BREEDING METHODS

The goal of Plant Breeder is to create superior crop cultivars. A cultivated variety or cultivar, denotes a group of related plant within a specie maintained either by sexually or asexually propagation whose distinguishable characters are of agricultural significance.

Cultivar is an international term for the category known in different languages by different names. e.g. ‘Variety’ in English, ‘Veriete’ in French, ‘Sort’ in Scandiavian languages and in Russian ‘Ros’ or ‘Varieteit’ in Dutch and ‘Razza’ or ‘Varieta’ in Italian.

KINDS OF CULTIVARS

A cultivar (variety) may be any of this following:

CLONE: A genetically uniform assemblage of individuals, derives originally from a single individual by vegetative propagation e.g. cuttings, divisions, grafts or apomixes.

LINE: An assemblage of sexually reproducing individuals of uniform appearance, propagated by seeds or by spores, its stability maintained by selection to a standard.

OPEN-POLLINATED VARIETY: An assemblage of individual showing genetically differences but having one or more characteristics by which it can be differentiated from other cultivars (varieties).

F_1 HYBRIDS: A uniform assemblage of individuals which is a first generation hybrid (F_1) reconstituted on each occasion by crossing two or more breeding stocks, maintained either by inbreeding or as clone, or recurrently made as F_1 hybrids.

Methods of improvement have been developed for cultivars of all kinds.

(A) The improvement of vegetative propagated crops (mainly fruits crops, woody ornamentals, potato, sugarcane, yam, cassava) involves production of a single desirable genotype. In developing population from which to select a desirable genotypes inbreeding should be avoided.

(B) Breeding methods for the improvement of sexually propagated crops depends on the genetic structure of the cultivars which is governed by the natural method of pollination. The amount of cross-pollinating ranges from essentially none in such plants as soybeans to 100% in dioecious and self-incompatible plants. For breeding purposes, two main groups are recognized.

i) Naturally self-pollinated plants in which cross-pollination is less than 4%.

ii) Naturally cross-pollinated plants in which cross-pollination exceeds 40% e.g. maize.

Self-pollinated plants are ordinarily homozygous for practically all genes. The exceptions are the results of chance cross-pollination and mutations. In such plants heterozygosity is usually quickly eliminated as a consequence of natural inbreeding. The basic problems in improving self-pollinated plants lie in producing and selecting the best homozygous genotype. Once this is accomplished, the problem of genetic maintenance is much smaller than it is with cross-pollinated species.

The genes in naturally cross-pollinated, seed-propagated plants are recombined constantly from generation to generation. The problems encountered in improving cross-pollinated plants include maintaining uniformity while avoiding the decline in vigour associated with homozygosity. Once a desirable population is achieved, there is still the perpetual problem of maintenance. One method of maintaining both uniformity and heterozygosity is to produce hybrids through the crossing of selected diverse inbred lines.

INTRODUCTION

The first step in any crop improvement programme is to assemble the natural variants available (i.e. cultivars and related wild specie). From a study of their performance it may be possible to make an immediate improvement merely by choosing some cultivars not being grown. There should be Plant Genetics and Germplasm Institute to carry out the exploitation and introduction of genetic variability. Collections of germplasm or germplasm bank are currently available for many crops in many crop research institutes all over the world.

Genetic variability is the raw material of the Plant Breeder. The richest source of genetic variability for a particular cultivated species has been shown to be its geographical area of origin.

SELECTION

Selection refers to differential reproduction of individual in a population. Selection is achieved by preserving favourable variants and eliminating undesirable ones. Selection is often a natural process, because in the absence of human interference those plants adapted to survive and reproduce leave the most descendants.

Almost all the crops in cultivation today were domesticated before the advent of written history. Improvement of these crops has been continuous as a result of human selection either consciously or unconsciously over the years. Many of such cultivated species are now very different from their wild ancestors.

The efficient use of selection process is one of the principal tools of a plant breeder. However, selection does not create genetic variability but merely act on the genetic variation already available. Thus, the Breeder must first of all create a variable population form which to select. He must be able to recognize and propagate those individual with superior characteristics. The proper choice of parental materials is one of the crucial decision in any breeding programme.

IMPORTANCE OF MODE OF REPRODUCTION

The mode of reproduction of a crop determines its genetic composition, which, in turn, is the deciding factor to develop suitable breeding and selection methods. Knowledge of mode of reproduction is also essential for its artificial manipulation to breed improved type. Only those breeding and selection methods are suitable for crops which does not interfere with its natural state or ensure the maintenance of such a state. It is due to such reasons that imposition of self-fertilization on cross-pollinating crops leads to drastic reduction in their performance.

