sowing: Sowing of male parent and female parents are adjusted in such a way that both parents come to flowering at the same time.

- ✓ CSH-5, MS 2077 A must be sown 10-15 days earlier to the male CS 3541,
- ✓ CSH 6, the female parent MS 2219 A can be sown simultaneously with CS 3541
- ✓ CSH 9, the female parent MS 296 A must be sown 7-10 days earlier than male CS 3541 in November- December season.

2. Spraying growth retardent MH 500 ppm at 45 DAS, delays flowering in advancing parent. MH wont dissolve in water and hence dissolve it in NaOH and then mix with water.
3. Urea spraying 1% to the lagging parent.
4. Withhold one irrigation to the advancing parent.
5. Spraying CCC 300 ppm will delay flowering.

Roguing:Do It in both line

Off type:

In female line remove : off types, wild types, pollen shedders, rogues, partials, volunteer plants, diseased plants, R line, mosaic plants, late / Early flowering plant

In male line remove : Rogues, A line, Diseased plants, Late / early flowering plants, Wild types

Types of contamination

- Presence of B line in A line called as pollen shedders

  Presence of A line in Bline called as off type
- Presence of R line in B line called as rogue
- Presence of B line in B line called as rogue
- Presence of B line in Rline called as rogue
- Presence of B line in R line called as rogue
- Pollen shedders and off type cause physical contamination, whereas, rogue cause physical and genetical contamination.

Pollen shedders

Presence of B line plants in A line are called pollen shedders.

Partials

In certain A line plants, a part of the earhead-shed pollen due to the removal of sterility due to parental impurity (or) developmental variation or temperature.

Field Standards

	Isolation distance	
	FS	CS
Offtypes (max) Varieties	0.05	0.10
Hybrids	0.05	0.10
Pollen shedders (max)	0.05	0.10
Designated diseased plants (max) (Ergot and smut)	0.05	0.10

Designated disease

1. Kernel smut
2. Head smut

3. Sugary disease of sorghum
    - ❖ It is specific to hybrid
    - ❖ Occur due to low seed set
    - ❖ Spray rogor 0.03% (or)
    - ❖ Endosulfan 0.07%

Method of harvesting

Male and female lines should be harvested separately. The male rows are harvested first and transported to separate threshing floor. Like that female rows are harvested and threshed separately.

Threshing

- ✓ At the time of threshing the seed moisture content should be reduced around 15-18%. Threshing can be done by beating the earheads with bamboo sticks.
- ✓ While using the mechanical threshers, care should be taken to avoid mechanical damage.

Drying

Seed should be dried to 12% for short term storage and 8% for long term storage.

Processing

The sorghum seeds can be processed in OSAW cleaner cum grader using 9/64" round perforated metal sieve.

Seed treatment and storage

- ✓ The seeds are treated with captan or thiram @ 2 g/kg of seed and pack it in cloth bag at 12% moisture content for short term storage and 8% moisture content in 700 gauge poly ethylene bag for long term storage.
- ✓ The seeds can also be treated with halogen mixture @ 3 g/kg of seeds. The halogen mixture is prepared by mixing $CaOCl_2$ and $CaCO_3$ +*Albizzia amara* at the rate of 5:4:1 and this mixture is kept in an air tight plastic container for 1 week. After one week the mixture is used for seed treatment.
- ✓ The treated seeds can be stored upto 12 months under open storage and upto 18 months in moisture vapour proof containers, provided it is not

infested by the storage insects.

Seed yield : 3000 kg ha^{-1}

Seed standards

	Foundation seed	**Certified seed**
Physical purity (%)	98	98
Inert matter (%)	2	2

Other crop seed	5 kg^{-1}	10 kg^{-1}
Weed seed	10 kg^{-1}	20 kg^{-1}
Other distinguishable variety	10 kg^{-1}	20 kg^{-1}
Ergot disease by number	0.020%	0.040%
Moisture content		
Moisture pervious container	12	12
Moisture vapour proof container	8	8

Chapter No.24

IDEOTYPE BREEDING

Crop ideotype refers to model plants or ideal plant type for a specific environment. In broad sense an ideotype is a biological model which is expected to perform or behave in a predictable manner within a defined environment. More specifically, crop ideotype is a plant model which is expected to yield greater quantity of grains, fibre, oil or other useful product when developed as a cultivar. The term ideotype was first proposed by Donald in 1968 working on wheat.

