RAMA UNIVERSITY

www.ramauniversity.ac.in

FACULTY OF AGRICULTURE SCIENCES AND ALLIED INDUSTRIES

(Crop Improvement I (Kharif))

For

B.Sc. Ag (Third Year)

Course Instructor

Dr Shiv Prakash Shrivastav

FASAI(Genetics and Plant Breeding)

Rama University, Kanpur

(Major Breeding objectives and Procedure)

Definition, Aim, Objectives and Scope of Plant Breeding Definition :

Plant breeding can be defined "as an art and science" and technology of improving the genetic make up of plants in relation to their economic use for the man kind.
or
Plant breeding is the art and science of improving the heredity of plants for the benefit of mankind.
or
Plant breeding deals with the genetic improvement of crop plants also known as science of crop improvement.
or
Science of changing and improving the heredity of plants

Aim :
Plant breeding aims to improve the characteristics of plants so that they become more desirable agronomically and economically. The specific objectives may vary greatly depending on the crop under consideration.

Objectives of Plant Breeding :

1. Higher yield : The ultimate aim of plant breeding is to improve the yield of "**economic produce on economic part".** It may be grain yield, fodder yield, fibre yield, tuber yield, cane yield or oil yield depending upon the crop species. Improvement in yield can be achieved either by evolving high yielding varieties or hybrids.
2. Improved quality: Quality of produce is another important objective in plant breeding. The quality characters vary from crop to crop. Eg. grain size, colour, milling and baking quality in wheat. Cooking quality in rice, malting quality in barley, colour and size of fruits, nutritive and keeping quality in vegetables, protein content in pulses, oil content in oilseeds, fibre length, strength and fineness in cotton.
3. Abiotic resistance : Crop plants also suffer from abiotic factors such as drought, soil salinity, extreme temperatures, heat, wind, cold and frost, breeder has to develop resistant varieties for such environmental conditions.
4. Biotic resistance : Crop plants are attacked by various diseases and insects, resulting in considerable yield losses. Genetic resistance is the cheapest and the best method of minimizing such losses. Resistant varieties are developed through the use of resistant donor parents available in the gene pool.
5. Change in maturity Duration / Earliness : Earliness is the most desirable character which has several advantages. It requires less crop management period, less insecticidal

sprays, permits new crop rotations and often extends the crop area. Development of wheat varieties suitable for late planting has permitted rice-wheat rotation. Thus breeding for early maturing crop varieties, or varieties suitable for different dates of planting may be an important objective. Maturity has been reduced from 270 days to 170 days in cotton, from 270 days to 120 days in pigeonpea, from 360 days to 270 days in sugarcane.

6. Determinate Growth : Development of varieties with determinate growth is desirable in crops like mung, pigeon pea (*Cajanus cajan*), cotton (*Gossypium sp.*), etc.

7. Dormancy : In some crops, seeds germinate even before harvesting in the standing crop if there are rains at the time of maturity, e.g., greengram, blackgram, Barley and Pea, etc. A period of dormancy has to be introduced in these crops to check loss due to germination. In some other cases, however, it may be desirable to remove dormancy.

8. Desirable Agronomic Characteristics : It includes plant height, branching, tillering capacity, growth habit, erect or trailing habit etc., is often desirable. For example, dwarfness in cereals is generally associated with lodging resistance and better fertilizer response. Tallness, high tillering and profuse branching are desirable characters in fodder crops.

9. Elimination of Toxic Substances : It is essential to develop varieties free from toxic compounds in some crops to make them safe for human consumption. For example, removal of neurotoxin in Khesari – lentil (*Lathyruys sativus*) which leads to paralysis of lower limbs, erucic acid from *Brassica* which is harmful for human health, and gossypol from the seed of cotton is necessary to make them fit for human consumption. Removal of such toxic substances would increase the nutritional value of these crops.

10.Non-shattering characteristics: The sha ttering of pods is serious problem in green gram. Hence resistance to shattering is an important objective in green gram.

11.Synchronous Maturity : It refers to maturity of a crop species at one time. The character is highly desirable in crops like greengram, cowpea, castor and cotton where several pickings are required for crop harvest.

12.Photo and Thermo insensitivity: Development of varieties insensitive to light and temperature helps in crossing the cultivation boundaries of crop plants. Photo and thermo-insensitive varieties of wheat and rice has permitted their cultivation in new areas. Rice is now cultivated in Punjab, while wheat is a major *rabi* crop in West Bengal.

13.Wider adaptability: Adaptability refers to suitability of a variety for general cultivation over a wide range of environmental conditions. Adaptability is an important objective in plant breeding because it helps in stabilizing the crop production over regions and seasons.