For teaching purpose, plant breeding is presented as four categories:

Line breeding (autogamous crops)

Population breeding (allogamous crops)

Hybrid breeding (mostly allogamous crops, some autogamous crops),

Clone breeding (vegetative propagated crops).

METHODS OF BREEDING SELF-POLLINATED/AUTOGAMOUS CROPS

Two fundamentally different types of populations of self-pollinated crops exists.

1) Mixture of different homozygous lines-found in a collection of cultivars. In this type of population, selection consists of determining the best genotype by testing. The best genotype can be duplicated from the selfed-seeds.

2) A mixture of different heterogeneous genotypes, as found in the generation of cross between homozygous cultivars. This population consists of many different genotypes with varying degree of heterozygosity. To obtain an improved type from this type of population, the

best genotype must be selected and then transformed into homozygous, true-breeding line without loosing the essential characteristics of the selected individual.

PEDIGREE BREEDING

Pedigree selection is widely used for self-pollinating crops. Individual plants are generally selected from a segregating population (typically the F_2 generation) and selection proceeds between and within progenies in each subsequent generation until genetic purity are reached.

Since selfing bring absent 50% or more homozygosity in each generation, the variation between lines is halved with each generation. Thus, at the fifth generation, the line derived from single plant selection will be homozygous fro more than 95% of their genes. If testing shows any of these lines to be superior to the existing cultivars, it can be named as a new cultivar.

PROCEDURE OF PEDIGREE METHOD

First year: Hybridization of selected parents

2nd year (F_1): 10 – 30 seed spaced planted, harvested in bulk.

3rd year (F_2): (i) 2000 – 10,000 plant space plated

(ii) 100 – 500 superior plant selected

4th and 5th year: (i) Individual plant progeny space-planted

(ii) Superior plant selected

6th year: (i) Individual plant progeny planted in multi-row plot

(ii) Superior plant selected from superior progenies

7th year: (i) As in (i) and (ii) for F_5

(ii) Preliminary yield trial (PYT) may be conducted.

8th year: (i) PYT

(ii) Quality test

9th – 13th year: (i) Coordinated yield trial

(ii) Disease and Quality test

14th year: (i) Seed increase for distribution

ADVANTAGES OF PEDIGREE

1) It gives the maximum opportunity for the breeder to use his skill and judgement for selection of plants, particularly in the early segregating generation.

2) It is well suited for the improvement of character which can be easily identified and inherited.

3) Transgressive segregates for yield and other quantitative characters may be recovered in addition to the improvement in specific character.

4) It takes less time than bulk method to develop a new variety.

5) Plants and progenies with visible defects and weakness are eliminated of early stape in the breeding programme.

6) The breeder may often be able to obtain information about the inheritance of qualitative characters from the pedigree method.

DISADVANTAGES OF PEDIGREE

1) Maintenance of accurate pedigree records takes up valuable time.

2) Selection in a large number of progenies in every generation is laborious and time consuming.

3) No opportunity for natural selection to influence the population.

4) Selection for yield in F_2 and F_3 is ineffective.

MASS SELECTION

Mass selection can also be used in the improvement of self pollinated crops by planting segregating populations in large plots and harvesting in bulk. Selection may be practiced in each generation by eliminating undesirable plants. After 5 to 10 generations, the population will consist of heterogeneous mixture of somewhat selected homozygous genotypes. The best genotype is then determined by testing. Mass selection permits a large pool of germplasm to be manipulated and carried along.

The combination of mass selection and pedigree selection is well suited for self-pollinated crops. Pedigree selection may be utilized in the early segregating generation to exploit the major genetic differences to eliminate undesirable types. Then mass selection technique may be used. Most modern breeding techniques involve a combination of these systems.

STEPS IN MASS SELECTION

First year: A large number of phenotypically similar plants are selected for their vigour, plant type, disease resistance etc. The number many vary from few hundred to few thousands. Seeds from selected plants are composited to raise next generation.

Second year: The composite seeds are planted in a Preliminary Yield Trial along with standard variety as check. The variety from which the selection was made should also be included as a check to determine if there has been an improvement due to selection. Phenotypic characteristics are critically observed.

Third to Six year: The variety is evaluated in a coordinated yield trials of several locations.

