22.Population improvement programmes, recurrent selection, synthetics and composites

Population Approach to Breeding of Self -Pollinated Crops

Self-fertilization of F_I hybrids leads to a very rapid increase in homozygosity. After several generations of self-pollination, about 94 per cent of the genes would become homozygous. Even in F_2, half of the genes are in homozygous state. Thus self fertilization quickly separates the progeny from a hybrid into a large number of purelines. As a consequence, selection in such a segregating population only picks out the genes combinations present in the population primarily as a result of recombination in F_2.

This reduces the chance of recombination between linked, especially tightly linked genes and of recovery of rare transgressive segregants. There is no opportunity for changing the genotype of the plant produced by recombination in F_I, F_2 and to some extent, in F_3.Thus the two obvious limitations of breeding methods based on self-pollination of the hybrid (e.g., pedigree and bulk methods) are: first, the recombination is limited to two or, at the best, three generations, and second, there is no possibility for further changing the genotype of the segregants.

A population breeding approach has been suggested to overcome these problems. In population breeding, outstanding F_2 plants are mated among themselves in pairs or in some other fashion. The intermating of selected F_2 plants restores heterozygosity in the progeny, which provides for a greater opportunity for recombination. This also brings together the desirable genes from different F_2 plants and would help in the accumulation of favourable genes in the intermated population. Thus the chances of the recovery of transgressive segregants would increase considerably. This process may be repeated one or more times.

This procedure is similar to recurrent selection in cross-pollinated crops. A variation of this approach would be to intermate F_3 or later generation progenies. This would allow a more effective selection of desirable progenies than in the case of F_2 where individual plants have to be selected. As noted previously, selection in F_2 based on individual plants is of little value, particularly for characters like yield. Selection based on F_3 or F_4 progenies would be more desirable. Intermating of selected plants may be continued for two or more generations.

This idea of population approach was first suggested by Palmer in 1953. It is not commonly used at present, but may find a greater application in the future, as improvements due to the pedigree method would become less and less marked. Evidently, the population approach is akin to recurrent selection commonly used in cross-pollinated crops and often it is referred to as such. The chief limitation of recurrent selection in self-pollinated crops is the difficulty in making the large number of required crosses by hand (emasculation and pollination).

This difficulty may be overcome by using genetic or cytoplasmic male sterility. When genetic male sterility is used, selection is confined to the male sterile (ms ms) plants in each generation. Seeds from the selected male sterile plants are generally harvested in bulk. The progeny from such plants may be expected to have both male sterile (ms ms) and male fertile (Ms ms) plants in almost equal proportion. Further, the seeds produced on the male sterile plants would be produced by pollination by the male fertile plants in the population. Thus the use of male sterility effectively ensures intermating among the plants in the population and eliminates the needs for tedious and time-consuming hand emasculation and pollination.

Results from recurrent selection are available in tobacco and soybean. In tobacco, Matzinger and coworkers selected the plants before flowering and intermated them. A linear response of 4.9 and 7 per cent per cycle to selection for decrease plant height and for increased leaf number, respectively, was obtained for five cycles of selection. Further, there was no evidence for a reduction in variability as a result of the selection. Brim and coworkers carried out six cycles of recurrent selection for increased protein content in two segregating populations of soybean and three cycles of selection for yield and three cycles of selection for high oil content in another segregating population. There was an increase of 0.33 and 0.67 per cent / cycle in protein content of the two populations, of 5.3% per cycle in yield and of 0.3% per cycle in oil content. These findings amply demonstrate the effectiveness of recurrent ,selection in improving yield and yield traits in self-pollinated crops.

In 1970, Jensen proposed a comprehensive breeding scheme which provides for the three basic functions of a versatile. breeding programme. Firstly, it allows the development of F2, F3 etc. (selfing series) at every stage of the breeding programme, which permits the isolation of purelines for use as commercial varieties. Secondly, it requires intermating among the selected plants/ lines in each stage; the progenies from these intermatings form the basis for the next stage of the selfing series in the breeding programme.

Thus the breeding programme progresses in two different directions: (1) Vertically, through the selfing series leading to the isolation of commercial varieties, and (2) horizontally, through intermating among the selected plant / lines; this generates the recurrent selection series.

Thirdly, new germplasm may be introduced at any stage of the programme by intermating it with some of the selected plants of that stage. This permits the retention and or the creation of large amounts of variability for effective selection through several cycles, and the introduction of new genes in the breeding material, if so desired. This breeding scheme is known as Diallel Selective Mating Scheme (DSM) and is designed to serve both short-term and long-term breeding objectives.

A breeder may create more than one such population for a crop, each population being developed to fulfill a specific objective. This scheme has not been widely used primarily due to the difficulties in making the large number of crosses required in this scheme. Jensen has suggested the use of male sterility to overcome this difficulty in the same way as in the recurrent selection scheme discussed earlier. Further, DSM is much more complicated than the simple pedigree method which still is the favourite breeding method for selfpollinated crops.

