METHODS OF BREEDING CROSS-POLLINATED CROPS MASS SELECTION

One of the oldest and widely used breeder's procedure with cross-pollinating crops. It is based on phenotypic selection of fruits that can be identified, they are the fruits that can be easily picked, it also effective in sorting at and accumulating gene at particular quantitative characters which can be seen or measured easily and therefore can be used as bases for selection. It can be used in open-pollinated maize to develop variety change in earliness to maturity, height of plant, size of ear, type identification by continuous mass selection.

PROCEDURE

Several hundreds or thousands of desirable individual plants are selected based on their phenotype, harvest and the seeds bulked without any progeny test to produce the next generation in a single plots Selection can be carried out by tagging or roughing when number of selected plants is few.

During the next growing season, crop is inspected at regular interval throughout the life cycle of the plants/crops to remove off types (plants that have arise because they have escaped to be unobserved in the previous season or those that develop due to spontaneous mutation). The bases for combined with specific characteristics, which appeal to the breeder.

The purposes of mass selection are

1) Improvement of local varieties

2) Purification of existing pure-line varieties.

The efficiency with which is accomplish under a system of random selection depends on

1) The effect of genes for desirable characters: The success of mass selection of a particular trait is higher if such trait is being controlled by genes with additive effects than genes with dominance effect.

2) Heritability of the trait: Mass selection is based on the choice of phenotype. Its success depends to the large extent on the heritability of the desirable trait. If the level is high, the progenies in the subsequent generation would be similar to the selected phenotype. If on the other hand, it is low, which is the case with many quantitative traits, the progenies might differ from the selected phenotype.

3) Genotype x environment interaction: Selection will not be successful if G x E is high, this is the case with genes with low heritability.

4) Sample or Population size: Sample size especially with open pollinated lines should be as large as possible to avoid inbreeding depression which frequently cause yield reduction.

The breeding progress that may be made by mass selection is limited because of three main causes.

1) Inability to identify superior genotypes from the phenotypic appearance of single plants.

2) Uncontrolled pollination, so that selected plants are pollinated by both superior and inferior pollen parents

3) Strict selection leading to reduce population size which in turn might lead to inbreeding depression.

RECURRENT SELECTION

The recurrent selection schemes were devised in relation to heterosis breeding. The idea was to ensure the isolation of superior inbreds from the population subjected to recurrent selection from their ultimate utilization in the production of hybrids and synthetic varieties. Recurrence selection is effective in increasing the frequency of desirable genes in the population.

The recurrent selection schemes are in four different types based on the ways in which plants with desirable characters are identified.

1) Simple recurrent selection for phenotype
2) Recurrent selection for general combining ability
3) Recurrent selection for specific combining ability
4) Reciprocal recurrent selection

Generally, recurrent selection is particularly useful where:

1) The frequency of genes for particular quantitative character is to be increased or concentrated.
2) When you want genetic recombination to increase by providing for recombination among lines derived from different foundation lines.
3) Maintenance of genetic variability in the breeding population is needed.

PROCEDURE FOR RECURRENT SELECTION

First year (i) Several phenotypically superior plants selected

(ii) Selected plants self-pollinated

(iii) Seeds harvests separately

(iv) Seeds evaluated, superior seeds retain

Second year (i) Individual plant progeny planted

(ii) Possible intercrosses made

(iii) Equal amount of seeds from all intercrosses composited

Third year (i) Composited intercross seeds planted

(ii) As in (i) to (iv) in the first year

Four year (i) Individual plant progency planted

(ii) As in (ii) to (iii) in the second year.

The cycle continues until the desired aim is achieved or when there is no more progress in terms of desired characters.

Recurrent selections meant to include reselection generation after generation of selection provide for genetic recombination, thus selection among isolated inbred lines or clones is not recurrent until such selected plants are interbred and a new cycle of selection is initiated.

ADVANTAGES

1) The highest performance of this breeding method is set not by the genotype of a single foundation plant but by the most favourable combination of genes contained in the group of foundation.

2) The satisfactory individuals showed within selfed or mildly inbred lines estimated in the populations of recurrent selection.

3) Since the rate of inbreeding can be kept at a low level, it is possible to maintain high genetic variability and hence provide for effective selection over a longer period.

