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Core: Paper – IX Genetics, Cytogenetics and Plant Breeding

UNIT - 5

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PLANT BREEDING

Man is dependent directly or indirectly on plants for his basic necessities- food, clothing, and eltes Man has been cultivating and conserving plants according to his teeds since the time emorial and even now various agricultural crops are grown for food grains, fibres, oil seeds water and feed for domestic animals and for other plant products of commercial importance. The s try to increase the production of crops in various ways such as by selecting good varieties of ups for cultivation, application of manures and fertilizers, proper irrigation, disease and pest control Beices removal of weeds and so on. But the good environmental conditions can enhance the yield f any crop upto a certain limit. The production, however, can be increased further only by ch pew plant varieties as may utilize the environmental conditions mare efficiently and to a greater t than the y by developing varieties This is possible only by changing the heredity of existing varieties

The present-day plants and animals are products of natural and artificial breeding. Plant breeding concerned with the production of improved new crop varieties that are superior to existing varieties amany characters. Plant breeding also helps in introducing many superior qualities originally found a different plants of particular crop into a single plant.

J.M. Pochmann (1959) defined plant breeding as "the art and science of changing and improving the heredity of plants

According to D. C. Smith (1966), plant breeding is the arn and science of improving the genetic patterns of plants in relation to their economic uses.

Objectives of Plant Breeding

The main aims and objectives of plant breeding are to improve the qualities of plants so that they are much desirable agronomically and economically. The specific objectives vary greatly depending upon the crops under consideration. The main objectives of plant breeding have been listed here as follows:

1 To evolve new varieties of crops which have better yielding potency than the local crop varieties. To increase the yield of desired plant products such as, grains, fodder, fibres, oils and so on.

2 To increase the qualities of crops with regard to size, colour, shape, taste, nutrients contents, milling, keeping and cooking ete, of grains, vegetables, flowers and fruits and many special qualities as high sugar contents in sugar crops, strong, long and fine fibres in fibre crops, high protein contents in pulses, appealing flavour, high sugar and starch content and large size of fruits in fruit crops. To evolve such varieties of crops as are suitable to producers and consumers both and can meet the requirements of the consumers to a good extent.

3. Te produce varieties that are resistant to fungal, bacterial diseases, insects and pests:

4. To change the duration of crop maturation according to need. Synchronous maturity is highly

desirable in certain crops like mung bean (Vigna radiata), pigeon pea (arhar) etc

5. To develop varieties as may utilize fertilizers and irrigation efficiently and to a greater

Extent

6. To obtain suitable varieties for particular agroclimatic region To develop varieties with a wide range of adaptability.

7. To develop varieties with a wide range of adaptability.

8. To change the, growth habit of crops as needed. The development of plant varieties that are tolerant to moisture stress and salts would be useful in increasing the production in rainfed areas and saline soils respectively. Winter hardiness would be desirable in certain situation

9. To produce new plant varieties for new seasons and new areas

10. To eliminate toxic substances from the consumable parts to make them safe for human consumption. For example, khesari (Lathyrus sativa) seeds have a neuro-toxin. BN-oxalyl amine alanine (BOAA) which causes paralysis. Similarly, erucic acid found in Brassicu seeds is harmful to human health. Elimination of such toxic substances would increase the nutritional value of these crops

Historical Account

The history of plant breeding in India can be traced back to the Vedic period (1500 to 800 B.C.). Among the oldest crops grown in this country were wheat, sugarcane, rice, cotton, ctc. The excavations of Mohanjodaro and Harappa (in undivided India) which existed over 5000 years ago stand good witness to the same European tasted sugarcane hundreds of years after it was grown in India. Crops were maintained at high standards. Cotton grown in India in ancient period was of fine qualities und muslin of Dacca (undivided India) was famous all over the world. The Dacca muslin was so fine that it could be compared with the spider's web and also with the finest quality cloth of modern time and the story that a full length piece of 40 yards of the muslin could be wrapped over a thumb or packed into a match box

Plant breeding began when man first chose certain plants for cultivation. The process of bringing a wild species under human management is referred to as domestication.

The early plant breeders improved their crops by selecting only superior type of healthy plants in mass and collecting their seeds for cultivation purpose. During selection time they considered only external characters of plants and seeds. Actually, they had no idea about the scientific principles behind the methods they followed. In the early days of human civilization there prevailed a general feeling in the people that better crop yield could be achieved by pleasing God.

Migration of human population from one place to another was also responsible for the movement of cultivated plant species. The introduction of plant species or varieties into a new area forms an integral part of plant breeding today.

Besides selection and plant introduction, cross breeding was also in practice in ancient days. Babylonians and Assyrians pollinated date palms artificially as carly as 700 B.C

Camerarious developed for the first time the plant hybrid by a cross between hop plant and hemp. Thomas Fair Child (1717) obtained artificial hybrid by cross pollinating red flowered and pink flowered species of sweet williams. Linnaeus (1707-1778) believed that new plant species developed by natural hybridization. Joseph Koelreuter made over 500 different crosses during 1760s and 1770s in Germany

Carl Gaertner published an account of his 10,000 breeding experiments in 1849. Similar hybridization experiments were performed by Thomas Andrews Knight in 1780, John Goss and Alexander Seton in 1820, French botanist Charles Naudin, and Mendel.

Le Conteur and Shireff in 1840 used individual plant selection and progeny test to develop able cereal varieties. Vilmorin (1856) developed progeny test and employed the method suitable successfully in improvement of sugar beet (Beta vulgaris). Nilsson and his associates at Svalof, Sweden a detail method of individual plant selection around 1900 and in 1903 Johannsen developed proposed pureline theory that provided the genetic basis for individual plant selection

Plant breeding on scientific basis started developing only after the rediscovery of Mendel's laws of heredity in 1900. Recent discoveries in the field of cytogenetics have provided very useful tool to the plant breeders and have enabled them to achieve wonderful results. G.H. Shull has made a noteworthy contribution on breeding in maize (Zea mays). He found that inbreeding produced a considerable loss of vigour (inbreeding depression). But when the weak inbred lines were crossed the resulting hybrids were found to be more vigorous than the original variety. These observations led to Production of hybrid varieties in several crops like maize, jowar (Sorghum bicolor), bajra (Pennisetum americanum). The science of plant breeding is very much advanced now and has been associated with other disciplines of modern sciences such as, genetics, cytology, taxonomy, plant physiology and biochemistry, plant pathology, bacteriology, entomology, biometrics, agronomy etc.

METHODS OF CROP IMPROVEMENT

The principal aim of plant breeding is to evolve improved plant varieties that have many good qualities in them and are superior to existing varieties in several respects. The crop improvement has been achieved through several methods such as () plant introduction and acclimatization. () simple and honoured methods of selection, (uit) hybridization, (iv) mutation breeding, and (m) breeding for disease resistance.

INTRODUCTION AND ACCLIMATIZATION OF CROPS

Plant introduction is the process of introducing plants into a new locality with different climate from their natural growing places. In other words, introducing a genotype or a group of genotypes of plants into a new place where they have not been grown earlier is plant introduction. The plant only

introduction may be intercontinental, intercountries, inter-states or inter-districts. The introduction is followed by acclimatization. The process of acclimatization refers to adaptation or adjustment of the population of introduced plants for a number of generations in a new locality with changed agroclimatic conditions.

Purpose of Introduction

Introduction of plants is done for several purposes as listed below:

1. To introduce new crop plants in an area.

2. For direct use in agriculture, forestry and industries. Many exotic varieties of food crops, grasses, trees and medicinal plants have been introduced in India. Several varieties of wheat have been introduced in India from Mexico, some varieties of rice have been introduced from Japan and Philippines. Germplasm of many varieties of crops, medicinal plants and forest trees are introduced on exchange or gift basis from foreign countries to India.

3. For Aesthetic Purpose. Several ornamental herbs, shrubs, forest trees and lawn gasses are imported from foreign countries as well as from other states and grown in the gardens, parks and forests for their aesthetic values and decoration purposes.

4. For Genetic Improvement of Economic Crops. Several promising varieties of crop plants and their wild relatives are introduced from different countries and other states and they are utilized in hybridization programme for transferring useful genes from exotic varieties into the local or indigenous varieties,

5. To Protect from Diseases and Pests. Sometimes, certain economically important crops are introduced in new areas to protect them from diseases and pests. As for instance, rubber plant (Hevea) was introduced in Malaya from South America to save that from a leaf disease and coffee was introduced in South America from Africa to prevent loss due to leaf rust.

6. For Scientific Studies. Sometimes collection of plants are made from different parts of the world for the purpose of studies on biosystematics, evolution and origin of species.

History of Plant Introduction

The majority of crop plants have moved from their primary centers of origin to new areas to the activities of man. Plant wealth of almost all the nations to a larger extent are the introduction Most of the crops were introduced in pre-historic. For several centuries the agencies of plant introduction were settlers, traders, travellers , invades, pilgrims, explorers, etc and the primarily due result of plant introductions were made either knowingly or unknowingly. Mung, mustard, pear, apple and walnut Juglans regia) were introduced from the Central Asia Centre of Origin, Sesame, jowar, pigeon pea. Asian cotton (Gossypium herbaceum) and finger millet (Eleusine .coracana) were introduced in India from Africa in pre-historic period. Muslim invaders brought cherries and grapes from Afganistan to India. Portuguese introduced chillies , potatoes, sweet potato, maize, groundnut, cashewnut (Anacardium occidentale) and tobacco in sixteenth century. Tea (Camelia sinensis), litchi and loquat from China, cabbage, cauliflower and other vegetables from Mediterranean, mahogany timber tree from West-Indies were introduced in India in the last quarter of 18th century by East India Company. A number of botanic gardens, various agricultural and horticultural research

stations, forest departments have introduced crop plants, medicinal plants, horticultural plants, forest trees and several other plants of economic values from foreign countries to India: Quinine and Hevea rubber trees were introduced in India from South America by Kew Botanic Gardens, England.

Centres of Origin of Cultivated Plants:

It is evident from the study of geographical distribution of plants that the species of plants are not uniformly distributed throughout the world. The part of earth between 20's and 37'N including South East Asia, China, Indochina, India, Malaya, Archipelago, South West Asia, Tropical Africa, Avicenia, Central America, South America, Mexico abounds in different kinds of vegetation and the species show maximum diversity of forms in these regions. The regions or areas having species with maximum diversity of forms were termed the Primary centres of origin of cultivated crops by N.L Vavilov in 1936. According to the concept of centres of origin of cultivated plant species put forth by Vavilov, the then Director of Institute of Plant Industries, Leningrad, the cultivated crops of the world originated in these primary centres of origin. In other words, the places where the crop species show mAximum diversity of forms, genetic variability and heritability and the primitive ancestral species are in abundance are referred to as primary centres of origin. In the central region of the primary centres of origin occur dominant genes and in peripheral part, there occur recessive genes. These places display continuous variability in a particular crop species. In these primary centres of origin, plants occur in wild state. Later, when the crop species move to different places primarily due to activities of man hybridization and mutations occur in wild forms and the useful variations or changed wild forms are selected and protected by man. The wild forms contain dominant genes and their cultivated forms possess recessive genes

Besides the primary centres of origin, there are some regions where some crop species show considerable diversity, although, they did not originate there and only recessive genes are prevalent there. These regions are referred to as secondary centres of origin of those species. The secondary centres of origin of crop plants are not inhabited by closely related wild species. For example, Oat (Avena sativa) shows maximum variability in Spain and several species occur over there, yet all related species do not occur there. Therefore, Spain cannot be primary centre of origin but it is the secondary centre of origin of Oats.

J.R. Harlen in 1948 planned an expedition to Turkey for the exploration of plants and in the course of journey he found tremendous plant diversity in some small patches of land to which he named microcentres. From such microcentres some precious plants may be obtained and utilized in experimental studies relating to biosystematics and origin of cultivated species.

N.L. Vavilov recognised the following centres of origin of cultivated species and grouped them into Old World Centres of Origin and New World Centres of Origin.

Old World Centres of Origin

The old world centres of origin include the following centres

1. **The China Centre of Origin.** This centre is considered to be the oldest and the largest independent centre of origin of cultivated crops in the world. It includes mountainous parts of Central and Western China and neighbouring tracts. Jowar (Sorghum species), soybeans (Irvine max) opium poppy (powersoner), tea (Cumeliu sinensis), radish (Ruphume sativa) brinjal (Solamum melongena), Cucumis species, buckwheat (Fagopyrum esculentum) ete, are considered to have originated in the China Centre of Origin. This centre is also considered to be the place of ongin of apple, plums (Prumer divaricata), pench (Promis persica), orange (Citrus mobilis apricot (Primer armenia), ete. Thes is the secondary centre of origin of sesame Swamun inudica), turnip (Brussica rapa), Rajma (Phasolus vulgaris), cowpea (Vigna anguiculata), beans and marie (Zea may)

2. <u>The Hindustan Centre of Origin.</u>

The Hindustan Centre of Origin has been divided in the following two centres of origin by Vavilov (1935).

<u>2-A. Indo-Burma Centre of Origin.</u> Excepting Punjab and North Western parts, whole of India and Burma are included in this centre it is considered to be the centre of origin of rice (Orea Nativa), Sugarcane (Saccharum officinarum), pigeonpea (Cajanus cajan), chickpea (Cicer arietinum), Mung (Vigna radiata), Cowpea (Vigna anguiculata), Jowar (Sorghum vulgare), bean (Dolichos lablab), lettuce (Lactuca indica), Cucumis sativas, oat (Avena sativa), Yams (certain species of Dioscorea) etc. All tropical fruits such as guava (Psidium guayava). Jamun (Eugenia jumbolana), Mango (Mangifera indica) are considered to have originated in this centre. Deshi cotton (Gossypium arborem), Jute (Corchorus sp.), Sushania degyptiacu, indigo (Indigofera sp.), black pepper (Piper nigrum), arecanut, some citrus species, coconut (Cow macufer), cardemam etc,, also originated in this centre of origin.

<u>2-B. The Siam-Malaya-Java Centre of Origin.</u>

It includes Malaya, Java, Sumatra, Philippines Indochina etc. Several important plants like turmeric (Curcuma domestica), ginger, black pepper, hemp (Canabis sativa), cardemom, banana (Musa paradisiaca), some species of citrus, and several fruits are thought to have originated in this centre of origin.

3. <u>The Central Asia Centre of Origin.</u>

It is also known as Afganistan Centre of Origin. This centre includes Northwest India (Punjab, Kashmir), Afganistan, Russia, Northwest Frontier Province. Tadjikistan, Uzbekistan and adjoining areas. Important crops like Russian wheat (Triticum aestivum), club wheat (7Triticum compactum), sunn hemp (Crotolaria juncea), carrot, Pea (Pisum sativum), mung, radish (Raphanus sativus), onion (Allium cepa), garlic (Allium sativum), spinach (Spinacea oleracea), broad bean (Vicia faba), brassicas, linseed, and some fruits like apple (Pyrus malus), almond (Pyrus amygdalus), grapes (Vitis vinifera), pistacia nut (Pistacia vera), apricot (Prunus americana), pear (Pyrus communis) are supposed to have originated in this centre. It is the secondary centre of origin of rye (Secale cereale).