14.Varieties for New Seasons : Traditionally maize is a *kharif* crop. But scientists are now able to grow maize as *rabi* and *zaid* crops. Similarly, mung is grown as a summer crop in addition to the main *kharif* crop.

Scope of plant breeding (Future Prospects)

From times immemorial, the plant breeding has been helping the mankind. With knowledge of classical genetics, number of varieties have been evolved in different crop plants. Since the population is increasing at an alarming rate, there is need to strengthened the food production which is serious challenge to those scientists concerned with agriculture. Advances in molecular biology have sharpened the tools of the breeders, and brighten the prospects of confidence to serve the humanity. The application of biotechnology to field crop has already led to the field testing of genetically modified crop plants. Genetically engineered rice, maize, soybean, cotton, oilseeds rape, sugar beet and alfalfa cultivars are expected to be commercialized before the close of 20th century. Genes from varied organisms may be expected to boost the performance of crops especially with regard to their resistance to biotic and abiotic stresses. In addition, crop plants are likely to be cultivated for recovery of valuable compounds like pharmaceuticals produced by genes introduced into them through genetic engineering. It may be pointed out that in Europe hirudin, an anti-thrombin protein is already being produced from transgenic *Brassica napus.*

Undesirable effects

Plant breeding has several useful applications in the improvement of crop plants.
However, it has five main undesirable effects on crop plants.

1. Reduction in Diversity : Modern improved varieties are more uniform than land races. Thus plant breeding leads to reduction in diversity. The uniform varieties are more prone to the new races of pathogen than land races which have high genetic diversity.

2. Narrow genetic base : Uniform varieties have narrow genetic base. Such varieties generally have poor adaptability.

3. Danger of Uniformity : Most of the improved varieties have some common parents in the pedigree which may cause danger of uniformity.

4. Undesirable combinations : Sometimes, plant breeding leads to undesirable combinations. The examples of man made crops having undesirable combination of characters are *Raphanobrassica* and Pomato.

5. Increased susceptibility to minor diseases and pests : Due to emphasis on breeding for resistance to major diseases and insect pests often resulted in an increased susceptibility to minor diseases and pests. These have gained importance and, in some cases, produced severe epidemics. The epidemic caused by *Botrytis cinerea* (grey mold) in chickpea during 1980-82 in Punjab and Haryana. The severe infection by Karnal bunt (*Tilletia sp.*) on some wheat varieties, infestation of mealy bugs in Bt cotton.

History and development of plant breeding

- About 10,000 years ago when man is believed to have started agriculture.
- Plant breeding began when man first choose certain plants for cultivation.
- The process of bringing a wild species under human management is referred to as **domestication**
- Domestication may be the most basic method of plant breeding
- All other breeding method become applicable to a plant species only after it has been successfully domesticated.
- Domestication continuous today and is likely to continue for some time in future
- Ex : In case of timber trees medicinal plants, microbes

- During the long period of historic cultivation natural selection has definitely acted on the domesticated species.
- Movement of man from one place to another brought about the movement of his cultivated plant species
- 700 BC - Babylonians and Assyrians pollinated date palm artificially
- 17th century - several varieties of **heading lettuce** were developed in France
- **1717 - Thomas Fair Child - produced the first artificial hybrid, popularly known as Fair Child's mule, by using carnation with sweet William**
- 1727 - The first plant breeding company was established in France by the vilmorins.
- 1760-1766 - Joseph koelreuter, a German, made extensive crosses in tobacco.
- 1759-1835 – Knight was perhaps the first man to use artificial hybridization to develop several new fruit varieties.
- Le couteur and Shireff used individual plant selections and progeny test to develop some useful cereal varieties
- 1873 - the work of Patrick Shireff was first published.
- He concluded that only the variation heritable nature responded to selections, and that there variation arose through 'natural sports' (= mutation) and by 'natural hybridization' (= recombination during meiosis in the hybrids so produced).
- 1856 - Vilmorin developed the progeny test and used this method successfully in the improvement of sugar beets.
- 1900 - Nilson-Ehle, his associates developed the individual plant selection method in Sweden.
- 1903 - Johannsen proposed the pureline theory that provided the genetic basis for individual plant selection.
- The science of genetics began with the rediscovery of Gregor Johan Mendel's paper in 1900 by Hugo de veris, Tshermark and Correns which was originally published in 1866.
- The modern plant breeding methods ha ve their bases in the genetic and cytogenetic principles.
- Numerous workers who determined the various modes of inheritance have contributed to the development and understanding of plant breeding.
- The discovery of chromosomes as carriers of genes has led to the development of specialized plant breeding methods for chromosome engineering.
- The totipotency of plant somatic and gametic cells allows regeneration of complete plants from single cells. This, coupled with the development of recombinant DNA technology, has enabled the transfer of desirable genes from any organism into plants. Crop varieties developed in this manner are already in cultivation in several countries.

