Population Improvement Approach

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Abstract

Population improvement is an accumulation of desirable alleles in a population through various breeding procedures. Population improvement approaches such as Mass selection& its modification, Progeny selection, Ear to row method& its modification, Recurrent selection, Disruptive selection, Biparental mating, Diallel selective mating system are used to for development of superior genotypes in a population. Cross pollinated crops are highly heterozygous and heterogeneous. Consequently, they show varying degrees of inbreeding depression. Therefore, inbreeding should be avoided or kept to a minimum in cross pollinated crops. Individual plants are heterozygous and their progeny would be heterogeneous and usually different from the parent, due to segregation and recombination. Therefore, desirable genes can be seldom fixed through selection in cross pollinated crops except for highly heritable qualitative characters. Therefore, the breeder's goal is to increase the population's frequency of beneficial alleles. In cross-pollinated crops, the genotype of the individual plants is typically not very significant, especially in population improvement programmes. Instead, it is more significant to look at the frequency of desirable alleles or genes in the population as a whole.

Keywords: *Mass selection, Recurrent selection, population improvement methods.*

I. INTRODUCTION

Population improvement uses a variety of breeding approaches to accumulate favorable alleles in a population. In self-pollinated crops, selection is used to identify plants with the best genotypes. These plants are then used to create distinct pure lines, or their seeds are bulked to create a mixture of pure lines. The reason for this is that self-pollinated plants are naturally homozygous and don't typically exhibit noticeable inbreeding depression. Cross-pollinated plants, on the other hand, typically exhibit mild to severe inbreeding depression. As a result, (1) cross-pollinated species must avoid inbreeding or keep it to a minimum. The progeny from such plants would be heterogeneous and typically different from the parent plant due to segregation and recombination because, (2) individual plants from such crops are highly heterozygous. Because of this, beneficial genes are rarely fixed through selection in cross-pollinated populations, (3) with the possible exception of highly detectable quantitative qualities with large heritabilities and qualitative features. Therefore, the breeder's goal is to make beneficial alleles more prevalent in the populations. (4) As a result, the frequency of good genotypes or gene combinations would rise. The population's phenotype would be positively altered as a result. It should be obvious that, especially in population enhancement programmes, the genotype of the individual plants in cross-pollinated species usually does not matter much. The worth of a population is determined by the frequency of advantageous genes or alleles in the population as a whole. Population improvement is the process of using various breeding strategies to increase the number of desirable alleles in a population; the breeding techniques employed in this process are known as population improvement approaches.

II. POPULATION IMPROVEMENT METHODS

Breeding practices that accumulate beneficial alleles in populations are simply population improvement techniques. For population improvement, the following strategies are employed.

A. **Mass selection& its modification**
B. Progeny selection
C. Ear to row method& its modification
D. Recurrent selection
E. Disruptive selection
F. Biparental mating
G. Diallel selective mating system

A. Mass selection & it's Modification

A large number of plants of similar phenotypes (having desirable trait) are selected and their seeds are mixed together to constitute a new variety.

Steps/Features:

- A certain number of plants are chosen based on their genotype; these plants are then permitted to open pollinate, and the seed produced by them is bulked together to produce the following generation. A physiologically variable population in which variations are genetic in nature is one in which mass selection is used for selection.
- In 1903, W. Johansen is credited with creating the fundamentals of mass selection.
- By choosing and concentrating superior genotypes that already exist in the population, mass selection for population improvement tries to improve the performance of the whole population.
- Phenotypic performance is the only factor in selection.
- The heritability of the trait under selection has a significant impact on this method's effectiveness.
- For features that can be recognised or selected prior to, or at the time of flowering, mass selection may be very effective. Such features in maize could include flowering, leaf angle, thrips resistance, decreased plant and ear height, decreased anthesis silking interval, and tolerance to pre-flowering illnesses, to name a few. Instead of an entire cast of characters, mass selection may be efficient for a single trait or a combination of a few features.

- Only maternal parents (female) are used in mass selection, and pollen parents are unaffected.
- To enhance the frequency of advantageous alleles, the selection cycle may be repeated once or more; in this scenario, the strategy is typically referred to as phenotypic recurrent selection.
- A sufficient number of plants should be chosen to minimise inbreeding.
- The number of genes determining a trait's character, gene frequencies, and heritability are the main factors influencing mass selection's effectiveness**.**

Applications of Mass Selection

- Improvement of local varieties
- Purification of existing pure line varieties
- Applied to protect the integrity of a well-known cultivar
- To eliminate the undesired plants from their breeding program, some breeders adopt mass selection (Negative mass selection).