Merits of population Approach

1. The population approach provides for greater opportunities for recombination. This is made possible by restoring heterozygosity through intermating of selected plants.
2. This approach helps in the accumulation of desirable genes in the population. This is also brought about by the intermating of selected plants from segregating generation.

Demerits of Population Approach

1. The success of this approach depends upon the identification of desirable plants in F_2 and the subsequent segregating generations. This is very difficult, if not impossible, for complex characters like yield which show low heritability. This may be avoided to some extent by using later generation (F_3 or F_4) progenies; replicated yield data may also be used.
2. Another draw back of this approach is the intermating of selected plants. This may become a major limitation in some crops because crossing in many self-pollinated species is difficult and time consuming.
3. The time taken to develop a new variety through population approach would be always greater than that by the pedigree method.
4. There is no convincing evidence for the benefits from the population approach. It has been argued that increased recombination may be detrimental, as it would break the

desirable linkage. But such a criticism assumes that all or most of the new gene combinations (recombinations) will be inferior to the existing ones. Such an assumption is not entirely valid since crop improvement is based on the creation of new and desirable gene combinations.

Breeding Methods for Cross Pollinated Crops

Populations of cross pollinated crops are highly heterozygous. When inbreeding is practiced they show severe inbreeding depression. So to avoid inbreeding depression and its undesirable effects, the breeding methods in the crop is designed in such a way that there will be a minimum inbreeding. The breeding methods commonly used in cross pollinated crops may be broadly grouped into two categories.

I. Population improvement

A. Selection

a) Mass selection

b) Modified mass selection

Detasseling

Panmixis

Stratified or grid or unit selection

Contiguous control.

B. Progeny testing and selection

a) Half sib family selection

i) Ear to row

ii) Modified ear to row.

b) Full sib family selection.

c) Inbred or selfed family selection.

i) S_1 self family selection

ii) S_2 self family selection.

C. Recurrent selection

a) Simple recurrent selection

b) Reciprocal recurrent selection for GCA

c) Reciprocal recurrent selection SCA

d) Reciprocal recurrent selection.

D. Hybrids

E. Synthetics and Composites.

Mass selection

This is similar to the one, which is practiced, in self-pollinated crops. A number of plants are selected based on their phenotype and open pollinated seed from them are bulked together to raise the next generation. The selection cycle is repeated one or more times to increase the frequency of favourable alleles. Such a selection is known as phenotypic recurrent selection.

Merits

i) Simple and less time consuming

ii) Highly effective for character that are easily heritable.

Eg. Plant height, duration.

iii) It will have high adaptability because the base population is locally adapted one.

Demerits

1. Selection is based on phenotype only which is influenced by environment
2. The selected plants are pollinated both by superior and inferior pollens present in the population.
3. High intensity of selection may lead reduction in population there by leading to inbreeding.

To over come these defects modified mass selection is proposed they are

a) Detasseling

This is practiced in maize. The inferior plants will be detasseled there by inferior pollen from base population is eliminated.

b) Panmixis

From the selected plants pollen will be collected and mixed together. This will be used to pollinate the selected plants. This ensures full control on pollen source.

c) Stratified mass selection

Unit selection

Here the field from which plants are to be selected will be divided into smaller units or plots having 40 to 50 plants / plot. From each plot equal number of plants will be selected.

The seeds from selected plants will be harvested and bulked to raise the next generation, by dividing the field into smaller plots, the environmental variation is minimized. This method is followed to improve maize crop. It is also known as Grid method of mass selection

B) Progeny Testing and Selection

a) Half sib family selection

Half sibs are those, which have one parent in common. Here only superior progenies are planted and allowed to open pollinate.

1. Ear to row method

It is the simplest form of progeny selection. Which is extensively used in maize. This method was developed by Hopkins

a) A number of plants are selected on the basis of their phenotype. They are allowed to open pollinate and seeds are harvested on single plant basis.

b) A single row of say 50 plants i.e. progeny row is raised from seeds harvested on single plant basis. The progeny rows are evaluated for desirable characters and superior progenies are identified.

c) Several phenotypically superior plants are selected from progeny rows. There is no control on pollination and plants are permitted to open pollinate.

Though this scheme in simple, there is no control over pollination of selected plants. Inferior pollen may pollinate the plants in the progeny row. To over come this defect, the following method is suggested.

a) At the time of harvest of selected plants from base population on single plant basis, part of the seed is reserved.

b) While raising progeny rows, after reserving part of the seeds, the rest are sown in smaller progeny rows.

c) Study the performance of progenies in rows and identify the best ones.

d) After identifying the best progenies, the reserve seeds of the best progenies may be raised in progeny rows.

e) The progenies will be allowed for open pollination and best ones are selected. There are number of other modifications made in the ear to row selection.

For example,

i. The selected progenies may be selfed instead of open pollination

ii. The selected plants may be crossed to a tester parent. The tester parent may be a open pollinated variety, or inbred

iii.The progeny test may be conducted in replicated trial.

b) Full sib family selection

Full sibs are those which are produced by mating between selected plants in pairs. Here the progenies will have a common ancestry. The crossed progenies are tested.

