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V Sem

Crop Improvement-I (Kharif crops)

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BIHAR AGRICULRAL UNIVERSITY

B. Sc. Agriculture
Theory Teaching Manual

Course Title : Crop Improvement-I (Kharif)

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Contents of APG311

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Chapter No.: 01
Centers of Origin of Crop Plants

Centers of Origin of Crop Plants

The origin of crop plants is now basic to plant breeding in order to locate wild relatives, related species, and new genes (especially dominant genes, sources of disease resistance).Knowledge of the origins of crop plants is vitally important in order to avoid genetic erosion, the loss of germplasm due to the loss of ecotypes and landraces, loss of habitat (such as rainforests), and increased urbanization. Germplasm preservation is accomplished through gene banks (largely seed collections but now frozen stem sections) and preservation of natural habitats (especially in centers of origin).

VAVILOVIAN CENTRES OF DIVERSITY:

N.I. Vavilov (1926,1951), a Russian geneticts and plant breeder, was the pioneer man who realized the significance of genetic diversity for crop Improvement. Based on his studies of global exploration and collection. Vavilov proposed eight main centres and three subsidiary centres of diversity.

The concept of centers of Origin was given by N.I. Vavilov in 1926. He identified eight main centres and three sub-centres of diversity. **He proposed or Law of Parallel variation.**

Law of Parallel variation: The concept of Parallel variation or **law of Homologous series of variation was developed by N.I. Vavilov. (1951) based on his study of crop diversity and centres of origin. Law of Homologous series of variation** states that a particular variation observed in a crop species is also expected to available in another related species also Vavilov used principle of homologous series of variation as a clue for discovering similar characters in related species.

The Eight Vavilovian Centers: Old *World*

I. **Chinese Center**: The largest independent center which includes the mountainous regions of central and western China, and adjacent lowlands. A total of 136 endemic plants are listed, among which are a few known to us as important crops.

Cereals and Legumes

1. Broomcorn millet, *Panicum miliaceum*
2. Italian millet, *Panicum italicum*
3. Japanese barnyard millet, *Panicum frumentaceum*
4. Kaoliang, *Andropogon sorghum*
5. Buckwheat, *Fagopyrum esculentum*
6. Hull-less barley, *Hordeum hexastichum*
7. Soybean, *Glycine max*
8. Adzuki bean, *Phaseolus angularis*
9. Velvet bean, *Stizolobium hassjoo*

Roots, Tubers, and Vegetables

1. Chinese yam, *Dioscorea batatas*
2. Radish, *Raphanus sativus*
3. Chinese cabbage, *Brassica chinensis, B. pekinensis*
4. Onion, *Allium chinense, A. fistulosum, A. pekinense*
5. Cucumber, *Cucumis sativus*

Fruits and Nuts

1. Pear, *Pyrus serotina, P. ussuriensis*
2. Chinese apple, *Malus asiatica*
3. Peach, *Prunus persica*
4. Apricot, *Prunus armeniaca*
5. Cherry, *Prunus pseudocerasus*
6. Walnut, *Juglans sinensis*
7. Litchi, *Litchi chinensis*

Sugar, Drug, and Fiber Plants

1. Sugarcane, *Saccharum sinense*
2. Opium poppy, *Papaver somniferum*
3. Ginseng, *Panax ginseng*
4. Camphor, *Cinnamomum camphora*
5. Hemp, *Cannabis sativa*

II. Indian Center: This area has two subcenters.

A. Main Center (Hindustan): Includes Assam and Burma, but not Northwest India, Punjab, nor Northwest

Frontier Provinces. In this area, 117 plants were considered to be endemic.

Cereals and Legumes

1. Rice, *Oryza sativa*
2. Chickpea or gram, *Cicer arietinum*
3. Pigeon pea, *Cajanus indicus*
4. Urd bean, *Phaseolus mungo*
5. Mung bean, *Phaseolus aureus*
6. Rice bean, *Phaseolus calcaratus*
7. Cowpea, *Vigna sinensis*

Vegetables and Tubers

1. Eggplant, *Solanum melongena*
2. Cucumber, *Cucumis sativus*
3. Radish, *Raphanus caudatus* (pods eaten)
4. Taro, *Colocasia antiquorum*
5. Yam, *Dioscorea alata*

Fruits

1. Mango, *Mangifera indica*
2. Orange, *Citrus sinensis*
3. Tangerine, *Citrus nobilis*

4. Citron, *Citrus medica*
5. Tamarind, *Tamarindus indica*

Sugar, Oil, and Fiber Plants

1. Sugar cane, *Saccharum officinarum*
2. Coconut palm, *Cocos nucifera*
3. Sesame, *Sesamum indicum*
4. Safflower, *Carthamus tinctorius*
5. Tree cotton, *Gossypium arboreum*
6. Oriental cotton, *Gossypium nanking*
7. Jute, *Corchorus capsularis*
8. Crotalaria, *Crotalaria juncea*
9. Kenaf, *Hibiscus cannabinus*

Spices, Stimulants, Dyes, and Miscellaneous

1. Hemp, *Cannabis indica*
2. Black pepper, *Piper nigrum*
3. Gum arabic, *Acacia arabica*
4. Sandalwood, *Santalum album*
5. Indigo, *Indigofera tinctoria*
6. Cinnamon tree, *Cinnamomum zeylanticum*
7. Croton, *Croton tiglium*
8. Bamboo, *Bambusa tulda*

B. Indo-Malayan Center: Includes Indo-China and the Malay Archipelago. Fifty-five plants were listed,
including:

Cereals and Legumes

1. Job's tears, *Coix lacryma*
2. Velvet bean, *Mucuna utilis*

Fruits

1. Pummelo, *Citrus grandis*
2. Banana, *Musa cavendishii*, *M. paradisiaca*, *H. sapientum*
3. Breadfruit, *Artocarpus communis*
4. Mangosteen, *Garcinia mangostana*

Oil, Sugar, Spice, and Fiber Plants

1. Candlenut, *Aleurites moluccana*
2. Coconut palm, *Cocos nucifera*
3. Sugarcane, *Saccharum officinarum*
4. Clove, *Caryophyllus aromaticus*
5. Nutmeg, *Myristaca fragrans*
6. Black pepper, *Piper nigrum*
7. Manila hemp or abaca, *Musa textilis*

III. Central Asiatic Center: Includes Northwest India (Punjab, Northwest Frontier

Provinces and Kashmir),
Afghanistan, Tadjikistan, Uzbekistan, and western Tian-Shan. Forty-three plants are listed for this center,
including many wheats.
Grains and Legumes
1. Common wheat, *Triticum vulgare*
2. Club wheat, *Triticum compactum*
3. Shot wheat, *Triticum sphaerocoecum*
4. Pea, *Pisum sativum*
5. Lentil, *Lens esculenta*
6. Horse bean, *Vicia faba*
7. Chickpea, *Cicer arientinum*
8. Mung bean, *Phaseolus aureus*
9. Mustard, *Brassica juncea*
10. Flax, *Linum usitatissimum* (one of the centers)
11. Sesame, *Sesamum indicum*
Fiber Plants
1. Hemp, *Cannabis indica*
2. Cotton, *Gossypium herbaceum*
Vegetables
1. Onion, *Allium cepa*
2. Garlic, *Allium sativum*
3. Spinach, *Spinacia oleracea*
4. Carrot, *Daucus carota*
Fruits
1. Pistacia, *Pistacia vera*
2. Pear, *Pyrus communis*
3. Almond, *Amygdalus communis*
4. Grape, *Vitis vinifera*
5. Apple, *Malus pumila*
IV. Near-Eastern Center: Includes interior of Asia Minor, all of Transcaucasia, Iran, and the highlands of
Turkmenistan. Eighty-three species including nine species of wheat were located in this region.
Grains and Legumes
1. Einkorn wheat, *Triticum monococcum* (14 chromosomes)
2. Durum wheat, *Triticum durum* (28 chromosomes)
3. Poulard wheat, *Triticum turgidum* (28 chromosomes)
4. Common wheat, *Triticum vulgare* (42 chromosomes)
5. Oriental wheat, *Triticum orientale*
6. Persian wheat, *Triticum persicum* (28 chromosomes)

7. *Triticum timopheevi* (28 chromosomes)
8. *Triticum macha* (42 chromosomes)
9. *Triticum vavilovianum*, branched (42 chromosomes)
10. Two-row barleys, *Hordeum distichum, H. nutans*
11. Rye, *Secale cereale*
12. Mediterranean oats, *Avena byzantina*
13. Common oats, *Avena sativa*
14. Lentil, *Lens esculenta*
15. Lupine, *Lupinus pilosus, L. albus*

Forage Plants

1. Alfalfa, *Medicago sativa*
2. Persian clover, *Trifolium resupinatum*
3. Fenugreek, *Trigonella foenum graecum*
4. Vetch, *Vicia sativa*
5. Hairy vetch, *Vicia villosa*

Fruits

1. Fig, *Ficus carica*
2. Pomegranate, *Punica granatum*
3. Apple, *Malus pumilo* (one of the centers)
4. Pear, *Pyrus communis* and others
5. Quince, *Cydonia oblonga*
6. Cherry, *Prunus cerasus*
7. Hawthorn, *Crataegus azarolus*

V. Mediterranean Center: Includes the borders of the Mediterranean Sea. Eighty-four plants are listed for
this region including olive and many cultivated vegetables and forages.

Cereals and Legumes

1. Durum wheat, *Triticum durum expansum*
2. Emmer, *Triticum dicoccum* (one of the centers)
3. Polish wheat, *Triticum polonicum*
4. Spelt, *Triticum spelta*
5. Mediterranean oats, *Avena byzantina*
6. Sand oats, *Avena brevis*
7. Canarygrass, *Phalaris canariensis*
8. Grass pea, *Lathyrus sativus*
9. Pea, *Pisum sativum* (large seeded varieties)
10. Lupine, *Lupinus albus*, and others

Forage Plants

1. Egyptian clover, *Trifolium alexandrinum*
2. White Clover, *Trifolium repens*
3. Crimson clover, *Trifolium incarnatum*

4. Serradella, *Ornithopus sativus*

Oil and Fiber Plants

1. Flax, *Linum usitatissimum*, and wild *L. angustifolium*
2. Rape, *Brassica napus*
3. Black mustard, *Brassica nigra*
4. Olive, *Olea europaea*

Vegetables

1. Garden beet, *Beta vulgaris*
2. Cabbage, *Brassica oleracea*
3. Turnip, *Brassica campestris, B. napus*
4. Lettuce, *Lactuca sativa*
5. Asparagus, *Asparagus officinalis*
6. Celery, *Apium graveolens*
7. Chicory, *Cichorium intybus*
8. Parsnip, *Pastinaca sativa*
9. Rhubarb, *Rheum officinale*

Ethereal Oil and Spice Plants

1. Caraway, *Carum carvi*
2. Anise, *Pimpinella anisum*
3. Thyme, *Thymus vulgaris*
4. Peppermint, *Mentha piperita*
5. Sage, *Salvia officinalis*
6. Hop, *Humulus lupulus*

VI. Abyssinian Center: Includes Abyssinia, Eritrea, and part of Somaliland. In this center were listed 38
species. Rich in wheat and barley.

Grains and Legumes

1. Abyssinian hard wheat, *Triticum durum abyssinicum*
2. Poulard wheat, *Triticum turgidum abyssinicum*
3. Emmer, *Triticum dicoccum abyssinicum*
4. Polish wheat, *Triticum polonicum abyssinicum*
5. Barley, *Hordeum sativum* (great diversity of forms)
6. Grain sorghum, *Andropogon sorghum*
7. Pearl millet, *Pennisetum spicatum*
8. African millet, *Eleusine coracana*
9. Cowpea, *Vigna sinensis*
10. Flax, *Linum usitatissimum*

Miscellaneous

1. Sesame, *Sesamum indicum* (basic center)
2. Castor bean, *Ricinus communis* (a center)
3. Garden cress, *Lepidium sativum*

4. Coffee, *Coffea arabica*
5. Okra, *Hibiscus esculentus*
6. Myrrh, *Commiphora abyssinicia*
7. Indigo, *Indigofera argente*

New World

VII. South Mexican and Central American Central: Includes southern sections of Mexico, Guatemala,
Honduras and Costa Rica.

Grains and Legumes

1. Maize, *Zea mays*
2. Common bean, *Phaseolus vulgaris*
3. Lima bean, *Phaseolus lunatus*
4. Tepary bean, *Phaseolus acutifolius*
5. Jack bean, *Canavalia ensiformis*
6. Grain amaranth, *Amaranthus paniculatus leucocarpus*

Melon Plants

1. Malabar gourd, *Cucurbita ficifolia*
2. Winter pumpkin, *Cucurbita moshata*
3. Chayote, *Sechium edule*

Fiber Plants

1. Upland cotton, *Gossypium hirsutum*
2. Bourbon cotton, *Gossypium purpurascens*
3. Chayote, *Sechium edule*

Miscellaneous

1. Sweetpotato, *Ipomea batatas*
2. Arrowroot, *Maranta arundinacea*
3. Pepper, *Capsicum annuum, C. frutescens*
4. Papaya, *Carica papaya*
5. Guava, *Psidium guayava*
6. Cashew, *Anacardium occidentale*
7. Wild black cherry, *Prunus serotina*
8. Cochenial, *Nopalea coccinellifera*
9. Cherry tomato, *Lycopersicum cerasiforme*
10. Cacao, *Theobroma cacao*
11. *Nicotiana rustica*

VIII. South American Center: (62 plants listed) Three subcenters are found.

A. Peruvian, Ecuadorean, Bolivian Center: Comprised mainly of the high mountainous areas, formerly
the center of the Megalithic or Pre-Inca civilization. Endemic plants of the Puna and Sierra high elevation
districts included:

Root Tubers
1. Andean potato, *Solanum andigenum* (96 chromosomes)
2. Other endemic cultivated potato species. Fourteen or more species with chromosome numbers varying from 24 to 60.
3. Edible nasturtium, *Tropaeolum tuberosum*. Coastal regions of Peru and non-irrigated subtropical and tropical regions of Ecuador, Peru and Bolivia included:

Grains and Legumes
1. Starchy maize, *Zea mays amylacea*
2. Lima bean, *Phaseolus lunatus* (secondary center)
3. Common bean, *Phaseolus vulgaris* (secondary center)

Root Tubers
1. Edible canna, *Canna edulis*
2. Potato, *Solanum phureja* (24 chromosomes)

Vegetable Crops
1. Pepino, *Solanum muricatum*
2. Tomato, *Lycopersicum esculentum*
3. Ground cherry, *Physalis peruviana*
4. Pumpkin, *Cucurbita maxima*
5. Pepper, *Capsicum frutescens*

Fiber Plants
1. Egyptian cotton, *Gossypium barbadense*

Fruit and Miscellaneous
1. Passion flower, *Passiflora ligularis*
2. Guava, *Psidium guajava*
3. Heilborn, *Carica candamarcensis*
4. Quinine tree, *Cinchona calisaya*
5. Tobacco, *Nicotiana tabacum*

B. Chiloe Center (Island near the coast of southern Chile)
1. Common potato, *Solanum tubersum* (48 chromosomes)
2. Wild strawberry, *Fragaria chiloensis*

C. Brazilian-Paraguayan Center
1. Manioc, *Manihot utilissima*
2. Peanut, *Arachis hypogaea*
3. Rubber tree, *Hevea brasiliensis*
4. Pineapple, *Ananas comosa*
5. Brazil nut, *Bertholletia excelsa*
6. Cashew, *Anacardium occidentale*
7. Purple granadilla, *Passiflora edulis*

Microcentres: Small areas within the centres of diversity exhibit tremendous genetic diversity of some crop plants. These areas referred as micro-centres. Microcentres are important source of collecting valuable plant forms and also for the study of evolution of cultivated species.

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 with in 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.. According to IPGRI (1993), PGR include the following categories of plants:
i) Cultivated varieties (cultivars) in current use;
ii) Newly developed varieties;
iii) Obsolete cultivars;
iv) Primitive cultivars (land races);
v) Wild and weedy relatives of cultivated varieties and
vi) Special genetic stocks (including elite and current breeders' line and mutants)

Kinds of Germplasm

The germplasm consists of various plant materials of a crop such as
land races , advanced (homozygous), breeding materials,obsolete cultivars, wild forms of cultivated species , modern cultivars, wild relatives, mutants

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

2. **Obsolete Cultivars**

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

3. **Modern cultivars**

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

4. **Advanced breeding lines**

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

5. **Wild forms of cultivated species**

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

6. **Wild Relatives**

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

7. **Mutants**

Mutation breeding is used when the desired character is not found in the genetic stocks of cultivated species and their wild relatives. Mutations do occur in nature as well as can be induced through the use of physical and chemical mutagens. The extra variability which is created through induced mutations constitutes important components of genepool. Mutant for various characters sometimes may not be released as a variety, but they are added in the

genepool. The germplasm includes those carrying gene mutations, chromosomal aberrations and markers genes etc. are considered special genetic stocks. They are useful in breeding programmes.

The gene pool system of classification

The pool of a crop includes all cultivars, wild species and wild relatives containing all the genes available for breeding use.
Based on degree of relationship, the gene pool of crops can be divided into three groups (Harland and Dewet, 1971) , *viz.*,

- ✓ **Primary gene pool**
- ✓ **Secondary Gene pool**
- ✓ **Tertiary gene pool**

These are briefly discussed below:
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.

Secondary gene pool (GP2) : This type of gene pool is also known as gene pool two (GP2). The genetic material that leads to partial fertility on crossing with GP1 is referred to as secondary gene pool. It includes plants that belong to related species. Such material can be crossed with primary gene pool, but usually the hybrids are sterile and some of the progeny to some extent are fertile. Transfer of gene from such material to primary gene pool is possible but difficult.
Tertiary gene pool (GP3) : The genetic material which leads to production of sterile hybrids on crossing with primary gene pool is termed as tertiary gene pool or gene pool three (GP3). It includes material which can be crossed with GP1, but the hybrids are sterile. Transfer of genes from such material to primary gene pool is possible with the help of special techniques.

Types of seed collections
Based on the use and duration of conservation, seed collections are of three types

- **Base collections**
- **Active collections**
- **Working collections**

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 upto 100 years.

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 programme. These collections are used for evaluation, multiplication and distribution of the accessions. They are usually maintained by multiplying the seeds of their own accessions. But from time to time, base collection material should be used for regeneration of these collections. Germination test is carried out after every 5-10 years to assess the reduction in seed viability.

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 collections.

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

Exploration

Exploration refers to collection trips and collection refer to tapping of genetic diversity from various sources and assembling the same at one place. The exploration and collection

is a highly scientific process. This process takes into account six important items, *viz*, (1) sources of collection, (2) priority of collection, (3) agencies of collection, (4) methods of collection, (5) methods of sampling and (6) sample size.

Merits and Demerits

There are several merits and demerits of exploration and collection of germplasm, some of which are as discussed below:

Merits:

1. Collection helps in tapping crop genetic diversity and assembling the same at one place.
2. It reduces the loss of genetic diversity due to genetic erosion.
3. Sometimes, we get material of special interest during exploration trips.
4. Collection also helps in saving certain genotypes from extinction.

Demerits:

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

2. **Germplasm conservation**

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

Germplasm conservation refers to maintain the collected germplasm in such a state that there is minimum risk for its loss and that either it can be planted directly in the field or it can be prepare for planting with relative ease when ever necessary. There are two important methods of germplasm conservation or preservation *viz.*,1. In situ conservation 2. Ex situ conservation

***In situ* conservation**

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

This method of preservation has following main disadvantages

Each protected area will cover only ve ry small portion of total diversity of a crop species, hence several areas will have to be conserved for a single species.

The management of such areas also poses several problems.
This is a costly method of germplasm conservation

Merits : Gene sanctuaries offer the following two advantages.
A gene sanctuary not only conserves the existing genetic diversity present in the population, it also allows evolution to continue. As a result, new alleles and new gene combinations would appear with time.
The risks as sociated with ex situ conservation are not operative.

2**. *Ex situ* conservation**

Conservation of germplasm away from its natural habitat is called ex situ germplasm conservation. This method has following three advantages.
It is possible to preserve entire genetic diversity of a crop species at one place.
Handling of germplasm is also easy
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**

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

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.

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.

6. It helps in acclimatization and purification of the material.

6. **Utilization**

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

a) Cultivated Germplasm

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

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

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.

Table 4: Estimates of germplasm holdings in major national PGR systems and international centres

Country/IARC	Categories concerned	Total
USA	All crops	557,000
China	All crops	400,000
	Rice (National Rice Research Institute)	61,000
	Wheat (National Gene Bank)	40,000
USSR	All crops	325,000
IRRI	Rice	86,000
ICRISAT	Sorghum, millet, chickpea, peanut, pigeon pea	86,000
ICARDA	Cereals, legumes, forages	77,000
India	All crops	76,800
CIMMYT	Wheat, maize	75,000
CIAT	Common bean, cassava, forages	66,000
IITA	Cowpea, rice, root crops	40,000
CIP	Potato, sweet potato	12,000

There are two broad approaches to PGR conservation and these are:1) *In situ* conservation and

2) *Ex situ* conservation

In situ conservation: Demands the establishment of nature or biosphere reserves, national parks, or special legislation to protect endangered species. UNEP (1992) defined it as the conservation of ecosystem and natural habitats, and the maintenance and recovery of viable population of species in their natural habitats or where they have developed their distinctive properties.