Merits of Mass Selection

- Due to the lack of regulated pollination and progeny testing, this method of plant breeding is the easiest, simplest, least expensive, and fastest.
- Extensive yield trials may not be necessary before the better strain is made available as a new variety because it is expected to be similar to the original population in the spectrum of adaptation.
- It is quite effective in enhancing visually distinctive and highly heritable traits. For instance, plant height, ear size, maturity date, etc.
- There is just one generation of the selection cycle. As a result, one cycle of selection is finished every generation.
- Breeders don't have to do much work because selection is solely dependent on phenotype.
- An approach that requires less time and resources.

Limitations of mass selection

- **Lack of information on progeny performance**: The phenotype of each individual plant is used to guide the selection of plants. The environment has a significant impact on the majority of the quantitative features. As a result, superior phenotype is frequently a poor indicator of superior genotype.
- **Lack of control on male parentage**: Due to the fact that the chosen plants are allowed to open-pollinate, both superior and inferior plants existing in the population can pollinate them. As a result, selection was less effective.
- This approach employs population variability, hence it can only be used to improve varieties that exhibit genetic variation.
- The complex impact of soil variation on plant phenotypic.
- Mass selection is ineffective for features with low heritability, such grain yield.

Modifications of Mass Selection

By appropriately altering the selection process, the two main flaws in mass selection

- the inability to control the pollen source and the unclear impact of the environment on the phenotypes of particular plants can be fixed.
- These alterations are briefly explained below.

- The field's inferior plants are removed, and the surviving plants are permitted to open pollinate. This change exerts some control over the pollen source however it is necessary that only the traits that are visible prior to flowering can be used to distinguish inferior plants.
- All of the chosen plants pollen is gathered, bulked up, and utilized to fertilize the chosen plants. This plan guarantees total control over the pollen source, but it can only be used with characters that can be chosen before pollen is shed.
- **Stratified mass selection**: The idea that environmental diversity, including soil fertility heterogeneity, will be significantly smaller inside the small plots than that in the entire field served as the inspiration for this improvement. So it is anticipated that selection within the plots will be more successful than it would be without any stratification.
  - This adaptation, which Gardner proposed in 1961 and is also known as the "grid method of mass selection,"
  - The field from which the selection will be made is separated into numerous small plots, each of which will include 40–50 plants.
  - From each of the small plots, an equal number of superior plants are chosen, i.e., the selection is made within the plot, not between the plots.
  - To produce the following generation, the seeds from all of the chosen plants are combined.
- After every one to two or four plants of the variety under selection, single cross hybrid plants of a consistent genotype are planted as checks. Plants undergoing selection have yields that are indicated as a percentage of the yield of the closest reference plant. This plan is made to reduce the impact of the environment on the crop production of the chosen plants. It makes use of contiguous control techniques.
- Honeycomb design - A. Fasoulas suggestion Each individual plant is compared to the other six individual plants that are equally spaced out from it in the centre of a regular hexagon.
- Plants can be cultivated on a hill surrounded by six other hills to create a hexagon, minimizing the negative impacts of interplant competition and creating a shared microenvironment (one hexagon encompasses seven hills).

B. Progeny Selection

The simplest form of progeny selection is the ***ear to row method.*** This method was developed by Hopkins in 1908 and used extensively in maize.

C. Ear to row method

This is the simplest scheme of half-sib selection applicable to cross-pollinated species.

Generalized steps in breeding by ear-to-row

- On the basis of their superior phenotype, 50–100 plants are chosen. They are let to be open-pollinated, and each plant's seeds are collected separately.
- From each chosen plant, a single row of 10 to 50 plants, or a progeny row, is grown. Superior progenies are found by evaluating the progeny rows for desirable traits.
- From the superior progenies, a few phenotypically superior plants are chosen. The plants are allowed to open pollinate, and there are no restrictions on pollination.
- The selection process is repeated after the selected plants are used to develop small progeny rows.

Modifications of Progeny Selection

In order to overcome the defect described above, the following modification may be used.

- During the first year, a few plants are chosen based on their phenotype. The chosen plants' open pollinated seed is gathered separately.
- Small progeny rows are grown and assessed in the second year. Each residual seed from the chosen plants is stored individually. Superior offspring are found.
- Third Year: The population chosen for planting in the third year is made up of the residual seed from the plants that produced the superior progenies (identified in the second year). Open pollination is allowed for plants. The selection cycle may be repeated one or more times after a number of plants are chosen based on phenotype.

Numerous varieties of maize were created as a result of the widespread usage of this modified ear-to-row breeding technique. Only plants from higher progenies are permitted to mate using this strategy. But compared to the ear-to-row strategy, 2 years are needed for each selection cycle as opposed to just 1.