4. **<u>Near East or Persian Centre or Asia Minor Centre of Origin</u>**. This centre includes Asia minor, whole of Transcaucasien Iran, highlands of Turkmanistan, etc. Nine species of Triticum including T. monococcum, T. durum, T. turgidum, rye, alfalfa (Medicago sativa), persian clover (Trifolium resupinatum), carrot (Dancus carota), cabbage (Brassica oleracea), Avena species, Lactuca sativa and fruits like pomegranate (Punica granata), pear, almond, chestnut (Castenea sp.). water melon and Cucumis melo are supposed to have originated in this centre. This is the secondary centre of origin of coriander (Coriandrum sativum), black mustard (Brassica nigra). rape (B. campestris), leaf mustard (B.japonica), turnip (8. rapa).

5. **Mediterranean Centre of Origin**. This centre is considered to be the place of origin of some cultivated species of wheat such as durum wheat (Triticum durum), emmer wheat (T. dicoccum), oat (Species of Avena), barley (Hordeum vulgare), lentil (Lens culinaris), several species of Lathyrus, pea (Pisum sativum), chick pea, broad bean (Vigna faba), clover (Trifolium species). vetch (bicas sertiva), mustard (several species of Brassica), onion, garlic, beet (Beta vulgaris). Asparagus officinalis, lavender, Pepermint (Mentha species).

6. Abyssinian Centre.

Some important crops such as barley, emmer wheat, lentil (Lens culinaris). linseed (Linum usitatissimum), bajra (Pennisetum americanum), jowar (Sorghum bicolor). chickpea, sem Dolichos lablab), pea, safflower (Carthemus tinctorius), sesame, castor (Ricinus communis), okra (Abelmoschus esculentus), coffee (Coffea arabica) are considered to be originated in this centre of origin. It is the secondary centre of broad bean.

New World Centres of Origin

Expeditions in new world were made in 1932 and the following centres of origin were recognized

7. **The South Mexican and Central American Centre of Origin**.

It is also known as the Mexican Centre of origin. It includes South Mexico and Central America. Maize (Zea mays), rajma (Phaseolus vulgaris), lima bean (Phaseolus lunatus), sweet potato (Ipomoea batatas), tobacco Nicotiana tabacum), Gossypium hirsutum, purpureascens, chillies (Capsicum annuum), pumpkins (Cucurbita melanosperma), melons (Cucumis melo), papaya (Carica papaya) arrow Toot (Maranta arundinacea), and some other crops originated from this centre of origin.

8. **The South American Centre of Origin**.

It includes high mountaineous regions of Peru, Bolivia, Columbia, part of Chile and Brazil, whole of Paraguay and Ecuador. Many cultivated species of Potatoes, maize, lima bean, peanut (Arachis hypogea), tomatoes, egyptian cotton (Gossypium barbadense) and quinine (Cinchona calysaya), cassava (Manihot Atilissima), rubber (Hevea sp.) originated in this centre.

Recently one more centre namely USA Centre of Origin has been introduced in which two crops sunflower (Helianthus annuus) and Jerusalem artichoke (Helianthus tuberosus) are believed to have originated.

Procedure for Plant Introduction and Acclimatization

Plant materials are introduced following a definite procedure. This involves the following steps:

(1) Collection of plants from other sources

(ii)Despatch of material

(iii) Plant Quarantine.

(iv) Cataloguing.

(v) Evaluation of introduced material.

(vi) Multiplication and distribution to growers

1. Methods of Germplasm Collection

The sum total of hereditary material or genes present in a species is known as germplasm of that species. Collection of a large number of genotypes of a species and its relatives is called germplasm collection or gene bank. When the collections are large and include genotypes from all over the world, it is called world collection. Germplasm collections furnish the richest source of variability The crop inprovement ultimately depends upon the variability of germplasm to be utilized in breeding programme.

The desired material is demanded directly from the concerned agency or authority of the foreign country through plant introduction organisation of the country. The needed material can be had easily from Food and Agricultural Organization (FAO) which maintains world catalogues of genetic stocks of wheat, rice and some other crops. The material can also be obtained through Embassies of friendly countries or through many international agencies existing in the courity either on exchange basis or us gift or against payment.

6. Multiplication and Distribution

The individuals with promising features are selected from the introduced population, multipli released as varicosities after necessary trials. Introductions having desirable characters are maintained for future use which are utilized in hybridization programmes. They are supplied to other workers request.

Types of Plant Introduction

Plant introductions are of two types

1. Primary Plant Introduction. The promising varieties of cultivated plants have b introduced in India from the foreign counties from time to time and some of the er varieties have been proved to be superior to indigenous or local varieties, Such varieties h been adapted for cultivation as such. When the introductions are made for changing wild upaca into cultivated ones or when the introduced genotypes are released as such as new varieties ar cultivation in an aren with new or changed agroclimatic conditions they are called primary Introductions. Some examples of primary introductions are listed here as under

(i) *New Crop Specier*. Several important crops grown in India are introductions. Potatom maize, groundnut, chillies, coffee, rubber, guava, grapes, pineapple, papaya, etc ad some ornamentals like Goldmohr, Phlox, Salvia, Aster, etc, are introductions. Soybee and sugarbeet were introduced in 1960. Oil palms and jojoba were recently introduced in India which are presently in trial stage.

(ii) *Directly Relased Varieties*. Varieties of wheat, Ridley variety of wheat developed in Australia is grown in Utr Pradesh, Punjab, Himachal Pradesh. Mexican Dwarf wheat varieties Sonora 64 ad Lernia roso introduced in India were released for cultivation directly.

Oat (Avena sativa). Several Australian varieties of oat such as Kent, Flaming Gold Green graph, Mountain etc. and Algerian variety "Grey Algerian introduced in India have been released directly as varieties for cultivation

Rice (Oryza sativa). Paddy varieties China-10 introduced from China and IR-O TR-8, and IR-28 introduced from International Rice Research Institute (IRRI), Philippines and the variety Taichung Native-1 developed in Taiwan and introduced in India were released as varieties for cultivation which are very successful in several rice growing directly belts of the country.

Pea (Pisum sativum). "Bonneville And 'Early Badger' varieties of Pea introduced from America are doing well in India.

Tomato (Lycopersicum esculentum). "Sious' variety of tomato introduced from America is directly released for cultivation in India.

Several introductions of vegetable crops such as cowpea, cauliflower, onion, lettuce, watermelon have been relased directly as varieties for cultivation in India.

2. Secondary Introductions.

If the introduction of wild species or cultivated varieties is made for developing genetically improved variety by selection or cross hybridization, it is referred to as secondary introduction. Secondary introductions are more important than the primary ones

1. Varieties Selected from Introductions. Many cultivated varieties of crops have been developed through selection directly from the exotic varieties introduced in India. Kalyan sona and Sonalika varieties of wheat were selected from introductions from CIMMYT, Mexico. The varieties Jamnagar Giant', 'Improved Ghana' of Bajra, Pusa Lal', 'Pusa sunahari' varieties of sweet potato, Pusa Basmati' variety of cowpea, and Japanese white' and 40-days' varieties of radish have been selected from introducted materials.

2. Varieties Developed through Hybridization. Several introductions have been involved in hybridization with indigenous crops for their improvement. All dwarf wheat varieties are derived from crosses with Mexican dwarf wheats. The majority of dwarf rice Varieties possess dwarfing genes Dee-geo-woo-gen either from Taichung Native or IR-8. Pusa Ruby' tomato variety was developed from a cross between Meeruty and Sioux, an American variety Hybrid maize, jowar (Sorghum bicolor) and bajra (Pennisetum americanum) varieties have one parent (the male sterile or female parent) which is introduction. All the recently released varieties of sugarcane have been derived from introduced noble canes (Saccharum officinarum).

Plant Introduction and Quarantine

The cultivation of introduced plant materials has often created serious problems of diseases, insect pests and weeds. Man himself has violated the prohibitary measures and has been responsible for the spread of several diseases, insects and weeds in new areas where they were not known to exist earlier. Several diseases, pests and weeds have found their ways from one country to another along with introduced plant materials and have caused tremendous damage and other problems in India. Some noxious weeds like Parthenium, Phylaris minor which were not known in India a few years back, have entered our country along with imported food grains. Now they are spread all over the country and creating problem in agriculture.

Plant Introduction Agencies in India

A centralized plant introduction agency was initiated at Indian Agricultural Research Institute (IARI) New Delhi in 1946. In 1956 that unit was converted into Plant Introduction and Exploration Organization. Subsequently in 1961 it was made an independent Division of Plant Introduction In 1976, this division was reorganised as National Bureau of Plant Introduction under Indian Council of Agricultural Research (ICAR). In 1977, its name was changed to National Bureau of Plant Genetic Resources (NBPGR). It has its head office at New Delhi. The nature of activities of the Bureau remained the same but the scope and the activities have increased considerably. It is responsible for introduction and maintenance of the germplasm of agricultural and horticultural plants. NBPGR has the following four stations for testing the introduced plant materials:

1. Simla (Himachal Pradesh). It represents the north hilly temperate zone, approximately 2300 m above sea level

2. Amaravati (Maharashtra). It represents the central

3. Jodhpur (Rajasthan). It represents arid zone. zone or mixed climatic zone,

4. Kanya Kumari (Tamil Nadu). It represents the tropical zone

NBPGR is the central agency for the introduction and export of germplasm and it is assisted in its activities by the various Central Research Institutes of ICAR The activities of NBPOR are listed here as under:

1. Introduction of germplasm from other countries the as required.

2. Arranging explorations within and outside the country to collect valuable germplasm

3. Screening and quarantine of introduced plant materials.

4. Testing, multiplication and maintenance of germplasms obtained from various sources at its sub-stations or Central Research Institutes of ICAR

5. Supply of germplasm to scientists and institutions on request. If germplasms are not available in the country, they are procured from outside and then supplied.

6. Maintain a record of plant name, variety name, propagating materials, special characteristics, source, date and other relevant information about the materials received.

7. Supply of germplasm to the counterparts in other countries or their agencies

8 To publish its exchange and collection lists and catalogues. News letter containing such published by Food and Agriculture Organisation (FAO).

9. To set up natural gene sanctuaries of plants where genetic resources are endangered.

10. Improvements of certain medicinal and aromatic plants.

Demerits of Plant Introduction

Plant introduction, no doubt, helps in crop improvement and it is an easy method of crop improvement, yet slight carelessness in handling introduced materials may cause several problems which are listed below:

1. Diseases. Some diseases of foreign origin may enter along with the introduced materials and cause damage not only to introduced crop but also to other local crops

2. Weeds. Some introduced plants in new environment behave as dangerous weeds and create nuisance, as for example, Lantana camera was introduced in India as ornamental plant but soon that spread as problem weed along the rail tracks and in orchards Argemone mexicana, Eicchornea crassipes (water hyacinth), Phylaris minor, Parthenium etc., are some of the instances of weeds which were introduced in India from other countries along with imported plant materials.

3. Insect pests. Several insect pests found their way in India alongwith introduced plants, as for example, wooly aphis of apple, fluted scales of citrus, rubber moth from Italy were introduced in India alongwith introduced plant materials.

4. Sometimes the introduced materials do not prove to be beneficial and thus the money and

SELECTION

Selection of good quality plant from their population has been in use from the remote past. The selection is of the following two kinds:

1) Natural selection
2) Artificial selection.

Natural Selection

This is a continuous and autonomous process which is influenced by natural factors. According to Darwin's theory of natural selection, over-production of plants creates struggle for existence in them and the environment induces in them many new variations that make certain plants most suitable and others less adapted to live in the prevailing environmental conditions. Finally, the natural selection comes in operation due to which suitable and most fit varieties survive well and less fit and weak plants do not persist and eventually they are eliminated from the environment (survival of the fittests) Because of natural selection, the plant species are gradually adjusted towards advantageous

direction The cultivated crops have probably been evolved from wild types through natural selection. Certain climatic and regional races are the results of this process.

Artificial Selection

Farmers and plant breeders choose certain individual plants of good quality from mixed populations for the purpose of taking qualitative as well as quantitative yield from them. This is known as artificial selection. In other words, artificial selection is a process which involves the selection of certain individual plants from a mixed plant population having both desired and undesired qualities. The following are three artificial methods of plant selection:

(i) Mass selection,

(ii) Pure-line selection

(iii) Clonal selection

1. Mass Selection.

Mass selection is the oldest and simplest method of the crop improvement which is still in use by the farmers This method is indirect and unsystematic. This method is used in those varieties which are cross-pollinated and self-defective. In this process, fruits of Galt hat are superior in desired traits (elites or best and healthy plants) are selected from the fields either during or after harvesting and they are thrashed together. The mixture of seeds so obtained is called 'mass' and hence the name of process mass selection. Sometimes seeds with extreme characters (best looking and most healthy ones) are selected directly. In the next year, the mixture of seeds is sown en masse and new crop is raised and again the same practice of selection is applied. This process is repeated till there reaches a state of complete uniformity in the plants with regard to desired characters. This process takes about 8 years. The general procedure for evolving a variety by mass selection process is outlined as under:

(1) In the first year, desired plants, heads or seeds possessing all the possible desired characters are collected in pretty good number from the pre-determined places or fields

(ii) In the second year, the composite seeds of each mass selection are sown in the isolated fields and the progeny grown, and the plants allowed to self or cross-pollinate naturally.The elites are selected and others with undesired characters are removed.

(iii) In the third, fourth and fifth years, the selected mass is subjected to repeated yield trials and the yield of elites is compared with the yield of old variety.

(iv) In the sixth, seventh and 8th years the selected varieties are sent to different regional research stations and grown there to determine the adaptability and yield in different regions.

(v) At the end of 8th year the variety is multiplied, named, recommended and released for general cultivation

There are two divergent opinions on the question whether the mass selection should best cultural conditions or under normal or even unfavourable conditions. According to Hallet (1869),

mass selection should be practised under most favourable cultural conditions. But, Rimpau (186/) suggested that it should be practised under ordinary or even unfavourable cultural conditions with minimum supply of water, nutrients, etc.

Limitations

1. It is applicable to crops that show some degree of heterozygosity. Tha heterOzygosity associated with cross-pollination, this is why mass selection is practised in cross-pollinated crops.