Ex situ conservation: *Ex situ* conservation is the conservation and maintenance of samples of living organisms outside their natural habitat, in the form of whole plants, seed, pollen, vegetative propagules, tissue or cell cultures. Vavilov was the first to recognize the value of genetic diversity and created first modern seed bank in St Petersburg. Botanic gardens and arboreta: Botanic gardens are the gardens which maintain collections of live plants

mainly for study, scientific research, conservation and education. Botanic gardens have a dual mission of conservation and education. It also play role in recreation and tourist attraction. According to Chakravarthy and Mukhopadhyay (1990), a botanic garden can broadly be called a living repository or refugia of plants arranged and maintained on some scientific basis and where the collections are usually labeled or marked for identification. Botanic gardens are central in the *ex situ* conservation and exploration of the global plant biodiversity.

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 (Jorge *et al.* 2010). 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. Genebanks 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 as long as some important factors were taken into consideration. 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. In addition, production of transgenic tree species and molecular breeding procedures require functional cryopreservation protocols.Three major genetic risks in *ex situ* collections are genetic drift, adaptation to cultivation and mutation accumulatio

Chapter No.: 03
FLORAL BIOLOGY

The Flower:

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 particular vertical 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.

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. 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.

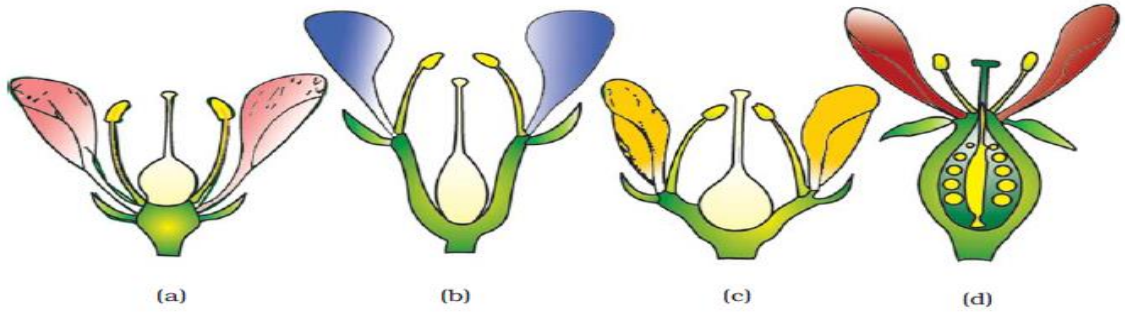

Figure 1: Position of floral parts on thalamus: (a) Hypogynous (b) and (c) Perigynous (d) Epigynous

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

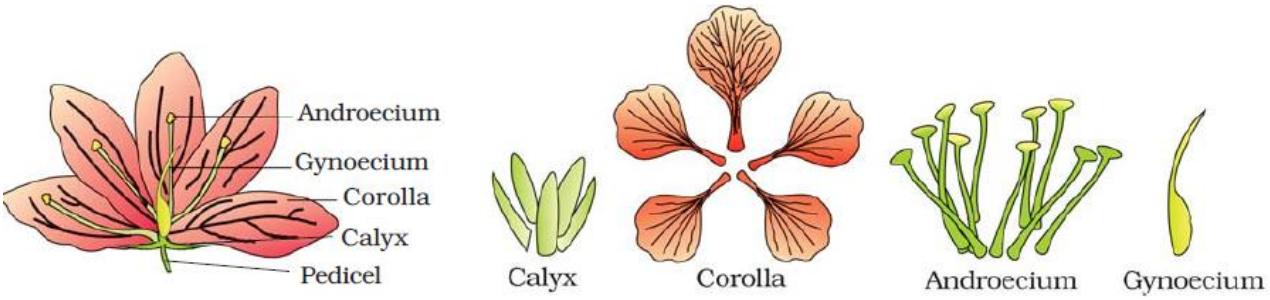

Figure 2 : Parts of a flower

(gamopetalous) or united (polypetalous). 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.3). 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.

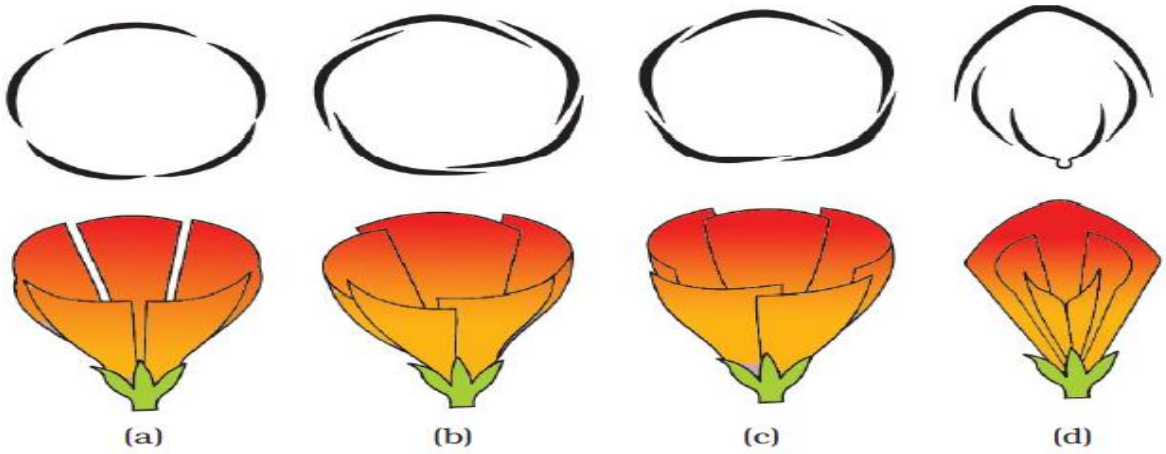

Figure 3: Types of aestivation in corolla: (a) Valvate (b) Twisted (c) Imbricate (d) Vexillary

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 fertilisation, the ovules develop into seeds and the ovary matures into a fruit

Chapter No.: 04
Study of genetics of qualitative and quantitative characters

MENDELIAN TRAITS VS POLYGENIC TRAITS:

The history of plant breeding is about 12000 years old when it started with the cultivation of useful crop plants in captivity of human beings. Since the plants have lived with human beings and the process have become so interdependent that their coexistence has become inevitable. Over years civilization has changed resulting in tremendous increase in human needs, as a result of which man has always attempted to change plants to his own benefit. Plant breeding is the art and science of the genetic improvement of plants through the process of selection for various Agronomically important characters and plant breeding efforts always include an element of chance, because number of genotypes and environments and consequent phenotypes to be evaluated are limitless.

Qualitative traits:

The rediscovery of Mendelian principles in the beginning of 20th century totally revolutionized the manipulation of crop plants. Mendel was the first to offer simple and reasonable explanation for the process of heredity. Mendel observed seven clearcut visible traits (Table 1) in garden pea (*Pisum sativum*) and postulated laws of inheritance of characters.

Table 1. Contrasting qualitative characters handled by Mendel

Sl.No.	Character	Dominant form	Recessive form
1.	Seed shape	Round	Wrinkled
2.	Cotyledon colour	Yellow	Green
3.	Seed coat colour	Grey	brown White
4.	Pod shape	Inflated	Constricted
5.	Unripe pod colour	Green	Yellow
6.	Flower position	Axial	Terminal
7.	Stem length	Long	Short

The work of Mendel forms the basis of genetics and the analysis of his data provides one of the classic examples in genetic data analysis. Interestingly Mendel's success relied on the existence readily recognizable, distinct phenotypes arising from different forms of a gene, called alleles. Allelic differences cause the morphology, physiology or behaviour of the organism to alter in such a way as to catch the eye of the experimenter. Allelic differences of this sort produce phenotypic differences which are clear-cut and not greatly influenced by environment. Such pronounced differences are called qualitative differences and arise from major allelic differences at one or two genes. These genes are called major genes.

Quantitative traits:

The mathematical foundations for the study of quantitative variation were first laid by Galton (1989). He studied the physical and mental characteristics of human beings. He observed that taller individuals, produced taller children on an average. To measure the degree to which such characteristics were inherited, new biometical techniques such as correlation and regression were developed by Galton and his students. He established that hereditary transmissions is equilinear from the two parents leading to the proposal of Law of Ancestral Heredity. Thus, although segregation and assortment of individual hereditary factors could not be determined, the "biometricians" were able to demonstrate statistically that there was resemblance between relatives with respect to numerous quantitative characters. In the absence of detailed knowledge about genes it appeared to them that many of the quantitative traits were determined by mixing or blending process. After the discovery of Mendels' work (1900) different views formed the basis for the two main groups among geneticists, namely "Mendelians" who proposed that heritable characters were qualitative and discontinuous (discrete) in distribution and "biometricians" who believed that the heritable variation was basically quantitative and continuous in distribution. Johannsen (1909), in demonstrating the occurrence of quantitative genetic variation, stated that both heritable and non heritable factors were responsible for variations observed in the seed weight of beans (*Phaseolus vulgaris*)

Original Seed lot => Seed weight 15 cg ↔ 90 cg Selected 19 seeds Selfing 19 pure lines => 1st pure line - heavy - average 64 cg 19th pure line – light – average 35 cg Observations:

1. There were intergrades between 35 and 64 cg.
2. Within each purline, seeds of various weight occurred.

However, variability with in each pureline was less. Johannsen provided evidence to show that this variability was not genetic in origin but was due to slight differences in various environmental factors which affected individual plants to different degrees. Johannsen's experiment helped to explain that continuous variation observed for quantitative traits resulted from joint action of genotypes and environment. Yule (1906) proposed that continuous quantitative variation could result from a large number of genes, each giving smaller effect on the characters measured. Nilsson – Ehle (1909) investigated kernel colour of wheat. There were three genes Aa, Bb, Cc involved in determination of kernel colour. A B C (red) were dominant over a b c (white). Each of these 3 gene pairs (Aa / Bb / Cc) segregated in a Medelian fashion, such that selfing the heterozygote Aa produced 3 red (A-) and 1 white (aa); two gene pairs segregated in 15: 1 and three gene pairs in 63 : 1 ratio. It was observed that each dominant gene added a degree of redness to kernel. From this study it was realized that phenotypic expression was proportional to the factor dosage and phenotypic variation would be continuous. Continuity would be completed by the blurring effect of non-heritable agencies. Because there were appropriately named " multiple factor". The effects of multiple factors are usually too small to be traced; they cannot be individually isolated.

The form "multiple factor" was replaced by "Polygene" by Mather (1941). Polygenes are genes with small effect on a particular character which suppliment each others effects to produce observable quantitative changes. These quantitative effects are in some cases additive.

Table 2: Features of qualitative and quantitative traits

Sl.No.	Qualitative traits	Quantitative traits
1.	Discrete classification is possible	. Variation is continuous
2.	Governed by few genes – major genes or oligogenes. Effect of each gene is detectable	Governed by many genes, each with small additive effect. . The effect of each gene cannot be measured.
3.	The effect of environment is nil or very less.	Environmental effect is large.
4.	Decline in vigour consequent to inbreeding & regain in vigour due to hybridization cannot be seen	Can be seen

Chapter No.: 05

Important concepts of breeding self pollinated, cross pollinated and vegetatively propagated crops

Various approaches (*viz.,* selection, hybridization, mutation, etc) that are used for genetic improvement of crop plants are referred to as plant breeding methods or plant breeding procedures or plant breeding techniques. The choice of breeding methods mainly depends on the mode of pollination, mode of reproduction, gene action and breeding objective of crop species. Plant breeding methods are generally classified on the basis of application of crop improvement (general methods, special methods and population improvement approaches) and hybridization (meth ods involving hybridization and methods not involving hybridization).

Various breeding procedures that are more commonly used for the genetic improvement of various crop plants are known as general breeding methods. Such breeding methods include introduction, selection (pure line selection, mass selection, progeny selection), hybridization (pedigree, bulk and backcross methods), heterosis breeding, synthetic and composite breeding. On the other hand, those breeding procedures that are rarely used for improvement of crop plants are referred to as special breeding methods. Such

methods include: mutation breeding, polyploidy breeding, wide crossing or distant hybridization and biotechnology. Four breeding approaches, *viz.,* recurrent selection, disruptive matin g and selection, diallel selective mating system and biparental mating are used mainly for population improvement.

Classification of Plant Breeding Methods

Basis of classification and Types of methods	***Breeding methods included***
A. Application in crop improvement	

(1) General Methods	Plant introduction, Pure line selection, mass selection, progeny selection, pedigree method, bulk method, back cross method, SSD, clonal selection, heterosis breeding, synthetics and composites.
(2) Special Methods	Mutation breeding, Polyploidy breeding, transgenic breeding, molecular breeding.
(3) Population Improvement	Recurrent selection, disruptive selection, diallel selective approaches mating system, biparental mating.

B. Hybridization

(1) Methods involving hybridization	Pedigree, bulk, backcross and SSD Methods: heterosis breeding, and population improvement approaches and molecular breeding (marker aided selection).
(2) Methods not involving hybridization	Plant Introduction, pureline selection, mass selection, progeny selection, clonal selection, mutation breeding and transgenic breeding.

There are some differences in the breeding methods used for self pollinated and cross pollinated species. Self pollinated species are homozygous, hence we can start hybridization directly. Cross pollinated species, on the other hand, are highly heterozygous. Hence we can not start hybridization directly. First we have to develop inbred lines by selfing or inbreeding and then only hybridization can be taken up. We have to exploit homozygosity in self pollinated crops and heterozygosity in cross pollinated species. Asexually propagated species such as sugarcane, potato, sweet potato, etc., are highly heterozygous. Hence, F_1 hybrids in

such crops exhibit segregation and selection can be practiced in F_1 generation. The superior clones are identified and further multiplied. The maintenance or conservation of hybrid vigour is easy in such crops because of asexually propagation.

Methods of Breeding Autogamous species

Plant breeding methods that are used for genetic improvement of self pollinated or autogamous species include:

1. Plant Introduction
2. Pureline selection
3. Mass selection
4. Pedigree method
5. Bulk method
6. Single seed descent method
7. Backcross method
8. Heterosis breeding
9. Mutation breeding

10. Polyploidy breeding

11. Distant hybridization

12. Transgenic breeding.

Four breeding approaches, *viz.*, recurrent selection, disruptive selection, diallele selective mating, and biparental mating are used for population improvement.

Methods or Breeding Allogamous species

Breeding methods that are used for genetic improvement of cross pollinated or allogamous species include

(1) Plant introduction
(2) Mass and progeny selection
(3) Backcross method
(4) Heterosis breeding
(5) Synthetic breeding
(6) Composite breeding
(7) Polyploidy breeding
(8) Distant hybridization
(9) Transgenic breeding

Mutation breeding is rarely used in allogamous species. Three breeding approaches *viz.*, recurrent selection, disruptive mating and biparental meting are used for population improvement.

Methods of Breeding Asexually Propagated Species

Important breeding methods applicable to asexually propagated species are

(1) Plant Introduction (2) Clonal selection (3) Mass selection
(4) Heterosis breeding (5) Mutation breeding (6) Polyploidy breeding
(7) Distant hybridization

(8) Transgenic breeding.

Mass selection is rarely used in asexually propagated species.

Brief account of breeding methods

Plant introduction is applicable to all three groups of crop plants, *viz.*, self pollinated,

cross pollinated and asexually propagated species. It is an old est and rapid method of crop improvement. The introduced material may be used in three ways *viz.*,

(1) Directly as a variety

(2) As a variety after selection

(3) As a parent in the hybridization for development of variety or hybrid

Pureline selection is applicable to self pollinated species. It is also used sometimes in cross pollinated species for development of inbred lines. A single best pure line is released as a variety. Thus a pureline variety is homozygous and homogeneous population.

Mass selection is common in cross pollinated species and rare in self pollinated and asexually propagates species. In self pollinated crops, a mass selected variety is a mixture of several purelines. Thus it is a homozygous but heterogeneous population. In cross pollinated species, a mass selected variety is a mixture of several hetero and homozygotes. Thus, it is a heterozygous and heterogeneous population

Progeny selection is used in cross pollinated species. A variety developed by this method is heterozygous and heterogeneous population because it consists of several hetero and homozygotes.

Pedigree method is applicable to both self and cross pollinated species. In self pollinated crops progeny of a single best homozygote is released as a variety. Thus a variety developed by this method has a homozygous and homogeneous population. In cross pollinated species, it is used for developed of inbred lines. Bulk nad single seed descent methods are used in self pollinated species. Progeny of a single best homozygote is released as a varie ty by these methods. Thus, varieties developed by these methods are homozygous and homogeneous.

Backcross method is applicable in all three groups of crop species. This method is used for transfer of oligogenic characters from a donor source to a well adapted variety. This method is also used for development of multilines, Isogenic lines and transfer of male sterility. This method is more effective in transferring oligogenic characters than polygenic traits. The end product of backcross method is similar to parent variety expect for the character which has to be transferred from the donor source.

Multiline varieties are developed in self pollinated species. They are mixture of several Isogenic lines, closely related lines or unrelated lines. Thus a multiline variety is a homozygous but heterogeneous population.

Clonal selection is used in asexually propagated species. In this method progeny of a single best clone is released as a variety. Such variety has heterozygous but homogeneous population.

Heterosis breeding is used in/all the three groups. However, it is common in cross pollinated and asexually propagated species and rare in self pollinated species. A hybrid variety has homogeneous but heterozygous population. Synthetic and composite varieties are developped in cross pollinated species. Such varieties consist of several homozygotes and heterozygotes and thus constitute a heterogeneous population.

Mutation breeding is common in self pollinated and asexually propagated species and rare in cross pollinated species. A mutant variety differs from parent variety in one or few characters. A mutant differs from a segregant in two main ways. Firstly, the frequency of segregants is very high and that of mutant is extremely low (0.1%). Secondly, mutant differs from parent variety in one or few characters, where as a segregant differs from parent material in several characters.

Polyploidy breeding is common in asexually propagated species and rare in self and cross pollinated species. A polyploidy variety differs from parent variety in chromosome numbers and exhibit gigant morphological characters.

Distant hybridization is used in all the three types of crop species. However, this method is used for transferring some desirable genes from wild species to the cultivated ones. Generally, backcross method is used for transfer of oligogenic characters and pedigree method for transfer of polygenic characters.

Transgenic breeding is applicable to all three types of crop species. This method is used to solve specific problems which can not be solved by conventional breeding techniques. This method will serve as a tool and can not be used as a substitute for conventional breeding methods.

Recurrent selection is common in cross pollinated species and rare in other two

groups. It is used for accumulating favourable genes in a population *i.e.,* for population improvement. Other approaches which are used for population improvement include disruptive mating, diallel selective mating (DSM) and biparental mating. DSM is used in self pollinated species and other two techniques can be used both in self and cross pollinated species.

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Chapter No.: 06

Major breeding objectives and procedures including conventional and modern innovative approaches for development of hybrids and varieties of Major Kharif crops for yield, adaptability, stability, abiotic and biotic stress tolerance and quality (physical, chemical, nutritional)

RICE (*Oryza sativa*) 2n = 24

Rice is a staple food for above 60% world‟s population. It is called as the queen of cereals occupying 11% of world crop area. India is the foremost country of the world in area of rice cultivation and second to China in rice production. In India rice in cultivated in about 45 million ha area with production of 106.65 million tons (2013-14). It is cultivated from 8^0N to 35^0N latitudes and the crop grows under widely varying conditions of rainfall, altitude and climatic conditions. Presently, the area under irrigated ecosystem is about 20.6 million ha with productivity of 3.6 ton ha and the rainfed area is 24.4 million ha with uncertainty of available water. Though rice production has increased about three folds from 30 million tons (1966) to 106.65 million tons (2013-14), but likely demand of rice of 143 million ton by 2025 has to be met by increased productivity as there is little scope to increase in rice area in future.

Origin: S.E. Asia
Distribution:
Rice is one of the oldest cultivated crops. The two cultivated species of rice are
***Oryza sativa* - Asian rice**
***O. glaberrima* - African rice.**

Oryza sativa (Asian rice) and *Oryza glaberrima* (African rice) are the only cultivated species in the genus Oryza, although there are about 22 wild species. Based on extensive historical, archeological genetic and cytogenetic evidences, researchers inferred that the large belt extending from North Eastern hills in India to the mountain ranges of the mainland South East Asia and South West China could be the primary center of origin of *O. glaberrima*. Ecogenetic differentiation due to migration, selection led to the various centers of diversity of cultivated rice in the foot hills of Himalayas, Chattisgarh area of Madhya Pradesh, Jeypore tract of Orissa in India, Myanmar, North parts of Thailand, Yunnan Province of China etc. for Asian rice and river Niger basin and areas around Guinean coast for African rice. It is believed that the Asian cultivated rice *O. sativa* has originated from perennial floating wild rices of Asia and African cultivated rice from natural wild rices in tropical West Africa.