Ideotype Breeding

Ideotype breeding can be defined as a method of crop improvement which is use to enhance genetic yield potential through genetic manipulation of individual plant character.

Main features of ideotype breeding are

1.Emphasis on individual trait

In ideotype breeding, emphasis is given on individual morphological and physiological trait which enhances the yield. The value of each character is specified before initiating the breeding work.

2.Includes yield enhancing traits

Various plant characters to be included in the ideotype are identified through correlations analysis. Only those characters which exhibit positive association with yield are included in the model.

3.Exploits physiological variation

Genetic differences exist for vario us physiological characters such as photosynthetic efficiency, photo respiration, nutrient uptake, etc. Ideotype breeding makes use of genetically controlled physiological variation in increasing crop yields, besides various agronomic traits.

4.Slow progress:

Ideotype breeding is a slow method of cultivar development, because incorporation of various desirable characters from different sources into a single genotype takes long time. Moreover, sometimes undesirable linkage affects the progress adversely.

5.Selection: In ideotype breeding selection is focused on individual plant character which enhance the yield.

6. Designing of model

In ideotype breeding, the phenotype of new variety to be developed is specified in terms of morphological and physiological traits in advance.

7. Interdisciplinary approach

Ideotype breeding is in true sense an interdisciplinary approach, it involves scientist from the disciplines of genetics, breeding, physiology, pathology, entomology.

continuous process

Ideotype breeding is a continuous process, because new ideotypes have to be developed to meet changing and increasing demands.

Features of crop ideotypes

The crop ideotype consists of several morphological and physiological traits which contribute for enhanced yield or higher yield than currently prevalent crop cultivars. The morphological and physiological features of crop ideotype differ from crop to crop and sometimes within the crop also depending upon whether the ideotype is required for irrigated cultivation or rainfed cultivation. Ideal plant types or model plants have been discussed in several crops like wheat, rice, maize, barley, cotton and beans. The important features of ideotype from some crops are

Wheat

The term ideotype was coined by Donald in 1968 working on wheat. He proposed ideotype of wheat with following main features:

1. **A short strong stem:** It imparts lodging resistance and reduces the losses due to lodging.
2. **Erect leaves:** Such leaves provide better arrangement for proper light distribution resulting in high photosynthesis or CO_2 fixation.
3. **Few small leaves**: Leaves are the important sites of photosynthesis, respiration and transpiration. Few and small leaves reduce water loss due to transpiration.
4. **Larger ear**: It will produce more grains per ear.
5. **An erect ear**: It will get light from all sides resulting in proper grain development.
6. **Presence of awns**: Awns contribute towards photosynthesis.
7. **A single culm.**

The concept of plant type was introduced in rice breeding by Jennings in 1964, the term ideotype was coined by Donald in 1968. He suggested that in rice an ideal or model plant type consists of

1. Semi dwarf stature
2. High tillering capacity and
3. Short, erect, thick and highly angled leaves
4. More panicles /m2,
5. High (55% or more) harvest index.

Now emphasis is also given on physiological traits in the development of rice ideotype.

MAIZE

IN 1975, Mock and Pearce proposed ideal plant type of maize.

1. Stiff-vertically-oriented leaves above the ear.
2. Maximum photosynthetic efficiency.
3. Efficient translocation of photysynthate into grain.
4. Short interval between pollen shed and silk emergence.
5. Small tassel size.
6. Photoperiod insensitivity
7. Cold tolerance
8. Long Grain -filling period

BARLEY

Rasmusson (1987) reviewed the work on ideotype breeding and also suggested ideal plant type of six rowed barley.

1. Short stature
2. Long awns
3. High harvest index
4. High biomass.
5. Kernel weight and kernel number were found rewarding in increasing yield.