2. The application of mass selection is much limited to self-pollinated plants because they are pure and homozygous.

3. There is no check on cross-pollination in the selected plants. This can cause further heterozygosity

4. Superior variety cannot be separated easily from the slightly inferior variety

2. Pure-line Selection. Johanssen (1903) was the first to introduce the term "pure-line". Johanssen grew seeds of bean (Phaseolus vulgaris) separately and selfed them repeatedly. In this way he made purity in the individuals. Since progeny became more and more homozygous by repeated selfing, the chances of variability became least. Johanssen defined pure-line as a group of descendants selected among progeny of single genetically pure and self-fertilized individuals. Hayes, Immer and Smith (1955), Sinnot, Dunn and Dobhzansky (1950), Poehlman (1959), Darlington and Mather (1952) all have defined pure-lines in more or less similar ways.

In simple terms, the pure-line can be defined as a group of plants obtained from a single homozygous (genetically uniform) and self-fertilized plant. Before Johanssen developed this method of selection in 1903 and started his systematic experiment with bean, Vilmorin in France had also started single plant selection.

Pure-line selection is also called 'individual plant selection', 'inbred selection', 'progeny selection', single line selection (because single plant is selected, inbred and its progenies are maintained separately) and also as pedigree selection (this system is named after Pedigree, a Swedish seed station of Svalof).

General Procedure. The method of production of a variety by the pure-line selection consists in testing the progenies of a single individual plant from the mixed population of naturally self pollinated crops. It takes nearly 9 to 10 years to produce a variety. In general, the procedure is outlined below:

(1) In the first year, 50 or more plants or heads of desired quality are selected out from mixed population of crop at the time of harvesting. The seeds from individual plants are picked separately and numbered.

(ii) In the second year, 25-30 seeds of individual plants are grown in individual rows. Every tenth row is seeded to some standard variety for comparing the selected population with it. The undesired plants as well as diseased plants, are removed from the rows. The selected plants are tested for disease resistance by inoculating the suspension of spores of pathogens on the plant body. The progenies of rows are harvested and seeds of plants in each row composited together and composite produce of each row is maintained separately which is treated as experimental strain.

(iii) In the third year, each experimental strain of second year is grown in 4 or 5 rows instead of one row as in the second year. The superior strains are maintained and undesired and diseased

plants are removed from the field. The seeds of each strain are composited separately after harvesting,

(iv) in the 4th, 5th and 6th years seeds of cach strain are sown in small seven rows-plots Every 5th plot is seeded to some standard strain or local strain for comparing the selected and local strains. The inferior and diseased plants are removed and superior ones are maintained. The yield trials are made during these years and finally two or three superior strains are selected as improved strains.

(v) In the 7th year seeds of finally selected strains are multiplied and sent to various research stations

(vi) In the 8th, 9th and 10th years, they are grown at different regional research stations to determine the comparative yield and adaptability under different cultural conditions. The breeder then finally selects one (or at the most two) and give to it variety name and releases it for general cultivation in the recommended area.

Advantages of pure-line selection

(1) Pure-lines may be used as a new improved varieties which are uniform in appearance performance.

(ii) Pure-lines may be used as a parent in cross-breeding programmes (III) By this method different stains are easily purified from self-pollinated crops.

(iii) This process is easier than hybridization, This process is difficult because

1)it requires much labour and time, and

2) it requires careful attention and thorough observation.

3. Clonal Selection. In some plants seeds are either lacking or they are of low viability, Such conditions enforce the plants to use vegetative organs for their propagation. Further, in some fruit trees as orange, mango, apple, etc., there exist wide heterozygosity and high degree of polyploidy. If they propagate by seeds, they may exhibit many variations that may affect the purity of race and may also result in low production. Many crops, such as, bananas, potato sugarcane, onion, garlic, turnip, grapes, ginger, Colocasia propagate through their vegetative part. A group of plants that are derived from the vegetative organs of a single plant is known as clone. In simple terms, a clone may be defined as a progeny of a single plant obtained by vegetative propagation,

The chief characteristics of a clone are as follows:

(1) A clone is obtained by vegetative propagation of single plant and it propagates vegetatively in future generations.

(ii) The plants of a clone are genetically alike and since in a clone genetic constancy is ensured, it is immaterial whether the parent is homozygous or heterozygous. (111) The clones retain their original characters after many years of vegetative propagation, i.e., they are stable,

The clonal selection is concerned with the selection and propagation of best individuals of clones from mixed population of vegetatively propagated crops.

General procedure. Superior clones are selected on the basis of their phenotypic characters from mixed population of a local as well as introduced varieties of crops, Selection of individual is made always among the clones and never within a clone because all the members of a clone are genetically identical

The units of selection, as well as method involved, are different in different crops. Some are listed here:

1. Pieces of underground stem - Colocasia, yam, banana, pineapple, Aloe, Agave, potato, Chrysanthemum, onion, garlic, etc.

2. Stem Cutting - Sugarcane, sweet potato, grapes, betel, pepper, rose, jasmine, Croton, Clerodendron, Thespesia, etc.

3. Runners - many grasses

4. Bulbils - Dioscorea

5. Grafts and buds- Mango, Citrus, rose, apple, etc. Sugar beet, turnip, Dahlia, etc

6. Roots – Sugar beet, Turnip, Dahlia , etc

The selected units are grown by vegetative methods and then they are compared with the normal variety. The diseased and poor quality clones are removed and best clones are selected and sent to different regional research stations where they are grown for determining their yield and adaptability under the particular set of conditions for three continuous years. Finally best clones are given variety names and multiplied, recommended and released for general cultivation.

Since in the course of vegetative multiplication variations do not arise in the clones, the characters of clones remain stable. Nevertheless, the clones can be improved by the following methods:

(i) By inducing mutations and chromosomal changes in somatic cells which eventually produce mutant buds. The somatic buds are then grown vegetatively. If found suitable, the clones buds are maintained.

(ii) **By Hybridization.** Improvement of clone is also possible in those cases where cross-breeding can be done between the different varieties of clonal populations and viable seeds can be produced. The hybrids obtained from cross-breedings are studied and compared with standard variety. If found suitable, they are named, multiplied, recommended and released for general cultivation.

In sugarcane, which is propagated vegetatively by stem cutting, it was believed that seeds were ally non-viable. Thus, nobody could even think about introducing any improvement in its clones. In 1998 it was noticed that some of the seeds in certain clones were viable but for very short period after maturation and their viability was lost within a few weeks. This discovery provided great scope for improvement of sugarcane and very significant breeding work has been done at the Imperial Sugarcane Station of Coimbatore with spectacular success. Many new and excellent

varieties of sugarcane could be produced by crossing cultivated varieties of canes with wild species and with other genera like Sorghum (Jowar) and bamboos.

Importance of clonal selection--Selection of clones is important because

(1) it is the only method for improving clonal crops, (ii) it offers opportunity for exploiting desirable bud mutations, and

(ii) it maintains the purity of race in heterozygous state.

HYBRIDIZATION

Hybridization can be defined briefly as the method of producing new crop varieties by crossing two genetically different parents. According to the nature and relationship of plants to be crossed, the process is divided into the following types:

1. Inter-varietal hybridization. In this, cross is made between plants of two different varieties which belong to the same species. It is sometimes called intra-specific hybridization. Many new varieties of cultivated crops have been evolved by this method.

2. Intra-varietal hybridization. In this, plants to be crossed have different genotypes but belong to the same variety,

3. Inter-specific or Intra-generic hybridization. In this, cross is made between two different species of same genus. Inter-specific crosses have been successfully tried in wheat, cotton, tobacco, mustard, Luffa, etc.

4. Inter-generic hybridization. In this, plants belonging to two different genera are crossed. Raphanobrassica, sugarcane-Sorghum, sugarcane-bamboo, wheat-rye (Triticale), wheat Aegilops hybrids are results of intergeneric crosses.

Objects of Hybridization

1. To evolve a variety having all the desirable characters, such quality, resistance to as, high yielding capacity, good climate, etc diseases and drought, adaptability to particular place and

2. To produce useful variations by introducing recombinations of characters.

3. To produce and utilize hybrid vigour.

Techniques for Hybridization

The following informations are essential before making crosses:

1. Details of male parent.

2. Details of female parent.

3. Whether plants are unisexual or bisexual.

4. Time of anthesis (opening of flowers) and harvesting of plants.

5. Whether flowers are self or cross-pollinated.

The various steps involved in the operation of hybridization programmes are described below:

1. Selection of Parents. Desirable male and female parents are selected from the available materials keeping in mind all the important characters to be combined.

2. The parents are grown in isolated places and are self-pollinated repeatedly in order to bring homozygosity in desired traits. The parents to be crossed should be grown keeping in mind time they take in their maturation and flowering. Both the parents should mature at the same time

3. Preparation of Female and Male Parents

A. Female parent

(a) Emasculation. The majority of the crops bear bisexual flowers and therefore, for making crosses in normally self-pollinated crops, emasculation is essential. Removal of anthers before they dehisce and shed their pollens from bisexual flowers of female parent is known as emasculation. It is done in order to prevent self-fertilization and therefore, it is usually performed before opening of the flower buds (anthesis). In plants with unisexual flower, the female flowers are bagged before their stigmas become receptive. In hermaphrodite, protandrous and protogynous flowers, the emasculation is done before the anthers shed their pollen.

There are several methods of emasculation:

(1) In the case of large flower buds, it is easily performed by opening the flower bud by means of sterilized forceps and fine needle and then removing the anthers. The instruments are sterilized before use by dipping them in rectified spirit. The emasculation should be done without causing injury to other floral parts, such as, sepals, petals, and pistil (Figs. 38.1 and 38.2).

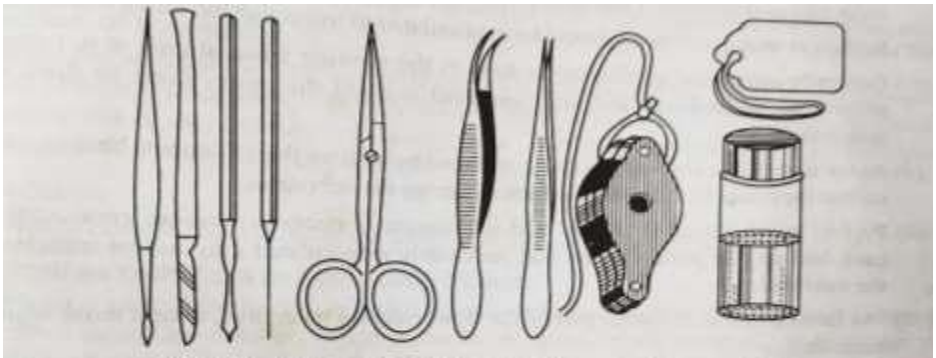
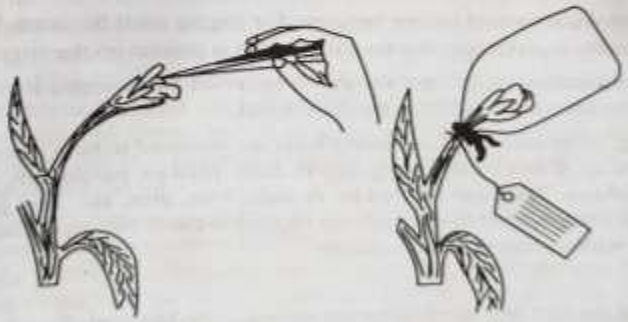


Fig. 38.1 Instruments and the materials required in emasculation.



(a) (b)

Fig. 38.2 Emasculation of flower bud
a. An immature flower bud is opened and anthers are being removed by forcep.
b. Emasculated flower bud is enclosed inside a bag and a label is tagged to the bag.

(ii) Emasculation by Hot Water Treatment. In the cases where the flowers are small hermaphrodites and are crowded in dense inflorescences, as for example, in bajra, jowar. rice, etc., emasculation by forceps and needle is rather very difficult and it requires special skill and technique. In such cases the gynoecium can withstand a temperature at anthers are killed The emasculation is performed in one operation by dipping the whole inflorescence in hot water at temperature between 45°C and 50 C for a definite period (I to 10 minutes) The emasculation in some cases is carried out also by dipping inflorescences into cold water or into alcohol for definite period (Fig. 384)

(iii) In some self-pollinated crops, emasculation is eliminated by the use of male sterile plant in which anthers are sterile. Male sterility can be induced artificially by spraying 24D naphthalene acetic acid (NAA), maleic hydrazide (MA) and tri iodobenzoic acid on the immature flower buds

The following precautions should be taken during emasculation:

(i) Immature flower buds should be selected but that should not be too young In mature buds there is possibility of self-pollination and in very young buds parts are not well differentiated, they may be injured

(ii) Besides the emasculated bud, all other buds, flowers and fruits should be removed in order to avoid confusion and mistake.

(iii) Sufficient number of buds should be emasculated to minimise the chance of failure.

(iv) Generally emasculation should be done in the evening when stigma is not receptive, anthers do not dehisce and buds can heal at night the injury done to them during the next emasculation

(v) As far as possible anthers should be removed by holding their filaments between forceps so that they may not get burst or broken during the operation

(vi) Perfect sterilization of fingers and instrument is necessary before emasculation of each bud so that pollen of the bud previously emasculated may not be transferred to the next bud.

(vii) As far as possible, no other part of the flower should be injured, except those which are necessary

(viii) After emasculation buds should be left in their natural form.

(ix) After emasculation and before bagging, the stigma must be carefully examined wit hand lens for ascertaming that no pollen grain is present on the stigma

(x) During musculation, arither should be collected and counted to make sure that all of them have been removed from the flower bud,

(b) Bagging. After emasculation flower buds are enclosed in bags of convenient sizes that are made up of thin butter paper, muslin cloth, plastics, parchment, glassine, celophi or polyethene The bags are tied by threads, wire, pins, etc. This process is known as bagging Emasculated flower buds are bagged to check cross-pollination of emasculated flowers with undesired foreign pollens

B. Male Parent

(i) Irrespective of the fact that the flowers are unisexual or bisexual, the unopened flower bude of male parent are covered as in the case of female parent in order to avoid the contamination of pollen grains and to make sure that pollen of the bagged flowers are of the same plant and not of any other plant

(ii) **Collection and Storage of Pollen**. Pollen grains for the purpose of crossing are collected from bagged male flowers. Pollens or anthers are collected in petridishes or in paper bags just aller dehiscence and they are placed in vials or capsules for future use.

4. Cross Pollination

It is performed by removing bags of emasculated flowers and dusting or brushing the stigmas of pistols with the collected pollen of male parent. In wheat, whole anther is inserted between lemma and palea with the help of forceps. After crossing female flowers are bagged again. In Bajra and Jawar, pollen and penicle parents are grown side by side and crossing is done by enclosing male: penicle and emasculated female penicles in one bag. This ensures automatic crossing

5. Labelling

The emasculated and crossed flowers are bagged, tagged and labelled property. The labels are tagged to the bags with help of threads. The labelling card should bear the following details.

1. Ref. No.....

2. Date of emasculation....

3. Date of crossing.....

4. Details of male parents.....

The above entries should be made soon after the pollination

Breeders keep complete and up to date records of their works in a separate field record book

6. Collection of Hybrid Seeds

After maturity of seeds, the crossed heads are collected along with their labels separately in envelopes. In the next season, the seeds of each head are sown separately to raise F1 generation. All the plants of F1 are genetically similar and may look exactly alike. They may sometimes show hybrid vigour, i.e. increased growth, size, yield or function over the mean of parents.