Crop Systematics and Species Relationship

Rice belongs to the genus *Oryza* of the tribe Oryzae under the sub- family Oryzoidae in the grass family Graminae (Poaceae). Around 20- 25 species are recognized and are broadly grouped into

four complexes viz., Sativa, Officinalis, Ridley and Meyeriana (Table1). The Sativa complex comprises the cultivated species of *O. sativa* and *O. glaberrima* and their weedy/wild ancestors. Based on cytological investigations, the species relationship as understood revealed that the genus includes diploid (*O. sativa, O. glaberrima* and their wild relatives, *O. officianlis, O. australiensis* and *O. punctata*) with 2n=24 chromosomes and tetraploid (*O. minuta, O. latifolia, O. alta, O. Punctata, O. malamphuzhaensis, O. grandiglumis, O. longiglumis* and *O. ridelyi*)
with 2n=48 chromosome species. Genome analysis done on the basis of chromosome pairing behaviour and fertility in the inter-specific hybrids, these species were grouped under six distinct genomes designated as A, B, C, D, E and F.
The grains of wild rices, *O. rufipogon* are essentially similar to those of cultivated rices, only that they are more slender, owned and are shed easily to facilitate easy dispersal. Cultivated rices are predominantly self fertilize while wild rices are largely cross fertilized, pollination taking place by wind.

Table1. Species complexes and classification of different species under genus Oryza

Species	**Ploidy**	**Genome**	**Chr. No. (2n)**	**Distribution**
I.S*ativa C*omplex				
O. sativa	Diploid	AA	24	World wide
O. glaberrima	Diploid	$_{A}g_{A}g$	24	Africa
O. barthii	Diploid	$_{A}g_{A}g$	24	Africa
O. longistaminata	Diploid	$_{A}g_{A}g$	24	Africa
O. nivara	Diploid	AA	24	Tropical Asia (India)
O. rufipogon	Diploid	AA	24	Tropical Asia
O. mesidionalis	Diploid	AA	24	Tropical Australia
O. glumaepetula	Diploid	AA	24	South America
II. *Officinalis*				
Complex				
O. officinalis	Diploid	CC	24	Tropical Asia to New Guinea
O. eichingeri	Diploid	CC	24	East and West Africa
O. rhizomatis	Diploid	CC	24	Sri Lanka
O. minuta	Tetraploid	BBCC	48	Philippines, New Guinea

O. punctata	Diploid	BB	24	North East Tropical Africa
	Tetraploid	BBCC	48	North East Tropical Africa
O. latifolia	Tetraploid	CCDD	48	Latin America
O. grandiglumis	Tetraploid	CCDD	48	South America
O. australiensis	Diploid	EE	24	Australia
III. *Meyeriana*				
Complex				
O. granulata	Diploid	FF	24	South and South East Asia
O. meyeriana	Diploid	FF	24	South East Asia
O. brachyantha	Tetraploid	-	48	Africa

O. schlechteri	Tetraploid	-	48	New Guinea
IV. *Ridleyi* Complex				
O. longiglumis	Tetraploid	-	48	New Guinea
O. ridleyi	Tetraploid	-	48	South East Asia

Evolution and Domestication

Many authors suggested that evolution of *O. sativa* from the perennial *O. rufipogon* would have been mediated through an annual wild species. *O. perennis* was believed to be common ancestor for both the cultivated species that had diverted into *O. nivara* and *O. barthii* and got domesticated in South and South-east Asia and Tropical West Africa respectively. Cultivated rice is a secondary balanced polyploid derived from an ancestral graminaceous species with a basic chromosome number of 5. During the evolutionary process, two of the chromosomes were duplicated resulting in two types of plants viz., 2n-14, and 2n=10. The amphidiploid of the cross between two variants (2n=12) resulted in the cultivated rice and its wild ancestors with 2n=24 chromosomes. The Asian rice comprises of a perennial wild species *O. rufipogon* an annual wild species *O. nivara*, while *O. longistaminata* and *O. barthii* are the perennial and annual wild progenitors of *O. glaberrima* respectively.

The subspecies or varietal groups of *O. sativa* viz., *indica*, *japonica* and *javanica* evolved due to natural and human selection for desired quality and adaptation to new niches. They are believed to have evolved from three different populations of *O. nivara* then existed in different regions. The hill rices of South- East India, the *japoncia* like types of South-West China and the hill rices of Indo- China are said to have directly evolved from the annual wild species in the respective regions.

The *aus* ecotype of West Bengal is believed to be evolved from upland rices of South-East India, while *aman* type from introgression of *rufipogon* genes into *aus* type in the lower Gangetic valley. Similarly, the s*ali* type of Assam had evolved from introgression of *O. rufipogon* genes into *japonica* like type in the Brahmaputra valley. Migration of hill rices of mainland South East Asia to Indonesia following introgression of genes from *O. rufipogon* had led to the evolution of *javanica* type. The ecotypes of *O. sativa* evolved with the following characteristics:

Indica*: *Indica rices are well adapted to, and occur in the tropical and sub-tropical Asia (India, Southern China, Vietnam, Thailand, Myanmar, the Philippines, Bangladesh, Sri Lanka etc.). These are tall plants with weak stems, long and droopy leaves, sensitive to low temperature and photoperiod.

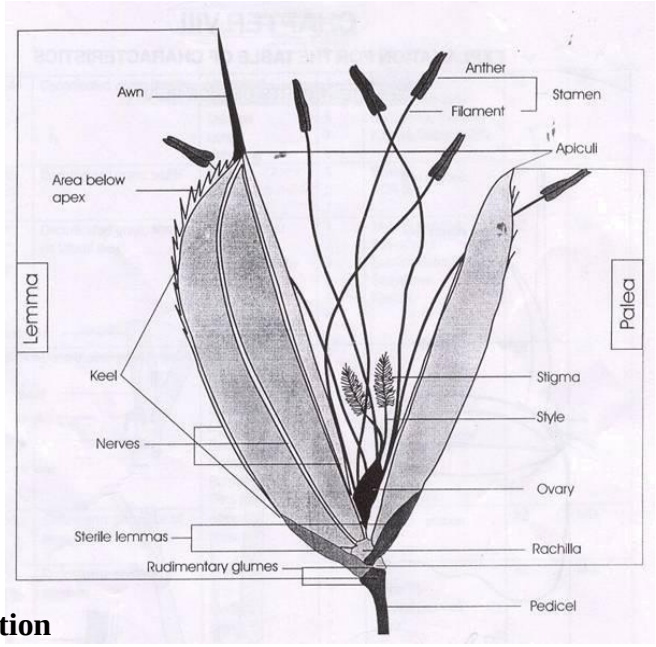
***Japonica* (*Sinica*):** adapted to sub-tropical and temperate regions of Korea, Japan, North China,

etc. These are characterized by more leaves, few tillers and are relatively resistant to shattering. The grains are short, broad and lower in amylose content that makes the grain sticky when cooked.

***Javanica*:** These are the intermediate types which were selected in Indonesia from tropical varieties. They are tall, thick stemmed, low tillering, resistant to shattering and have broad stiff leave, long awns and large bold grains.

Floral Biology

Rice is predominantly a self pollinated crop, although cross pollination occurs to an extent of 5 per cent. However, higher out crossing is observed in wild relatives of rice such as *O. longistaminata* and *O. sativa f* sp*ontanea*. The inflorescence of rice is a terminal panicle consisting of primary, secondary and tertiary branches. The panicle bears single flowered spikelets. Each individual spikelet consists of two short sterile lemmas (outer glumes) a normal fertile lemma and palea. The fertile lemma is either awnless or short or long owned. The fertile lemma and palea enclose the sexual organs which consist of six stamens and a pistil. The stamens are composed of bilobed anthers borne on the slender filaments, while the pistil consists of an ovary with a ovule and two feathery stigma lobes borne on feathery bifid stigma. At the base of lower two transparent lodicules which play a predominant role in the opening of the floret are present. In general there will be around 150-200 spikelets per panicle.



Rice Inflorescence

Anthesis and Pollination

Spikelet in a panicle bloom in nearly fixed order. Spikelets on the top branches open first and the spikelets on the lower branches open last. It takes 4 to 7 days for complete opening of all the spikelets in a panicle. The anthesis of rice inflorescence normally occurs between 10 a.m. and 2.0 p.m., although weather conditions influence floret opening to a great extent and also with the type of cultivars. Anther dehiscence may coincide with opening of lemmas to shed pollen on the

stigma. The lemma and palea close after the pollen grains are shed from the anther sacs. From anthesis, the panicle takes around 30-35 days to grain maturity. The fruit is known as caryopsis enclosed by lemma and palea that forms the husk.

Objectives of Rice Breeding

Increasing production is achievable by capturing the yield potential of the existing varieties, stabilizing and increasing yield through developing varieties with resistance to biotic and abiotic stresses are the main breeding objectives for rice.

Enhancing Yield: Rice yields ranged from as little as 1 t/ha in many countries of Africa to more than 6 t/ha in China, Japan and South Korea. Genetic improvements in rice and the development of modern rice varieties, along with improved cultivation practices, account for the impressive growth in the production. To meet the increasing demand for rice, development of varieties with high yield potential by combining morphological characteristics like semi-dwarf high tillering, thick culms, compact panicles, erect leaves to reduce shading and utilize solar radiation efficiently and physiological characteristics like early maturity, photo-insensitivity and fertilizer responsiveness. The broadening the genetic base of the present day high yielding varieties necessitates the initiation to identify tall landraces with diverse and still unexploited yield genes and pool the harmonious ones by convergent recombination breeding for evolving varieties with higher yield potential.

Stability and Adaptability: Stability particularly in yield refers to the ability of the plant genotype to express yield potential over a wide range of environments. The rice crop is grown over a wide range of climatic conditions and soil types including drought prone areas between 45^0N and 40^0S and over land from sea-level up to 3000 meters above the sea level. Hence we need to develop varieties for different agro-ecological situations. Constraints to productivity of rice crop due to seasonal fluctuations, such as low light intensity, floods, submergence, drought and others factors need to be taken into account to develop varieties that are suited to a specific location. Characterization and demarcation of areas on the basis of their relative vulnerability to weather aberration help in develop varieties to utilize still unexploited and under exploited seasonal variations to maximize the productivity potential.

Disease and Pest Resistance: The rapid development of dwarf high yielding rice varieties and their spread together with high management and intensive cultivation resulted in the outbreak of pests and diseases. Yield losses due to pests and diseases were estimated to be around 10-51% (Kalode and Krishnaiah, 1991). Rice harbours about hundred pests of which atleast twenty are important. Besides age old problem of blast and brown spot, rice crop today suffers from viral, bacterial and other fungal diseases as well as from many insect-pest damage. Development of virulent strains of pathogen and rapid emergence of insect biotypes emphasizes the need to pyramid different resistant genes into an elite genetic background. Identification of suitable novel donor sources as well as understanding their genetic control of inheritance is necessary for the development of varieties with resistance/tolerance to the specific pests/diseases and deployment in target areas. Crop management following the Integrated Pest Management as well as Integrated Disease Management also plays an important role in resistance breeding strategies.

Quality: Rice grain quality is a combination of many characteristics that affect its market value and utilization as food. Breeding objectives for quality in rice may be grouped into four classes: Market quality, Milling quality, Cooking and processing quality, and Nutritional quality.

Market quality: Market quality refers to the general appearance and physical properties of rice grain such as size, shape, uniformity of grain, hull pubescence, translucency, colour, freedom from chalkiness of kernel, etc. Depending on the geographical region, the preference of various quality traits also varies. Rice is classified in the market as long grain, medium grain or short grain as well as length/width ratio, thickness and grain weight. Each grain type possesses specific milling, cooking and eating qualities.

Milling quality: The unhusked rice grain is called rough rice or paddy. It is converted to brown rice by shelling the hulls and converted to milled rice by removing off the outer bran layers. The milling quality is determined by the yield and head rice (whole and broken grains of three quarter size or larger) to total rice, short and medium grain cultivars normally give larger mill yields than long grain cultivars. The milling output or recovery of head rice of advanced breeding lines need to be evaluated rigidly to ensure that newly released cultivars will produce high yields of head rice and total milled rice.

Cooking and processing quality: Cooking quality of rice is determined by physico-chemical properties of starch. Among them, amylose content determines the relative stickiness or dryness of cooked rice. Varieties with high amylose (> 25%) content cook dry and flaky, while those low amylose content cook sticky. Gelatinization temperature (GT), determines resistance to cooking. In India, moderate GT as well as intermediate amylose content is preferred.
Water uptake, amylose content and alkali reaction which measures gelatinization temperature are rated as predictors of cooking and processing characteristics. High amylose content, medium G and low water absorption characterize long grain cultivars whereas low amylose, low GT and high water absorption characterize medium and short grain cultivars.

Nutritional quality: Breeding for improved nutritional quality would be beneficial if it could be accomplished without any yield loss. Protein averages about 8% in brown and 7% in milled rice. Although relatively low in protein compared to other cereals, the nutritional value rice protein is high due to its favourable balance of amino acids. Milled rice is relatively poor in fat, protein and a number of vitamins and micronutrients, particularly deficient in lysine, vitamin A, iron and zinc. Biofortification for enrichment of vitamin A as well as micronutrients into elite genetic background is also an important objective of breeding for quality. Gene sources for high iron (Nilagrosa, Jalmagna, Tong Lan, Mo Mi, Azucina) and zinc (Conjay Roozay, Zuchem, Xua Bue Nuo) are an important resources for the improvement of quality in rice.

Aromatic rices: Among the best quality rices which are grown in India, the aromatic rices, Basmati rice are important fetching highest premium in the International market for its unique quality. The Basmati rices are characterized by long slender superfine grains with pleasant aroma, extra elongation of kernel and soft texture, palatability, easy digestibility of cooked rice which is unmatched by any other rice variety. Besides Basmati, India also owns a large number

of non-Basmati aromatic rice varieties grown and adapted to the specific agro-ecological conditions of the different rice growing regions of the country.

The traditional Basmati cultivars are tall, prone to lodging, photoperiod and temperature sensitive and very low yielding. Therefore, to combine the quality attributes of basmati rice in the high yielding background, a systematic programme on genetic improvement of Basmati rice was initiated at Indian Agricultural Research Institute, New Delhi and other state Agricultural Universities. This resulted in the development of varieties like Basmati-217, Type-3, Basmati-370, Taraori Basmati, Basmati-386 and Ranbir Basmati, Sabarmati, Impoved Sabarmati, Pusa 33 etc. which laid foundation for the Basmati breeding programme.

Pusa Basmati-1, the first semidwarf photoperiod insensitive and high yielding Basmati rice variety has revolutionized the Basmati rice production. This variety contributes nearly 50 percent of the total Basmati rice export in value terms approximately Rs.1000 crores per annum. Intensive breeding efforts and rigorous screening for grain and cooking quality characters resulted in the development varieties like Punjab Basmati-1, Kasturi, Mahi Sugandha were released. Recently several varieties namely, Pus Sugandh-2, 3, 4, (Pusa 1121) and 5, Yamini (CSR30), Vasumati and Pant Sugandh Dhan-15 have been released. Pusa RH-10, is the World‟s first superfine grain aromatic rice hybrid, with 40 percent higher yield was developed at Indian Agricultural Research Institute, New Delhi. Molecular analysis has revealed chromosome 8 (aroma), chromosome 1,2,3,6 and 11 (kernel elongation), chromosome 1, 2, and 7 (amylose content) chromosome 3, 4, 6 and 7 (grain length) and chromosome 10 (grain breadth) important for quality traits.

Methods of Breeding

Rice breeding in India was initiated at the beginning at 20th century. In 1952, FAO started a *japonica-indica* hybridization project aimed at transferring genes for fertilizer responsiveness from *japonicas* to *indicas* for increasing yields in South and South East Asian countries while retaining the quality and adaptability of *indicas* suited to these countries. A parallel scheme was taken up by the Indian Council of Agricultural Research (ICAR) for Indian states. The *japonica-indica* hybridization project could achieve limited success because the *japonica* parents selected from temperate regions were thermo-and photo-sensitive and also the hybrid combinations resulted in highly sterility due to restricted recombination. Only four varieties namely, Malinja and Mahsuri in Malaysia, ADT 27 in Tamil Nadu (India) and Circna in Australia could be released through this programme. To boost production and productivity in all the rice growing states and to have a coordinated approach to rice research at National level, an All India Coordinated Rice Improvement Project (AICRIP) was established by ICAR, in 1965 with headquarters at Hyderabad. The various breeding approaches for increasing rice production representing diverse ecological zones can be grouped into conventional approaches and molecular approaches.

1**. Conventional Approach**

(i). **Varietal improvement**: The major break through in rice breeding as achieved with semi-dwarf, fertilizer responsive non-lodging plant type with greater capacity to trap solar energy for increased photosynthesis through efficient foliar architecture with the development of TN-1an *indica* rice from the cross between tall *indica* Tsai-Yuan-Chung and Dee-geo-wu-gen (DGWG) dwarf mutant.

(ii) **Introductions:** played an important role in varietal improvement so as to enlarge and enrich genetic variability. The International Rice Research Institute (IRRI) located at Los Banos, Philippines through extensive breeding programmes has been distributing improved cultivars and breeding lines throughout the world. Mahsuri from Malaysia; Taichung (Native) 1, Taichung 65 and Tainan 3 from Taiwan; IR8, IR20, IR36, IR50, IR64 etc. from IRRI have become very popular and opened the gateway to green revolution. Similar Indian varieties like Jaya, Rasi, Sona, Swarna etc. being adopted in several countries. International Network for Genetic Enhancement of Rice (INGER) has proved an excellent vehicle to take advantage of exotic varieties / breeding lines.

a**. Pure line breeding:** This simple breeding / selection approach had its strength in the early years of breeding in the existing rich variability to isolate improved strains or varieties which have been widely cultivated. The process of purification starts either at farmer‟s field or farmer‟s strains raised at experimental station. Seed harvested from promising plants are raised in successive generations till they become uniform and stable. Following seed increase, the chosen best line(s) is intensively evaluated in replicated yield trial before it is released for commercial cultivation. Several hundred varieties have been developed by pure line selection. Some of the varieties develop through pure line selection that became very popular are with quality characteristics like GEB24, Mozhgolukulu, Basmati370, Taraori Basmati, etc., saline tolerant varieties like SR26B, Ptb33, Co44, Latisail etc. and deepwater rices FR13.

b. **Pedigree method**: Pedigree method of breeding is the most common method of rice breeding. Rice being a self pollinated, recombination breeding consisting of controlled crosses betweenparents of choice followed by selection for superior recombinants in the segregating generations for targeted traits is the widely employed approach in rice improvement. To combine a set of trait that make a variety unique, convergent improvement approach which involves stepwise addition of constituent traits is the best approach. Pedigree method is followed for improvement of both qualitative and quantitative traits where land / laboratory facilities and manpower are adequate while modified-pedigree or mass-pedigree method of selection is followed when selection environment is not appropriate to discriminate desirable genotypes from undesirable ones. In mass pedigree method, the segregating generations are bulked up to five generations from F_2 followed by pedigree selection. The selection methodology employed also varies depending on the genetic control of target trait as well as conducive environment for effective selection. Shuttle breeding which involves raising of breeding populations alternatively at two agro-climatically diverse environments by practicing selection at one center and advancing generation at the other to take advantage of its favourable weather or selection and generation advance at both the centers.

(ii).**Breeding for Biotic Stresses:** Resistance of host plant has been at greater importance in controlling spread of disease and pests. Several concerted efforts were made to evaluate rice germplasm against various pests and diseases and to identify sources of resistance. Utilizing these donors, resistance was incorporated into rice varieties developed for different rice ecosystems. However, of the sources available only a few donors were utilized for the development of various resistant varieties thereby leading to narrow genetic base of the present day. Hence, we need to utilize these sources to broaden the genetic base of the cultivars. Through conventional methods like selection, hybridization many varieties which are resistant to various biotic stresses have been developed. Wide hybridization between rice and related wild spreads has played an important role in the utilization of useful genes from wild species for resistance against brown plant hopper, white backed plant hopper, bacterial blight, blast and tungro. Various strategies to effectively manage the disease/pest either by sequential release of varieties with matching resistance gene or varietal mosaic consisting of planting varieties carrying different resistance gene is yet another approach in the endemic areas.

(iii). **Breeding for resistance to abiotic stresses**: Abiotic stresses are caused by several factors such as high temperature, stress, low temperature or cold stress, excess of water causing submergence stress, water-logging stress or flooding stress or water deficit stress like drought, increased salts chemicals etc. that the plant development at various stages. Varietal tolerance is the most reliable and cost effective strategy, although the nature of their genetics as well as stress environment is complex in nature. Of the various breeding strategies, pure line selection in the native well adapted varieties to a given stress environment as short term approach is given emphasis. In order to develop high yielding varieties combining tolerance to abiotic stresses there is need to identify donors possessing different mechanisms of tolerance to abiotic stresses.