Seventh year: The variety may be released for cultivation if found suitable and if recommended.

APPLICATION OF MASS SELECTION

In self-pollinated crops, mass selection has two basic applications

(1) Improvement of local varieties

(2) Purification of existing varieties

ADVANTAGES OF MASS SELECTION

1) Since a large number of plants are selected, the adaptation of the original variety is not changed.

2) Reduction in time and cost because extensive and prolong yield trials are expensive.

3) It retains considerable genetic variability.

4) It is a less demanding method. The breeder can devote more time to other breeding programmes.

DISADVANTAGES OF MASS SELECTION

1) The varieties show variations.

2) The improvement through mass selection is generally less than that through pure-line.

3) It is not commonly use in self-pollinating crops.

4) In the absence of progeny test, it is impossible to determine if the selected plant is homozygous.

5) The varieties are more difficult to identify than pure line in seed certification programme.

6) It utilizes the variability already present in the population.

PURE-LINE BREEDING

This is the development of the new varieties from the old 'Land' varieties that have passed down from generation to generation of the farmers. Although they may be reasonably similarly in gross morphology, lines within a farmer variety may be different in agricultural value. Most plants selected from such varieties can be expected to be homozygous and hence the starting point of a new true breeding variety.

PROCEDURE

Select a number of single plant, compare their progenies in field trials; and save the single most valuable progenies as a new variety. Many valuable varieties are traced back to a single chance variant noticed and selected by farmers.

BACKCROSS BREEDING

A cross between hybrid and one of its parents is known as backcross. In the backcross breeding, the hybrid and the progenies in the subsequent generations are repeatedly backcross to to that of the parent to which it is backcrossed. At the end of the 6 – 8 backcrosses, the progeny one of the parents. As a result, the genotype of a backcross progeny becomes increasingly similar would be almost identical with the parent use for backcrossing.

OBJECTIVE

This is to improve one or two specific defect of a high yielding variety, which is well adapted to the area and has other desirable characteristics. The characters lacking in this variety are transferred to it from a donor parent.

REQUIREMENT FOR SUCCESSFUL BACKCROSSING

1) Suitable recurrent parent must be available which lacks in one or two characters.

2) Suitable donor parent.

3) Character to be transferred must have high heritability.

4) A sufficient number of crosses should be made so that the genotype of the recurrent parent is recovered in full. Ordinarily 6 – 7 backcrosses are sufficient for the purpose.

BULK POPULATION BREEDING

In this method, F_2 and subsequent generations are backcrossed in mass or as bulk to raise the next generation. At the end of the bulking period, individual plants are selected and evaluated in a similar manner as in pedigree method of breeding. It is suitable for handling the segregating generation of cereals, smaller millet, grain legumes and oil seeds.

USES

1) Isolation of homozygous lines

2) Waiting for the opportunity of selection

3) To provide opportunity for natural selection to change the composition of the population.

NOTE: In bulk method, the population is carried to F_6 or F_7 as bulk, by the time the population approaches 96% homozygosity.

PROCEDURE

First year: Selected parents are hybridized.

Second year: F_1 space planted, seeds harvested in bulk.

3rd to 7th year: F_2 – F_6 planted of commercial seed rate, seeds harvested in bulk, use of artificial selection, disease epiphytontics etc.

8th year i.e. F_7 is space planted, individual plant selected and seeds harvested separately.

9th year: (i) Individual plant progenies grown

(ii) Inferior progenies eliminated

10th year: (i) Preliminary Yield Trials using standard variants as checks.

(ii) Quality test done

11th – 15th year: (i) Multiplication yield trials

(ii) Seed increase for distribution

ADVANTAGES OF BULK BREEDING

1) Simple, convenient and inexpensive

2) Isolation of desirable types thus becomes much easier.

3) Natural selection increases the chances of superior the in the population.

4) Little work or attention is needed in F_2 and subsequent generation.

5) No pedigree record is to be kept which saves time and cost.

6) Artificial selection may be practiced to increase frequency of desirable genes.

7) It is suitable for studies on the survival of genes and genotypes in population.

DISADVANTAGES OF BULK BREEDING

1) Longer time to develop new variety.

2) It provides little opportunity for breeder to exercise his skill.

3) Large number of progenies at the end of the bulking period.

4) Information on the inheritance of characters can not be obtained.

5) In short term, bulk i.e. isolation of homozygous lines, natural selection has little effect on the genetic composition of population.