7.Final Steps

The final step consists in the selection, testing, naming and releasing the variety.

Methods of Hybridization

This step consists handling of F, and subsequent generations by different selection methods. The methods of hybridization are different for self- and cross-pollinated crops

1. Hybridization in self-pollinated crops. Many crop plants, such as, wheat, barley, oat, rice, cotton, tobacco, potato, peas and beans are self-pollinated. The different selection methods of hybridization in self-pollinated crops are as follows:

(a) Pedigree method.

(b) Bulk method.

(c) Back cross method.

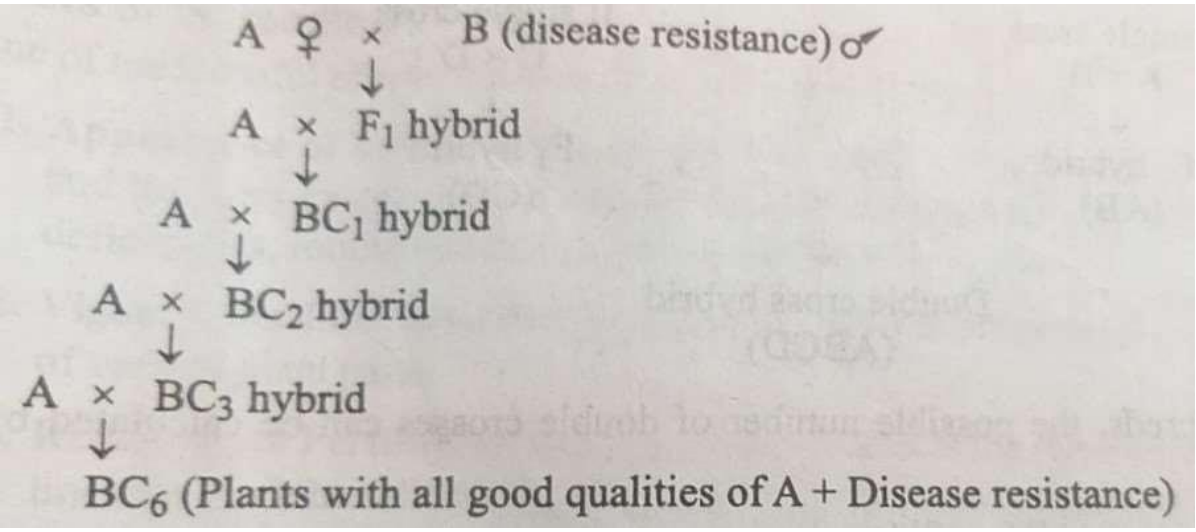
(d) Multiple cross method

(a) Pedigree method. In this method, desirable hybrids of F1 population are selected on the basis of desired characters. The seeds from each selected plant are collected and grown separately in rows and F2 is raised. Again in F2best performers are selected and the product from these plants are sown separately in rows to raise F3, and the same process is repeated up to F6 until it becomes homozygous and fairly uniform. Undesirable varieties are discarded during the selection process. In this way, a complete ancestral record of each progeny is maintained. Finally the progeny of Fare tested in bulk and then named, recommended and transferred to the farmers

(b) Bulk method. In this method hybrid plants are grown in bulk. In F2, plants with many desirable traits are selected and bulked together to form F3. Seeds obtained from selected F2 are sown in masse and in F3 and subsequent generations same method of selection is repeated and the process is continued up to F6. or F7 till the homozygosity is obtained. Finally plants with superior quantities are named and released for cultivation after conducting yield trials at different stations.

(c) Back-cross method. In this method, F1 hybrids are crossed with one of the parents. The object of this cross is to transfer a particular quality of one parent into another lacking it. Disease resistance,

drought resistance, all such characters are introduced into susceptible crops with many good qualities. This method is used in the improvement of both self and cross-pollimated plants. Suppose, a good variety A (recurrent or recipient parent) lacks some desirable characters which are present in an inferior variety B (donor variety). Now the desirable character, say, disease resistance of B is transferred to A by crossing A with B. The F1 hybrids, instead of allowing self-pollination in them, are back crossed with the recurrent parent A. The hybrids of first back cross (BC1) are again crossed with recurrent parent A and this back crossing is repeated for several generations (upto BC6 generation) till desirable character is obtained. At the end of BC6 the selected plants are selfed to make the population homozygous with regard to new character. The process can be shown in the following way:

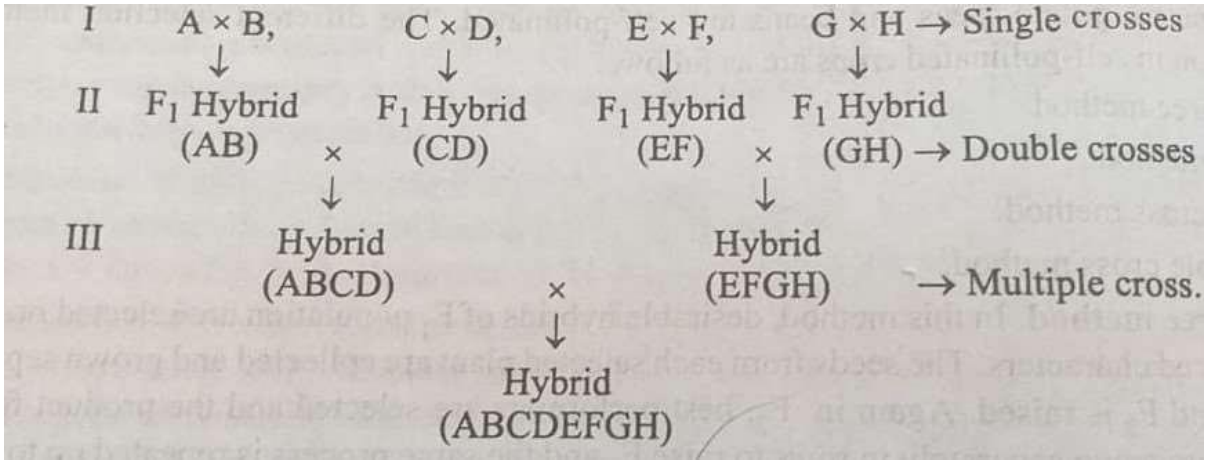


The method of back-crossing is regarded as the best because:

(i) the required characters of a plant can be brought easily into the desirable variety, and

(ii) fertility is established and sterility can be minimised after repeated back-crossing.

(d) Multiple cross method. In this method, a series of bridge crosses are made and the desirable monogenic characters, which are found scattered in many pure line parents are combined together in one variety Suppose there are 8 varieties, cach with one good quality. Then the qualities of these 8 varieties are combined into one by the following method:



The hybrids of multiple crosses are selfed and F2 is raised. Further breeding is carried plants lose out either by pedigree or by bulk method of selection.

11. Hybridization in cross pollinated crops. Common crops which are cross pollinated are maize, rye, cucurbits, fruit trees and forage crops. In these crops, the desirable characters, originally found scattered in different purelines (inbreds) are combined in the following ways:

(a) Single cross

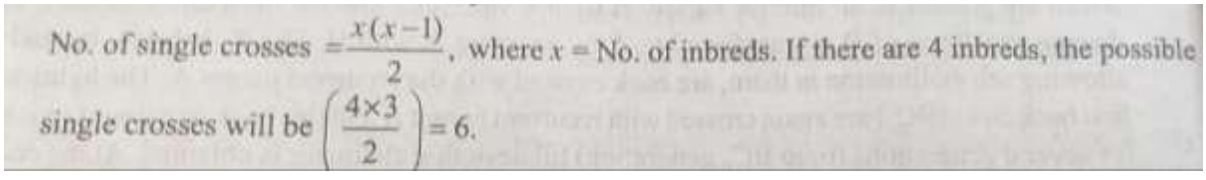
(b) Double cross

(c) Three way cross

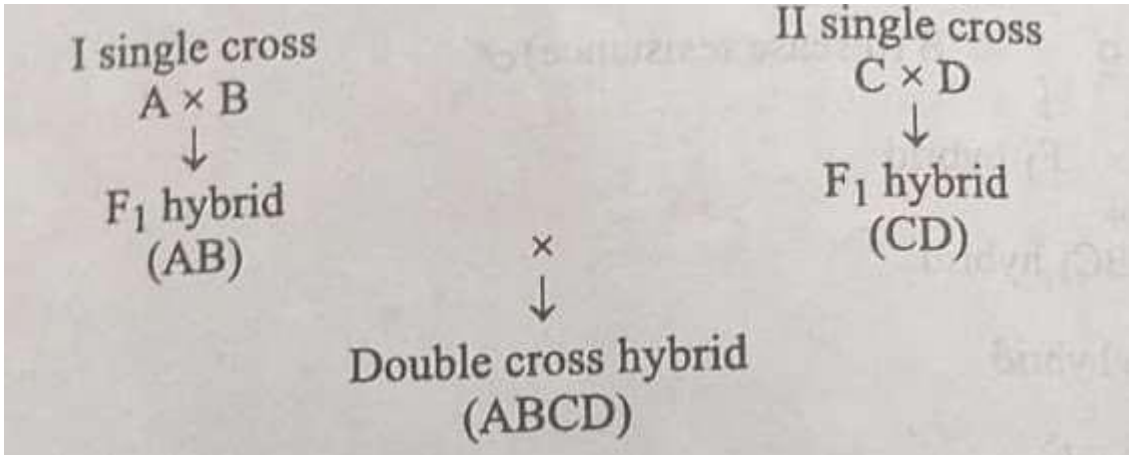
(d) Top cross (or Inbred x variety)

(e) Synthetic cross.

(a) Single cross, It is a cross between two inbreds, e.g., A x B or Cx D. The hybrids are directly distributed to farmers for cultivation purpose. If there are many inbreds, the number of possible single crosses can be calculated by the formula:



(b) Double cross. It is a cross between the F1 hybrids of two different single crosses, each involving two different inbreds



If there are many inbreds, the possible number of double crosses can be calculated by the following formula:

$$\text{No. of double crosses} = \frac{x(x-1)(x-2)(x-3)}{8}, \text{ where } x \text{ is the number of inbreds.}$$

(c) Three way cross. This is a cross between F1 hybrid of a single cross and an inbred which is used as male parent, e.g. [(Ax B)xC].

(d) Top cross. It is a cross between an inbred and open pollinated variety

Variety x inbred

(e) Synthetic cross. In this a number of inbreds are crossed in order to combine different characters into one variety

HYBRID VIGOUR OR HETEROSIS

Hybrid vigour is a hereditary process by which two genetically different individuals when crossed with each other produce F, hybrids which are superior to the best parent or mean value of the two parents in respect of size, growth, yield and fertility. The superiority of F, hybrids over parents is referred to as hybrid vigour. G.H. Shull in 1914 used the term heterosis for hybrid vigour and this term was unanimously accepted in 1922. The term heterosis was used for the growth and vigour arising due to heterozygosity and thus, the terms hybrid vigour and heterosis were used for the same process and were synonyms

There has been considerable confusion due to use of various terms for describing heterosis and also due to the use of heterosis in different contexts.

Brubaker (1964) suggested that the term heterosis should be used for the genetical expression of beneficial effects of hybridization. But, Powers (1944) suggested that heterosis should be used for the apparent expression of one or more characters in the hybrid as may be superior or inferior to that of any of the two parents. According to this view heterosis and hybrid vigour are not synonyms because the term hybrid vigour is used for increased size or vigour of the hybrid as compared to that of their parents, whereas the heterosis may be of two types: (a) **positive heterosis**

or superiority of hybrids, and (6) **negative heterosis** or inferiority of the hybrids over their parents. Whale (1924) has tried to explain the difference between hybrid vigour and heterosis and suggested that the superiority of hybrid over better parent should be termed hybrid vigour and the mechanism by which superiority or hybrid vigour is developed should be termed heterosis. Now the use of the term heterosis is preferred to hybrid vigour because plant breeders compare the F1 hybrids with their parents and in this comparison F1 hybrids may be found to be either superior or inferior to their parents.

Although heterosis refers to both superiority and inferiority of the hybrids over their parents In plant breeding generally the superiority of the hybrid over parents is taken into consideration define heterosis. Usually the following two criteria are used for comparing the hybrids with their parents:

(i) Superiority of hybrids over the superior or better parent.

(ii) Superiority of hybrids to the mid-parent value or the mean value of the two parents. Realising the above criteria Witzer and associates (1968) and Fonseka and Paterson (1968) used the term heterobeltiosis for the superiority of hybrids over the better parent

Thus, *the superiority of the hybrids over the mean value of the two parents is termed heterosis and the superiority of the hybrids over the better parent is called heterobeltiosis.*

For clarity and simplicity, it is desirable to avoid use of many terms to describe somewhat different situations.

General Aspects of the Expression of Heterosis

1. Hybrid vigour is a normal process plants and animals but in cross-pollinated plants it is more in conspicuous than in self-pollinated ones.

2. It is a natural process and occurs more automatically in heterozygous plants than in homozygous plants.

3. Heterosis does not manifest equally in all hybrids of a species. From the studies on inter varietal crosses in maize, it became clear that some of the hybrids showed heterosis while others did not. Crosses between distinct types of genetically diverse varieties exhibited greater heterosis than those involving closely related

4. Heterosis is governed by genetic factors varieties.

5. Heterosis shows maximum manifestation in F, hybrids and in F, and subsequent generations it decreases gradually because the genes producing heterosis segregate.

6. Heterosis is directly related to specific combining ability of the parents. Heterosis shows maxi mum manifestation in the hybrids of such parents as have got high specific combining abilities

7. In some agricultural crops, heterosis is large enough to be used in production of hybrid varieties, eg, in maize, jowar, bajra, wheat, barley, rice, cotton, sunflower, brinjal, onion, tomato, tobacco, brassica, castor, radish, carrot, cucumber etc.

Effects of hybrid vigour. The different effects of heterosis are as follows:

1. Heterosis results in the increase in size of the plants.

2. It increases the yield of the crop.

3. It increases the number and size of fruits and seeds.

4. It increases the fertility of plants.

5. It increases the vitality of plants.

6. It results in more efficient germination and growth.

7. It induces early flowering and fruit setting.

8.It increases the disease resisting power of plants.

9. It makes the plants more suitable for dry conditions The non-beneficial heterosis shows effects that are quite reverse of the positive ones

Causes of Heterosis

Many hypotheses have been advanced by different workers to explain the causes of heterosis. These have correlated the phenomenon with genetic and physiological causes.