(iv). **Mutation breeding**: Mutation breeding is very useful in situations where only one or two simple changes in well adapted local cultivars are needed so as to include gene complexes for tolerance to biotic and abiotic stresses, grain quality etc. A wide array of physical and chemical mutagens has been evaluated on rice and a wide array of economically useful point mutations affecting plant height, leaf, panicle, grain type has been recovered. Some of them have been either released directly as mutant varieties used as donor sources for improving specific characters. Among the notable mutants were early maturing Reimei of Japan, RD 15 of Thailand, dwarf statured fertilizer responsive Jagannath of India, Calrose 76 of the USA.

Heterosis breeding: Heterosis in rice was reported first by Jones (1926) followed by many researchers to an exploitable level for grain yield. The first commercially usable CMS (Cytoplasmic Male Sterility) line Wild Abortive (WA) type as a spontaneous male sterile plant in a population of wild rice *O. sativa f spontanea* was developed by Chinese scientists. This effort led to the successful development of hybrid rice technology where China released the first hybrid for commercial cultivation in 1976. Hybrid rice has a yield advantage of 15-20% over the best inbred varieties. Following the success of hybrid rice in China, IRRI initiated research to evolve hybrids ideally suited to tropical environment. Similarly countries like India, the Philippines, Vietnam launched hybrid rice breeding programme.

Rice, with its wide variability, shows both nuclear and cytoplasmic male sterility system, many of these systems have been commercially utilized for hybrid seed production. There are three

types of hybrid development system based on the number of parental lines involved: Three line hybrid system, Two line hybrid development system, One line hybrid development system.

a**. Three line hybrid development system**: It is based on cytoplasmic genetic male sterility stem, involving a CMS line, maintainer line and fertility restorer line designated as A, B and R lines respectively. This male sterility system is the result of interactions between male sterility inducing cytoplasm and nuclear fertility restorer genes. The genetic constitution A, B and R lines are rf rf / S, rf rf / N and Rf Rf / S/N, respectively. A CMS line is maintained by crossing it with its B line (maintainer line) . The A and B lines are similar in all respects except the former is male sterile and the later is male fertile. The restorer gene possesses dominant fertility restoring gene. The hybrid seed is produced by crossing A and R lines and is fully fertile. The seed harvested from A-line after pollination with „R" line is the hybrid seed. This three line system has been widely used in India particularly the WA source for the development of hybrids.

b. **Two line hybrid development system:** It can be obtained in two ways. One is the use of chemical hybridizing agents (CHA) or gametocides, which when sprayed on the panicle kills the pollen and makes the plant sterile. This male sterile plant can be crossed with other parental line to obtain hybrid seed. Another method of obtaining two line rice hybrid is the use of Environmental Sensitive Genic Male Sterility (EGMS) where male sterility is induced by environmental conditions like Temperature (TGMS) and photoperiod (PGMS) and has been reported to be under genetic control. In this system, only a male sterile line and pollinator are required. Hence seed production is easy and economical.

Temperature sensitive genetic male sterility (TGMS) system: The first TGMS line of rice, Annong-IS was isolated as a spontaneous mutant in China and the sterility is controlled by a recessive gene. In rice, temperate of more than 28^0C, the TGMS lines are male sterile, while at lower temperature (below 24^0C), these lines transform into fertile. Some other TGMS lines are Annong S, Hennong S, Novin PL 12, IR 68945, Pei Ai 64S etc. In tropics, where consistent temperature differences are found at different altitudes or during different seasons in the same location, TGMS system is ideal for developing two line hybrids.

Photoperiod sensitive Genetic male sterility (PGMS) system: Rice is a short day plant, as the onset of short days is accompanied by panicle initiation, heading and flowering. The PGMS system, which is under the control of recessive gene, induces male sterility in response to day length of more than 18 hours, while these male sterile plants transform into male fertile when grown in day length less than 10 hours. The first PGMS source was reported in the *japonica* cultivar Nongken 58S. Some other PGMS lines are Zennongs, X 88 and 700 IS. Using this system, the hybrid seed production can be undertaken in the longer day length seasons, while the seed of PGMS line can be multiplied in the shorter day length areas / seasons.

Advantages of two line system over three line system:

There is no need for a maintainer line; hence development of hybrids is easy and simple. Any genotype can be utilized as pollinator parent thus ensuring greater flexibility in the choice of

parents in hybrid combination.Negative side effects of male sterility inducing cytoplasm on the F_1 plants can be avoided.

The seed production programme is simple and more efficient. The field area ratio between the female parent‟s seed multiplication, hybrid seed production, and commercial cultivation of an F_1 hybrid is 1:100:10000 as against 1:50:5000 in three line systems in rice.
In case of CHA induced male sterility system the female line multiplication and hybrid seed production can be undertaken at a common location.

c**. One line system of hybrid development:** It is based on utilization of apomixis for hybrid seed production. In this system hybrid plant is produced by crossing two parental lines and it can be maintained indefinitely by apomixes without losing the genotypic constitution of the hybrid. This system is still in a preliminary state and has not generated any stable hybrid till now.

(vi). **Molecular breeding approaches in rice:** Advance in cellular and molecular biology techniques has given newer dimensions to rice breeding, genetics and genomics. Several new varieties have been developed and new traits introduced using cell and tissue culture techniques. Rice being the most important cereal crop is a major target for cellular and molecular genetic manipulations with focus on recovering fertile transgenic plants. Introduction of alien genes in rice through genetic transformation has now become routine. Transfer of DNA through protoplasts, biolistic method and *Agrobacterium* mediated methods are being used for rice transformation. Transgenic *Bt* rice with cry genes with excellent levels of resistance against stem borers have been developed. Similarly coat protein mediated protection against viral diseases is underway.

Improvement of nutritional quality through genetic transformation of rice plant with engineered provitamin-A biosynthetic pathway with three genes, phytoene synthase (psy), phytoene desaturase and lycopene cyclase is in progress. Efforts are on to transfer these genes to other varieties of commercial importance through backcrossing and marker assisted selection (MAS). In India, scientists at Directorate of Rice Research (DRR) and Indian Agricultural Research Institute (IARI) are carrying out backcrossing programme to introduce these genes into Indian varieties.

Using various marker techniques major genes conferring resistance to gall midge, brown plant hopper (BPH), white backed plant hopper (WBPH), green leaf hopper (GLH), bacterial leaf blight (BLB), blasts etc. have been tagged and mapped. Besides, closely linked and often flanking PCR based markers have been developed for marker aided selection (MAS) and marker aided backcrossing (MAB) protocols. Using these markers, the geneticists and breeders can now combine the most suitable major and minor gene in a controlled manner leading to breeding by design strategy. Another significant advantage of developing closely linked markers is the map based cloning of the gene. Development of varieties with durable resistance to BLB, blast etc. is the focus of a coordinated effort at IRRI and National Agricultural Research System using molecular marker technology. Huang and his group used DNA marker assisted selection to pyramid four bacterial blight resistance genes Xa4, xa5, xa13 and Xa21. Breeding lines with two, three and four resistance genes developed and tested for resistance to bacterial pathogen, which

are being utilized in several countries for marker assisted pyramiding into their elite genetic background.

In India, utilizing these sources, many research groups have initiated pyramiding resistance to BLB into elite genetic background. At DRR, Hyderabad, marker assisted pyramiding (xa5, xa13 and Xa21) has been carried out to incorporated BLB resistance into an elite cultivar BPT 5204 (Samba Mahsuri). Similarly, a network project on gene pyramiding for multiple biotic stresses has been initiated. In Rice, gene pyramiding in already wide spread cultivars viz. BPT-5204, IR 64, Pusa Basmati-1, Lalat for BLB, blast and/or gall midge has been initiated at DRR, CRRI, IARI and SAU using conventional and molecular approaches.

Table 2: Genes to be pyramided in specific cultivars at different centre

Centre	Cultivar	Genes for resistance to		
		BLB	Blast	Gall midge
DRR, Hyderabad	BPT 5204, IR64	*xa*13 +*Xa*21	*Piz* + *Pik*^{h}	*Gm*1 + *Gm*4
CRRI, Cuttak	Swarna, Lalat	*xa*13 + *Xa*21	*Piz* + *Pi*9	*Gm*1 + *Gm*4
IARI, New Delhi	Pusa Basmati-1,	*xa*13+ *Xa*21 (Pusa 1460 released)	*Piz* + *Pik*^{h}	-
	Pusa 6A/6B, PRR 78	*xa*13	*Piz*	
		*xa*13 + *Xa*21	*Pi*9	

Future Research to Enhance Production and Productivity of Rice

- Genetic resource management of farmer‟s varieties, land races, commercial cultivars, parental lines of released hybrids and wild relatives.
- Evaluation of germplasm in *in situ* conditions.
- *In situ* conservation of land races and documentation are the priority areas
- Enhancement of yield potential and stability for irrigated, rainfed lowland and upland situations, and also for different farming practices such as aerobic rice and boro rice.
- Enhancement of yield through development of hybrid rice by utilizing *indica* / *japonica* derived parental lines. Improvement of grain quality, which include pleasant aroma, linear kernel elongation on cooking and soft texture, keeping in view regional preference and export demand. Developing rice varieties suitable for cultivation under aerobic situations.

- Marker aided selection for enhancement of yield and incorporation of resistance to biotic and abiotic stresses

MAIZE (*Zea mays*)
2n = 20

Maize (*Zea mays*) is an important cereal crop of the world. It ranks next to wheat with respect to production. Being a C_4 plant, it is physiologically more efficient and has higher grain yield and wider adaptation over a wide range of environmental conditions. The important maize growing countries are the USA, China, India, Brazil, Mexico, Philippines, South Africa and Indonesia. Maize has a wider range of uses than any other cereal as animal feed, human food and for hundreds of industrial purposes. Being a C_4 plant, maize is most productive in terms of food nutrients produced per unit land area, per unit of water transpired and per unit of time under the conditions for C_4 plants.

In India, the area under maize is around 9.07 million ha with a production of 24.26 million ton with a productivity of 2676 kg / ha (2013-14). Maize is grown mainly during *kharif* season although it is also cultivated during *rabi* as well as summer season. Major maize growing states in India are Andhra Pradesh, Karnataka, Bihar, Himachal Pradesh, accounting about 30 % of the maize acreage. In Bihar, the area under maize is around 7.32 lakh ha with a production of 29.04 lakh matric ton with a productivity of 3966 kg / ha (2013-14).

Origin : Central America

Maize is indigenous to the Americas, and was the principal food grain of Native Americans. Corn was domesticated about 8,000 years ago in wild form. The closest ancestor of maize was believed to be teosinte, from which the present day maize evolved. Evolutionary forces such as mutation, hybridization, genetic drift and selection aided by human beings resulted in differentiation of teosinte into maize and further differentiation of maize into over 300 races. These races got adapted to different agro-climatic regions away from the centre of origin. Modern corn cultivars differ from primitive corn in having more productive plants with increased number as well as weight of individual kernels on a cob of corn.

Various hypotheses have been proposed to explain the origin of maize. According to one hypothesis the corn originated by a single domestication from the basal branching teosinte sub sp. *Zea mays* L. spp. parviglumis or from the lateral branching subspecies *Zea mays* L. spp. mexicana by dual domestication from the two subspecies. Similarities between maize and teosinte is in being monoceous in flowering habit, with staminate and pistillate flowers born in separate inflorescence while the later differs from corn in that the pistillate spikes bears 60-12 kernels in hard, triangular, shell like structures and is prone to seed shattering. Recent molecular studies revealed that maize and teosinte maintain distinct genetic constitutions despite gene introgression between them.

Crop Systematics and Species Relationship

Maize belongs to tribe *Maydaea* of the family Graminae. The tribe *Maydaea* consists of seven genera viz. *Coix* (2n=10/20), *Chionachne* (2n=20), *Sclerachne* (2n=20), *Trilobachne* (2n=20) and *Polytocta* (2n=20) under old world group and *Zea* and *Tripsacum* under new world group. Varieties that had similar morphological physiological, genetic and cytological characteristics were grouped together into distinct races. These races are of important to breeders‟ search for germplasm containing particular characters of use in the breeding programme. These races are mainly classified into six kernel type viz. flint, dent flour, pop, pod and sweet corn. Of these races, the most important races being Corn Belt dent, the southern dents and the northern flints and the most productive race is the US Corn Belt Dent which is a hybrid of northern flints and southern dents. In India greater diversity among maize germplasm exists in the North Eastern Himalayan region, where land races with untapped alleles do exist. These land races have been described as Sikkim primitives by Dhawan (1964). Besides these races, there are several local varieties from Jaunpur, Jullundhar, Anantnag, Hyderabad, Coimbatore, Rudrapur Malan and Sikkim.

Progenitors: *Z. teosinte* (Most preferred*)* and *Zea tunicata* It belongs to the tribe Maydeae of family gramineae.

Wild relative: Teosinte: There are three species of teosinte of which *Zea mexicana* is annual diploid (2n = 20) like maize.

Gamma grass another close relative belongs to genus *Tripsacum*

The genes *Zea* characterized by male terminal inflorescences with paired staminate spikelets and lateral female inflorescences with single or paired pistil late spike lets. *Genus Zea* contains four species

***Zea mays* (2n = 2x = 20) = Corn**
***Zea mexicana* (2n = 2x = 20) = Annual teosinte**
***Zea perennis* (2n = 4x = 40) = Perennial tetraploid teosinte**
***Zea diploperennis* (2n = 2x = 20) Perennial diploid teosinte**

Floral Biology
Maize is a monoecious cross pollinated plant with staminate flowers borne in the tassel and pistillate flowers on a cob. Self pollination is about 5 %. The main stem of the corn plant terminates into a tassel (male inflorescence).

The main axis and branches of the tassel bear spikelets usually in pairs, one sessile and the other pedicellate. Each spikelet bears two florets each with a lemma, a palea, three stamens two lodicules and a rudimentary pistil. The pollen grains are very small, light in weight and easily carried by wind.

Shoot buds are formed in the leaf axils. About midway up the stalk, one or two shoot buds develop into lateral shoots bearing the female inflorescence known as the ear. The ear shoot is composed of a shank which bears modified leaf sheaths as husks and the internodes of the shank

are highly condensed. On the ear shoot, pistillate spikelets are borne in pairs in longitudinal rows from base to tip. Each spikelet has two flowers of which one is fertile and other being sterile. The ovary is surrounded by a long slender, bifid style known as the silks. Silks function both as style and stigma throughout their length.

Maize is protandrous in nature wherein pollen shedding begins before the emergence of silks thus facilitating cross pollination via wind borne pollen grains. Pollen shedding begins about 2 or 3 days after the tassel is fully emerged and it continues for few days. Fertilization of ovules begin one-third up from the base of the ear. Kernels borne on an ear remain intact covered by husks without any seed dispersal mechanism. The maize kernel is a one seeded fruit (caryopsis).

Objectives of Breeding

Since maize has wide range of food and industrial uses, the breeding objective depend on various factors like targeted end product of the market, farmer‟s perspective, specific agroclimatic situation as well constraints and production levels. Maize being of C_4 plant, the breeding objective should exploit the inherent productive potential of crop.

Yield improvement: The most important objective is to increase grain yield which is a quantitatively inherited complex trait and its expression is influenced by several yield component. The various yield components contributing to yield in maize include number of ears, number of kernel rows, number of kernels per row, test weight and shelling percentage. Grain yield is also dependent on several physiological characteristics such as nutrient uptake, photosynthesis, translocation, sink size and transpiration. Maize is a C_4 plant, has a higher rate of photosynthesis. Grain yield is also affected by genes associated with characters that contribute to the stability of production, such as optimum maturity, stalk quality, resistance to biotic and abiotic stresses.

Adaptability and stability: Development of varieties or hybrids with wide adaptability and stability is to ensure higher and stable returns to the farmers. Adaptability is also a complex objective that is affected by various factors like agro-climatic conditions of the region, soil fertility level, tillage practices as well as tolerance to cold, heat and drought.

Maize is a short day plant and the time of flowering is influenced by photoperiod and temperature. **Development of photoinsensitive varieties / hybrids** is the priority so as to facilitate its cultivation throughout the year. In tropical and sub-tropical climates, it can be grown throughout the year as soil moisture and other factors are not limiting, while in temperate regions the growing season is restricted to frost -free period. Hence hybrids with cold tolerance and early maturity have advantage of enabling different cropping systems. Similarly early maturing hybrids are adapted to the shorter growing seasons in higher latitudes and lower latitudes with longer growing season. Adaptation of hybrids / varieties depends on the productivity of the soil as well as they respond more to the fertility levels.

In addition to higher yield performance, the cultivars should possess inherent potential to perform well over a wide range of environments particularly in areas where it is cultivated

during seasons characterized by erratic rainfall as well as in environments for which resistance / tolerance to stresses is very important i.e. when grown in less favourable environments. Prolificacy is considered to be an important mechanism contributing to stability. Breeding for appropriate maturity as determined by the agroclimatic factors is an important objective.

Breeding for disease and pest resistance: The most serious diseases of maize in India are turcium leaf blight (*Drschlera turcica*), *maydis* leaf blight (*D. maydis*), post-flowering stalk rot complex (*Macrophomina phaseolina, Fusarium spp., Cephalsporium spp*.), downy mildew (*Perenosclerophthora soghi*) and common rust (*Puccinia sorghi*). Similarly insect pests like stem borers, army worms, aphids, cutworm, jassids, thrips, root worm, leaf miner etc. are important that are causing severe losses at various stages of crop growth. Understanding the genetic control of these diseases and insect pests as well as the identification of resistance sources against them is important so as to plan an appropriate breeding strategy. Methods of creating artificial epiphytotic conditions, to facilitate the selection of resistant genotypes and incorporation of resistance genes into the inbred lines and hybrids, are being developed.

Breeding for quality: The maize kernel is composed of approximately 7% starch, 10% protein, 5% oil, 2% sugar and 1% ash. The maize protein is called Zein and is low in biological value due to low concentration of the essential amino acids lysine and tryptophan. Maize breeders have made significant progress in altering the composition of various quality traits. Several mutants have been discovered and developed to alter the starch fractions of the maize endosperm. Genes that modify either the structure or quality of the kernel endosperm have been effectively used to develop specialty corn. A break through was made with the discovery of opaque-2 gene which doubled the lysine and tryptophan content in the endosperm and breeding efforts led to the development of opaque-2 based hybrids, synthetics and composites although they have poor agronomic characters which are being improved.

Thus the breeding objectives for quality not only emphasize their improvement but also the agronomic characteristics as well. Physical quality of grain is usually measured by kernel hardness, kernel breakage susceptibility (brittleness) and stress cracking. To improve physical quality of maize grain, breeding for grain resisting mechanical damage and drying grain at low temperature is being carried out. Nutritional quality includes protein concentration as well as amino acid balance. In general, the increase in grain yield increases the starch concentration of the grain while reducing the grain protein concentration. The correlation need to be broken to develop varieties with high yield and protein concentration. It was also found that the greater nitrogen supply increased grain protein concentration linearly while grain yield response to added nitrogen had a diminishing return relationship. We need to identify genotypes that can accumulate more protein even at low nitrogen concentration by changing physiological architecture of the plant itself. Market quality includes kernel size, kernel weight and extractable starch depending on the specific end use. Environmental and genetic factors appear to be more important than agronomic practices for physical quality and extractable starch parameters. In general dry millers prefer uniform large, unbroken, kernels as well with low phytate concentration. Hence objective of quality breeding in maize include the development of cultivarswith high protein and balanced amino acid profile and also high oil, waxy, amylase and low phytate to the quality parameters specifically associated with intended end use.

Methods of Breeding

Maize is a cross pollinated crop. The breeding methods should focus on exploitation of the heterozygosity in a desirable direction as well as large scale exploitation of hybrid vigor. The cultivar may be open pollinated population or hybrid. Major breeding methods in maize are population improvement and hybrid breeding. All these methods involve selection which acts on existing indigenous and exotic variability or variability created through hybridization, gene segregation and recombination.

Introduction: Many of the introductions have been used directly as commercial cultivars in many countries including India such as composite Laxmi and Suwan released in Bihar state and these introductions also used as a source material to develop cultivars or inbred lines.

Population improvement: Population improvement aims at increasing the frequency of favourable alleles in the population and at the same time maintaining considerable genetic variability. It involves various recurrent selections procedures that are broadly classified into intra-population improvement and inter-population improvement schemes.

Intra-population improvement:
(i**). Mass selection**: It involves selection of ears on the basis of plant and ear characteristics and harvested seeds are bulked to grow the next generation and the process is repeated for several cycles. Mass selection was the only method adopted earlier to improve local maize types grown by the farmers. Later, varietal hybridization involving indigenous germplasm, accompanied by mass selection resulted in the development of many open pollinated varieties. Because of its limitations to identify superior genotypes based on phenotype alone as well no control over pollination and severe inbreeding depression led to the various modifications of the mass selection procedures, although varieties like KT 41 and Basi were developed by mass selection method in India

Various modified mass selection methods are:
(a) **Modified mass selection** without pollen control which was also known as Grid method developed by Gardner in 1964. In this method, experimental area is divided into sub-plots or grids and selection for superior traits is carried out within the grid, which are bulked for growing the next generation.