Modified ear-to-row method:

Basic or conventional ear-to-row selection did not significantly outperform mass selection. J. H. Lonnquist (1964) put forth an innovation that has been by far the most effective progeny selection strategy. Replicated studies are conducted in a variety of settings to examine the half-sibling families. The strategy was to control environmental and G–E interactions better. This approach allows for the separation of environmental impacts and a more precise estimation of each progeny's true value.

The detasselled progenies in the crossing block are pollinated by the pollen from the rows planted after every two progeny rows, which is a random bulk of all the selected progenies. The yield trial is used to identify superior progeny. The best plants are chosen from the crossover block's superior progenies, and their seeds are harvested separately.

In this plan, each selection cycle is complex in a single year, the pollen source is controlled, and the evaluation of the progeny is based on a duplicated experiment. (4) Selected plants are mated in pairs to produce seeds for progeny tests. These seeds are produced when the plants within a progeny are complete siblings, meaning they share both of their parents. This is commonly known as ***full-sib family selection.***

Merits of Progeny Selection

The progeny selection schemes, except those for recurrent selection, have the following advantages.

- Progeny tests are used in progeny selection instead of individual plant phenotypes to make the decision. The progeny test reflects the genotype far more accurately than the phenotype does. In order to identify superior genotypes, progeny selection is therefore much more effective than mass selection.
- If care is made to choose a sufficient number of plant descendants and if the chosen descendants are not related, inbreeding may be prevented.
- The choosing process is still quite easy and straightforward. However, some of the changes are laborious and more complicated.

Demerits of Progeny Selection

Other than recurrent selection, the progeny selection techniques have the following flaws.

- In the majority of progeny selection techniques, open pollination of plants is permitted with no restrictions on pollination. As a result, only the maternal parent is considered in the selection. As a result, selection is less effective.
- A large number of progeny selection strategies are intricate and time-consuming.

D. Recurrent Selection

A modified version of progeny selection is recurrent selection. It varies from progeny selection, nevertheless, in two key ways. In progeny selection, the plants are open-pollinated, but in recurrent selection, they are self-pollinated. Second, whereas in progeny selection they are open-pollinated, the offspring of selected plants are intermated in all feasible combinations in this procedure.

Hayes and Garber introduced the concept of recurrent selection in 1919, while East and Jones separately did so in 1920. However, the aforementioned scientist omitted important information.

As a result of his trials with early testing for GCA in maize, Jenkins provided the first in-depth explanation of this type of breeding approach in 1940. Hull's 1945 suggestion of a thorough strategy of recurrent selection for SCA gave the technique its name.

Recurrent selection is a method that involves repeated selection over several generations while allowing for interbreeding of selects to promote genetic recombination, according to Hull (1952).

This is one of the breeding techniques used to enhance cross-pollinated crops. Here, individual plants are chosen using progeny testing or phenotypic criteria. Selfing is done on the single-selected plants. They interbreed (cross in all conceivable ways) in the following generation to create the population for the following round of selection.

The advantages of recurrent selections are

- The rate of inbreeding can be kept at low level
- The frequency of favourable genes in the population will be increased and so
- The chance of obtaining satisfactory individuals from the population will be increased because greater opportunity for recombination is present.

There are four types of recurrent selections.

1. Simple recurrent selection
2. Recurrent selection for General Combining Ability (GCA)
3. Recurrent selection for Specific Combining Ability (SCA)
4. Reciprocal recurrent selection

1. Simple Recurrent Selection/ Phenotypic Recurrent Selection

Several desirable plants are chosen and self-pollinated using this technique. The chosen plants are cultivated in separate progeny rows in the following generation. The progenies are manually crossed in every configuration that is possible. To produce the following generation, an equal amount of seed from each cross is combined. The initial selection process is now complete. From this, a number of desirable plants are chosen and self-pollinated. Inter crosses are created and progeny rows are grown. The next generation is raised using a composite of an equal number of seeds.

Main features of Simple recurrent selection

- The tester is not used in this scheme
- It does not measure the combining ability
- The population's frequency of favorable genes can be increased by recurrent selection.
- Characters with a high heritability are most suited.
- This strategy just needs two seasons to complete one cycle of selection.

2. Recurrent selection for general combining ability/ Half sib RS with heterozygous tester:

In this instance, the progenies chosen for progeny testing are obtained by mating the chosen plants with a parent that has a diverse genetic background. A common parent that is mated to several lines is known as a tester parent. To gauge the ability of the chosen lines to combine, such a set of crosses is used. An open pollinated variety, a synthetic variety, or a segregating generation of a multiple cross is referred to as a tester with a broad genetic foundation. This is an extension of Jenkin’s (1940) scheme used for development of short term synthetics.