Genetic causes of Heterosis. Two hypotheses based on experimental works have been forth by various workers to account for the heterosis. These are as follows:

(1) Dominant factors hypothesis. This was advanced by Bruce (1910). According to this theory, the increased vigour results due to larger number of favorable dominant genes in hybrid than in parents. The cross breeding generally results in the accumulation of large number of dominant genes in the hybrids and finally hybrid vigour. For example, a cross between pure-line AAbbcc and inbred aa BB CC gives a genotype Aa Bb Cc. When all the three dominant genes are favorable in the hybrid, it will show increased vigour than the parents. It is important to note that maximum vigour is seen in F1 hybrids and this vigour goes on gradually decreasing inF2 , F3, F4, F5 and other subsequent generations because of segregation of factors.

(ii) Overdominance hypothesis. This hypothesis was proposed independently by G.H. Shull (1903) and East (1908). According to exponents of this hypothesis, the heterozygote is superior to,homozygote and hybrid vigour increases with the increase in the amount of heterozygosity. In simple terms, heterozygous A1 A2 is superior to A1A1 and A2 A2 The genes A1, and A2, govem different functions, therefore, the heterozygote is more vigorous than the inbreds.

Physiological Causes of Heterosis. The heterosis can be attributed to the following physiological causes.

(i) Cytoplasmic-nuclear interaction hypothesis. Some prominent breeders like Leivis, A.F. Shull, Michaelis and many others have opined that heterosis or hybrid vigour might be caused by interaction of cytoplasm and nucleus. It is due to the effect of changed nucleus and relatively unchanged cytoplasm upon each other.

(ii) Greater Initial Capital (Potential) hypothesis. According to this hypothesis, hybrid vigour is due to an increased initial embryo size or due to the so-called greater initial was proposed by Ashby (1930)

Importance and Practical utility of Hybrid vigour

This phenomenon results in hybrids that have better characters (*i.e.*, large size, high productivity, early maturation, resistance to diseases, pests and drought than the inbreds). Many ornamentals and fruit trees, valuable vegetables, good quality cereals are results of cross breeding of inbreds.

Hybrid vigour has been extensively utilized in the improvement of both plants and animals. The earliest work on heterosis has been done on maize. The self-fertilized progeny in this crop is inferior in size, vigour and yield as compared to open pollinated plants. The F_1 hybrids from different inbred lines are found to be much superior to their parents in yield and other characters (Fig. 38.6). The hybrid maize varieties have led now to such a phenomenal increase in yield that almost all the varieties of maize cultivated in USA are hybrids. In other parts of the world including India, a great majority of high yielding varieties of maize presently under cultivation are developed from four double crosses. The high yielding maize cultivars propagated in India are Ganga 101 [a double cross (CM 103 × CM 104) × (CM 201 × CM 105)], Ganga safed hybrid-2, a high starch product of three way cross (CM 400 × CM 300) × CM 601, Ganga 3, Ganga 5, EH 238, EH 450, Ganga hybrid 89 which is a product of double cross [(CM 116 × CM 107) × (CM 202 × CM 117)], Himalayan hybrid 123, a product of double cross [(CM 202 × CM 205) × (CM 113 × CM 112)], Deccan 101, a double cross hybrid [(CM 202 × CM 206) × (CM 114 × CM 115)], VL Makka 54, a double cross hybrid [(CM 107 × CM 108) × (CM 203 × CM 204)].

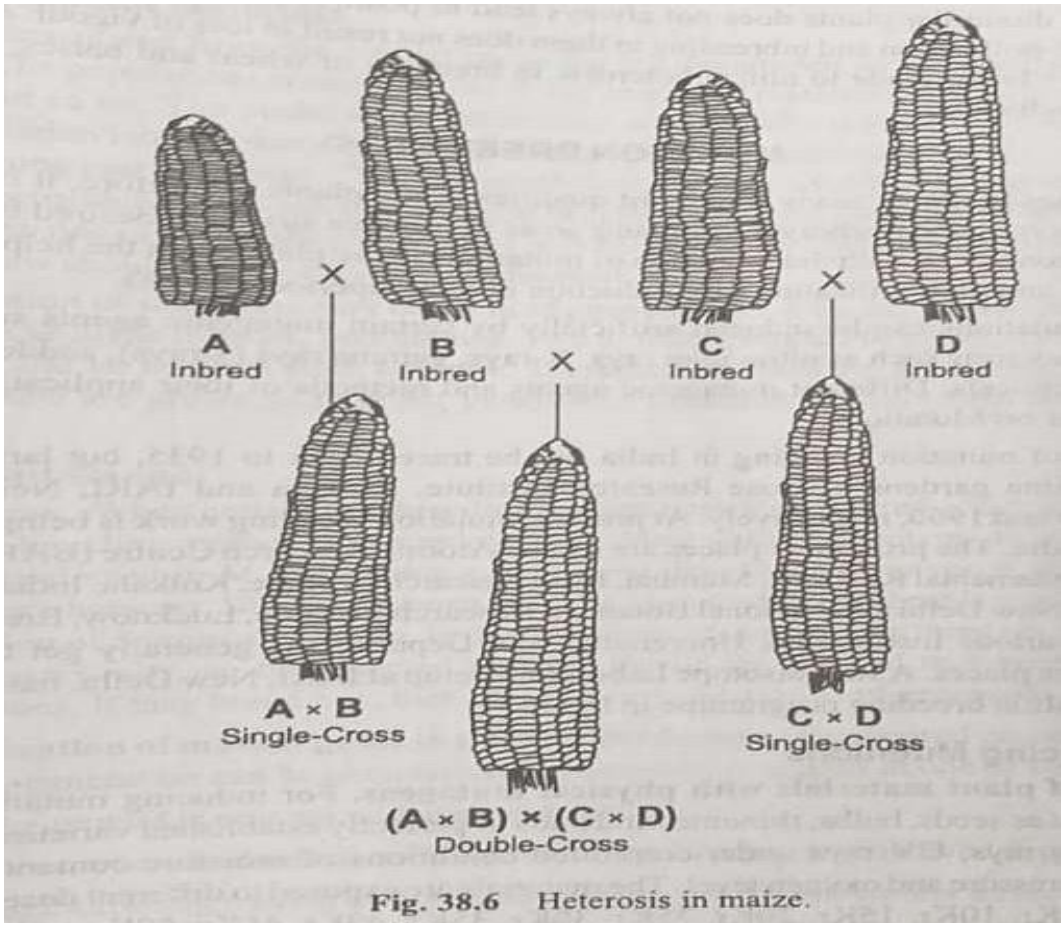


Fig. 38.6 Heterosis in maize.

Similarly, interspecific crosses in Sorghum have yielded extraordinary hybrid with increased stem thickness and height, larger leaves and bigger panicle. In rice and tobacco also inter-varietal and inter-specific crosses have yielded hybrids with increased yield potency.

In some cases, however, the vigour in the hybrids showed variation. In Sorghum some inter-specific hybrids showed positive heterosis but in some other cases the hybrids were found to be either intermediate between the two parents or they were inferior to parents. Heterosis is commonly used in the form of hybrids or synthetic varieties in cross-pollinated or often cross-pollinated crops.

In India much work has been done on heterosis breeding in a number of self-pollinated crops of economic value such as sugarbeet, brinjal, lady's finger, cotton, tomato, radish, onions, cabbage, maize, sugarcane, rice, Sorghum, cucumber, squashes, coconut, sunflower etc. Hybrid vigour has led to the improvement of the plants in many traits such as height, size, productiveness, earliness, viability, resistance to diseases and pests, drought, etc. Many ornamentals, fruit trees and vegetables, good quality cereals are the results of cross breeding of inbreds. They are heterozygous for most of their desirable genes and they possess hybrid vigour to a marked degree. Since inbreeding in them leads to the appearance of detrimental traits, many of them are propagated vegetatively by cuttings, grafting, budding etc. Hybridization produces better and valuable plants and the vegetative propagation preserves valuable traits and vigour.

Crossing of dissimilar plants does not always lead to positive heterosis. In wheat and burley mostly there is self-pollination and inbreeding in them does not result in loss of vigour. Attempts have been made and are being made to utilize heterosis in breeding of wheat and barley, but so far no success has been achieved.

MUTATION BREEDING

Mutation sometimes produces many important qualities in the plants. Therefore, it can be used in changing the genotypes and phenotypes of plants so as to produce strains of desired type. Mutation breeding is, thus, concerned with the induction of mutations in the plants with the help of mutagenic agents (mutagens) and their utilization for production of new superior varieties.

In plants, mutations can be induced artificially by certain mutagenic agents such as atomic radiations of various sorts such as ultraviolet rays, X-rays, gamma rays (x-rays), sudden heat shocks and mutagenic chemicals, Different mutagenic agents and methods of their application have been from such given in the chapter on Mutations

The history of mutation breeding in India can be traced back to 1935, but large scale work started when Gamma gardens of Bose Research Institute, Kolkata and IARI, New Delhi were established in 1959 and 1960, respectively. At present, mutation breeding work is being carried out at several places in India. The prominent places are Bhaba Atomic Research Centre (BARC), Trombay, Tata Institute of Fundamental Research, Mumbai, Bose Research Institute, Kolkata, Indian Agricultural Research Institute, New Delhi and National Botanical Research Institute, Lucknow. Breeders carrying out researches at various Institutions, Universities and Departments generally get their materials irradiated from these places. A Radioisotope Laboratory setup at IARI, New Delhi, has provided new momentum to mutation breeding programme in India.

Methods of Inducing Mutations

(i) Treatment of plant materials with physical mutagens

For inducing mutations, the plant materials such as seeds, bulbs, rhizomes and buds of perfectly established varieties are irradiated with x-rays, y-rays, UV rays under controlled conditions of moisture content, temperature, atmospheric pressure and oxygen level. The materials are exposed to different doses of mutagenic rays, say at SKr, 10Kr, 15Kr, 20Kr, 25Kr, 30Kr, 35Kr, 40Kr, 45Kr, SO T and so on, and for cach treatment many seeds, say 500 to 2000 or more are exposed. Dry seeds are less responsive to irradiation than the seeds pre-soaked in water

The control and treated seeds are germinated in petridishes and germination percentage is recorded. The germinated seeds are then transferred to experimental plots and emergence of seedlings in field is recorded. The particular radiation dose which reduces the germination to 50% is termed as lethal dose 50% or L.D. 50. For different crops fifty per cent lethal doses are different. The increase in the radiation dose brings exponential increase in chromosomal aberrations and linear increase in gene mutations.

(ii) Treatment of plant materials with chemical mutagens.

Chemical mutagens such as Ethyl methane sulphonate, Ethyleneimine or Methyl methane sulphonate are used in solution format different concentrations. The mutation frequency depends on dose concentration x time), temperature, pH and some other factors. For inducing mutations seeds, either dried or pro soaked in distilled water for a few hours are placed in freshly prepared solutions of chemical mutagens at different concentrations, say at 0.025%, 0.05%, 0.1%, 0.2%, 0.3%, 0.4%, 0.5% and so on, for two to six hours or even longer period. To avoid dissociation of chemical mutagen, the treatment is generally given at low temperature and the acidity of solution is controlled by use of buffer solutions. The treated plant materials are washed in running water for 2-3 hours and then placed in petridishes for recording the germination percentage. The germinated seeds are finally transferred to experimental plots.

Handling of Mutant Materials

The populations raised from the treated materials are designated as M1 generation (First mutant generation). The populations raised from the X-ray irradiated materials are specifically designated as X1, X2, X3, and so on. The plants in M1, generation are critically studied for their morphology and reproductive behaviour. Primary effects of mutagens are manifested in colour, shape, venation of leaves, branching and flowers etc. The abnormal plants in each treatment are labelled and their seeds are collected separately. Ten seeds from a single M1 plant in cereals may be sufficient. If M1, generation is too large then one or two seeds per M1 plant will be enough for raising M2 generations. Every tenth to twentieth row should be sown by control material.

Segregation of mutations desired may occur in M2 generation, so the selection of plants with for a particular characters can be made from M2 populations. Two to five best possible plants characters should be selected from one row. The selected plants are selfed and the seeds obtained from such plants are grown to raise M3 generation. Selection of best plants is again made in M3 generation

Use of Mutant Genes

(1) Direct use. When certain true breeding mutant lines with desired genes are established, then suitable breeding methods are employed to obtain desired genotype. In autogamous species, mutants selected in M, generation can be used directly as genotype if they breed true for a particular character. Sharbati Sonora, a single gene mutant in what is a selection from mutant population of Sonora-64 variety. In cross-pollinated populations there occurs a greater degree of heterozygosity, so the selected mutants should be allowed to inbreed for six or seven generations. If they breed true, then they can be used as mutant genotypes.

(ii) Incorporation of mutant genes in self-fertilized crops. The desired genotypic recombination after M, generation can be obtained from autogamous species in one of the following ways:

(a) The mutant is crossed with parental variety.

(b) Two or more mutants from the same parental variety are involved in pedigree program,

(C) Back-crossing mutant as donor parent with a different variety as recipient parent.

(ii) Incorporation of Mutant genes in Allogamous species. In cross fertilized species, the desired genotype can be achieved through hybridization by the mutants followed by inbreeding and recurrent selection. Though mutation breeding in cross-pollinated crops is difficult, yet mutagenesis increases variability to widen the range for selection. Further, it can be used in developing male sterile lines.

POLYPLOIDY BREEDING

In somatic cells, chromosomes are present in homologous pairs whereas, in gametes chromosomes are present in single set. Hence, each organism has two types of chromosome numbers, the somatic chromosome number (2n) and the gametic chromosome number (n). However, each genetic set is formed of either a group of different chromosomes or a few groups of such chromosomes. Hence in some cases, the gametic set consists of a few numbers of identical sets. Here, each of such sets represents a basic set of chromosomes and the number of chromosomes in such a set can be called the basic chromosome number (x). Hence n may be equal to x, 2x, 3x etc. when n = x, the organism is diploid, when n = 2x, the organism is a tetraploid and when n = 3 x, it is a hexaploid (2n = 2x, 4x and 6x, %3D respectively). Besides this type of variation, absence or additional presence of individual chromosomes can also be seen in organisms. Such variations can be exploited in plant breeding because they bring about desirable character changes in many cases. Variations in chromosome number can be classified as shown Table 4.2.

Table 4.2 Variations in chromosome number

Type	Characters
I. Euploidy	Numerical changes in the entire genome
(a) Monopolidy	Only one set of genome (x)
(b) Hapolidy	Only the haploid (gametic) set of genomes (n)
(c) Diploidy	Two sets of genomes (2x)
(d) Polypoidy	More than 2 sets of genomes (3x onwards)
(i) Tripolidy	3x
(ii) Tetraploidy	4x
(iii) Pentaploidy	5x
(iv) Hexaploidy	6x
II. Aneuploidy	Change in the number of one or a few chromosomes
(a) Hypoploidy	Loss of chromosomes from the diploid set
(i) Monosomy	Loss of one chromosome from the diploid set (2n – 1)
(ii) Nullisomy	Loss of one chromosome pair from the set (2n – 2)
(b) Hyperploidy	Additional presence of chromosomes along with the diploid set
(i) Trisomy	Addition of one chromosome to the set (2n + 1)
(ii) Tetrasomy	Addition of one pair of chromosomes (2n + 1)

Haploidy Breeding

Haploids can be used in many ways in plant breeding. They are useful for the development of purelines and inbred lines and for the production of aneuploids. Purelines can be obtained by chromosome doubling of haploids. Such purelines can be used as cultivars or parents in hybridization

Production of haploids

Haploids originate spontaneously in small numbers. Haploid production can be induced by inter-specific crons, une of alien cytoplasm, anther culture, pollination with foreign pollen, delayed pollination, use of irradiated pollen, temperature shock, chemical treatment etc.