(b**) Ear to row selection or Half-sib progeny selection**: It was developed by Hopkins. In this method, the superior ears are selected from the source population and are kept separate without bulking. In the next year, progeny rows of each individual ear are raised from half the seed and based on superior progeny rows, the remaining seed of the selected progeny rows is bulked to constitute an improved population.

(c**) Modified ear to row selection** proposed by Lonnquist (1964) in which the progenies are evaluated over locations in replicated traits.

(ii) **Half-sib family selection**: Individuals having one parent in common are called half-sibs. The half-sib families are developed by random mating in an isolated plot or by pollinating plant with bulk pollen of a large number of plants. Small amount of seed of half-sib families are evaluated and the remnant seed of the selected families is used to reconstitute the population. Ear to row method is a type of half-sib selection and has been widely used in maize improvement programme.

(iii) **Full-sib selection**: Individuals having both parents common are known as full sibs. Full sibs are produced by crossing selected plants in pairs in the source population and the crossed seeds are used for progeny test as well as for reconstituting the improved new base population.

(iv**) Selfed progeny selection**: The selfed progeny is produced by selfing the selected plants from the source population. They may be S_1 for one or S_2 for two selfings. The progenies are evaluated and selected ones are recombined to constitute a new improved population in which the 2^{nd} cycle of progeny selection may be carried out.

Inter population improvement:

Inter-population improvement involves one / two population and aims at simultaneous improvement of one / two heterozygous and heterogeneous populations. Yield has been the primary trait of selection for the inter-population selection methods. These methods include:

Simple recurrent selection.
Recurrent selection for gca.
Recurrent selection for sca.
Reciprocal recurrent selection.
(a) Half-sib reciprocal recurrent selection
(b) Full-sib reciprocal recurrent selection

(i). **Simple recurrent selection**: In this method a number of plants with desirable phenotype are selected and selfed. In the next year, progeny rows from the selfed seeds of the selected plants and the progenies are intercrossed in all possible combinations and equal amount of seed from each cross is composited to produce the next generation. From composited population, a round of recurrent selection is carried out. Recurrent selection is effective in increasing the frequency of desirable genes in the selected population. It is most suited for characters with high heritability.

(ii**). Recurrent selection for general combining ability (RSGCA):** In case of recurrent selection for gca, the progeny for progeny testing are obtained by crossing the selected plants to a broad base tester (an open-pollinated variety, a synthetic variety or the segregating generations of double or multiple cross). In the first year, a number of phentoypically outstanding plants are selected from source population. Each selected plant is selfed as well as crossed to a number of randomly selected plants from a tester with broad genetic base. In the second year, the test cross progeny are evaluated in a replicated trial. The selfed seed from those plants that produced superior test cross progenies (as identified in the second years) are planted in the progeny rows and are intercrossed in all possible combinations. Equal amount of seeds from all the intercrosses

are composited to obtain the next generation. This completes original cycle of selection and further recurrent selections are carried out in the same manner. RSGCA is effective in increasing the yielding ability of the population obtained at the end of selection cycle. It also accumulates genes for superior GCA.

(iii) **Recurrent selection for specific combining ability (RSSCA):** It was proposed by Hull (1945). The procedure is identical with that for GCA, except that in this an inbred is used as tester than an open pollinated variety. RSSCA helps to isolate from a population, such lines that will combine well with a given inbred and is useful in exploiting heterosis due to non-additive gene action.

(iv). **Reciprocal recurrent selection (RRS):** It was proposed by Comstock, Robinson and Harvey in 1949 for the improvement of two different populations in their ability to combine well with each other. Two genetically broad based populations (A and B) such that „A" serves as tester for B and „B" serves as tester for A. This method is as effective as RSGCA when additive gene action predominates and is as effective as RSSCA when non-additive effects are of major importance. The modification of these methods is full-sib reciprocal recurrent selection as well as half-sib reciprocal recurrent selection.

Development of synthetic varieties: A synthetic variety is a variety produced by crossing in all combinations a number of inbred lines (with high gca that combine well with each other) and a synthetic variety is maintained by open pollination in isolation. In maize, development of synthetics includes:

- Evaluation of lines on the basis of general combining ability.
- These selected lines are intercrossed in all possible combinations.
- Equal amount of seed from these crosses is composited to constitute a synthetic.

Development of composite varieties: Composite varieties in maize are derived by mixing the seeds of several phenotypically outstanding lines and allowing open pollination among the mixed lines. The lines used to produce a composite variety are rarely tested for combining ability.

Hybrid breeding: Exploitation of heterosis through hybrids can be mainly attributed to the pioneering work done by G.H. Shull and D.F. Jones. Various types of hybrids in maize based on inbred lines are:

Single crosses hybrid - A single cross hybrid is produced by crossing two unrelated inbreds which produce best performing F_1 hybrids.

Three way crosses hybrid - A three way cross hybrid is produced by crossing a single cross with an inbred line. Hence it involves three inbred lines. = (A x B) x C.

Double cross hybrid - Produced by a cross between two single crosses. Four unrelated inbred lines are involved = (A x B) x (C x D).

Top-cross hybrid - Crossing an inbred with an open pollinated variety also known as inbred-variety hybrid.

Double top-cross hybrid - A double top cross is the progeny of a single cross and a variety [(Ax B) x variety].

Various operations in the production of hybrids are:

- ✓ Development of inbred lines
- ✓ Evaluation of inbred lines.

Production of hybrid seed.

(i). Development of inbred line: Inbred is a nearly homozygous line developed by continued inbreeding usually selfing accompanied by selection. Five to six selfing are required to produce inbreds. The plants selected for developing inbred lines may be derived from open pollinated varieties, synthetics and composite or from a F_2 population of crosses of desirable of desirable parental lines.

(ii). **Evaluation of inbred**: Evaluation of inbred is done either by phenotypic evaluation or top cross test or by single cross evaluation to identify the superior inbred lines. Hence inbred lines with high GCA are selected for hybrid development.

(iii). **Hybrid seed production**: Growing two rows of inbred lines used as male parent and six rows of female lines in isolation is the common method of producing hybrid corn in India. The female lines are detasseled before they produce the pollen. In hybrid seed production, the female and male parental lines are grown in the ratio of 6:2 rows. The female rows are detasseled before the male inflorescene shed pollen and these detasseled female lines are pollinated by male and the seed produced on these detasseled plants is the hybrid seed. In case male sterility is utilized, the female line need not be detasseled as it does not produce functional pollen grains. In USA, detasseling and CMS system are used. The requirement of hybrid seed production are (1) easy detasseling of the female parent, (2) effective pollen dispersal from male parent to ensure a satisfactory seed set in the female parent.

Hybrids for Special Uses

Hybrids in maize are also being developed for special purposes, such as sweet corn, popcorn and waxy corn in addition to the larger use for feeding livestock and corn-milling industry. Sweet corn hybrids are called as Super sweet due the presence of shrunken-2 (sh2) gene which increases sugar content along with extended peak quality in these hybrids. Waxy corn is used in the manufacture of adhesives, gums, paper sizing and puddings due to the presence of amylopectin a special type of endosperm starch.

Biotechnology in Maize Improvement

Use of molecular techniques has many applications in crop improvement. Identification of tightly linked molecular markers to the genes of interest can be indirectly used to select for the desirable allele in marker assisted selection. They can be used to accelerate the backcrossing of such an allele or gene or in pyramiding several desirable alleles. Markers can also be used to dissect polygenic traits into their Mendelian components or quantitative trait loci. Maize was one of the first major crop species for which a complete molecular marker map was developed. One of the most studied traits at CIMMYT, Mexico is abiotic stress tolerance.

In maize extensive genome mapping based on molecular markers has been accomplished. DNA based markers along with conventional breeding procedures are being utilized to develop QPM (quality protein maize) genotypes with improved nutritional quality. Similarly, development of markers for genes related to quality such as Sugary-1, Shrunken-2 in sweet corn breeding programmes has been carried out, so as to incorporate those genes into elite genetic and agronomically superior genotypes through marker assisted selection. Various genetic transformation techniques provide an important tool for quality improvement as well as introduction of genes for insect and disease resistance.

Future Research to Enhance Production and Productivity of Maize

Enhancement of yield potential through breeding for single cross hybrids. The yield components should include number of ears, kernel rows and kernels per row, kernel test weight and shelling percentage which need to be given due importance in the endeavour of enhancing the grain yield. Selection for prolificacy (plants with more than one ear) is another potential trait for enhancing productivity

Development of vigorous inbred lines for tolerance to inbreed in stress and better yield required for seed production.

Stability of performance of hybrids under varied agro-ecological conditions and a biotic stresses especially under water stress conditions. The useful traits for drought resistance include small male tassel, small leaf area, profligacy, leaf elongation, heat tolerance, high abscisic acid content.

Development of hybrids and composites with higher level of resistance / tolerance to biotic stresses, which is possible by identification of inbreds possessing multiple disease and pests resistance.

Development of quality protein maize with higher contents of essential amino acids, lysine and tryptophan.

High oil content is also an important goal for some maize breeding programme as the maize oil is of higher industrial value. Due to increased demand for specialized products, there is need to breed varieties / hybrids for human and live stock health, nutrition and taste.

Transgenic corn has to be made reality in the country with increased content of starch, oil and protein.

SORGHUM (*Sorghum bicolor*) 2n = 2x = 20

Sorghum is one of the most important food crops in a semi – arid tropics. Origin: S.E. Africa

Progenitor of sorghum: *S.arundinaceum*

Distribution:

A number of land races, wild forms found in S.E. Africa, says the origin Ethiopia in Africa from there it spread to other parts of world. It is grown in Africa, south and central India.

The latest classification was done by Harlan and De Wet (1972).

*1.**Bicolor*** **(B): Grain elongate, glumes clasping the grain which may be completely covered or ¼ exposed.**

2.Guinea **(G): Grains flattened dorso-ventrally.**

3.Caudatum**(C): grains asymmetrical, glumes 1/2 the length of the grain.**

4.Kaffir **(K):** Grains symmetrical (spherical), glumes clasping in varying length.

*5.**Durra*** **(D):** Grains rounded obovate, wedge shaped at the base and broadest slightly above the middle; glumes very wide.

According to them, the cultivated sorghum *Sorghum bicolor* is divided in to five basic races based on the coverage of glume on the grain

Breeding objectives

- High grain yield
- High forage yield
- Breeding for non-lodging sorghums.
- Dual purpose genotypes with high grain and fodder biomass potential per unit time.
- Early maturity
- Resistance to biotic stresses (diseases like grain mold, downy mildew, rusts, leaf blight, leaf spots etc.
- Resistance / Tolerance to insects like shoot fly, stem borer, gall midge etc.
- Resistance to abiotic stresses like salinity, drought with resistance to low HCN content.
- Breeding for quality characters like bread making, redgrain for biscuit making protein and lysine content.
- Breeding for spe cial traits like sweet sorghums and striga resistance.
- To isolate alternate sources of cytoplasmic genic male sterile lines

Breeding Procedure:

Sorghum is often cross pollinated crop. So to maintain varietal purity isolation distance of 400 meters is necessary. Compared to other often pollinated crop like red gram, maintenance of inbreds is easy in sorghum. By putting brown paper and selfing the genetic purity can be maintained.

Introduction : Varieties of milo and kafir sorghum introduced from USA are used in conversion programme to convert the local long duration photo sensitive varieties to short duration, non-photo sensitive lines.

2.**Selection** : Old varieties like Co1, Co2, Co4 are all selection made from local land races.

3.**Hybridization and selection**

a**) Inter varietal**

(IS 4283 x Co 21) x CS 3541, Three way cross derivative Co 25 (MS 8271 x IS 3691) - Single cross derivative Co26

b) **Inter specific**

Heterosis breeding : Use of CMS lines.

CSH 5 2077 A x CS 3541

Mutation breeding :

X ray mutant from CSV 5 (148)

Co 19 is a natural mutant from Co 2

6**. Back cross method :**

By following backcross method of breeding sorghum conversion programme was initiated. The long duration photosensitive germplasm was converted in to photo insensitive short duration sorghums. This was done at USA Similar programme was done at ICRISAT also.

7**. Population improvement** :

With the use of cytoplasmic genetic male sterility as well as genic male sterility we can go for population improvement. The local land races can be used as pollinators and by half sib family selection, we can isolate lines. We can follow recurrent selection idea to develop superior inbreds.

8. **Use of Apomictic lines :**

Some apomictic lines have been identified which can be utilised in breeding programme and by vegetative propagation we can fix up heterosis. E.g. R473 from Hydrabad.

Breeder centers:

International sorghum improvement work is carried out by ICRISAT (International Crop Research Institute for Semi Arid Tropics). In India at Directorate of Sorghum Research (DSR), Hyderabad

Practical Achievements:

Hybrids are developed by using cytoplasmic genetic smale sterility combined kafir 60 Varieties: CSV1 CSV-2, CSV-4, M35-1, CSV-13

Hybrids: CSH-1, CSH-2, 3 etc for *kharif* and CSH 7, 12, 13 for *Rabi*

PEARL MILLET (*Penisetum americanum)*

(Bajra – Bulrush Millet) (2n=14)

Pearl millet is also known as Bajra, is an important food crop of semi arid tropics. It is also grown as fodder crop

Origin: W. Africa

Distribution:
Africa, India, Pakistan, South East Asia, USA and Europe
The cultivated *Pennisetum glaucum* belongs to the section penicillaria.
Progenitors :. *Pennisetum purpureum;*. *P.qumulatum;*. *P. orientale*

Breeding objectives :
1. **Breeding for high grain yield**
To get high yields the following plant characters are necessary more number of tillers well filled, compact, long panicle,heavy grains.
Uniformity of ripening.

Under irrigated conditions photo insensitivity and early maturity are essential for multiple and relay cropping.

2. **Breeding for improved grain quality.**

It can be achieved by incorporating yellow endosperm to improve vitamin A content or white endosperm to improve protein content.

3. **Breeding for drought tolerance :**

This can be achieved thro‟ evolving lines having shorter duration so that they can escape drought, lines with more adventitious roots, lines with high leaf water potential and high chlorophyll stability index are to be evolved.

4. **Breeding for disease resistance**

Downy mildew is the major disease. Ergot and smut comes next. Of late, rust at late stage is also becoming a major problem. Lines having Local Bellary cytoplasm (732 A) are observed to be downy mildew resistant.

5. **Breeding for alternate source of cytoplasm in male sterile lines.**

Original Tift 23 A evolved at Tifton, Georgia is highly susceptible to downy mildew. Because of this the HB series went out of cultivation. The indigenous 732 A obtained from Bellary is resistant. Similarly L 111A of Ludhiana is also tolerant.A1,A2,A3 and A4 are there 732 A belongs to A4 cytoplasm.

6. **Breeding for to have high forage value** :

The forage cumbu must have following characters.

- ✓ high sugar content in the stem juice
- ✓ Increased leaf number with more breadth.
- ✓ Digestibility.

Breeding Procedures

Introduction : Hybrid bajra from Punjab. Tift 23 A from USA
Selection : Pure line selection : Co 2, Co 3,
Hybridisation and selection
Interspecific hybridisation. *Pennisetum glaucum* x *P.purpureum* Cumbu napier hybrids.

Heterosis breeding : Hybrid bajra

In earlier days before the identification of male sterile lines utilising the protogynous nature hybrids were released. The hybrids were produced by sowing both parents in the ratio of 1:1. After the discovery of cytoplasmic genic male sterile line Tift 23A by Burton in Tifton, Georgia led to development of hybrids. Earlier hybrids of India *viz.*, HB1, HB2 to HB5 were produced utilising Tift 23 A. But due to susceptibility to downy mildew they went out of cultivation. Even before the discovery of CGMS lines by Burton it was discovered by Madhava Menon and his coworkers at Coimbatore. Unfortunately due to failure of publishing it was not recognised. To over come the problem of downy mildew male sterile lines L 111A and 732 A were isolated and at present used in breeding programme. There are number of CMS lines developed by private agencies like Nath seeds, Mahyco, Mahendra.

5. **Population improvement :**

ICRISAT entry WCC 75 is an example for population improvement. This was developed from world composite by recurrent selection method. It was developed from derivatives of numerous crosses between diverse sources of germplasm and Nigerian early maturing land races known as „Gero" millets. Another example is ICMV 155 of ICRISAT.

6. **Synthetic varieties** :

Synthetics are produced by crossing in isolation a number of lines tested for their GCA. E.g. ICMS 7703.

It is a result of crossing between 7 inbred lines of India x African crosses

7. **Mutation breeding**

At IARI Tift 23 A was gamma irradiated and 5071 A resistant to downy mildew was evolved. With this the hybrid NHB 3 was evolved (5071 A x J 104)

Breeding centers:

International Crops Research Institute for Semi Arid Tropics (ICRISAT,) Hyderabad All Indian Pearl Millet improvement project (AIPIP) Jodhpur (Rajasthan)

Practical achievements

Varieties: PS B – 8, PSB 15, mukta

Hybrids : HHB 45, HHB 50 from Hissan GHB 30, GHB – 27 from GujaratChina, Argentina, Australia and south and central plains of US.

RED GRAM (*Cajanus cajan)* (2n = 22)

Pigeon pea / Red gram is an important pulse crop next to chickpea in India. India is a largest producer i.e. 90% of the world‟s production

Origin: Africa and India

Distribution: India, Uganda, Kenya, West Indies, Burma etc. In India, Maharashtra, Uttar Pradesh, Madhya Pradesh, Karnataka, Gujarat and Andhra Pradesh and under irrigated belt in Punjab, Haryana and Rajasthan.

Progenitor: *Cajanus cajanifolius; Atylosia lineate*

Genus *Cajanus* and *Atylosia* and have many similarities. *Cajanus* has more than 30 species. The view is that *Cajanus* arose from *Atylosia* . In western ghats, West Bengal and Orissa, *Atylosia* species are known as wildtur. Now this genes has been included in *Cajanus.*

Breeding objectives:

Evolution of long duration high yielding variety suitable for rainfed to replace the local land races :

SA1 - Released during 1940

To evolve short duration (105 days) varieties suitable for irrigated / mixed crop with ground nut.

ICPL 87 - ICRISAT

Breeding for bold grain type with desirable seed coat color
HY 3C long duration variety with dull white seed coat and bold grains.

Breeding for vegetable type

Green pods with bold seeds are used as substitute for green peas in some areas are perennial types

Breeding for resistance to pests.

Heliothis is the major pest, terminal cluster types are highly susceptible. All our varieties are highly susceptible.

Breeding for disease resistance :

Sterility mosaic, root rot, blight are important diseases. Wild species *Cajanus scaraboides*, *C.lineata* are having resistance.

Breeding for high protein content and quality

Mean protein content 23%. The wild species have 27% to 29% , Red seed coat contains more polyphenol (Tannin) than white seed coat. So preference is towards white seed coat. Red grain contains lesser amount of sulphur containing amino acid. When we increase protein content there will be lesser amount of these amino acids. So care is to be taken to increase them.

Breeding high yielding perennial redgram suitable for bund cropping

Breeding procedures

Introduction :

E.g. Prabhat short duration variety from IARI, ICPL 87 from ICRISAT.

Pure line selection

Earlier breeding work was based on the assumption that Redgram is a self pollinated crop.
However it was later found to be often cross pollinated crop.

Hybridization and selection :
Mass selection :
Population improvement :

Using male sterile line and recurrent selection methods.

Two populations are used, one is seed parent and the other is pollen parent. The seed parent must have one or two easily identifiable recessive character and the pollen parent more dominant genes. The seed and pollen parents are sown in alternate rows so as to maximize natural cross pollination.The F1‟s and selfed ones are identified in So generation. The identified F1s are space planted in the next generation S1. In S2generation they are yield tested in 3 environments and best ones are either recycled or taken to conventional breeding programme.

Mutation breeding

LRG-30 variety was susceptible to wilt was irradiated and wilt resistant variety was developed as ICPL-270

Heterosis breeding

Red gram Ideal plant type a) Long duration: The genotype that have steady rate of growth and have a moderate harvest index. High seed weight; Long pods; Increased number of pod bearing branches.

b) Short duration :Dwarf in nature with erect branches having high dry matter production High seed wt.