RECURRENT SELECTION FOR PHENOTYPE

In this type of RS, plants are selected on the basis of phenotypic scores taken on individual plants or their selfed progenies. Since test crosses are not made, the effective use for recurrent selection for phenotype is restricted to characteristics with sufficiently high heritability so that an accurate phenotypic reevaluation of the characteristics can be made visually or by simple effectiveness in breeding for improved combining ability for yield. E.g. it can be used to concentrate genes for resistance to leaf blight of maize.

RECURRENT SELECTION OF GENERAL COMBINING ABILITY

In this type of RS, a number of plants which appeal to the breeder are selected from the source population. These selected plants are selfed and also crossed to heterozygous tester stock to identify the selected individual with good general combining ability.

Heterozygous means that the tester has a broad genetic base.

A tester is a common pollen parent, which may be a standard variety or test hybrid of a single cross.

Test cross is the cross between the superior progeny and the testers.

RECURRENT SELECTION FOR SPECIFIC COMBINING ABILITY

This type of RS has the same operational procedure as recurrent selection for general combining ability except for different tester. Here the progeny test is with homozygous tester line i.e tester line with narrow genetic base. It is either an inbred line or a selfed plant. With this kind of selection procedure, it is possible to increase the proportion of each cycle of selection as well as to increase the frequency of desirable genes in the inbred lines.

RECIPROCAL RECURRENT SELECTION (RRS)

This method employs two heterozygous source populations A is B. each of which is the tester for the other. These two populations must be genetically unrelated.

PROCEDURE

Select a number of plants from population A and outcross with a sample of plants from source B.

Select a number of plants from population B self them and make crosses with A and evaluate progeny performance from population A and B singly. The plant selected are then interbred each source group separately, group bulk the seeds separately and the resulting cross seeds will serve as a source population for another cycle.

Population developed by RRS will be utilized by producing commercial seeds from crosses between A and B source groups.

HYBRID VARIETIES BREEDING

This refers to the production of heterozygous population from crosses of homozygous lines.

Hybrid breeding is mostly applicable to cross pollinated crops where exploitation of heterosis is relied upon. It however has limited usefulness in self-pollinated crops. It came into prominence with maize.

There are two technical steps in the production of hybrid seeds for cross-pollinated crops.

1) Production of homozygous lines

2) Crossing of these lines to obtain hybrid sees.

PRODUCTION OF HOMOZYGOUS LINES

Usually through continue inbreeding. In self-pollinated crops, homozygous lines occur naturally but in cross-pollinated crops they must be produced by the Plant Breeder.

A) In perfect flower species: The inflorescence merely needs to be bagged to exclude foreign pollen.

B) In Monoecious crops: The pistillate flower must be protected and pollens must be collected and applied to the stigma surface of the pistil.

C) A number of crops resist self fertilization because of incompatibility mechanisms. Foreign pollen will be required to effect fertilization. Haploid can also be produced which can be doubled latter.

Although maximum heterosis is obtained by crossing two diverse inbred lines, a number of other combinations produce hybrid vigour. The various kinds of crosses that are referred to as hybrid in the trade are distinguished as follows.

Single cross hybrid: Inbred x Inbred (A x B) A single cross hybrid is usually made by alternate planting of 2 rows of seed parents to one row of pollinator-inbred line in an isolated plot. The seed parent should be detasselled. The planting distance of the crop should be the normal or standard spacing for the chosen crop. The tassel on the male parent is left on the plant to fertilize the seed parent (female parent). The planting agent is wind.

Three-way-cross: F1 hybrid x inbred i.e.

i) Inbred x Inbred – F_1 (seed parent)

ii) F_1 x Inbred (Pollinator)

The single cross is used as the female parent. To be successful, the inbred line being used, as the male parent must also excel in pollen production.

Double cross: F_1 hybrid x F_1 hybrid. It involves four inbred and two single crosses i.e. it is the hybrid between two single crosses involving four inbred lines. In this type of hybrid, the seed used for commercial planting is produced on a single cross seed parent (female parent) that yields 2 or 3 as much as any inbred lines. Pollen is produced in abundant by the other single cross. The superior pollen producing ability of the single cross pollinator permit planting rate of 6 rows of seed parents to 2 rows of pollen parent.

ADVANTAGES OF HYBRID

1) Distinctly more productive than even the base open-pollinated varieties.

2) They are much more disease resistant.

3) They have significantly better stock strength.

DISADVANTAGES OF HYBRID

1) The yield ability of the hybrids lack consistent superiority from year to year. Hence farmers get new set of seed seasonally. Synthetic varieties can be used to curb this.