History of plant breeding in India

- 1871 – The Government of India created the Department of Agriculture
- 1905 – The Imperial Agricultural Research Institute was establish in Pusa, Bihar
- 1934 – The buildings of the institute damaged in earthquake
- 1936 – Shifted to New Delhi
- 1946 – Name was changed Indian Agricultural Research Institute
- 1901-05 – Agricultural Colleges were established at Kanpur, Pune, Sabour, Llyalpur,

Coimbatore
- 1929 – Imperial council of Agricultural Research was established
- 1946 – Name was change to Indian Council Agricultural Research
- 1921 – Indian Central Cotton Committee was established – Notable researches on breeding and cultivation of cotton. Eg : 70 improved varieties of cotton
- 1956 – Project for intensification of regional research on cotton, oilseeds and millets (PIRRCOM) was initiated to intensify research on these crops – located at 17 different centres through out the country
- 1957 – All India Coordinated maize improvement project was started with objective of exploiting heterosis
- 1961 - The first hybrid maize varieties released by the project
- ICAR initiated coordinated projects for improvement of the other crops
- 1960 – First Agricultural University established at Pantnagar, Nainital, U.P.

Scientific contributions of eminent scientists
Name of the Scientists Contributions
Allard and Bradshaw **-** G x E interaction
Recurrent Selection for SCA **-** Hull
Recurrent Selection for GCA **-** Jenkins
Dominance hypothesis **-** Davenport
Gene for gene hypothesis **-** Flor
Pureline concept **-** Johannsen
Backcross method **-** Harlan and Pope
Double cross scheme **-** Jones
Cytoplasmic Genetic Male sterility **-** Jones and Davis
Ear to row method **-** Hopkins
Colchicine **-** Blackslee and Nebel
Single Seed Descent Method **-** Goulden
Self incompatibility **-** Lewis
Vertifolia effect **-** Van Der Plank
Centres of diversity, Law of homologus series **-** Vavilov
Grater initial capital hypothesis **-** Ashby
Progeny test **-** Vilmorin
First artificial hybrid **-** Thomas Fairchild
Triticale **-** Rimpau
Mutation **-** Hugo de Vries
Sprophytic System of self incompatibility **-** Hughes and Babcock
Bulk method **-** Nilsson & Ehle
Raphano brassica **-** Karpenchenko
Heterosis **-** Shull
Male sterility **-** Jones and Davis
Father of hybrid rice **-** Yuan Long Ping
Self incompatibility classification **-** Lewis

Mechanism of insect resistance - Painter
Modified bulk method - Atkins
Components of genetic variance classification - Fischer
Male sterility in maize - Rhoades
Microcentre - Harlan
Chemical mutagen - Aurbach
Multiline concept - Jenson
Green revolution in India - M.S. Swaminathan
Semidwarf rice varieties at IRRI - T.T. Chang
Forage breeder - G.W. Burton
Forage breeder - T.J. Jenkin
Soyabean breeder - E.E. Hartwig

Some Indian Plant Breeders and their contributions

T.S. Venkatraman - An eminent sugarcane breeder, he transferred thick stem and high sugar contents from tropical noble cane to North Indian Canes. This process is known as noblization of sugarcane.
B.P. Pal - An eminent Wheat breeder, developed superior disease resistant N.P. varieties of wheat.
M.S. Swaminathan - Responsible for green revolution in India, developed high yielding varieties of Wheat and Rice
Pushkarnath - Famous potato breeder
N.G.P. Rao - An eminent sorghum breeder
K. Ramaiah - A renowned rice breeder
Ram Dhan Singh - Famous wheat breeder
D.S. Athwal - Famous pearlmillet breeder
Bosisen - An eminent maize breeder
Dharampal Singh - An eminent oil-seed breeder
C.T. Patel - Famous cotton breeder who developed world's first cotton hybrid in 1970
V. Santhanam - Famous cotton breeder

Concepts of breeding Self pollinated, Cross pollinated and asexually propagated crops

The mode of pollination and reproduction play an important role in plant breeding. Based on this, crop plants are divided into three groups *viz.*

1. Self Pollinated
2. Cross pollinated
3. Vegetatively propagated

Self Pollinated Species:

These are all self fertilizing species. In these species development of seed take place by self pollination (autogamy). Hence self pollinated species are also known as autogamous species or inbreeders. Various plant characters such as homogamy, cleistogamy, chasmogamy, bisexuality etc. favour self fertilization. Some important features of autogamous species are

1. They have regular self pollination
2. They are homozygous and have advantage of homozygosity, means they are true breeding.
3. Inbreeders do not have recessive deleterious genes, because deleterious genes are eliminated due to inbreeding by way of gene fixation.
4. Inbreeding does not have any adverse effects on inbreeders.
5. In autogamous species, new gene combinations are not possible due to regular self pollination.
6. Inbreeders are composed of several component (homozygous) lines. Hence variability is mostly among component lines.
7. Inbreeders have generally narrow adaptation and are less flexible.

Methods of Breeding in Autogamous Species

1. Plant introduction
2. Pureline selection
3. Mass selection
4. Pedigree method
5. Bulk method
6. Single seed descent method
7. Backcross method
8. Heterosis breeding
9. Mutation breeding
10. Polyploidy breeding
11. Distant hybridization
12. Transgenic breeding

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

Cross pollinated species

This group refers to cross fertilizing species these species produce seed by cross pollination (allogamy) hence, referred to as allogamous species or out breeders. Various plant characters which promote cross pollination which include dichogamy, monoecy, dioecy, heterostylely, herkogamy, self incompatibility and male sterility. Some important features of out breeders are

1. They have random mating. In such population, each genotype has equal chance of mating with all other genotypes
2. Individuals are heterozygous and have advantage of heterozygosity
3. Individuals have deleterious recessive gene which are concealed by masking effect of dominant genes.
4. Out breeders are intolerant to inbreeding. They exhibit high degree of inbreeding depression on selfing.

5. Cross pollination permits new gene combinations from different sources.
6. In these species, variability is distributed over entire population.
7. They have wide adaptability and more flexibility to environmental changes due to heterozygosity and heterogenety.

Methods of Breeding Allogamous species

1. Plant introduction
2. Mass and progeny selection
3. Back cross method.
4. Heterosis breeding
5. Synthetic breeding
6. Composite breeding
7. Polyploidy breeding
8. Distant hybridization
9. Transgenic breeding
10. Mutation breeding (rarely)

Three breeding approaches viz., recurrent selection, disruptive mating and biparental mating are used for population improvement.

Asexually propagated species

Some crop plants propagate by asexual means i.e. by stem or root cuttings or by other means. Such species are known as asexually propagated species or vegetatively propagated species. Such species are found in both self and cross pollinated groups. Generally asexually propagated species are highly heterozygous and have broad genetic base, wide adaptability and more flexibility.

Methods of breeding Asexually propagated species

1. Plant introduction
2. Clonal selection
3. Mass selection (rarely used)
4. Heterosis breeding
5. Mutation breeding
6. Polyploidy breeding
7. Distant hybridization
8. Transgenic breeding

BREEDING POPULATIONS

The genetic constitution of plants is determined by mode of pollination. Self pollination leads to homozysity and cross pollination results in heterozygosity to exploit homozygosity in self pollinated crops and heterozygosity in cross pollinated species, because inbreeders have advantage of homozygosity and outbreeders have advantage of heterozygosity. Based on genetic constitution, breeding populations are of four types *viz.,*

1. Homogenous
2. Heterogenous
3. Homozygous
4. Heterozygous

1. Homogenous population

Genetically similar plants constitute homogenous populations. Examples of
homogeneous populations are pure lines, inbred lines, F1 hybrid between two pure line or inbred
lines and progeny of a clone. Pure lines and inbred lines generally have narrow adoption.

2. Heterogenous populations

Genetically dissimilar plants constitute heterogenous populations. Examples are land races, mass selected populations, composites, synthetics and multilines. Heterogenous populations have wide adaptability and stable performance under different environments.

3. Homozygous populations

Individuals with like alleles at the corresponding loci are know as homozygous. Such individuals do not segregate on selfing. Thus non-segregating genotypes constitute homozygous populations. Examples are pure lines, inbred lines and mass selected populations in self pollinated plants. Thus pure lines and inbred lines are homozygous and homogeneous and mass selected varieties of self pollinated crops and multi lines are homozygous and heterogenous, because they are mixtures of several pure lines.

4. Heterozygous populations

Individuals with unlike alleles at the corresponding loci are referred to as heterozygous. Such individuals segregate into various types on selfing. This includes F1 hybrids, composites and synthetics. Thus F1 hybrids are heterozygous but homogeneous and composites and synthetics are heterozygous and heterogenous population. Such populations have greater buffering capacity to environmental fluctuations.