Autopolyploidy Breeding

Autopolyploidy is the condition in which the same genome (x) is present in an organism more than two times. Autotriploid (3x) and autotetraploid (4x) plants are important in plant breeding,

Autotriploids possess three identical sets of chromosomes, Autotriploidy occurs naturally in low frequency. They can be produced by crossing an autotetraploid (4x) with a diploid of the same species (2x). Triploids are usually sterile and non-seed producing. Hence, autotriploidy breeding is very important in fruit crops like banana, apple, grape, watermelon etc.

Autotetraploids (4x) possess four copies of the same genome. They may arise spontaneously or can be induced by doubling the chromosomes of diploid species by colchicine treatment. Autotetraploids are large and vigorous. Examples of autotetraploid crops are rye, grapes, groundnut, potato and coffee.

Allopolyploidy Breeding

Allopolyploids are polyploids in which more than one genome are present. An allotetraploid is otherwise called amphidiploid because it contains two genomes twice (X1 X1, + X2,X2). There are overal allopolyploid crop plants that developed in nature spontaneously Bread wheat (Triticum aestivum) (20 = 6x = 12) is an allohexaploid with three genomes: two A genomes from Triticum monococcum (20) = 2x = 14), two B genomes from an unknown progenitor (2n = 2x = 14) and two D genomes from Triticum tauschi (2n = 2x = 14). Tetraploid American cotton (Gossypium hirsutum: 2n = 4x = 48) developed from two diploid species (Gossipium herbaceum var. africanum: 2n = 2x = 24, an Old World species and Gossipium raimondii: 2n = 2x = 24, a New World species).

In tobacco, the cultivated species Nicotiana tabaceum (2n = 4x = 48) is an amphidiploid of Nicotiana sylvestris (2n = 2x = 24) and Nicotiana tomentosa (2n = 2x = 24) and the cultivated species Nicotiana rustica is believed to be an amphidiploid of Nicotiana paniculata (n = 2x = 24) and Nicotiana undulata (2n = 2x = 24). In Brassica, there are diploid and amphidiploid species.

Brassica napus in an amphidiploid of Brassica campestris (n = x= 10) and Brassica oleracea (n = x = 9) and Brassica juncea is an amphidiploid of Brassica campestris and Brassica nigra (n = x= 8).

Production of artificial allopolyploids by inter-apocific and inter Genetic crosses and subsequent chromosome doubling has been carried out with different levels of success. Chromosome doubling in usually effected by treating the diploide with a chemical known as colchicine. Colchicine (C, H, OS in an alkaloid obtained from the seeds of the Liliaceous plant Colchicum autumnale. Colchicine is applied in concentrations ranging from 0.01% to 0.5%. It is applied to growing tips, meristematic cells, seeds and buds in aqueous nolutiona or mixed with lanolin. Duration of treatment varies from 24 hours to 96 hours depending upon the plant species.

Colchicine induced polyploidy known as colchiploidy. It induces polyploidy by inhibiting spindle formation during cell division. Chromosomes do not get segregated at the time of meiosis, resulting in the production of diploid gametes, which on fusion give rise to polyploid plants

Applications of all polyploidy breeding

Allopolyploids can be used to produce new crop species, for inter specific gene transfer and for bridge crosses. Many artificial allopolyploids have been synthesized in different crops. Raphanobrassica is the first example of intergeneric hybridization in planta. This was developed by Karpenchenko in 1927 by crousing radish (Raphanus sativus, n = 9) with cabbage (Brassica oleracea, n = 9). He developed an amphidiploid by hybridization and chromonome doubling. He could not combine the agronomical characters of the crops. The hybrid had the roots of cabbage and leaves of radish. However, this experiment proved the feasibility of intergeneric hybridization.

Tetraploid species of wheat and cotton have been produced artificially by interspecifie hybridization and induction of amphidiploids. Another significant example of intergeneric bybridization followed by polyploidization is the synthesis of the new cereal triticale, Triticale is a man made cereal produced by crossing whent with rye. Tritiene combine the winter hardiness and high protein content of rye and the bread-making, quality of wheat. Hexaploid and octoploid triticales have been developed in this way (Figure 4.1(a) and (b)). Hexaploid triticale in agronomically superior to octoploid triticale.

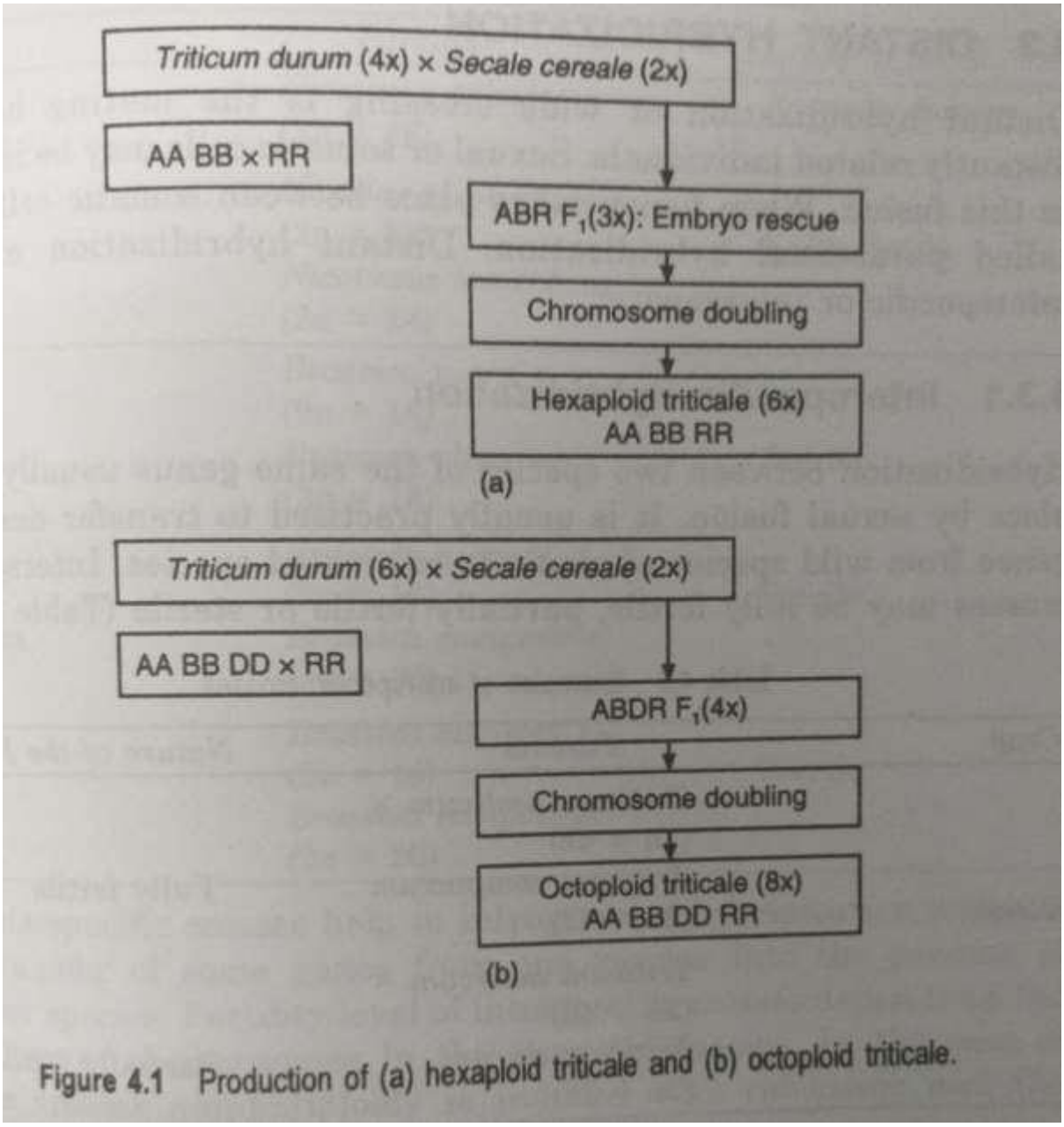


Figure 4.1 Production of (a) hexaploid triticale and (b) octoploid triticale.

Bridge crosses: These are crosses that help in the hybridization between two incompatible species. First, a cross is made between one of the two species and a compatible species. Then the amphidiploid produced in this way is crossed with the second species.

BREEDING OF WHEAT (Triticum Species)

Wheat is the most important food crop used by man. The origin of cultivated wheat is still a controversial subject. From the available records, it appears that wheat originated in South West Asia. It is a general belief that Aryans brought wheat to India and Afghanistan and from the centre of origin this crop spread to European countries. In the United States, wheat was first cultivated in the 17th century along the

Atlantic coast. Wheat is grown extensively throughout the world. Among the major wheat growing countries, the maximum area under wheat is in Soviet Russsia followed by USA, China and India. In regard to yield per hectare, the United Kingdom ranks first followed by West Germany

Aims of Wheat Breeding

Breeding of wheat in India is carried out with the following objectives.

(i) to evolve a high yielding variety,

(ii) to produce wheat that makes good chapatis and stores better under primitive conditions of grain storage,

(iii) to evolve varieties resistant to rusts, Brown rust (Puccinia triticina), black rust (P graminis tritici) and yellow rust (glumarum), smuts, leaf blight, ear cockle, etc,

(iv) to evolve climatically suitable and prolific varieties, and

(v) recent trend in wheat breeding has been to evolve dwarf wheat varieties both for increasing yield potential of this crop through effective use of water and fertilizers and to remove some of the factors responsible for instability and stagnation in yield.

Methods of Wheat Breeding

The breeding work on wheat in India has reached to a very advanced stage and now this country recognised as one of the top wheat breeding countries of the world. Attempts at improving wheat in this country have been made by -

I. introducing new varieties from other countries,

2. selection,

3. crossing certain varieties in order to combine many good qualities of different other varieties into one variety, and

4.recently mutation breeding work has also been attempted and many promising varieties with high yield potentials have been evolved

1. Introduction and Acclimatization. Several introductions of wheat varieties have been made into India but most of them have not been found much beneficial. Most of the foreign varieties imported by Howards were found to be late maturing under Indian growing conditions. The varieties "Ridley introduced into India from Australia green extensively Most of the introduced strains have been used extensively in lo tridiration, programs asa source of genes for discase resistance and dwarfnoss. Through bybridiantion penes for disease resistance and dwarfs have been transferred to adopted tynd several new vaieties have been developed.

In 1962, scientist at LARI, New Delhi, realized the importance of "Norin" genes in dwarfing the variety. These genes were discovered in Norin wheat variety in Japan Strain Norin 10, a Japanese wheat was brought to the USA by Dr. Soltan in 1946 Three dwarfing genes with additive effects have been identified so far in this strain With the Norin dwarfing genes, two dwarf varieties, Gaines, a dwarf winter wheat and a dwarf spring wheat variety were developed by Dr. Ovella Vogal Washington (USA) and Dr. NE Borlaug and associates at CIMMYT International Centre for Wheat and Maize Improvement (Mexico) respectively Seeds of these were obtained from Rockefeller Research Foundation and Mexican Ministry

Dr. N.E. Borlaug, the Nobel Prize Winner in Peace for the year 1978, and wheat breeder, visited India and despatched to LARI 100 kgs catch of 4 dwarf and semi-dwarf Mexican varieties of spring wheat Lerma Rojo-64 A, Sonora 63, Sonora 64 and Mayo 64 und small samples of 613 promising selections, The materials were grown at LARI, New Dellu, Ludhiana, Kanpur, Pant Nagar, Pusa, Bhowal and Wellington (Nigiri hilla) and were studied for their acclimatization capacity and reactions to different rusts. Those four strains were tested in 1964-65 under the All India Coordinated Wheat Trials and were also grown in farmer's fields under the National Demonstration Project with a view to demonstrate the new findings to farmers of the COuntry. Lerma Rojo 64 A and Sonora 64 were approved and recommended by the Central Variety Release Committee of Government of India for cultivation in immigrated arcas in 1965.

Seeds of S-227 S-307, S-308 and S-331 obtained from Mexico in 1963 were also subjected to trials in subsequent years and all were found to be of very high yield potentials. In 1967, these varieties were approved for general cultivation. A great majority of wheat varieties now grown in India are dwarfs. They are resistant to lodging, fertilizer responsive and high yielding. They are mostly resistant to rusts and other major diseases of wheat owing to the presence of resistance genes in their genotypes. These varieties are photo-insensitive and some of them are suitable for late sowing. This has made possible the cultivation of when in some non-traditional areas like West Bengal

2. Selection. When the wheat improvement programme was initinted by Howards at Pusa, several varieties with outstanding yield and qualities were developed by selection from local types Prior to the initiation of wheat improvement work in India, various mixed types of wheat were being grown in different regions under local names. In Punjab, Punjab type 9, Punjab type 11 and Punjab type 3 varieties were selected from the local types. Some of the other varieties selected from the local types were N.P. 4, N.P., 6, N.P. 12, 9-D, 8-A, K-13, K-54, C-46 (U.P.). A.O. 90 (M.P), etc.

3. Hybridization. Breeding work on wheat in India was carried extensively by Dr. B.P. Pal who was responsible for the release of several N.P. (New Pusa) varieties of wheat. Most of the important varieties of wheat developed in India in the last 50 years have been developed by hybridization. Different types of hybridization techniques have: been used to develop ne varieties, such as by back cross method composite crossing involving several selected varieties Breeding w 11. Jan which offered an opportunity to bring together innumerable genetic combinations. Some of the varieties evolved through hybridization are as follows:

Inter varietal hybrids N.P.165, N.P.710, (N.P.52 N.P. 165), NP 718 (NP.52 N.P. 165), N.P. 784, N.P. 785, N.P. 786, N.P. 790, N.P. 797, N.P. 798, N.P. 799, N.P. 809 (Democrat C. 518) (Spalding's prolific N.P. 114) E 220, N.P. 825, N.P. 828, C. 281 (C. 591x N.P. 4), C.285 (C 228xB. 256G-Kenya)R.S. 31-1 (Pb. C591x Jaipur red local)

Inter-specific hybrids - Niphad 4Motion Khapli x N.P.4).