Long pods.
Increased no of seeds / Pod Less flower drop.

c) **Breeding centers:**

Internation Crop Research Institute for Semi Arid Tropics (ICRISAT) Hyderabad

Practical Achievement:

Varieties: Prabhat, Vishakha, Sharada, ICPL – 87

Hybrids: ICPH – 8

SOYBEAN (*Glycine max*) 2n = 40

One of the important oil yielding crop of world it is miracle crop giving 42 – 45 per cent protein and 19-20 per cent oil it belongs to family leguminoseae Origin: China

Distribution: USA, Brazil, China, Argentina and India.
Progenitors: *Glycine max* is originated from *G. usuriensis and G. tomentolla*

Breeding objectives:

1**. Breeding for short duration high yielding varieties**

The yield of soy bean plant is determined by size, number of seeds per pod and number of pods / plant. The number of pods/ plant is determined by number of nodes / plant, number of pods / node. Each of the above components of yield are polygenic in inheritance and so it is complex. The duration is also determined by multiple genes. Maturity is correlated with height of the plant. Early varieties will be short is stature.

2. **Breeding varieties suitable for rice fallows**
Short plants 65 -70 days duration. Suitable for inter cropping also in banana and sugarcane.

3**. Breeding for quality**
Seed coat color and quality – Yellow, Black, Brown Green

Oil content and quality

Protein content

a) Seed coat color:

May be yellow, green, black, brown or combination of all the above colours. For oil extraction yellow color is preferred because of high oil content where as black seeded varieties are low in oil content but high is protein content.

b) Oil content and quality:

Oil content is greatly determined by environment :

Yellow seed coat varieties are rich in oil. Complex character determined by poly genes.

c) Protein content and quality:

Ranges from 35 to 50%, protein content is negatively correlated with oil content so while breeding for high protein content a compromise is to be made.

Breeding for vegetable type
Breeding for forage type of soybean
Breeding for non -shattering type E.g. Lee, Co2
Breeding for YMV resistant lines Co 2

Breeding Methods:

Introduction : EC 39821 from Taiwan - released as Co1
Pure line selection: Co1
Hybridization and selection: Clark,

Mutation breeding.

Breeding centers:

Asian Vegetable Research and Development Centre (AVRDC) Taiwan
International Institute of Tropical Agriculture (IITA) Nigeria
In India National Research Centre for Soybean (NRCS) Indore (M.P)

Practical Achievements:

Varieties: Bragg, Clark 63, Hardee, MACS 13 etc.

Black gram (*Vigna mungo*) 2n = 22

Origin: India

Distribution: India, Pakistan, Sirlanka, and South Asian countries. In India, Maharashtra, UP, MP, Karnataka, Gujarat A.P, Tamil Nadu and Rajasthan.

Progenitor: *Vigna mungo* var *silvestris*

Vigna radiata var sublobata – common progenitor of green gram and black gram.

Breeding objectives

Evolving medium duration high yielding varieties for dry land cultivation.
Evolving short duration high yielding varieties suitable for irrigated conditions.
This can be used as mixed crop in cotton, turmeric Short duration varieties are Co2, Vamban 1, 2 and 3.
Evolving short duration varieties suitable for rice fallow conditions
Breeding varieties resistant to diseases

Pest : White fly vector for YMV and leaf crinkle, leaf eating caterpillar

Breeding for better quality :24% protein. There are lines having 27% protein. These can be utilized.

Quality of black gram is determined by
Protein content

Methionine content 1.17%

cooking quality - Time

% of hard seeds.

Dal recovery 70%

Breeding methods

1. Introduction :

2. Pure line selection :

3. Hybridization and selection

Intervarital

Inter specific :

Vigna mungo x *V.mungo* var.*sylvestris* - Pantnagar. YMV resistant lines obtained. but pod shatters. More number of back crosses suggested.

Vigna mungo x *V.radiata* for increasing pod length, digestibility. Sterility is the main problem. Few plants obtained revert back to parental form.

4) Mutation breeding

Embryo rescue - Attempted in inter specific crosses.

Ideal plant type

For irrigated and Rice fallows

Determinate type, short duration, high dry matter producing with 30cm plant ht. Photo insensitive.

For rainfed condition .

Semi determinate with pod setting from base of the main stem; higher pod length and more number of seeds / pod.

Breeding centers: ICRISAT, - Hyderabad

ICARDA, - (International Crops for Agricultural Research in Dryland Areas) – Syria AVRDC - (Asian Vegetable Research and Development Centre)

IIPR - (Indian Institute of Pulse Research), Kanpur

Varieties:

Black gram : T9, T27, LBG-17, LBG-402

GROUND NUT (*Arachis hypogcaea*) (2n = 40)

It is important oil seed crops in India, grown in subtropical and warm temperate zone also called as peanut or monkey nut. It contains 45-55 per cent oil and 25-30 per cent protein. Origin: Brazil

Distribution:

India, China, USA, Africa, South and South East Asia In India, Gujarath, Andhra Pradesh, Karnataka and Tamil Nadu Maharashtra, Madhya Pradesh, Rajasthan Uttar Prdesh, Punjab.

Progenitor:

Arachis monticola

A – prostrata

A – silvestres

Putative parents and origin of cultivated ground nut.

The cultivated ground nut is a Allotetraploid having A and B genomes. The genus *Arachis* is sub divided into 7 sections. The cultivated ground nut comes under section *Arachis*. This section includes 12 species of which *hypogaea* is the only cultivated species having 2n = 40. The other one is *A.monticola*. The rest ten species are diploids.

Groundnut an unpredictable Crop

Ground nut is popularly known as unpredictable legume. Since the pods are borne below ground positively geotropic we cannot predict its performance before harvest as in the case of other crops. Further Ground nut is highly influenced by environment. If there is no favourable environment yield alone will not be affected but also the quality characters. Less boron means low shelling % and more of immature seeds moisture stress leads to lower yield as well as reduction in well developed kernels. Oil percentage is also influenced by environment. Excess moisture leads to more vegetative growth and reduction in yield. Compared to any other crop here. G x E interaction is more pronounced. Besides abiotic stress, biotic stress also play a major role rust and leaf spot in diseases, red hairy caterpillar and leaf minor in pests cause major havoc. Seed multiplication ratio is 1:5. This is also one of the bottlenecks in the spread of improved varieties.

Classification:

According to Smart 1961 *A.hypogaea* has been sub divided in to two sub species *viz. A.hypogaea* subsp. *Hypogaea, A.hypogaea* subsp *fastigiata*

According to this hypogaea the first two nodes bear vegetative branches then next two branches bear inflorescence

fastigiata : Inflorescence are borne on second and subsequent nodes of primary branches.

In India the cultivated types are grouped into

Bunch type Valencia Spanish bunch

Semi spreading - V*irginia* bunch

Spreading - V*irginia* runner.

Breeding objectives:

Breeding high yielding bunch ground nut with dormancy suitable for dry land conditions

The dry land bunch type sown during June - July often caught up in early N.E. monsoon rains which results in germination of varieties. So it is necessary to breed varieties having dormancy. Semi spreading varieties are dormant TMV 7 slightly dormant varieties, BSR.1, ALR 2 dormant for 15 days.

Breeding varieties for quality

High shelling percentage > 75%

High oil content (> 50%)

TMV 10 the semi spreading variety is having 52% oil. Oil content is highly influenced by environment. ALR. 2-52% oil

High sound mature kernel (SMK) Which is also influenced by environment. Increased boron application results in high shelling

percentage and high SMK %

Table purpose varieties

Hand picked kernel for export market. Valencia types are suitable for this.

Breeding disease resistance varieties.

Rust and leaf spot are causing major damage. If the onset of rust is in initial stage it results in total failure. Late leaf spot hinders harvest of crop due to foliage loss. Tomato spotted wilt virus or Bud necrosis of late gaining importance. NCAC 17090 - resistant

Breeding for pest resistant varieties

Breeding short duration (85 days) varieties suitable for irrigated conditions Breeding Methods:

Introduction:

All the ground nut lines are introduced ones.

Selection :

a) Pure line selection

TMV 2 - Selection from local Gudiyatham bunch. b) Mass selection

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JL 24 from Taiwan variety.

Hybridization and Selection Bunch x Bunch - VRI 2 (Co2 x JL 24)
SSP x Bunch - VRI 3 (R 33-1 x Ah selection)

A.monticola is used for thin shelled conditions and *A.villoulicarpa* for increased number of pods.

Mutation breeding

Gregory in USA extensively adopted and released varieties. Co2 EMS from POL 1

TMV 10 Natural mutant from Argentina local. TG 1 to TG 6 (Vikaram) from BARC Trombay.
GNLM - Gujarat Narrow Leaf Mutant.
Embryo rescue technique :

A.puscilla x A.hypogaea crosses. But not much successful. Cotyledon culture is a success.

Transgenic plants

Transgenic plants for disease resistance. Transfer of a particular gene from wild species thro‟

use of medium of carrier (plasmid) micro projectile bombardment direct transfer. Transfer of disease resistance gene from wild species through plasmid is a success.

Breeding centres: ICRISAT, Hyderabad
NRCG, (National Research Centre for Ground Nut Junagarh)

Practical Achievements

Varieties: Kadiri-3, JL-24, Tirupathi 1, 2, 3, 4 TMV – 2, J11, Vemanara, Jagtial-88

SESAME (*Sesamum indicum*) (2n=26)

It is an ancient oil seed crop of tropics and warm sub-tropics. It is also called as gingelly. Origin: India, and Ethopia (Africa)

Distribution: India, Pakistan, Africa, China, Mexico, Iran, Iraq etc.

Progenitors: Sesamum angustifolium

S. radiatum

Breeding objectives

Breeding high yielding varieties tolerant to drought.

Breeding white seeded varieties

Finest quality of oil is obtained from white seeded lines.

3. Development of mono stemmed varieties.

By this more population per unit area and yield can be increased. Monostemmed varieties are low yielders.

Development of multicapsule / axil and multicarpellary varieties.

Rice fallow varieties: Shorter in duration.

Non- shattering varieties African lines.

Resistant to disease Powdery mildew;

Phyllody - transfer from wild species.

Breeding Methods :

Introduction : African lines.

Pure line selection. TMV6 - Andhra local.

Hybridization and selection.

Inter varietial

Inter specific : Male sterile lines evolved by crossing with *S.malabaricum.*

4. Population improvement

5. Poly ploidy breeding

6. Heterosis breeding

Epipetalous nature makes emasculation and crossing easier Use of CMS lines is also being attempted.

7. Embryo rescue technique.

Varieties Gouri, Madhavi, Rajeshwari, Swetha

Cotton (*Gossypium sps*) (2n = 2x = 26; 2n = 4x = 52)

Cotton is grown in tropical and sub-tropical regions of more than 80 countries of the world.

Origin: Central Africa

Distribution: China, USA, India, Pakistan, Egypt. In India Rajasthan, Maharashtra, M.P.

Gujarat, A.P. Karnataka and Tamil Nadu.

Progenitors: *Gossypium africanum; G. raimondii*

Gossypium africanum – reached India by traders and travelers and differentiated into two species *G. herbaceum* and *G. arboreum*

Cultivated Species:

I. Asiatic cottons or old world cotton (Diploid cotton – 2n = 26)

G. arboreum –

G. herbaceum –

II. New world cotton (Tetraploid cottons – 2n = 52)

G. hirsutum – American / upland cotton

G. barbadense – Egyption / sea island cotton

G. hirsutum is predominant species which contributes about 90% to the current world production. Besides cultivated species there are about 46 wild species India is the only country where all the 4 cultivated species are grown for commercial cultivation.

Breeding objectives:

- High yield (more bolls, bigger bolls and high lint percentage)
- Early maturity

- Superior fibre quality
- Better plant type
- Resistance to diseases like fusarium wilt, rots etc.,
- Resistance to insects like boll worms, Jassids, Thrips etc.,
- Resistance to abiotic stresses.

Breeding Procedures:

Introduction : Cambodia cotton in South India, MCU- 1

Selection : K1 cotton reselection from SRT -1

Hybridization and selection

a) Inter varietal : MCU 5 - Multiple cross derivative

MCU 6 - Multiple cross derivative

MCU 9 - (MCU 5 x MCU 8)

b) Inter specific hybridization

African linted species *(G. africanum)* reached America through pacific ocean and after crossing with American lintless wild diploid species *G. rarimondii* gave birth to tetraploid cotton. The chromosome doubling took place in nature resulting in the development of fertile amphidiploids

4. **Heterosis breeding**

India is the first country in the world to release first commercial hybrid in cotton.

Both intraspecific and interspecific hybrids are evolved in cotton.

Intraspecific : G.*hirsutum* x G.*hirsutum* Shankar (H4) cotton of Surat (Gujarat 67 x American nectariless)

Interspecific hybrids : Varalakshmi (Laxmi x SB 289E) (*hirsutum*) x (*barbadense*)

4. Mutation breeding

MCU 7- Xray irradiated mutant of L 1143

MCU 10 - Gamma irradiated mutant of MCU 4

5. Population improvement followed in USA

Recurrent selection : Pima S1, Pima S4 of G.*barbadense*

Synthetic variety : Deltapine 15 developed at konyvllwer USA.

Composite : Pima 17 of G.*barbadense*.

Biotechnology has helped in developing transgenic cotton with resistance to Helicoverpa. The resistant gene has been transferred from bacteria *Bascillus thuringiensis* into cotton plant by Monsanto Seed Company in U.S.A.

Breeding centers:

International Cotton Advisory Committee (ICAC)

Central Institute of Cotton Research (CICR) Nagpur

All India Coordinated Cotton Improvement Project (AICCIP) Coimbatore

Varieties: MCU – 5, MCU – 10, K9, K10

Hybrids:

Interspecific hybrids - Varalakshmi, HB 224

Intraspecific hybrids - Dhanalaxmi, H4, H6

Desi cotton - DH 7, DH9

Male sterility based hybrids - Suguna, PKVHY3, ARDH- 7

JUTE

***Corchorus* sp (2n=14) Family: Tiliaceae**

The genus Corchorus includes about 40 species. In India only 8 species occur.

Two cultivated species are

***C.capsularis* : White jute** 50 races occur in this

C.olitorius : Tossa jute 8 races occur in this. Both the species are not crossable. Among the two olitorius yields more fibre/unit area. The fibre is finer, softer, more, lustrous and less rooty than capsularis. Olitorius occupies about 25% of jute area in India. One of the draw backs of Tossa jute is pre mature flowering if the varieties are sown earlier in March-April in early monsoon rains. The pre mature flowering leads to profuse branching and deterioration in fibre quality. Capsularis strains are characterised by a single flush of flowering at the end of single vegetative period. Based on maturity, the varieties in Capsularis are divided in to Early - Flowering in July Medium - August Late - September.

Breeding objectives:

1. **Breeding for high yielding short duration jute varieties**. Early varieties are generally low yielders whereas late varieties are high yielders. So to combine high yield with earliness is one of the main objectives. Yield is positively correlated with plant height, basal diameter of stem, fibre-stick ratio. Higher photo synthetic capacity with increased lamina length, breadth, petiole length and leaf angle at 400 also contribute to yield.

2. **Breeding for quality fibre** In jute quality is negatively, correlated with yield. The quality characters are

a**) Fibre length.**

b) Fibre strength

c) Fibre colour

d) Lustre

e) Percentage and quality of retting

f) Proportion of faults such as roots, spects, knots.

Environment plays a major rote in quality. Alternate and fluctuating bright sunshine, humidity and temperature and rainfall at minimal level are favourable for improved quality. Further retting in clear and slow running water gives good quality fibre. The tall and thick plants in general gives inferior fibre than that in short and thick plant.

Breeding for pest and disease resistant varieties: In pests, stem borer and aphids cause greater damage and in diseases Macrophomena is major. Though resistance sources are available in other related species, the crossability barrier prevents transfer.

4**. Breeding varieties for high seed yield** : Since jute is cut for fibre at 50% flowering stage, it is essential to reserve some plants for production of seeds. The fibre obtained from seed crop will be poor in quality. Hence it is necessary to breed varieties specially for high seed production with out loosing quality characters.

5. **Breeding for olitorius varieties having non-shattering habit coupled with non-pre flowering habit.** JRO 524 JRO 7885 Sudan green x JRO 632

Breeding Methods:

1. **Germplasm building** and Utilisation Central Jute Technological Research Institute, Calcutta is maintaining the Jute collections. This shows wide range of variability thus offering a great scope for improvement by selection and hybridsation.

2**. Introduction** : Introduced short duration varieties are Jap green, Jap red, Jaichung sudan green.

3. **Hybridization and selection** a) Inter vareital: Multiple crossing and selection are followed both in olitorius and capsularis improvement. In olitorius improved varieties are JRO 524, JRO 7885. In capsulanis JRL 412, JRL 919 Since yield and quality are negatively correlated a balance must be struck in breeding for improved varieties. b) Inter specific cross: So far not successful. Attempts were made by straight cross mixed pollen method, Stigmatic paste method, self anther paste method, stigma cut method polyploidy breeding. But none of them proved successful. Difference in embryo endosperm growth is the reason

4. **Mutation breeding** : Using x rays useful jute mutants were obtained at Calcutta JRC 7447 and Rupali two varieties.

MESTA, KENAF

BIMLI JUTE

Hibiscus cannabinus H.sabariffa Var.altissima

Malvaceae

In **Thailand Siami jute or Roselle in India**.

Both the species are important jute supplements and show wide adaptability unlike jute. At present both the species are known as Mesta.

Place of origin : *H.cannabinus* have its possible origin in Africa *H.sabadariffia* - Asia. Kenaf is used for making ropes, twines, fishing nets and also in the paper pulp making from kenaf stalks especially fine paper, structural boards.

H.cannabinus : **mesta**

Compared to jute mesta is of inferior in quality in respect of fineness, lusture, and colour. Mesta varieties show poor performance in spinning because the fibre is coarse, stiff, brittle and irregular in cross section mesta alone cannot be spun in jute machines unless it is mixed with jute in some proportion.

H.sabadarifra var.altissima **(Roselle)** Roselle is an useful substitute to jute. It is also called as Siamijute two types are available. i. Tall non branching types cultivated for fibre. ii. Dwarf, bushy wild type used as green and edible calyx as pickle.

Breeding objectives :

1. Breeding of high yielding short duration mesta varieties (Similar to Jute)
2. Breeding for quality fibre (Similar to Jute)
3. Breeding for pest and disease resistant varieties

Chapter No.: 07

Seed production Technology in self pollinated, cross pollinated crops and vegetatively propogated crops

The various steps suggested for maintaining genetic purity are as follows:

a. Providing adequate isolation to prevent contamination by natural crossing or mechanical mixtures
b. Rouging of seed fields prior to the stage at which they could contaminate the seed crop.
c. Periodic testing of varieties for genetic purity.
d. Avoiding genetic shifts by growing crops in areas in their adaptation only.
e. Certification of seed crops to maintain genetic purity and quality of seed.
f. Adopting the generation system.
g. Grow out tests.

Agronomic principles

1. **Selection of a Agro-climatic Region:** A crop variety to be grown for seed production in an area must be adapted to the photoperiod and temperature conditions prevailing in that area.
2. **Selection of seed plot:** The plot selected for seed crop must be free from volunteer plants, weed plants and have good soil texture and fertility The soil of the seed plot should be comparatively free from soil borne diseases and insects pests.
3. **Isolation of Seed crops:** The seed crop must be isolated from other nearby fields of the same crops and the other contaminating crops as per requirement of the certification standards.
4. **Preparation of Land:** Good land preparation helps in improved germination, good stand establishment and destruction of potential weeds. It also aids in water management and good uniform irrigation.
5. **Selection of variety:** The variety of seed production must be carefully selected, should possess disease resistance, earliness, grain quality, a higher yielder, and adapted to the agroclimatic conditions of the region.
6. **Seed treatment**

Depending upon the requirement the following seed treatment may be given

a. Chemical seed treatment.
b. Bacterial inoculation for the legumes.
c. Seed treatment for breaking dormancy.

7. **Time of planting:** The seed crops should invariably be sown at their normal planting time. Depending upon the incidence of diseases and pests, some adjustments, could be made, if necessary.
8. **Seed Rate:** Lower seed rates than usual for raising commercial crop are desirable because they facilitate rouging operations and inspection of seed crops.
9. **Method of sowing:** The most efficient and ideal method of sowing is by mechanical drilling.
10. **Depth of sowing:** Depth of sowing is extremely important in ensuring good plant stand. Small seeds should usually be planted shallow, but large seeds could be planted a little deeper.
11. **Rouging**: Adequate and timely rouging is extremely important in seed production. Rouging in most of the field crops may be done at many of the following stages as per needs of the seed crop.

    a. Vegetative / preflowering stage

    b. Flowering stage

    c. Maturity stage

12. Supplementary pollination

Provision of honey bees in hives in close proximity to the seed fields of crops largely cross pollinated by the insects, ensure good seed set thereby greatly increase seed yields.

13 .Weed control: Good weed control is the basic requirement in producing good quality seed. Weeds may cause contamination of the seed crop, in addition to reduction in yield.

14. Disease and insect control: Successful disease and insect control is another important factor in raising healthy seed crops. Apart from reduction of yield, the quality of seeds from diseased and insect damaged plants is invariably poor.

15. **Nutrition:** In the nutrition of seed crops, nitrogen, phosphorus, potassium, and several other elements play an important role for proper development of plants and seed. It is, therefore, advisable to know and identify the nutritional requirements of seed crops and apply adequate fertilizers.
16. **Irrigation:** Irrigation can be important at planting for seed crops on dry soils to ensure good uniform germination and adequate crop stands. Excess moisture or prolonged drought adversely affects germination and frequently results in poor crop stands.