COTTON

a. Ideotype for irrigated cultivation
b. Short stature (90-120 cm)
c. Compact and sympodial plant habit making pyramidal shape
d. Determinate in fruiting habit with unimodal distribution of bolling

e. Short duration (150-165 days)
f. Responsive to high fertilizer dose
g. High degree of inter plant competitive ability
h. High degree of resistance to insect pests and diseases, and
i. High physiological efficiency.
j. Earliness (150-165 days)
k. Fewer small and thick leaves
l. Compact and short stature, indeterminate habit
m. Sparse hairiness,
n. Medium to big boll size
o. Synchronous bolling
p. High response to nutrients
q. Resistance to insects and diseases

FACTORS AFFECTING IDEOTYPES

There are several factors which affect development of ideal plant type. These are briefly discussed below:

1. Crop Species

Ideotype differs from crop to crop. The ideotype of monocots significantly differs from those of dicots. In monocots, tillering is more important whereas in dicots branching is one of the important features of ideotype.

2. Cultivation

The ideotype also differs with regard to crop cultivation. The features of irrigated crops differ from that of rainfed crop. The rainfed crop needs drought resistance, fewer and smaller leaves to reduce water loss through transpiration. In dicots, indeterminate types are required for rainfed conditions, because indeterminate type can produce another flush of flowers if the first flush in affected by drought conditions.

3. Socio -economic Condition of Farmers

Socio-economic condition of farmers also determines crop ideotype. For example, dwarf *Sorghum* is ideal for mechanical harvesting in USA, but it is not suitable for the farmers of Africa where the stalks are used for fuel or hut constructions.

4. Economic Use

The ideotype also differ according to the economic use of the crop, for example, dwarf types are useful in *Sorghum* and pearl millet when the crop is grown for grain purpose. But when these crops are grown for fodder purpose, tall stature is desirable one. Moreover, less leafy types are desirable for grain purpose and more leafy genotypes for fodder purpose. The larger leaves are also desirable in case of fodder crop.

STEPS IN IDEOTYPE BREEDING

Ideotype breeding consists of four important steps,

1. Development of Conceptual Model

The values of various morphological and physiological traits are specified to develop a conceptual theoretical model. For example, values for plant height, maturity duration, leaf size, leaf number, angle of leaf, photosynthetic rate etc., are specified. Then efforts are made to achieve this model.

2. Selection of Base Material

Selection of base material is an important step after development of conceptual model of ideotype. Genotypes to be used in devising a model plant type should have broad genetic base and wider adaptability. Genotypes for plant stature, maturity duration, leaf size and angle and resistance are selected from the global gene pool of the concerned crop species. Genotypes resistant or tolerant to drought, soil salinity, alkalinity, diseases and insects are selected from the gene pool with the cooperation of physiologist, soil scientist, pathologist and entomologist.

3. Incorporation of Desirable Traits

The next important step in combining of various morphological and physiological traits from different selected genotypes into single genotype. Various breeding procedures, *viz* single cross, three way cross, multiple cross, backcross, composite crossing, intermating, mutation breeding, heterosis breeding etc., are used for the development of ideal plant types in majority of field crops.

4. Selection of Ideal Plant Type

Plants combining desirable morphological and physiological traits are selected in segregating populations and intermated to achieve the desired plant type. Morphological features are judged through visual observations and physiological parameters are recorded with the help of sophisticated instruments. Screening for resistance to drought,

soil salinity, alkalinity, disease and insects is done under controlled conditions.

PRACTICAL ACHIEVEMENTS

Ideotype breeding has significantly contributed to enhanced yields in cereals (wheat and rice) and millets (*Sorghum* and pearl millet) through the use of dwarfing genes, resulting in green revolution. Semi dwarf varieties of wheat and rice are highly responsive to water use and nitrogen application and have wide adaptation. **The Norin 10 in wheat and Dee-geo-Woo-gen in rice are the sources of dwarfing genes.** The genic cytoplasmic male sterile systems in *Sorghum* and pearl millet laid the foundation of green revolution in Asia (Swaminathan, 1972). Thus, ideotype breeding has been more successful for yield improvement in cereals and millets than in other crops.