2) They are costlier to produce than open-pollinated plant because a lot of work and manpower is needed.

SYNTHETIC VARIETIES (SV)

SV uses an appreciable out of hybrid vigour in addition to open pollination. SV is a variety maintains from open-pollinated seed following it's combinations among a number of selected genotypes. These genotypes can be clones, inbred lines a mass selected population (i.e. open pollination) superior for their good character. Also, this genotype must have been tested for combining ability and found to combine well with other parents to produce superior character.

The larger the number of genotypes that are tested for combining ability, the wider the genetic base of the synthetic varieties obtained. Some scientist after working with maize Hayes and Garber (1919) have this conclusion:

The production of improved variety through the recombination of several selfed lines/ strains has more advantage over either the single or double crossed plan (i.e. hybrid maize) in that the farmer can save his own seeds from the yearly crop and that yearly crosses need not be made.

STEPS INVOLVED IN PRODUCTION OF SYNTHETIC VARIETY

i) Isolation of one generation of one selfed lines.

ii) Test these lines in top crosses for yield and other characters (i.e. combining ability by looking for their F_1.

iii) Allow random mating among the better lines to produce synthetic variety.

iv) Repetition of the above processes of intervals after a generation of 2 open pollinations.

USES OF SYNTHETIC VARIETIES

1) Synthetic variety has value as reservoir of desirable germplasm (i.e. gene bank) because of its wide variability.

2) Also of value where the cost of hybrid seeds is too high compared to the value of accepted crop.

3) The greater variability of SV then that of double crosses permits more flexibility in meeting the changeable growing conditions of marginal areas.

4) Also useful were the commercial acreage available is too small to support a hybrid seed industry.

SELECTION IN ASEXUALLY PROPAGATED CROPS

Selection is straight forward in asexually propagated crops since any genotype may be perpetuated intact. Obtaining segregating populations from which superior genotypes may be found is the problem in breeding asexually propagated materials.

BREEDING OF ASEXUALLY PROPAGATED CROPS

Mode of reproduction:

All living things reproduce themselves before they die; the purpose of flowers in plants is to reproduce the plant. Seeds, which grow into new plants, develop from flowers. Some plants reproduce by (more or less strict) self-fertilization, other plants only (mainly) allow cross fertilization. Asexual propagation (vegetative propagation) can also occur in plants (e.g. cuttings from cassava plants). This gives a new plant which is genetically identical to its parent plant. All these differences change the way plant breeders work.

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 types. Those breeding and selection methods which are suitable for a crop, does not interfere with its natural state. They ensure the maintenance of such a state. It is for this reason that imposition of self-fertilization on cross-pollinating crops leads to drastic reduction in their performance (inbreeding depression)

Plant breeding is the propagation and genetic manipulation of plants, for the purpose of selecting improved offsprings. Here, it is therefore as applied to asexually propagated crops. Asexual reproduction covers all those modes of multiplication of plants where normal gamete formation and fertilization does not take place making these distinctly different from normal seed production crops. In the absence of sexual reproduction, the genetic composition of plant material being multiplied remains essentially the same as its source plant. Many plant species are propagated vegetatively e.g. potato, grapevine, fruit trees, cassava, some forest trees etc. Vegetatively propagated offsprings are used to develop stable varieties without any deterioration due to segregation of gene combinations. A vegetative part taken from a plant, such as a tuber, a root, a rhizome, a leaf or a stem, may be used for asexual vegetative propagation.

Clonal propagation is to obtain the largest possible superior genotype resulting in identical and uniform progenies which can’t be obtained by sexual propagation. This is so because plants arising from a clone are identical and have the same genetic constitution as the mother plant. Variability amongst plants within a single clone can be classified as environmental because they can not be inherited by progenies. The only form of heritable variability is somatic mutation which is inherited through the vegetative mode of propagation.

Grafting

Apart from direct vegetative propagation through tubers, rhizomes, corms etc, horticultural crops (fruit trees, grapevine, and decorative plants) can also be propagated by grafting. Grafting is joining the stems of two different plants of the same genus so that they grow together as one plant. The recipient plant which grows into the roots is called a STOCK while the vegetative part used for the grafting and which grows into the stem and branches is called a SCION. Grafting is not for production of new cultivars but for speedy propagation of superior genotypes that will be identical to the scion. Grafting may bring about larger variability than propagation without grafting. These changes may be classified into:-

(a) Non – heritable

- Modification – type changes
- Chimera – type changes

(b) Heritable

- Mutation – type changes

Non – Heritable

- Modification type changes

Most grafting methods practiced bring modification type changes. Such changes are :- more or less vigorous growth, larger or smaller fruits, earlier maturation on one stock than on another etc. These changes are not transferred to progenies by sexual means.