T. dicoceum:-Inter-varietal hybrids- N.P. 201 (N.P. 200 E 274)

T. durum-Inter-varietal hybrids-Hyb. 38 (A.O.13 E 220.) N.P.412 (Ekadania 69 Gazra).

4. Mutation Breeding. Dr. M.S. Swaminathan, formerly Director General of International Rice Research Institute, Manila (Philippines) did pioneering work in mutation breeding on wheat and the variety Sharbati Sonora was released under his direction at LA.R.L, New Delhi and for that he was awarded the Raman Magasway Award in 1978. Irradiation and chemical mutagen are being used to induce mutation in wheat. N.P. 836 was selected from x-ray irradiated N.P.799 at I.A.R.I., New Delhi

New Varieties

The following promising varieties of wheat have been recently released by the Central Varietal Release Committee, Government of India which have brought break through in the production mark of wheat in the country. Besides, many others are in advanced stages of testing

1. Kalyan Sona. This is selection of S. 227 (F-K58-N-N10B) Gabo 55, which is double dwarf wheat resistant to loose smut and hill bunt diseases. Grains are amber, hard and medium size. Il grows well under low fertility, irrigated as well as rainfed conditions. It possesses good chapathi and bread making property

2. Sonalika (S. 308). This is amber grained single gene dwarf derived through selection from S30R (Muxican Crous 11-53-388 An) (Y: 54 - N.10B). LR. IE B427. This variety is carly maturing which is resistant to all the three wheat rusts Grains are bold, sem-hand and amber.

3. Lerma rojo 64. It is a single dwarf wheat with wide adaptation and resistance to yellow and black nuts. It is derived from a cross (Yaque 50 × N. 10B) × L 52/Lt2. Grains are rod, soft and medium bold.

4. Safed Lerma. It is a semi-hard single pene dwarf derived from the Mexican cross (Y. 50 N. 10.B) (L52) LR3 (material back crossed thrice to Lerma Rojo-64 A)

5.Chhoti Lerma. It is white seeded two gene dwarf variety selected from the Mexican cross LR S. 64 (Sib) HURA. The variety is highly resistant to lodging and also resistant to all the three rusts

BREEDING OF POTATO

Aims of Potato Breeding

Breeding of Potato in India is carried out with the following objectives

1. High tuber yield

2 Early matury

3 Good storage and cooking quality

4. Tuber flesh colour, underwater weight of uben, starch content

5. Attractive skin colour

6. Resistance to fungal bacterial, leaf roll virus diseases and frost

Crossing Techniques

The flower-buds are emasculated in the evening. Flower bads that will open the next morning are selected and rest of the buds and flowers are removed. The petals of the selected flower buds are pushed apart and the five stamens removed with pointed forceps. The emasculated Flower-buds along with one or two leaves are bagged Emasculation is omitted in self-sterile lines Next morning, fully mature anthers from male parent are collected in a petridish and pollen collected on pen-knife or forceps is dusted over the stigma of the emasculated flower-buds. Flowers are tagged again after pollination

In the hybridization of this crop, there are two major difficulties

1. Some varieties do not flower due to photoperiodic effects and in some, flower buds fall before opening. Many cultivars show poor flowering and low fertility. Crossing work with primitive cultivars or wild relatives is hampered by several crossing barriers and by difference in plaidy levels. High degree of heterozygosity and low heritability of many important characters are the other stumbling blocks in potato breeding

2. Some varieties are either pollen sterile or they show pollen-stigma incompatibility. These difficulties have been overcome to some extent. The flowering in the flowerless varieties can be induced by periodical removal of tubers, by girdling of stem and by intergenerie grafts (potato with tomato). In hybridization, both inbreeding and inter-specific crosses are followed. Selling is easy in this crop. This can be done by covering the flowers by bags. Before attempting interspecific hybridization, crossability, compatibility and many other factors are considered In some cases, viable pollen cannot germinate on the stigma. In such cases, stigma along with a part of style is cut and then on the cut surface pollen is applied in Agar-sucrose-gelatin medium. Sometimes this difficulty can also be overcome by dusting the stigma with pollen at the bud stage.

Recently Released Important Varieties of Potato

It has been the policy of the C.P.R.I. to test new strains in the regional stations and also to make selection from their breeding plots where strains may be tested for adaptation and possible release as new varieties. Varieties developed by this co-operative programme are released jointly on recommendation by the state and institute. Varieties developed by C.P.R.I. are given a name which consists of two words, the first being Kufri, as for example, Kufri Red, Kufri Kundan, Kufri Sindhuri.

At present, nearly 500 varieties are on record, but here only most promising and high yielding popular strains that are released recently are listed:

	Variety name	Pedigree	Important Features of the Varieties
1.	Satha	Selection	Yield low, but early maturing, becomes ready in about 2 to two and half months, grown mostly in Bihar. Tubers small, white, smooth.
2.	Phulwa	Introduced in India from European countries, a century ago.	Tubers are small to medium, smooth, white, round, flesh yellow coloured, keeping quality good. Late maturing variety, grown in North India.
3.	Gola	Selection	White, pear shaped tubers, eyes set deeply, flesh white, early maturing.
4.	Up-to-date	Disease free clones selected from Military special, an introduced variety from Rangoon.	Early maturing, tuber large, smooth, oval and flattened, flesh white. It is most popular variety under cultivation in India and is particularly suited for Uttar Pradesh, Himachal Pradesh, Punjab, Madhya Pradesh, Bihar and Maharashtra.
5.	Darjeeling Red Round	Selection clone	Wide adaptability, tuber round, medium sized, eyes deep red coloured. Keeping quality poor. It matures slightly earlier than Phulwa.
6.	Craig's Defiance (Released in 1953).	Introduced from U.K. in 1953	Suited for cultivation in hills of H.P. and Punjab. Tubers are large, long, smooth, white with fleet eyes and white flesh.
7.	Kufri red (Released in 1957)	Selection from Darjeeling red round	Excellent yield in plains of U.P., Bihar and W.B. Tubers are smooth, red, round and flesh white. Keeping quality good.
8.	Kufri Alankar	Kennebec × ON 2090	An early tuberising, photo-insensitive, high yielding variety with oval to oblong tubers having white flesh and floury texture.
9.	Kufri Chamatkar	Phulwa × Ekishirazu	A medium maturing variety with uniform sized, smooth and shining tubers.
10.	Kufri Jeevan	M 109 × 698 D.	A late maturing, high yielding variety with oval white tubers It is resistant to late blight and *Cercospora* infections.

BREEDING OF PADDY OR RICE

(**Genus. Oryza) 2n = 24.**

Aims of Rice Breeding

Some aspects of rice breeding are as follows:

1. High yield, good table qualities (non-glutinous) and good response to fertilizers.

2. Resistance to drought and to blast diseases (Piricularia oryzae), stem rot (Helminthosporium sigmoidium), brown spot (caused by Helminthosporium oryzae), bunt of rice (caused by Neovossia horrida), false smut (caused by Ustilaginoidea virens), viruses and also resistance to insects and pests.

3. Earlyness of crop.

4. Flood resistance

S. Resistance to lodging and short stature of planta

6 Resistance to alkalinity and salinity of soil.

7. Non-shedding of grains from the panicle.

8.Dormancy of seeds

9.Combining the cooking quality and aroma acceptable to consumers

10 Insensitive to photoperiod

Breeding and Achievements

In India, investigations have been carried out at a number of research centres. Dr. K.Ramaiah, in Indian rice Breeder of International repute, Dr. Richharia und Ghose et al. have contributed much in the field of breeding. Major part of the genetical work on this crop has been done at Coimbatore Ai present, work on the improvement of rice is being carried out at the Central Rice Research Institute, Cuttack

Central Rice Research Institute, Cuttack (India)

CRRI was established by the Government of India in 1946 to conduct fundamental research on an All-India ban on all aspects of rice production, breeding. genetics, disease and insect problems. The institute was transferred to ICAR in 1965. The institute maintains 15.000 entries of nice germplasm. An All-India Coordinated Rice Improvement Project (AICRIT) was organized in 1965 for coordinating the breeding and other researches en rice conducted by the State and Central Government organizations in the country. The Rockefeller Foundation in India is co-operating in this coordinated effort to accelerate the nice breeding program in India. The popular varieties of rice presently under cultivation, like Jaya, Padma, Sona, Vijaya, Bala, Vani, Sakti are some of the notable achievements of CRRI.

International Rice Research Institute, Philippines

It was established on the campus of College of Agriculture, University of Philippines, Los Banos, in 1960 through the joint efforts of Rockefeller and Ford Foundations. The institute has initiated vigorous rice breeding program in order to develop high yielding photoperiod insensitive strains which may be utilized either directly or as parent material in rice breeding program throughout S.E. Asia The institute maintains world collection of tropical and subtropical rice germplasm consisting of some 42,000 entries The dwarf varieties of rice were first developed by IRRI.

Methods of Rice Breeding

The attempts at improving the rice of this country have been made by the following methods:

1.By selection of promising local strains.

2. By introduction and acclimatization of new varieties from foreign countries like Japan, China, USA, Philippines, Java, etc.

The development of dwarf rice (O. sativa) varieties has revolutionised the rice cultivation. These varieties were derived from Dee-geo-woo-gen', an early maturing dwarf variety of Japanica rice from Taiwan. "Taichung Native-1 developed in Taiwan and IR-8 developed at IRRI, Philippines were introduced for the first time in India in 1966 and grown extensively for a few years but later several superior Dwarf varieties of rice like Jaya, Ratna were., developed in the country replaced the introduced varieties. The Dwarf varieties are resistant to lodging, responsive to fertilizer application, high yielding and photo-insensitive. Many of the photo insensitive varieties were adopted for cultivation in certain non-traditional areas like Punjab Even in traditional areas where only one crop was possible in an year, it has now become possible to rotate early maturing rice varieties with wheat.

3. By crossing certain varieties in order to combine certain desirable characters found in different parental stocks into one variety.

Breeding work on rice has been carried out in almost all rice growing States of this country and many improved varieties have been evolved which give 20-50% higher yield than local varieties At present the number of high yielding varieties is more than 500.

The hybridization program involving O indicus and O. japanica , which is still under way has resulted in very promising materials with new genetic variability. Hybridization has been done on intervarietal and interspecific levels

In rice breeding, Taichung Native-I and IR-8 have contributed in some way or the other in the development of many high yielding varieties in India. The cross Taichung Native Ix T. 141 has yielded two superior varieties of rice; 'Jaya' and Padma', Padma has shorter maturation period and finer grains than Jaya. The other popular varieties of rice developed through hybridization and selection, include Bala, Karuna, Cauveri, Krishna, Ratna, Sabarmati, etc.

4. Mutation breeding and polyploidy have also been applied quite recently for specific purposes. A semi-dwarf rice variety; 'Jagannath' has been developed from Tall cultivated variety T 141 through mutagenesis with Gamma-rays. The variety is resistant to lodging, higher yielding, more responsive to fertilizer application than parent variety T 141. Another rice variety CRM 13-324' was also developed through mutagenesis. It has reduced height, shorter maturity period. higher yielding capacity than the parent variety Some of the good varieties with high yield potentials are given below: Selection. Adt. 1, Adt. 3, Adt. 5, 10, Co. 4, Co. 6, Co. 10, Co. 14, Mtu. 1, Mtu. 3, Mtu. 6, Mtu. 9, Mtu. 13, Ptb. 10, S.P-1, S.P.-2, Type-1 (a selection from variety Ram Jewan of Dehradun), Type 3 (a selection from the variety Chaul of Rampur), Type A 64 (a selection from the variety Hansraj of Unnao) etc

Interspecific Hybrids

Several species of Oryza have been involved in crosses with O. sativa for improving cultivated rice varieties, especially for transferring disease resistance genes from wild races to cultivated ones. O. longistaminata, O. nivara, O. perennis. O latifolia. O minuta, O. longighumis. O ride O. australiensis, O. alta, O. punctata and some others have been tested at I.R.R.I, and several Rice Research Institutes all over the world and genes resistant to blast and blight diseases, and insect pests have been identified in them. Further research on developing resistant varieties utilising these wild species are underway

Co. 31, LJ-1, Adt. 27 (GEB 24× Norin-8).

Varieties Produced by Mutation Breeding

P.500-28 (from T-1143) was developed at Bose Research Institute, Kolkata. It is high yielding variety.

Some Recently Released High Yielding Varieties

Ambemohar-157, Varangal 487, Andrew sail, Basmati-307, B.R. 46, Co. 4, Cc 26, FR. 13A, Hr. 35, Keresail, Mtu. I, Patna S. 1092, Adt. 27. Taichung-65, Taivan-3, LR. 5, I.R. 49, Nagina-22, Sudha, N.SJ. 98, NS 200, K-22, Kasi, T. 136, I, I 100, T. 21, T. 23, T. 26, T. 36, T. 3, NU. 10, Varieties Co.25, Co. 26, Hybrid Kashmere 60, M 42 are highly resistant to blast (Piricularia oryzae) and Co. 24, T. 141 is resistant to Helminthasporium. Var. S.P-268 is salt resistant and is good for cultivation in Orissa Dudhalchi, Jaisuria, Chakia 59, are flood resistant varieties which are suitable for cultivation in U.P. under deep water. Work on rice is still in progress and many new varieties are under trial at different Research Stations

BREEDING OF COTTON (Gossypium species)

Objectives of Cotton Breeding

The different objectives of cotton breeding are as follows:

1. Early maturity

2. Fibre quality Staples of long and fine type with tensile strength.

3. High ginning percentage.

4. Resistant to insects, Fesarium wilt, pink bollworm, bacterial blight or angular leaf spot, root,rot, etc.

S. Adaptability to particular climatic conditions and soils: Although breeding of cotton has been done in different states of this country, the extensive research work on cotton breeding has been carried out in Mumbai, Indore, Punjab, Coimbatore and IARI, New Delhi

In the year 1917 an Indian Cotton Committee was constituted to study and encourage the growth and production of long staple cotton in India. This led to the formation of Indian Central Cotton Committee in 1921 to assist in coordination of research work on cotton improvement. The committee also provided financial and technical assistance to research institutes and State experimental stations working on cotton. It established the Institutes of Plant Industry, Indore, the PIRRCOM Research Station, Coimbatore, and other experimental stations are conducting breeding and other research on cotton. The Cotton Technological Research Laboratory, Bombay is set up to assist cotton breeders by fibre testing and evaluating the spinning qualities of new varieties of

cotton. Since 1965, the research of the Indian Central Cotton Committee is being integrated into that of ICAR, New Delhi.

Methods of Cotton Breeding

The methods employed for improving

1. Introduction and acclimatization.

2. Selection.

3. Hybridization.

4. Mutation breeding

5. Use of polyploidy.

I. Introduction and Acclimatization. The work for improving cotton varieties in India was started in 1790. At that time Indian cotton was exported mainly to England, East India Company with a view to capture the cotton market started extensive trials of introduced varieties mainly of hirsutum origin towards the end of the eighteenth century. In the 19th century, many foreign varieties of cotton were introduced in this country from America, Brazil, Egypt, Sea Island and other countries but only a few of them were found to be useful.