17. Harvesting of Seed crops: It is of great importance to harvest a seed crop at the time that will allow both the maximum yield and the best quality seed.

18. Drying of seeds: In order to preserve seed viability and vigour it is necessary to dry seeds to safe moisture content levels.

19. Storage of raw seeds: The best method of sowing seed for short periods is in sacks or bags in ordinary buildings or godowns.

Maintenance of Genetic Purity during seed Production

Horne (1953) had suggested the following methods for maintenance of genetic purity;

1. Use of approved seed in seed multiplication
2. Inspection of seed fields prior to planting
3. Field inspection and approval of the Crop at critical stages for verification of genetic purity, detection of mixtures, weeds and seed borne diseases.
4. Sampling and sealing of cleaned lots
5. Growing of samples with authentic stocks or Grow -out test

Various steps suggested by **Hartman and Kestar (1968) for maintaining genetic purity** are as follows;

1. Providing isolation to prevent cross fertilization or mechanical mixtures
2. Rouging of seed fields prior to planting
3. Periodic testing of varieties for genetic purity
4. Grow in adapted areas only to avoid genetic shifts in the variety
5. Certification of seed crops to maintain genetic purity and quality
6. Adopting generation system

Safe guards for maintenance of genetic purity

The important safe guards for maintaining genetic purity during seed production are;

1. **Control of seed source**

2. Preceding crop requirement

3. Isolation

4. Rouging of seed fields

5. Seed certification

6. Grow out test

1. **Control of Seed Source :** The seed used should be of appropriate class from the approved source for raising a seed crop. There are four classes of seed from breeder seed, which are given and defined by Association of Official Seed Certification agency (AOSCA).

1. **Nucleus seed:** is the handful of original seed obtained from selected individual plants of a particular variety for maintenance and purification by the originating breeder. It is further multiplied and maintained under the supervision of qualified plant breeder to provide breeder seed. This forms the basis for all further seed production. It has the highest genetic purity and physical purity.

2. Breeder's seed: This is the progeny of the nucleus seed multiplied in large area under the supervision of plant breeder and monitored by a committee. It provides cent per cent physical and genetic pure seed for production of foundation class. Golden yellow coloured certificate is issued for this category by the production agency.

3. Foundation seed: Progeny of breeder's seed in handled by recognized seed producing agencies in public and private sector under the supervision of Seed Certification Agency in such a way that its quality is maintained according to the prescribed standard. Seed Certification agency issues a white colour certification for foundation class seed. Foundation seed is purchased by Seed Corporation from seed growers. Foundation seed can again be multiplied by Seed Corporation in the events of its shortage with similar seed certification standard.

4. Certified seed: Progeny of foundation seed produced by registered seed growers under the supervision of Seed Certification Agency by maintaining the seed quality as per minimum seed certification standards. Seed Certification Agency issues a bleu colour (Shade ISI No. 104, azure blue) certificate.

2. **Preceding Crop requirement :** This has been fixed to avoid contamination through volunteer plants and also the soil borne diseases.

3. **Isolation :** Isolation is required to avoid natural crossing with other undesirable types, off types in the fields and mechanical mixtures at the time of sowing, threshing, processing and contamination due to seed borne diseases from nearby fields. Protection from these sources of contamination is necessary for maintaining genetic purity and good quality of seed.

4. **Rouging of Seed Fields:** Roguing refers to removal of off type plants from the field of an improved variety. The main objective of rouging is to avoid contamination through mechanical

mixture and due to outcrossing. In self pollinated crops, generally roguing is done at three different stages.

(a) before flowering based on leaf and stem character

(b) after flowering based on flower characters

(c) before harvesting based on grain, ear, lint colour as the case may be.

Important features of the variety are taken into account during the process of rouging. Any plant deviating from the main features of the variety under multiplication is removed. In cross pollinated crop roguing should be completed before flowering. The diseased plant should also be removed to prevent the spread of disease and ensure good quality of the seed.

The existence of off type plants is another source of genetic contamination. Off type plants differing in their characteristics from that of the seed crop are called as off types. Removal of off types is referred to as roughing.

The main sources of off types are

a. **Segregation of plants for certain characters or mutations**

b. Volunteer plants from previous crops or

c. Accidentally planted seeds of other variety

d. Diseased plants

Off type plants should be rouged out from the seed plots before they shed pollen and pollination occurs. To accomplish this regular supervision of trained personnel is required.

5. **Seed Certification:** Genetic purity in seed productions maintained through a system of seed certification. The main objective of seed certification is to make available seeds of good quality to farmers. To achieve this qualified and trained personnel from SCA carry out field inspections at appropriate stages of crop growth. They also make seed inspection by drawing samples from seed lots after processing. The SCA verifies for both filed and seed standards and the seed lot must confirm to get approval as certified seed.

6. **Grow-out Test :** varieties that are grown for seed production should be periodically tested for genetic purity by conducting GOT to make sure that they are being maintained in true form. GOT test is compulsory for hybrids produced by manual emasculation and pollination and for testing the purity of parental lines used in hybrid seed production.

Field inspection is made by the inspectors of State Seed Certification Agency to examine the suitability of the crop for certification. The main purpose of field inspection to examine

1. Isolation distance
2. Percentage of off types
3. Objectionable weed seeds
4. Disease and insect incidence
5. General crop condition

The off types should not be more than the maximum standard prescribed for the crop. The maximum off type plants in the seed plot of foundation and certified seed are permitted from 0.05-1% depending upon the species.

The number of field inspection varies from 2 to 4 depending upon the crop species. When only two inspections are made in self pollinated crops, one is made one is made before flowering and another before harvesting. In case of three field inspections as in cross pollinated crops, one is made before flowering, second at the time of flowering and third before harvesting. In case of four inspections as in hybrid varieties crops, one is made before flowering, one at the time of flowering and two between flowering and harvesting.

Table: Minimum number of field inspections required for certification in different crops

Minimum Inspections	Name of the Crops
Two	Wheat, Triticale,barley, rice, black gram, green gram, soybean, chickpea, lentil, pigeon pea, cotton, sunflower, linseed, cowpea, cluster bean etc.
Three	Pearlmillet (varieties), sorghum (varieties), sesame, rapeseed and mustard, brinjal, chilli, carrot, radish, turnip, tomato etc.
Four	Maize (hybrids), sorghum (hybrids), pearlmillet (hybrids), cauliflower etc.

Seed Production Technology in Cross pollinated crops:

Hybrid is produced by crossing between two genetically dissimilar parents. Pollen from male parent (Pollen parent) will pollinate, fertilize and set seeds in female (Seed parent) to produce F1 hybrid seeds. For production of a hybrid crossing between two parents is important, the crossing process will results in heterosis. In self pollinated cross it is difficult to cross but in cross

pollinated crops it is easier. In nature to create genetic variability and for its wider adaptation in different environmental conditions, flowering plants has adopted many mechanisms for cross pollination. Cross-pollination results in genetic heterogeneity and show wider adaptations. Flowering plants have evolved a number of devises to encourage cross-pollination.

Those mechanisms are;

1. **Dicliny:** Flowers are unisexual. In monoecious plants male and female flowers are borne on the same plant (Cucurbits, Maize, Castor and Coconut). In dioecious plants male flowers are borne on different plants (Papaya, Cannabis, and Mulberry).
2. **Dichogamy:** Time of anther dehiscence and stigma receptivity are different forcing them for cross-pollination. The time gap between the two may vary from one day to many days. In protoandry anthers dehisce earlier than the stigma receptivity (Maize and Sunflower). In protogyny stigma become recetive earlier than the anther dehisce (Pearl millet and Mirabilis).
3. **Self-incompatibility:** self fertilization in avoided by recognizing the self pollen by the stigma (Brassica, Petunia, Lilium).
4. **Herkogamy:** there is spatial separation of the anthers and stigma. Their relative position is such that self fertilization cannot occur. The stigma projects beyond the anthers and therefore pollen cannot land on stigma. Lucerne stigma is covered with a waxy film. The stigma does not become receptive until this waxy membrane is broken by visit of honeybees resulting in cross-pollination.
5. **Male sterility:** Absence or atropy or mis or malformed of male sex organ (functional pollen) in normal bisexual flower. Male sterility is of three types: genetic male sterility, cytoplasm sterility and cytoplasmic- genetic male sterility.
6. **A combination of two or more of the above mechanisms may occur in some species.** This improves the efficiency of the system in promoting cross-pollination.

Requisites of hybrid seed production:

1. Breeder's responsibilities

(a) Develop inbred lines

(b) Identification of specific parental lines

(c) Develop system for pollen control

2. Major problems for breeders & producers

(a) Maintenance of parental lines

(b) Separation of male and female reproductive organs

(c) Pollination

Characteristics of parental lines

Female Parent	Male Parent
High seed yield	Good pollen production
Good seed characteristics	Plant height
Male sterility	Long shedding period
Lodging resistant	Fertility restoration

Basic procedures for hybrid seed production

1. Development and identification for parental lines
2. Multiplication of parental lines
3. Crossing between parental lines and production of F1

Methods of commercial hybrid seed production

1. Hand emasculation and pollination
2. Self-incompatibility
3. Male sterility
4. Dicliny: monoecious and dioecious

1. Hand emasculation and pollination

Hybrid seeds are produced manually by modifying the plant structure by removal of male organ from female plant before anthesis. This system is possible only when the male and female parts of a single flower or plants are separate. This is being adopted in bisexual perfect flowers where the androecium is removal with case. By removing the anther column or male part from female line, the sterility of female line is created and is dusted with the pollen of desired male parent.

2. Self Incompatibility

Self-incompatibility is a mechanism which avoids self fertilization through recognition of self pollen in or on stigma on the female pistil. But when pollen from other plant carried by wind or insects is accepted and sets seeds. Self-incompatibility will prevent self pollination (inbreeding) and promotes cross pollination (out crossing) and creates genetic variability. SI is seen in

hermaphrodite and homomorphic flowers. Self-incompatibility is a widespread mechanism in flowering plants that prevents inbreeding and promotes out crossing. The self-incompatibility response is genetically controlled by one or more multi-allelic loci, and relies on a series of complex cellular interactions between the self-incompatible pollen and pistil.

3. Male Sterility

Hybrid production requires a female plant in which no viable male gametes are borne. Emasculation is done to make a plant devoid of pollen so that it is made female. Another simple way to establish a female line for hybrid seed production is to identify or create a line that is unable to produce viable pollen. This male sterile line is therefore unable to self-pollinate and seed formation is dependent upon pollen from the male line.

In hermaphrodite flowers pollens are non-functional or inactive or sterile while, female gametes functions normally. It is the inability of plant to produce or to release functional pollen as a result of failure of formation or development of functional stamens, microspores or gametes. Male sterility can be either genetic or cytoplasmic or cytoplasmic-genetic. This prevents autogamy and permits cross pollination. Sterility is due to nuclear genes or cytoplasmic gene or both. In hybrid seed production process female is a male sterile line crossed with male fertility restorer line to get F-1 hybrid.

4. Dicliny: monoecious and dioecious

Monoecious: Flowers are unisexual and are present at different position on the same plant (eg. Cucumber). Terminal flowers are male flower. In the middle of the plant is female favouring cross pollination.

Dioecious: Male flowers and female flowers are on different plants.

Sex expression in dioecious and monoecious plants is genetically determined and can be modified to a considerable extent by environmental and introduced factors such as photoperiod, temperature, mineral nutrition and phytohormones. Amongst these, phytohormones have been found to be most effective agents for sex modification and their role in regulation of sex expression in flowering plants has been documented.

Chapter No.: 08

Hybrid seed production technology in Rice, Maize, Sorghum, Pearl millet and Pigeonpea

Hybrid Rice Seed Production; Hybrid vigour in rice has been first reported by Jones (1926). This has led to speculation regarding the production of hybrid rice by utilizing cytoplasmic male sterility. Most japonica rice has normal cytoplasm, but *indica* varieties with sterile cytoplasm and fertility restoring system have been identified. But difficulties have been encountered in obtaining sufficient seed set by cross pollination to make hybrid rice seed production economically feasible. After the implementation of UNDP/FAO project entitled "Development and use of hybrid rice technology in India" - the hybrid rice production in India has become a success story.

Hybrid rice seeds were produced using (cytoplasmic genic male sterility) three line system. The two genes Rf1 and Rf2 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 F1 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

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. b) Time 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 Favourable climatic condition for normal flowering are (i) Mean temperature 24-28°C (ii) Relative humidity 70-80% (iii) Day and night temperature difference 8-10°C. (iv) Sufficient sunshine (v) 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 (i) The growth duration of the R line (ii) Growth vigor of the R line (iii)Amount of pollen shed and (iv) 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, gibberellins application and supplementary pollination These techniques are very effective for increasing the out crossing 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 (GA3) GA3 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%). GA3 affects exertion of panicle completely out of flag leaf sheath. In India recommended dose of GA3 is 50g/ha using knapsack sprayer and 25g/ha with ultra low volume sprayer.

Advantage of GA3 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 and processing - the male parent harvested first - care should be taken to avoid admixture of male and female lines. - female line should be threshed separately in a well cleaned threshing floor - seed field dried in shade to 12% moisture content - packed in suitable, cleaned gunny bags after grading
Hybrid Rice CORH - 1 (MGR Rice) : Released in1994 Short duration, medium fine grain (Parentage : IR 62829A x IR10198-66-2R) Breeding method : Three line Breeding Season : May-June (Kar-Kuruvai) Duration : 110-115 days Yield : 6380 kg/ha

HYBRID SEEDS PRODUCTION TECHNIQUE IN MAIZE

Development of Hybrids:
Hybrids are the first generation (F1) from a cross between two pure lines, open pollinated varieties or clones that are genetically dissimilar. Most of the commercial hybrids are F1s from two or more pure lines (tomato, rice, Jowar) or inbred lines (maize, sunflower, caster etc.) Pure line: It is the progeny of single self-fertilized homozygous plant.
Hybrid breeding: Exploitation of heterosis through hybrids can be mainly attributed to the pioneering work done by G.H. Shull and D.F. Jones. Various types of hybrids in maize based on inbred lines are:

Single crosses hybrid - A single cross hybrid is produced by crossing two unrelated inbreds which produce best performing F_1 hybrids.

Three way crosses hybrid - A three way cross hybrid is produced by crossing a single cross with an inbred line. Hence it involves three inbred lines. = (A x B) x C.

Double cross hybrid - Produced by a cross between two single crosses. Four unrelated inbred lines are involved = (A x B) x (C x D).

Top-cross hybrid - Crossing an inbred with an open pollinated variety also known as inbred-variety hybrid.

Double top-cross hybrid - A double top cross is the progeny of a single cross and a variety [(Ax B) x variety].

Inbred line: It is a near homozygous line obtained by continues inbreeding in a cross pollinated crop followed by selection.

Top cross: when an inbred is crossed with an open pollinated variety it is known as an inbred variety cross or a top cross. The purpose of top cross is to estimate the GCA of the inbred line crossed with OPV. When the cross is made to assess the combining ability it is known as test cross. A test cross may be made with an inbred (for SCA), hybrid, synthetic or OPV (for GCA). The common parent used in the test cross is known as tester and the progeny derived from these crosses are known as test cross progeny.

Polycross: It is the progeny of a line produced through random pollination by a number of selected lines.

Varietal cross: When two open pollinated varieties are mated it is known as varietal cross or population cross.

History of hybrids: Hybrids were first commercially exploited in maize because the yielding ability Of OPV could not be improved by mass selection or progeny selection. In 1878 Beal had shown that certain varietal crosses showed substantial heterosis and he suggested that such varietal hybrids might be used as varieties. In 1908 Shull suggested a method for producing single cross hybrids in maize. He suggested that inbreds should be developed from OPV by continues self-fertilization. The inbreds that combined to produce superior hybrids should then be crossed to produce single cross hybrids.

Shull's scheme could not be exploited commercially because of the following reasons:

1. Outstanding inbred lines were not available to produce hybrids with higher yields than that of OPV.
2. Since the female parent was an inbred, the amount of hybrid seed produced per acre was low (30-40 % of OPV), consequently the hybrid seed was expensive.
3. The male parent was also an inbred, hence pollen production was poor. So more area was to be planted under the male parent. This made the hybrid seed more expensive.
4. The hybrid seed was poorly developed as it was produced on the inbred line. The seeds were irregular, undersized with poor germination, thus requiring higher seed rate.
5. Cost of hybrid seed was very high. The last four drawbacks were overcome by the double cross scheme proposed by Jones in 1918. Since in a double cross the female and male parent are single crosses, the seed and pollen production are abundant, seed quality and germination were high as a result the cost of hybrid seed was low. The first double cross maize hybrid was produced at the Connecticut Agricultural Experimental station and grown in Connecticut in 1921 and was named as Burr Learning Hybrid.

Various operations in the production of hybrids are:

Development of inbred lines.
Evaluation of inbred lines.

Production of hybrid seed.

1. **Development of inbred lines**: Inbred lines are developed by continues self fertilization of a cross-pollinated species. Inbreeding of an OPV leads to many deficiencies like loss of vigour, reduction plant height, plants become susceptible to lodging, insects and pests and many other undesirable characters appear. After each selfing desirable plants are selected and self pollinated or sib pollinated. Usually it takes 6-7 generations to attain near homozygosity. An inbred line can be maintained by selfing or sibbing. The purpose of inbreeding is to fix the desirable characters in homozygous condition in order to maintain them without any genetic change.

The original selfed plants is generally referred as S0 plant and the first selfed progeny as S1 second selfed progeny as S2 as so on. The technique of inbreeding requires careful attention to prevent natural crossing. The inbred lines are identified by numbers, letters or combination of both. In India inbred lines are developed and released through co-ordinate maize improvement scheme and are designated as CM (Co-ordinate maize), CS (Co-ordinate sorghum) etc.

CM-100-199 - Yellow flint
CM-200-299 - Yellow Dent
CM-300-399 - White Flint
CM-400-499 - White Dent
CM-500-599 - Yellow
CM-600-699 – White

Evaluation of inbred lines: After an inbred line is developed, it is crossed with other inbreds and its productiveness in single and double cross combination is evaluated. The ability of an inbred to transmit desirable performance to its hybrid progenies is referred as its combining ability.

GCA: The average performance of an inbred line in a series of crosses with other inbred lines is known as GCA.

SCA: the excessive performance of a cross over and above the expected performance based on GCA of the parents is known as specific combining ability Thus GCA is the characteristic of parents and SCA is characteristic of crosses or hybrids.

The inbreds are evaluated in following way.

a. **Phenotypic evaluation**; It is based on phenotypic performance of inbreds themselves. It is effective for characters, which are highly heritable i.e. high GCA. Poorly performing inbreds are rejected. The performance of inbreds is tested in replicated yield trials and the inbreds showing poor performance are discarded.

b. **Top Cross test:** the inbreds, which are selected on phenotypic evaluation, are crossed to a tester with wide genetic base eg. An OPV, a synthetic variety or a double cross. A simple way of producing top cross seed in maize is to plant alternate rows of the tester and the inbred line and the inbred line has to be detasselled. The seed from the inbreds is harvested and it represents the top cross seed. The performance of top cross progeny is evaluated in replicated yield trials preferably over locations and years. Based on the top cross test about 50% of the inbreds are eliminated. This reduces the number of inbreds to manageable size for next step. Top cross performance provides the reliable estimate of GCA.

c. Single cross evaluation: Out standing single cross combinations can be identified only by testing the performance of single cross. The remaining inbred lines after top cross test are generally crossed in diallel or line x tester mating design to test for SCA. A single cross plants are completely heterozygous and homogenous and they are uniform. A superior single cross regains the vigour and productivity that was lost during inbreeding and can be more vigorous and productive than the original open pollinated variety. The performance of a single cross is evaluated in replicated yield trial over years and location and the 44 outstanding single cross identified and may be released as a hybrid where production of single cross seed is commercially feasible.

In case of maize the performance of single cross is used to predict the double cross performance.

Number of Single crosses with reciprocals = n(n-l)

Number of single crosses without reciprocals = n(n-l)/2

Prediction of the Performance of Double Cross Hybrids :In a double cross hybrid, four inbred parents are involved. Theoretically, the potential of the double cross will be the function of the breeding value of these four parental inbreds. Therefore, based on the procedure of testing of the breeding value of inbreds, the performance of a double cross hybrid can be predicted through any of the four methods indicated by Jenkins (1934). Starting with the simplest procedure these methods are:

a) Top-cross testing (one cross per inbred) to know the breeding value of each of the four inbreds (total 4 top-crosses per double cross).

b) Mean of the four non-parental single crosses involved in (AXB) X (CXD) double cross, viz., (AXC), (AXD), (BXC) and (BXD) (total 4 non-parental single crosses per double cross).

c) Average yield performance of all possible six crosses [n(n-1)/2], namely AXB, AXC, AXD, BXC, BXD and CXD (total six crosses per double cross).

d) Average progeny-performance of each inbred can be determined by the mean performance of each inbred in all possible single crosses where it occurs (n-1 crosses per inbred). For instance, the mean performance of AXB, AXC and AXD will determine the average breeding value of the inbred A. Similarly, the mean of AXB, BXC and BXD will indicate the potential of the inbred B and so on (total 12 crosses per double cross).