- Chimera type changes

These are brought about by mixing of tissues after grafting. These changes are called chimeric changes and are different from modification type changes. Different types of chimeras (sectoral, periclinal, shoot with only scion tissue, shoot with only stock tissue) develop as a result of different modes of fusing and mixing of plant tissues of the stock and scion. These changes are sometimes so striking and unusual that it is difficult to accept them as non-heritable changes. Chimeras are maintained only by vegetative propagation and being used in a number of horticultural species.

Heritable changes

Various substances come to scion from stock during tissue fusing. The larger the difference between stock and scion, the more different are the substances exchanged between them. A possibility exists for some organic substances exchanged between scion and stock to be mutagenic and to cause in some cases mutations of a certain gene. The frequency of such changes is very low (thousandths of one percent).

Advantages of grafting

1. It allows the propagation of somatic or vegetative mutations which cannot be achieved by sexual means

2. It allows the stabilization and utilization of heterozygous genotypes (which is not possible in selfers and only in large population of crossers in equilibrium)

Source of materials for plant improvement

There are two (2) main sources of materials for plant improvement in vegetatively propagated crops:

(a) Clones or population of mixed clones usable for the production of stocks and scions (cultivars)

(b) Populations of seedlings usable for the production of stocks and scions.

Selection of clonal stocks and scions

Clones are genetically homogenous because all plants originate from one ancestral mother plant. But, in some cases not all members of a given clone have the same genotype e.g. in case of spontaneous mutation of certain buds or when one branch is diploid and another triploid etc). Clonal selection of positive/ beneficial mutants A heterogeneous population of mixed clones (from different ancestral mother plants) contains different genotypes and as such a good population for selection of clonal stocks or scions.

can produce new varieties

STOCKS: Selection of clonal stocks is important because different stocks are suitable for different cultivars as well as for various climatic and soil conditions. Success in production depends not only on the traits of the scion but also on that of the stock (Cummins and

Aldwinckle, 1983). Rootsocks obtained by clonal selection are therefore preferred to those from seedlings because they produce high uniformity of fruit bearing trees to allow for simultaneous application of chemicals, mechanized harvest and to meet market demands.

Criteria for selection of stock:

1. Propagation ability – propagation requirement of the commercial nursery
2. Graft compatibility – The stock must be compatible to most commercial scions (cultivars)
3. Yield – It must induce early flower buds and good fruit set together with regular and heavy production
4. Longevity – Good survival under the prevailing conditions
5. Resistance to diseases found in the soil e.g. *fusarium* wilt, nematodes etc.

SCIONS: Methods of mass and individual selection may be applied in the selection of clones for scions. The procedure of mass selection starts with positive selection of the plant materials to be used for cloning. When cloning is done and the scions are grafted unto certain stocks, negative selection (individuals) is conducted to remove weak and diseased nursery plants. Individual clonal selection is done for best trees or vines based on important agronomic traits because considerable variability exists in certain cultivars that make individual trees differ in productivity, quality, disease resistance etc. These selected trees or vines are then vegetatively reproduced (cloned). Examples are found in the development of walnut cultivar shampion on the basis of individual trees of a Yugoslav local population (Korac *et al*., 1988)

Selection of seedling stocks and scions:

Sexual reproduction of fruit trees produces populations of seedling which exhibits large genetic variability due to cross pollination and mutation. There are three (3) main sources from which to select seedlings:

1. Natural populations (populations in the wild)

2. Artificial populations (seeds develop as a result of uncontrolled mating in orchards, therefore fruit seeds produce a heterogeneous population which serves for selection of seedlings for new stock and scions).