A x B B x A

c) Inbred or selfed family selection

Families produced by selfing.

S_1 family selection

Families produced by one generation of selfing. These are used for evaluation and superior families are intermated (Simple recurrent selection).

S_2 family selection

Families obtained by two generations of selfing and used for evaluation. Superior families are intermated.

Merits of progeny testing and selection

1. Selection based on progeny test and not on phenotype of individual plants.
2. In breeding can be avoided if care is taken raising a larger population for selection.
3. Selection scheme is simple.

Demerits

1. No control over pollen source. Selection is based only on maternal parent only.
2. Compared to mass selection, the cycle requires 2-3 years which is time consuming.

Recurrent selection

This is one of the breeding methods followed for the improvement of cross pollinated crop. Here single plants are selected based on their phenotype or by progeny testing. The selected single plants are selfed. In the next generation they are intermated (cross in all possible combinations) to produce population for next cycle of selection.

The recurrent selection schemes are modified forms of progeny selection programmes. The main difference between progeny selection and recurrent selection.

i) The manner in which progenies are obtained for evaluation.

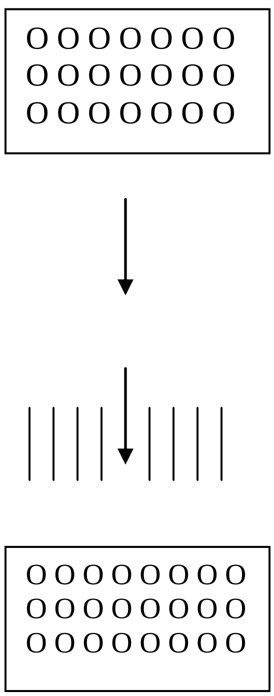
ii) Instead of open pollination, making all possible inter crosses among the selected lines.

The recurrent selection schemes are of 4 different types.

1. Simple recurrent selection

In this method a number of desirable plants are selected and self pollinated. Separate progeny rows are grown from the selected plants in next generation. The progenies are intercrossed in all possible combination by hand.

Equal amount of seed from each cross is mixed to raise next generation. This completes original selection cycle. From this, several desirable plants are selected and self pollinated. Progeny rows are grown and inter crosses made. Equal amount of seeds are composited to raise next generation. This forms the first recurrent selection cycle.



I Year

Original Selection Cycle

i) Several superior plants selected.
ii) Selected plants self pollinated
iii)Harvest on S.P. Plants
iv)Seeds evaluated superior plants identified

II Year

i) Progeny rows raised
ii) Inter cross made in all combination by hand
iii)Equal amount of seed bulked from each cross

First recurrent Selection cycle

III Year

i) Composited seeds raised
ii) Repeat the operation as in first year

IV Year

Repeat as in 2nd year

i) Recurrent selection is effective in increasing the frequency of desirable genes in the population
ii) Most suited for characters having high heritability
iii) Inbreeding is kept at minimum.

2) Recurrent selection for general combining ability

In this case the progenies selected for progeny testing are obtained by crossing the selected plants to a tester parent with broad genetic base.

A tester parent is a common parent mated to a number of lines. Such a set of crosses is used to estimate the combining ability of the selected lines. A tester with broad genetic base means an open pollinated variety, a synthetic variety or segregating generation of a multiple cross.

Recurrent selection for GCA can be used for two basically different purposes.

1. It may be used to improve the yielding ability and the agronomic characteristics of a population. In this case the end product will be a synthetic variety.
2. It may be used to concentrate genes for superior GCA. Here the end product will be superior inbreds. Such inbreds can be developed after a few cycles of RSGCA

3) Recurrent Selection for Specific Combining Ability

This is similar to RSGCA except, that in the case of Tester. Here the tester will be an INBRED instead of open pollinated variety. The other operations are similar to RSGCA. The objective of RSSCA is to isolate from population such lines that will combine well with an inbred. These lines are expected to give best hybrids in heterosis breeding.

4. Reciprocal recurrent selection

Proposed by Comstock, Robinson and Harvey. The objective is to improve two different populations in their ability to combine well with each other. In this method we can make selection for both GCA and SCA. Basically two populations A and B are used. Each serve as a tester for the other.

Ist year
1. Several plants selected in population A and B.
2. Selected plants are self pollinated
3. Selected plant from A is test crossed with plants inB and Vice versa. Harvest crossed plant on S.P. basis each.

2nd year
1. Separate yield trials conducted from test cross progenies of A and B
2. Superior progenies identified

3rd year
1. Selfed seed from plants producing superior test cross progenies planted.
2. All possible inter crosses made
3. Seeds harvested and composited

4th year

5th year

6th year

Use of RRS

1. Two populations are developed by this method
2. They may be intermated to produce a superior population with broad genetic base. This is similar to a varietal cross but in this case the populations have been subjected to selection for combining ability (GCA and SCA)
3. Inbreds may be developed from populations A and B. These inbreds may be crossed to produce a single cross or double cross hybrids.