These procedures of predicting the performance of double cross hybrids have been extensively investigated long ago. The available evidence shows that the method (b), i.e. mean performance of non-parental single crosses, is the most adequate and effective, since there is a close correspondence between predicted and realized yields of double crosses in maize. Fortunately, the total number of crosses required to be sampled per double cross is also the minimum, thus greatly facilitating the testing programme.

Hybrids for Special Uses

Hybrids in maize are also being developed for special purposes, such as sweet corn, popcorn and waxy corn in addition to the larger use for feeding livestock and corn-milling industry. Sweet corn hybrids are called as Super sweet due the presence of shrunken-2 (sh2) gene which increases sugar content along with extended peak quality in these hybrids. Waxy corn is used in the manufacture of adhesives, gums, paper sizing and puddings due to the presence of amylopectin a special type of endosperm starch.

HYBRID SEEDS PRODUCTION TECHNIQUE IN SORGHUM

In sorghum hybrid seed is produced by utilizing cytoplasmic genetic male sterile system. The source of male sterile cytoplasm used is Combined kafir. Hybrid seed production involves two steps;

1. **Maintenance of parental Lines (A-line, B-line and R-line)**

Commercial hybrid seed production (A x R) Maintenance of parental lines is generally referred as foundation seed production and hybrid seed production as certified seed class. The A-line can be maintained by crossing with B-line in an isolated plot, while in hybrid seed production A-line is crosses with R-line or fertility restorer line. The B-line and the R-line can be maintained just like normal varieties by following the required isolation and field standards. As the maintenance of B-line and R-line is just like normal varieties it is not discussed in detail.

Seed Production of B-line and R-line: The seed is produced in an isolated plot and it is similar to seed production of open pollinated varieties. However the isolation distance required and the fields standards are similar to that of maintenance of A-line.

Maintenance of A-line or Hybrid seed Production (AxR):

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 requirement: The isolation distance for maintenance of A-line (AxB) is 300 m from fields of other varieties of grain and dual purpose sorghum and same variety not onfirming to varietal purity and 400 m from Johnson grass, Sudan grass and other forage types. For commercial hybrid seed production (A x R) the isolation distance required is 200 m from fields of other varieties of grain and dual purpose sorghum, and same hybrid not confirming to varietal purity requirements of certification, 5 m from other hybrid seed production plot having the same male parent and 400 m from Johnson grass, Sudan grass and other forage types. Differential blooming dates for modification of isolation distance are not permitted

Planting ratio: The planting ratio of female to male plants is 4:2 with two rows of male parent all around the field.

Brief cultural practices: The success in hybrid seed production depends on synchronization of flowering between male and female parent. For maintenance of A-line synchronization of flowering will not be a problem as both A and B-lines are isogenic lines and come to flowering

at the same time, while in hybrid seed production synchronization will be a problem as A-line and R-line have different genetic constitution.

If there is any difference between the male and female parent for days to flowering the sowing dates should be adjusted for proper synchronization of flowering. The seed rate required is 8.0 kgs/ha of A-line and 4.0 kgs/ha of B or R-line. Other cultural practices similar to commercial crop production should be adopted for raising a good crop.

Cultural manipulation for nicking: Proper synchronization of flowering between A-line and R-line is a common problem. In-spite of taking the precautions like adjusting the sowing dates some times synchronization may be a problem. If the difference between the male and female parent is less than a week it can be manipulated by cultural practices. The parent which is lagging should be sprayed with 1 per cent urea solution 2-3 times at an interval of 2-3 days or additional irrigation should be given to the Lagging parent. Blowing air by perating empty duster with the mouth directed horizontally to the male ears, will help to disseminate pollen.

Rouging: Before flowering remove all offtypes from both seed parent and pollen rows based on morphological characters. Some of the precautions to be taken while rouging are

1. Start rouging before offtypes, volunteers and pollen shedders in female rows start shedding pollen
2. Out crosses can be easily identified be cause of their greater height and more vigorous growth and should be removed
3. At flowering rouging should be done every day to remove pollen shedders from female parent rows. The sterile types have only stigma or a pale aborted anthers without pollen, while the fertile ones have yellow colored plumpy anthers which shed large amount of residual pollen.
4. Remove all plants out of their place (i.e. plants in between the lines), and male plants in female rows and vice versa. Special attention should be given at the ends where there is a chance of male seed falling in female rows .
5. Remove other sorghum related plants like Johnson grass, Sudan grass and other forage types from the seed plot and from within the isolation distance.
6. Remove the plants affected by kernel bunt and head smut.
7. Pre harvest rouging may be done based on grain and ear characters.

Number of Field Inspections : A minimum of four field inspections should be conducted. The first field inspection should be conducted before flowering stage, second and third during flowering stag and fourth before harvesting. During the first field inspection verification should be done for volunteer plants, isolation requirement, errors in planting and the actual acreage sown. During the second and third field inspection verification should be done for isolation requirement, off types, diseased plants, pollen shedders and objectionable weed plants. Actual counts should be taken during second or third field inspection. Fourth or final field inspection should be done to verify for all the above factors and the off types can be identified based on panicle or seed characters.

	Foundation class	Certified class

Off types	0.05 %	0.10 %
Pollen shedders	0.05 %	0.10 %
Diseases plants	0.05 %	0.10 %

(kernel smut or grain smut and head smut)

Harvesting and threshing: Harvest the male rows first and keep their heads separate to avoid mixture male and female seed. Then harvest the female parental line and thresh it separately. Precautions may to taken while harvesting and threshing to avoid mechanical mixtures.

Seed Yield: The seed yield may be in the range of 4 -6 q/ha depending on the parent line and the cultural practices adopted.

HYBRID SEEDS PRODUCTION TECHNIQUE IN COTTON

1. **DOAK's method of hybrid seed production** In this method, manual emasculation of flowers is done one day before anthesis, and pollination next day morning. For convenience, the parental varieties are grown in same fields in the ratio of 4:1 (Emasculation and pollination is done as described earlier).

2. **Use of male sterile line Cytoplamic**. genic male sterility was developed by Vesta G. Meyer an American scientist. She obtained CMS lines by transferring hirsutum genome to the cytoplasm of wild species G.harknessi. Restorer lines were also developed in hirsutum and barbadense back ground. Genic male sterility was also observed in cotton but utilisation is difficult due to segregation of sterile line in 50:50 ratio of sterile and fertile and maintenance of sterile line is laborious. Another type of male sterility is transformation of staminal column into a petaloid condition. This was obtained when G.arboreum genome is transformed to cytoplasm of G.anamalum

3. Practical difficulties in use of CMS lines for hybrid seed production

a) Lack of simply inherited restorer gene that maintains fertility over a wide range of environment.

b) lack of development of good combiners possessing male sterile cytoplasm and restorer factor.

c) Lack of dependable and economic method of controlling pollination by insect pollen vectors.

4. Mutation breeding MCU 7- Xray irradiated mutant of L 1143 MCU 10 - Gamma irradiated mutant of MCU 4

5. Population improvement followed in USA

a) Recurrent selection : Pima S1 Pima S4 of G.barbadense

b) Synthetic variety : Deltapine 15 developed at konyvllwer USA.

c) Composite : Pima 17 of G.barbadense.

H. Special breeding techniques in cotton a) Bulked progeny method (Texas method) In commercial cotton varieties with a broad genetic base is desirable so that they have the adaptability to the requirement of varied and widely different environmental conditions. Texas method provides such plasticity. (i) Open pollinated seeds of selected F2 single plants are grown

in replicated randomized block design along with standard check variety. Best progeny are marked and harvested on single plant basis. Yield and fibre quality will be assessed and best ones will be selected and seeds will be bulked for testing in F4. (ii) Again the F4 bulks are also tested in replicated randomised block design the process done in F3 is repeated. (iii) The F5 and F6 progenies are tested in MLT and later released as variety.

b) Mass pedigree selection technique of Harland This system was used by Harland for the improvement of Peruvian cotton variety with spectacular success. First season : Examine a large number of selected single plant from a heterogenous commercial crop and fix up specification or norms for making selection. Second season:

(i) Grow progeny rows of single plants in replication

(ii) Examine bulk samples from these progeny rows and eliminate rows failing to confirm to the norms fixed during first season. This is known as bulk norm test (iii)Examine the single plants in the selected progeny rows and eliminate the plants failing to confirm to the norms. This is called 'single plant norm test'. Third season Repeat the bulk norms test as done in second season and select the best lines. Fourth season Mix the seeds of selected lines and raise the multiplication plot and distribute them.

Seed production of rice hybrids

Success of Hybrid Rice Technology depends on efficient and economic seed production on large scale. It determines whether the heterosis of hybrid rice can be fully exploited or not. It is reported that the yield of F1 hybrids will decrease by 0.8% when the seed purity decreases by 1%, so it is very important to establish a sustainable system of seed production to ensure the purity of hybrid seeds in hybrid rice development. The existing rice hybrids used in commercial production in India are developed by using cytoplasmic genetic male sterility and fertility restoration system (CMS system). This system involves three lines viz., cytoplasmic genetic male sterile line (CMS or `A' line), maintainer (`B' line) and restorer (`R' line) lines for developing rice hybrids.

Hybrid Seed Production using the CMS system involves the following two steps.

Production of `A' line (A x B); and

Production of Hybrid Seed (A x R)

The `B' and `R' lines are multiplied in the same way as inbred varieties. The procedure of hybrid rice seed production, in which two different lines including male sterile lines (seed parent) and restorer lines (pollen parent) are planted alternatively in a certain row ratio in the same field and the out-crossed seeds are harvested from the male sterile plants, differs from that of inbred varieties, in which only one line is grown and the selfed seeds are harvested. Therefore, in the whole process of hybrid seed production, it requires a set of complicated techniques centering on raising the out crossing rate to obtain a high seed yield. Rice is self-pollinated crop, where the

extent of natural out crossing is only 0.3 to 3.0%. Therefore hybrid rice seed production requires specialized techniques, which need to be thoroughly understood before embarking upon this venture. The success of hybrid seed production depends on various factors such as choice of field, isolation, seeding time, planting pattern and weather conditions during the period of flowering, roguing synchronization in flowering of parental lines, supplementary pollination techniques, proper harvesting, processing, packing and effective seed distribution etc.

Choice of location: Choosing a desirable location for hybrid seed production is very important. In the well isolated area, the paddy field with fertile soil, a desired irrigation and drainage system, sufficient sunshine, and no serious disease and insect problems are essentially needed.

Isolation: Rice pollen grains are very small and light, and can travel very far with the wind. In order to ensure the purity of hybrid seed and avoid pollination by unwanted rice varieties, the hybrid seed production plots should be strictly isolated by the following methods.

Space isolation: A space isolation of 50 – 100 m would be satisfactory for hybrid seed production, which implies that within this range no other rice varieties should be grown except the pollen parent.

Time isolation: Wherever, it is difficult to have space isolation, a time isolation of over 21 days would also be effective. It means that the heading stage of the parental lines in hybrid seed production plot should be 21 days earlier or later than that of other varieties grown within the vicinity.

Barrier isolation: In some places, the natural topographic features such as mountains, rivers, forests can serve as the most effective barrier. A crop barrier with maize, sugarcane, sesbania covering a distance of 30 m would also serve the purpose of isolation. Artificial barrier with polythene sheets of about 2 m height can also be used for small scale seed production. However, the most ideal locations are the areas covered with hillocks and mountains, which act as natural barriers.

Favorable climatic conditions: Climatic conditions have profound influence on the seed yields. Detailed information on the weather data of a given locality is necessary for fixing the seeding dates. Seeding of the parental lines should be planned in such a way that the flowering coincides with the most favorable climatic conditions, which are as follows:

Daily mean temperature of 24 – 30º C

Relative humidity ranging from 70 – 80 %

The differences between day and night temperatures should not be more than 8–10oc, preferably 5 – 7 º C

Sufficient sunshine with moderate wind velocity.

There should not be rains continuously for three days during the period of flowering.

Seed yields will be adversely affected if the temperature is below 20oc and above 35oc.

The Seed Production areas near forest, rivulets and valleys are better for getting higher seed production.

Seeding of parental lines in the seedbed

Puddle the seedbed field properly. Puddle the field twice at an interval of 6-7 days to destroy weeds, weed seeds and germinated rice seeds.

Prepare raised seedbeds (5-10 cm height) of 1m width of any convenient length. Provide drainage channels in between seedbeds to drain excess water.

Apply recommended fertilizer to the nursery beds Sow pregerminated seed uniformly on the seedbed (1-2 kg seed/20m2).

Use 15 kg of `A' line seed and 5 kg of `R' line seed to produce sufficient seedlings to grow one hectare.

Manage the seedbed properly for getting healthy and vigorous seedlings for transplanting.

Transplanting: Commence transplanting seedlings of A and R lines as and when they attain the age of 21-25 days, which ensures timely heading, and flowering of parental lines. Transplanting of older seedlings delays flowering and transplanting of younger seedlings advances flowering. If the transplanting of seedlings of `A' line is delayed, then delay transplanting the `R' line seedlings by the same number of days to synchronize flowering. Transplant one or two seedlings per hill of the `A' line and two seedlings per hill of `R' lines.

Transplanting in a specific Row Ratio & Row direction: In hybrid rice seed production the seed parent and pollen parent are planted in a certain row ratio at certain spacing. The row ratio and spacing of pollen parent and seed parent have a distinct effect on the hybrid seed yields. The row ratio or row proportion refers to the number of rows of the male parent (R line) to that of the female parent (A line) in a seed production plot. Suppose if we plant 2 rows of `R' line followed by 8 rows of `A', the row ratio can be taken as 2:8. In hybrid rice seed production plot the recommended male (R) to female (A) row ratio is 2:8. However, the row ratio may vary from region to region, depending on weather, management and parental lines. R and A lines can be planted in several row ratios of 2:8; 2:12; 3:10 etc.

Factors Influencing Row Ratio: The ratio of pollen parent (R line) to seed parent (A line) is determined by the characteristics of the parental lines.

Plant height of pollinator

Growth and vigour of the pollinator

Size of the panicles and amount of residual pollen

Duration and angle of floret opening in CMS lines

Stigma exsertion of CMS lines

To facilitate out crossing, the rows of male and female in the seed production plot should be perpendicular to the prevailing wind direction expected at flowering time of the parents.

Transplanting of the R line:

Transplant the seedlings of R line in paired rows

Leave a space of 145 cms inside block between paired rows of `R' line seedlings for transplanting 8 row blocks of `A' line seedlings.

Transplant 2-3 seedlings per hill with a row-to-row distance of 30 cms and plant-to-plant spacing of 15 cms.

Transplanting of CMS line (A line):

Transplant `A' line seedlings in blocks of 8 rows in between the paired rows of `R' lines
Transplant with 1-2 seedlings per hill at a spacing of 15 x 15 cms
Leave a 20 cms wide alleyway between A line rows and nearest R line row.
Spacings: Between `R' line rows: 30 cms Between `A' line rows : 15 cms Between `R' & `A' line blocks : 20 – 30 cms Between hills (`A' & `R' lines) : 15 cms Row Ratio : 2R: 8A
Transplanting Sequence: The transplanting sequence of seed parent and pollen parent in the hybrid rice seed production plot depends on the growth duration of seed parent (A line) and pollen parent (R line)
Seed parent (A line) has 10 day longer growth duration than pollen parent (R line): Transplant 25day old seedlings of the `A' line, 10 days earlier than the second `R' line seedlings. The seedlings of the R line are transplanted when the seedlings from the second R line seeding are 25 days old. At this time the age of seedlings from the first R line seeding will be 21 days old and the age of seedlings from third R line seeding will be 29 days old.
Table – 1: Seeding Sequence and seedlings age for transplanting

S. No.	**Seed/pollen parent**	**Seeding sequence**	**Seedling age for transplanting (days)**
1	A line	0 day	25
2	First R line	6th day	21
3	Second R line	10th day	25
4	Third R line	14th day	29

Seed parent (A line) has 10 day shorter growth duration than pollen parent (R line): The seedlings of the R line are transplanted when the seedlings from the second R line seeding are 25 days old. At this time the age of seedlings from the first R line seeding will be 21 days old and the age of the seedlings from the third R line seeding will be 29 days old. Later transplant 25 days old seedlings of the A line 10 days later than the second R line seedlings.
Roguing: The purity of hybrid rice seeds used in commercial production must be more than 98%. To meet this requirement, the purity of the restorer and CMS lines must be more than 99%. Therefore, in addition to ensuring strict isolation, it is necessary to remove all rogues from the seed production plots. Roguing is the removal of undesirable rice plants from the hybrid seed production plots. Undesirable rice plants are those plants either in A or R line rows that differ from plants that are true to type. Roguing helps to prevent the off-types from cross pollinating the true to type A line plants and thus enhancing the purity of hybrid seed. The undesirable plants come from many sources. They may be voluntary plants from the previous crop. Contamination due to improper isolation also result in the occurrence of off-types. Admixing during the process of harvesting, threshing, packing and handling are also other sources from which the off-types occurred. Therefore, due care is to be taken to remove the off-types during the cropping season. Roguing can be done at any time during the crop stage. Off-type rogues can be removed whenever they are identified – earlier the better. The most important stages for roguing are at maximum tillering, flowering and just before harvesting.

Flag leaf clipping: Normally the flag leaves are erect and longer than the panicles and they come in the way of easy pollen dispersal thus effecting the out crossing rate. The clipping of flag leaf helps in free movement and wide dispersal of pollen grains to give higher seed production. The flag leaves should be clipped when the main culms are in booting stage. Only half or two-third portion of flag leaf should be removed. However, flag leaf cutting is not advisable in the plots infested with diseases as this operation may spread the disease further.

Supplementary pollination: Rice is basically a self-pollinated crop and hence there is a need to go for supplementary pollination in order to enhance the extent of out crossing. Supplementary pollination is a technique of shaking the pollen parent so that the pollen is shed and effectively dispersed over the A line plants. Supplementary pollination can be done either by rope pulling or by shaking the pollen parent with the help of two bamboo sticks. Timing and frequency of supplementary pollination is very important. The first supplementary pollination should be done at peak anthesis time i.e. when 30-40 % of the spikelets are opened. This process is repeated 3 – 4 times during the day at an interval of 30 minutes. Supplementary pollination has to be done for 7-10 days during the flowering period.

Chapter No.: 09
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 workingon 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 etc.

8. **A 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:

- A short strong stem. It imparts lodging resistance and reduces the losses due to lodging.
- Erect leaves. Such leaves provide better arrangement for proper light distribution resulting in high photosynthesis or CO2 fixation.
- Few small leaves. Leaves are the important sites of photosynthesis, respiration and transpiration. Few and small leaves reduce water loss due to transpiration.
- Larger ear. It will produce more grains per ear.
- An erect ear. It will get light from all sides resulting in proper grain development.

- Presence of awns. Awns contribute towards photosynthesis.
- A single culm.

The concept of plant type was introduced in rice breeding by Jennings in 1964, through the term ideotype was coined by Donald in 1968. He suggested that in rice an ideal or model plant type consists of

- Semi dwarf stature
- High tillering capacity and
- Short, erect, thick and highly angled leaves
- More panicles /m2,
- High (55% ore 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.

- Stiff-vertically-oriented leaves above the ear.
- Maximum photosynthetic efficiency.
- Efficient translocation of photysynthate into grain.
- Short interval between pollen shed and silk emergence.
- Small tassel size.
- Photoperiod insensitivity
- Cold tolerance
- Long Grain -filling period

BARLEY

Rasmusson (1987) reviewed the work on ideotype breeding and also suggested ideal plant type of six rowed barley.

- Short stature
- Long awns
- High harvest index
- High biomass.
- Kernel weight and kernel number were found rewarding in increasing yield.

COTTON

- Ideotype for irrigated cultivation
- Short stature (90-120 cm)
- Compact and sympodial plant habit making pyramidal shape
- Determinate in fruiting habit with unimodal distribution of bolling
- Short duration (150-165 days)
- Responsive to high fertilizer dose
- High degree of inter plant competitive ability
- High degree of resistance to insect pests and diseases, and
- High physiological efficiency.
- Earliness (150-165 days)
- Fewer small and thick leaves
- Compact and short stature, indeterminate habit
- Sparse hairiness,

- Medium to big boll size
- Synchronous bolling
- High response to nutrients
- Resistance to insects and diseases.

FACTORS AFFECTING IDEOTYPES

There are several factors which affect development of ideal plant type. These are briefly discussed below:

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.

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.

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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. Semidwarf 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.

B.Sc. Ag
V Sem

Crop Improvement-I (Kharif crops)

Credit - 2(1+1)

As per ICAR
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