3. Known hybrid populations (mating of known cultivars in an orchard)

STOCKS: Seedlings from natural populations are mostly used for the production of stocks (sexually produced stocks). Seedlings are grown in a nursery and selected for one or more years depending on the plant species. Being heterogeneous populations, seedlings are separated into groups. Within group negative selection is practiced to eliminate seedlings which are poorly developed, susceptible to diseases or possess other undesirable traits. The best seedlings are transplanted and multiplied vegetatively (e.g. in large no of fruits such as peach, almond, cheery, olive, walnuts etc)

Disadvantage:

It is difficult to produce uniform and homogenous stocks (due to segregation) and consequently, the orchard differs in growth and productivity. This in turn creates problems in plant protection, picking and fruit quality (Pejkic, 1980). Vegetative or clonal stocks are quite uniform and are being used instead.

SCIONS: Artificial populations are used for the production of scions from which to select new cultivars. Artificial populations are rich sources of new cultivars because seedlings found accidentally in them may give rise to some novel cultivars. Seedlings from artificial populations are grown in a nursery, with individual selection based mostly on visual observations carried out. Examples are found in some apple cultivars, pear cultivars etc.

Known/Planned hybrid population

Natural and artificial populations result from natural hybridization. They do not fit into the concept of planned development of cultivars. Cultivars possessing certain desirable traits are developed on the basis of planned hybridization preceded by careful selection of parental pairs.

Particular attention must be paid to rootstock breeding because it is quite different from scion cultivar breeding. The physical environment (temperature, gas exchange, moisture, soil etc) are quite different in the rhizosphere than above ground of scion; the biotic environment (pathogens, insects, symbiotic relationships etc) and also, the physiology of root is quite different from that of the leafy portion (scion) of the tree.

Merits:

1. It comes out with new and desirable gene recombination
2. It allows for the vegetative use of F_1 generation which frequently contains the best recombination of genes of the two parents (highest level of heterozygosity)

3. Vegetative reproduction allows desirable genotypes from the F_2 and subsequent generations to be used without having to wait for them to become homozygous. Examples abound in a number of grapevines, peaches etc (self pollinating species) and also in cross-pollinated species where known parents were hybridized.

Apomixis:

Vegetative propagation can also be achieved by the use of seeds of apomictic origin. Apomixis is a type of reproduction in which the sexual organs or related structures take part, but in which seeds are formed without union of the male and female gametes, but in an essentially asexual way i. e. without fertilization (fatherless plants). Seeds formed in this manner are vegetative in origin and resemble only the female parent. As a reproductive method it eliminates genetic changes. All that is necessary in order to have identical seedlings the next season is to take seeds from prolific stock. The seedlings of the next generation are identical to each other and to the female parent plant, on account of their high uniformity, are very useful for the production of root stocks for citrus plants. Examples are also found in some species of forage grasses (*Panicum maximum, Eragrostis curvula* etc.) There are several types of apomixis of which apogamy, apospory, diplospory, and parthenogenesis are the most frequent:

(a) Apogamy

The embryo develops from the fusion of two haploid cells other than the eggs i.e. nuclei of the embryo sac. The cells are either synergids or antipodals. The resulting plant is diploid and it develops normally.

(b) Apospory

The embryo sac is formed directly from a somatic cell (2n), without reduction. The embryo in turn develops directly from a diploid cell in the embryo sac without fertilization.

© Diplospory

This occurs when the embryo develops from the megaspore mother cell without chromosome reduction.

(d) Parthenogenesis

The embryo develops directly from an unfertilized egg. If the chromosome number of the gamete (egg) has been reduced at meiosis and chromosome doubling of the unfertilized gamete does not occur, the embryo and the plant developing from it will be haploid. If the egg cell has an unreduced chromosome number (during meiosis) as a result of some abnormal occurrence (spindle fibres refusing to form) during meiosis, the embryo and plant will be diploid.

Some plant species are obligate apomictics while some are facultative apomictics.

- Obligate apomictics only reproduce by apomictic means, hybridization and gene recombination are precluded from their life cycle.
- Facultative apomictics have both apomictic and sexual reproduction.

N/B

It is important that a breeder be informed of the tendency of a species to produce seed by apomixis to avoid confusion and error in breeding experiments.

Advantages

(a) Crosses attempted in apomictic species would generally produce progenies identical to the mother plant.

(b) It can be used for the propagation of superior genotypes, especially if they are heterozygous. This is because a superior plant type which produces seed by apomixis will usually breed true for the characteristics of the mother plant.

Disadvantage

In case of obligate apomictics, in which hybridization and gene recombination are precluded, apomixis reduces genetic variability and therefore lowers breeding success. Facultative apomictics are thus preferred because they are open to gene recombinations and the development of new genotypes.