

production of hybrid seed. Male sterility is of two types : genetic and Cytoplasmic. Cytoplasmic male sterility is termed Cytoplasmic-genetic when restorer genes are known. In view of the importance of self-incompatibility and male sterility, a more detailed discussion on them follows later.

Genetic Consequences of Cross-Pollination. Cross-pollination preserves and promotes heterozygosity in a population. Cross-pollinated species are highly heterozygous and show mild to severe inbreeding depression and a considerable amount of heterosis. The breeding methods in such species aim at improving the crop species without reducing heterozygosity to an appreciable degree. Usually, hybrid or synthetic varieties are the aim of breeder wherever the seed production of such varieties is economically feasible.

Often Cross-Pollinated Species

In many crop plants (Table 3.1), cross -pollination often exceeds 5 per cent and may reach 30 per cent. Such species are generally known as often cross-pollinated species, e.g., Jowar, Cotton, arhar, safflower etc. The genetic architecture of such crops is intermediate between self-pollinated and cross-pollinated species. Consequently, in such species breeding methods suitable for both of them may be profitably applied. But often hybrid varieties are superior to others.

METHODS OF PLANT BREEDING

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

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

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

Classification of Plant Breeding Methods

Basis of classification and Types of methods

Breeding methods included

A. Application in crop improvement

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

B. Hybridization

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

There are some differences in the breeding methods used for self pollinated and cross pollinated species. Self pollinated species are homozygous, hence we can start hybridization directly. Cross pollinated species, on the other hand, are highly heterozygous. Hence we can not start hybridization directly. First we have to develop inbred lines by selfing or inbreeding and then only hybridization can be taken up. We have to exploit homozygosity in self pollinated crops and heterozygosity in cross pollinated species. Asexually propagated species such as sugarcane, potato, sweet potato, etc., are highly heterozygous. Hence, F₁ hybrids in

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

Methods of Breeding Autogamous species

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

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

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

Methods or Breeding Allogamous species

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

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

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

Methods of Breeding Asexually Propagated Species

Important breeding methods applicable to asexually propagated species are

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

Mass selection is rarely used in asexually propagated species.

Brief account of breeding methods

Plant introduction is applicable to all three groups of crop plants, *viz.*, self pollinated, cross pollinated and asexually propagated species. It is an old est and rapid method of crop improvement. The introduced material may be used in three ways *viz.*,

- (1) Directly as a variety
- (2) As a variety after selection
- (3) As a parent in the hybridization for development of variety or hybrid

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

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

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

Pedigree method is applicable to both self and cross pollinated species. In self pollinated crops progeny of a single best homozygote is released as a variety. Thus a variety developed by this method has a homozygous and homogeneous population. In cross

pollinated species, it is used for developed of inbred lines. Bulk nad single seed descent methods are used in self pollinated species. Progeny of a single best homozygote is released as a variety by these methods. Thus, varieties developed by these methods are homozygous and homogeneous.

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

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

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

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

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

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

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

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

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

Plant Introduction

Plant introduction consists of taking a genotype or a group of genotypes of plants into new environments where they were not being grown before. Introduction may involve new varieties of a crop already grown in the area, wild relatives of the crop species or a totally new crop species. Mostly materials are introduced from other countries or continents. But movement of crop varieties from one environment into another within a country is also introduction. Some examples of within the country introduction are popularization of grape cultivation in Haryana, Introduction of wheat in West Bengal, Rice in Punjab etc.

Primary Introduction : When the introduced variety is well suited to the new environment, it is released for commercial cultivation without any alteration in the original genotype, this constitutes primary introduction. Primary introduction is less common, particularly in countries having well organized crop improvement programmes. Introduction of semi dwarf wheat varieties Sonora 64, Lerma Roja and of semi dwarf rice varieties Taichung Native 1 (TN-1), IR-8 and IR-36 are some examples of primary introductions.

Secondary Introduction: The introduced variety may be subjected to selection to isolate a superior variety. Alternatively, it may be hybridized with local varieties to transfer one or few characters from this variety to the local ones these processes are known as secondary introduction. Secondary introduction is much more common than primary introduction. Examples of secondary introduction are Kalyan Sona and sonalika wheat varieties selected from material introduced from CIMMYT, Mexico.

History of Plant Introduction : crop plants have traveled into many new areas from their centres of origin. This movement of plants occurred with the movement of man. Most of these introductions occurred very early in the history. For example, mung mustard, pear, apple and walnut were introduced from the Central Asian Center of origin into various parts of India. Similarly sesame, Jowar, arhar, Asian Cotton and finger millet originated in Africa and traveled to India in the prehistoric period. From this it is clear that plant wealth of various nations is to a large extent the result of plant introductions.

For several centuries A.D. the agencies of plant Introduction were invaders, settlers, traders, travellers, explorers and naturalists. The plant introduction were made either knowingly or unknowingly. Muslim invaders introduced in India cherries and grapes from