Besides hirsutum introduced from America, several others have been introduced from Africa. A strain of hirsutum introduced from Uganda has been used to improve the staple length of Cambodian cotton in Tamil Nadu State. Recently one strain of G hirsutum has been introduced from Russia. That is being used in breeding experiment in Tamil Nadu. Andrews variety of G barbadense has been introduced into Tamil Nadu from Sea Island.

2. Selection. Selection of high yielding and disease resistant plants is the cheapest and quickest method of breeding, In cotton, both mass selection and pure line selection processes have been used Dharwar-American variety of cotton was developed through mass selection of an introduction of Gossypium hirsutum from U.S.A. The variety 'Dodahatti Local' was developed from Dharwar-American by mass selection

Two varieties, Gohari A-26 and Broach Desi 8 (BD 8) were selected from a variety of G. herbaceum by pure line method. BD8 was wilt resistant and has high yielding and good spinning value but it had a low ginning out turn (34%). An improved variety Buri 107 was isolated by pure line selection from Buri' variety of G. hirsutum. Cambodia- Coimbatore 2 (CC) and MCU IN (Madras Combodia Uganda) were also developed through pure-line selection

Gossypium hirsutum variety, MCU I was selected from the variety Coimbatore 4 (Co4) for having acceptable level of resistance to Black-arm under field conditions. Gadag I was developed by pure-line selection from Dharwar-American which was superior in yield and other agronomic features to parent variety but was susceptible to red leaf blight disease

3. Hybridization. Many varieties of cotton have originated either from natural hybridization or by artificial hybridization. Various types of hybridization, such as intervarietal and interspecific hybridization, back crossing, heterosis breeding have been used for improvement of cotton. Several promising varieties of cotton have been developed in India by hybridization. To remove the susceptibility to red leaf blight, Gadag I was crossed to Cambodia Coimbatore 2 (CC2) and variety Laxmi was selected which was better than Gadag 1 in ginning out turn, fibre properties earliness and resistant to red leaf blight.

Two cotton varieties 170-Co2 and 134-Co 2M, were developed by back cross method. G. hirsutum variety Dharwar-American 2-6-5 was crossed with G. arboreum variety Gaorani. 6. The F, was stenle; it set only a few seeds which gave rise to tetraploid plants perhaps as result of back cross to the G. hirsutum parent. The progeny from F were back crossed to G hirsutum varieties Dharwar-American (First back cross), Cambodia Coimbatore (CC2) (Second back cross) and Meade (Third back cross). From the back cross progeny 170-Co2' and 134 Co2M varieties were selected which had staple length of about 2.7 cm and were widely cultivated in Gujarat both under irrigated and rainfed conditions.

The characters other than disease resistance have been transferred by back cross method Good examples of this type available in cotton are G. hirsutum varieties Vijay, Vijay, Digvijay and Kalyan BD 8 has been used as recurrent parent in a back cross with Goghari A 26' which has a high ginning out turn (42-47%). High ginning out turn was transferred from Goghari A-26. the non-recurrent parent and a variety Vijay' was developed. Vijay was further improved by back cross method and the characters like better fibre length and early maturity were transferred to it from 1027 AL-F (non-recurrent parent) and the variety Digvijay was developed from the back cross program.

Heterosis breeding has also been utilized in developing many commercial cotton varieties. H.Varalakshmi, J.K. Hy I and CPH 2 are the hybrid cotton varieties. H, first hybrid cotton variety obtained from a cross between two G hirsutum strains is widely cultivated in India. The variety Varalakshmi is an interspecific hybrid between G. hirsutum * G. barbadense. Both the Hybrid cotton varieties, H, and Varalakshmi produce extra long staple of high quality. In additions a male sterile line "Gregg" is being used for hybrid seed production. All India Coordinated Cotton Improvement Project is extensively using this male sterile line to reduce the cost of hybrid seed production

4. Mutation Breeding Irradiation breeding has also been attempted for improving cotton varieties A variety Indore-2 was developed from Malwa Upland 4 by x-ray treatment at Plant Industry Indore, M.P. in the year 1950. x-ray treatment of the variety Maxilla acala caused 40-50% increase in hair density which renders the plants resistant to jassids.

5. Use of Polyploidy. The polyploidy has been found to be of good use in facilitating interspecific crosses between tetraploid American cotton (n = 26) und diploid Asiatic cotton (n = 13). In certain cases if the hybrids are found to be sterile, amphidiploidy makes them fertile.

Improved Varieties

The species-wise names of different improved strains are listed below

G. arboreum. This group includes varieties which are predominantly coarse and short stapled. though a few of them are medium stapled and fairly fine. They are grown in almost all cotton

growing states in India. Improved varieties include Vimar (NR Jarila), Jarila, Pratap, Malvi 9, Maljari (Malvi-9 x Jarila), H. 420 (Bani x Cernusum) × Com 170, Co2 or Deviraj (G. hirsutum * G.arboreum). 134-Co 2-M or Devitej (G. hirsutum G herbaceum), 1.S.C. 67 (G. hirsutum * G arboreum), Bhog. Daulat, Cocanadas 2, Gaorani 46. K. 2, K.5,K-7, AK-231, AK-235, R. R. 18, and C 520, Shyamali, G-27, 231-R

G. herbaceum. This group includes varieties that are generally much finer and longer in staple length than arboreum group. They are cultivated in Tamil Nadu, Andhra Pradesh, Kamataka, and Maharashtra. The improved varieties include Kalyan (Wagad 8 * Seg 22-3-1 * Wayad B). Vijay (B.D. 8 x Goghari A. 26 BD. 8), Digvijai (Vijai x 1027 ALF * Vijay), Vijapla (Vijay Vijay 1027 ALF), Wagad 8, Jayawant, Jayadhar, Westerns-1, Suyodhar S. 69. H-1 Suyog.

G. hirsutum. This group includes varieties with medium to long staple length. Its fibres are much finer than those of other groups. The varieties are grown largely in Punjab, Uttar Pradesh, Rajasthan, Andhra Pradesh, Tamil Nadu and Maharashtra.

G. barbadense, Andrews, Sea Island, Sujata, Co. pusa, Egyptian, and P.R.S.-72 are excellent varieties with long staple length. Sujata is high spinning egyptian type with extra long staple length suitable for irrigated cotton tracts in Tamil Nadu

Disease Resistant Varieties

Suyog, Vijay, Kalyan, Virnar, Jarila, H. 420, Jayawant, Jayadhar, and L.S.S varieties are wilt disease resistant.

Some other important varieties

Name-Variety	*Parentage*	*Yield per ha.*	*Maturity*	*Fibre length*
Pramukh (*G. hirsutum*)	Reselection of M_4 from Sindh. Released in 1965	10 Q.	190 days	23.63 mm
Shyamli (*G. arboreum*)	35/1 × C.J. Released in 1965	12 Q.	175 days	19.3 mm
Lohit (*G. arboreum*)	Selection from local sanguireum. Released in 1968	12 Q.	190 days	17.5 mm

BIOTECHNOLOGICAL APPROACHES IN PLANT BREEDING

Biotechnology is the old technology of using bilogical tools for the improvement of human life. The twentieth century witnessed tremendous advancements in different areas of biotechnoles like microbial technology, genetic engineering and in vitro culture technology In vitro culture technology, molecular genetics and genetic engineering have contributed new and unique tools and techniques to plant breeding

Applications of in vitro Culture Technology in Plant Breeding

In this culture is the culturing of cells, tissues and organs under Aseptic laboratory conditions in culture media. The culture medium generally contains the macronutrients and other supplementary

materials like micronutrients necessary for plant growth and other supplementary materials like vitamins, amino acids, carbohydrates and growth regulators.

Plant parts known an explants are cultured in the nutrient medium. Explants may be roots hypocotyls, cotyledons, leaves, shoot apices, nodal segments, anthers, embryos. etc. The explants are surface sterilized with disinfectants like sodium hypochlorite or mercury chloride, washed with sterile water and cultured in the treat media at 25+10C.

Usually, depending upon the nature of the plant, the nutrient medium and the hormonal combination, development of callus (a undifferentiated mane of time) or direct plantieta from the explant Lake place within 34 weeks

The callus is subcultured after every 34 weeks The subcultured callus in made to differentiate and produce the shoot system and root system, by altering the composition of the cultural medium. Somatic embryogenesis can also be attempted in callus culture. It is the development of embryo-like structures from cell culture Such somatic embryos can be encapslated in a suitable matrix like sodium alginate and synthetic seeds can be produced. Synthetic seeds can be stored for several years and used as natural seeds. The major applications of in vitro culture technology in plant breeding include micropropagation, somatic embryogenesis, exploitation of somaclonal variation, meristem culture, anther culture, pollen culture, embryo culture, protoplast culture, cryopreservation of germplasm, secondary metabolite production and in vitro mutagenesis from plant cell culture.

Micropropagation

This is the bulk production of clonal plants for rapid propagation. It is an important application of tissue culture technology in plant breeding. It is independent of seasonal and regional constraints. The plants produced in this way are true to type, ie. they resemble parent plants. Rapid multiplication of planting materials of unique plants with disease resistance and good quality can be carried out by this technique. Uniform behaviour of the clonal crop is highly advantageous in terms of agronomic and harvest practices. But the chances of susceptibility to new strains of pathogens and adverse environmental conditions are always associated with such genetically uniform crop populations.

Somatic embryogenesis

Somatic embryogenesis, encapsulation of the somatic embryos and their storage are very significant steps towards the conservation of genetic resources. These somatic embryos can be used for mass propagation also. Somatic embryogenesis is a process by which embryo-like structures develop from the callus (Figure 4.2). Somatic embryogenesis may be direct or indirect based on the absence or presence of a callus stage.

Figure 4.2 Somatic embryogenesis.

In the process of indirect somatic embryogenesis, embryos arise from callus. The process of somatic embryogenesis takes place in two stages: the induction of proembryonic cell masses or proembryos and the development of proembryos to somatic embryos. Induction of proembryonic masses takes place under high auxin content and development of somatic embryos under low auxin content.

Somatic embryosgeneis is best achieved in suspension culture. Somatic embryos are encapsulated in sodium alginate. Dripping of 2% sodium aliginate from a separating funnel into a 100 millimolar calcium nitrate solution can be used for encapsulation. The encapsulated embryos are placed in calcium for 20 minutes to form complex, rinsed in water and stored in closed containers. The coating material is packed with nutrient hormones and biofertilizers, if desired

Somaclonal variation

In vitro culturing induces different types of variations like gametoclonal variations, somaclonal variations and protoclonal variations. Gametoclonal variations are variations shown by plants which are regenerated by gametic culture techniques like anther culture or ovule culture. Somaclonal variations are observed among plants regenerated from callus cultures of somatic explants and protoclonal variations can be seen in plants regenerated from protoplast derived callus structures.

Somaclonal variations may be epigenetic or genetic. Epigenetic variations are temporary and reversible. Whereas genetic variations are stable and irreversible. In long-term cultures, considerable rearrangements in the genome at chromosome or gene level occur and these changes are hereditary in nature.

Somaclonal variations occur spontaneously in low frequencies: They can be screened and beneficial ones are isolated. Somaclonal variations can be induced through the application of pathotoxins, herbicides, salts, metabolic inhibitions, or temperature shocks. The rate of variation expected in tissue culture is approximately 15-10% which is very high in comparison to in vivo systems.

The plants regenerated from such callus can be tested for heritability, expressivity and stability and subjected to different levels of field trials. Induction of somaclonal variation is a cheap and quick method of inducing variations.

Meristem culture

Meristems are the growing regions of plants. Apical meristem present towards the stem apex of plants is always free from viral pathogens. In vitro culture of shoot apical meristem is widely used to clone pathogen free plants.

Anther and pollen culture

Development of haploid plants is necessary to breed genetically true breeding diploids. The best method to raise haploid plants is anther culture and pollen culture. The haploid plants produced in this way are subjected to chromosome doubling so as to produce genetically uniform plants. Haploids can be produced from female gametes also.

Embryo culture

Embryo culture is the culturing of embryos excised from the ovaries at earlier stages of their development. This technique helps to overcome problems associated with embryo development. Embryos are prevented from development by different factors like incompatibility with the female tissue, absence of endosperm etc. Hybrids produced by wide crosses usually fail to develop inside the ovaries of the mother plants. In such cases, the embryos can be rescued (the technique is called embryo rescue) and grown in culture media so as to produce viable progeny

Protoplast fusion

Wide crosses fail very often due to the cross-incompatibility of gametes. Fusion of the protoplasts obtained from parent plants followed by protoplast culture can be employed to overcome the problem of cross incompatibility. The technique involves isolation of the protoplauta of the desired cells, fusion of the protoplasts, selection of hybrid cells and culture of the hybrid cells.

The protoplasts are isolated from the mesophyll cells of plants or from the suspension cultures. To obtain protoplasts, cell wall of the mesophyll cells or suspension cells is removed either by mechanical or enzymatic method. The removal of cell wall makes the fusion of protoplast easy. The protoplast fusion takes place in three steps: (i) The plasma membranes of the protoplasts come in close contact, (11) fuse at small localized regions making protoplast bridges and (iii) then the bridges extend and round off forming homo or heterokaryons. One major difference in the case of somatic fusion is that there is equal contribution of cytoplasm by both the parents. Such hybrids can be called cybrids and they are very important in the transfer of cytoplasmic characters

After fusion, the product will be a mixture of parental type cells, homokaryotic fused cells and heterokaryotic fused cells. The fused cells are selected and cultured to produce somatic hybrids.

Cryopreservation of germplasm

This is the conservation of explants of genetic resources under in vitro conditions in liquid nitrogen, usually at 196°C. For the purpose, appropriate explants are selected, treated with certain chemicals (cryoprotectants) to make them resistant to chillingshock, cooled and finally stored in liquid nitrogen. The material is taken out only under critical situations and that too only after several years of storage.

Secondary metabolite production

Many plants, especially medicinal plants are important due to the presence of different secondary metabolites in them. Production of secondary metabolites in bioreactors in which plant tissues are grown in vitro can be employed as an alternative method for the bulk production of secondary metabolites.

In vitro mutagenesis

Mutations can be induced by the application of chemical or physical mutagens to in vitro culture. This technique is called in vitro mutagensis. The mutant cells can be selected and regenerated to give rise to commercially useful mutants of crop plants. Using pathotoxins or fungal culture filtrates, resistant cell lines can be screened and selected. Resistant cell lines have been selected in this way from potato, rice, maize, barley, wheat, sugarcane, oats ete. Amino acid analogues like amino ethyl cysteine and 5-methyl tryptophan are used for in vitro selection of cell lines with significant increase in amino acid levels which can be utilized for developing crops with improved nutritional quality. In vitro cell selection can be used in the development of agronomically useful mutations. This technique can be used to induce in vitro genetic variability which can be subjected to selection.