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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.

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 shattering 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.

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.

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.

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 F 1 hybrids, composites and synthetics. Thus F 1 hybrids are heterozygous but homogeneous and composites and synthetics are heterozygous and heterogenous population. Such populations have greater buffering capacity to environmental fluctuations.

Clonal selection

Some agricultural crops and a large number of horticultural crops are asexually propagated. Some common asexually propagated crops are sugarcane (S. officinarum), potato (S.tuberosum), sweet potato (I. batatas), Colocasia (Taro), Arum, Dioscorea (yams), Mentha, ginger (Zingiber sp.), turmeric (C. domestica), banana (Musa paradisiaca), etc., almost all the fruit trees, e.g., mango (Mangifera indica), citrus (Citrus spp.), apples (P. malus), pears (P.commun is), peaches (P. persica), litchi (Litchi chinensis), loquat (Eriobotrya japonica), etc:, and many ornamentals and grasses. Many of these crops show reduced flowering and seed set, 'e.g., sugarcane, potato, sweet potato, banana, etc., and some varieties of these crops do not flower at all. But many of these crops flower regularly and show satisfactory seed set. However they are propagated asexually to avoid the ill effects of segregation and recombination, both being the inevitable consequences of sexual reproduction.

Segregation and recombination produce new gene combinations due to which the progeny differ from their parents in genotype and phenotype. Asexual reproduction, on the other hand, produces progeny exactly identical to their parents in genotype because the progeny are derived from vegetative cells through mitosis. The advantage of asexual reproduction is immediately clear. It preserves the genotype of an individual indefinitely. It must be noted that this does not depend on the homozygosity of the genotype of an individual. Any genotype is preserved and. maintained through asexual reproduction. In contrast self-pollination preserves and maintains only homozygous genotypes giving rise to purelines.

Characteristics of Asexually Propagated Crops

1. A great majority of them are, perennial, e.g., sugarcane, fruit trees, etc. The annual crops are mostly tuber crops, e.g., potato, cassava (M. utilissima), sweet potato, etc.
2. Many of them show reduced flowering-and seed set. Many varieties do not flower at all. Only the crops grown for fruit, particularly where good fruit set depends upon seed formation, show regular flowering and satisfactory seed set.
3. They are invariably cross-pollinated.
4. These crops are highly heterozygous and show severe inbreeding depression.
5. A vast majority of asexually propagated crops are either polyploids, eg., sugarcane, potato, sweet potato, etc., or have polyploid species or varieties.
6. Many species are interspecific hybrid, eg., Banana (M. paradisiaca), sugarcane, Rubus, etc.
7. These crops consist of a large number of clones, that is, progeny derived from a single plant through asexual reproduction. Thus each variety of an asexually propagated crop is a clone.

Clone A clone is group of plants produced from a single through asexual reproduction. Thus asexually propagated crops consist of large number of clones, and they are often known as clonal crops. All the members of a clone have the same genotype as the parent plant. As a result, they are identical with each other in genotype. Consequently, the phenotypic differences within a clone do not have a genetic basis and are purely due to the environmental effects. A selection within a clone is thus useless. The various characteristic of a.clone are summarised below.

Identical Genotype- All the individuals belongings to a single clone are identical in genotype. This is so because a clone is obtained through asexual reproduction, which involves mitotic cell division only. Genetic variation in the progeny of a plant is produced chiefly by segregation and recombination, which occur during meiosis only. Thus the genotype of a clone is maintained indefinitely without any change.

Lack of genetic variation - The.phenotypic variation present within a clone is due to the environment only.This is so because all the individuals belonging to a single clone have the same genotype. The phenotype of a clone is due to the effects of genotype (G), the environment (E) and the genotype X 'environment interaction (G x E) the population mean. (μ). Thus the phenotype (P) of a clone may be expressed as follows. $P = \mu + G + E + GE$ Thus the phenotypic differences among clones would be partly due to E and GE components. Hence the efficiency of selection among clones, as among purelines, would depend upon the precision with which the E and GE components of phenotype are estimated.

Immortality- Theoretically, clones are immortal i.e., a clone can be maintained indefinitely through asexual reproduction. But clones usually degenerate due to viral or bacterial infection. A clone

may become extinct due to its susceptibility to diseases or insect pests. Further, genetic variation may arise within a clone changing its characteristics.

Severe Inbreeding Depression- Generally, clones are highly heterozygous and show severe loss in vigor due to inbreeding.

Clonal Selection - The phenotypic value of a plant or clone is due to the effects of its genotype (G), the environment (E) and genotype x environment (G x E) interaction. Of these, only the G effects are heritable. The environmental and interaction effects are non heritable and cannot be selected for. Therefore, a selection for quantitative characters based on observations on single plants is highly unreliable. In fact, plants selected in this way may be no better than a random sample. Further, a selection for characters like yielding ability, etc. on the basis of unreplicated clonal plots would often be misleading and unreliable. Therefore, the value of a clone can be reliably estimated only through replicated yield trials. However, selection for highly heritable characteristics, such as plant height, days to flowering, color, disease resistance, etc., are easy and effective even on the basis of individual plants or single plots. Clearly, these situations are the same as those in the case of sexually reproducing crops.

Selection Procedure- In view of these considerations, in the earlier stages of clonal selection, when selection is based on single plants or single plots, the emphasis is on the elimination of weak and undesirable plants or clones. The breeder cannot reasonably hope to identify superior' genotypes at this stage. In the later stages, when replicated trials are the basis of selection, the emphasis is to identify and select the superior clones. The various steps involved in clonal selection are briefly described below and are depicted in Fig.

1. First Year - From a mixed variable population, few hundreds to few thousand desirable plants are selected. A rigid selection can be done for simply inherited characters with high heritability. Plants with obvious weaknesses are eliminated.

2. Second Year Clones from the selected plants are grown separately, generally, without replication This is done in view of the limited supply of the propagating material for each clone, and because of the large number of clones involved. The characteristics of clones will be more clear now than in the previous generation when the observations were based on individual plants. The number of clones is drastically reduced and inferior clones eliminated. The selection is based on visual observations and on the basis of clonal characteristics. Fifty to one hundred clones may be selected on the basis of clonal characteristics.

3. Third Year Replicated preliminary yield trial is conducted. Suitable, checks included for comparison. Few superior performing clones with desirable characteristics selected for multilocation trials. At this stage, selection for quality is also done. If necessary, separate disease nurseries may be planted to evaluate the disease resistance of selected clones.

4. Fourth to Sixth Years Replicated yield trials are conducted at several locations along with a suitable check. The yielding ability, quality and disease resistance, etc. of the clones are rigidly evaluated. The best clone that is superior to the check in one or more characteristics is identified for release as a new variety.

5. Seventh Year The superior clone is multiplied released as a new variety.

Merits of Clonal Selection –

1. It is the only method of selection applicable to clonal crops. It avoids inbreeding depression, and preserves the gene combinations present in the clones.
2. Clonal selection, without any substantial modification, can be combined with hybridization to generate the variability necessary for selection.
3. The selection scheme is useful in maintaining the purity of clones.

Demerits of Clonal Selection-

1. This selection method utilizes the natural variability already present in the population; it has not been devised to generate variability.
2. Sexual reproduction is a prerequisite for the creation of variability through hybridization