Main Features

- Used to assess general combining capacity; selection is based on test cross performance
- Used to improve quantitative characters genetically; and uses a heterozygous tester with a wide genetic background. Typically, a tester variety is one that is open to pollination.
- Used to increase a population's capacity for general population combining for a character
- This strategy works better when there is partial dominance and less well when there is total dominance.
- This technique is used to enhance those traits controlled by additive gene action.
- Each cycle of selection must take three seasons or years to complete.

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

- This may be employed to increase population yield, and the finished product may be issued as a synthetic variety.
- The population may be utilized to isolate superior inbreds and to increase the frequency of desired genes in the population.

Procedure for recurrent selection for GCA

Initial Year - The base population is used to pick superior plants for the character that needs improvement. The chosen plants are selfed and crossed with a heterozygous tester with a diverse genetic background. Cold storage is where the selfed seed is kept.

Second years - Plants with good general combining ability (GCA) are identified after the crossing seed is sowed and the combining capacity of the chosen plants is assessed**.**

Third Year - From their self-sown seed preserved in a cold storage facility, selected platens with good GCA are used to produce offspring. All permutations of these offspring are interbred, and the resulting crossed seed is composited to create a new source population for further selection. The initial selection process is now complete. Another cycle can be finished in three years in the same way (4th-6th year). This is the first cycle of recurrent selection. To get the desired outcomes, many of these cycles can be performed.

3. **Recurrent Selection for Specific Combining Ability/ Half sib RS with homozygous tester:**

This is similar to RSGCA except, that in the case of Tester. Here the tester will be an **Inbred** (narrow genetic base) instead of open pollinated variety (broad genetic base). The other operations are similar to RSGCA

Main features

- The method is also employed to enhance polygenic characteristics.
- Selection is made on the basis of test cross performance
- A homozygous tester with narrow genetic base is used for testing specific combining ability. In other words, an inbred is used as a tester.-Used to enhance a population's capacity to combine specific traits into a character.
- Each cycle of selection must take three seasons or years to complete.

4. **Reciprocal Recurrent Selection**

Proposed by Comstock, Robinson, and Harvey in 1949. The objective is to improve the ability of two different populations to cooperate effectively. This approach is available for both GCA and SCA. Basically, populations A and B are used. Each serves as a test case for the other.

Main Features

- The scheme is also used for the improvement of polygenic characters.
- Selection is made on the basis of test cross performance.
- Two heterozygous populations each of which is the tester for other are used in this method.
- This method is used for improving a population both for GCA and SCA for specific character.
- This method is equally effective with incomplete, complete and over dominance.
- This method is used for the improvement of those characters which are governed by both additive and non-additive gene action.
- This method require 3 seasons or years for completion of each cycle of selection.

Use of Reciprocal Recurrent Selection

1. **Production of a synthetic variety**: To create a superior population with a wide genetic base, two populations may be interbred. This is comparable to a varietal cross, except in this instance the populations have undergone selection for the capacity to combine (GCA and SCA).

2. **Isolation of inbred line**: Populations A and B's improved version can be used to segregate inbreds. After being crossed, these inbreds will result in single- or double-cross hybrids.

Single cross: (A1 ×B1)
Double cross: (A1 ×A2) × (B1 ×B2)

A1 and A2 are two inbreds that have been isolated from population A, whereas B1 and B2 are inbreds that have been isolated from population B. The double cross would be able to express heterosis to its fullest extent as a result.

Efficiency of different Recurrent selection Schemes

- When dominance is insufficient Both reciprocal recurrent selection and recurrent selection for GCA are preferable to recurrent selection for SCA, yet neither is superior to the other.
- If complete dominance exists, all three techniques are equivalent.
- If there is over dominance Recurrent selection for SCA and reciprocal recurrent selection are both more successful than recurrent selection for GCA.
- RRS will outperform RSGCA and RSSCA in the case of epistasis, multiple alleles, and linkage disequilibrium. Thus, theoretically, it is reasonable to anticipate that RRS will be superior to both RSGCA and RSSCA in almost all practical circumstances.

Comparison between RSGCA & RSSCA

Particulars	RSGCA	RSSCA
Application	To improve polygenic traits	Also used to improve qualitative traits
Basis of selection	Test cross performance	Test cross performance
Tester used	Heterozygous	Heterozygous
Effectiveness	More effective with incomplete dominance	More effective with complete & over dominance
Uses	Used when additive gene action is important	Used when non-additive gene action is important
Impacts	It improves GCA of a trait	It improves SCA of a trait

E. Disruptive Selection

Marther (1953) and Thoday (1958, 1960) introduced the idea of disruptive selection to promote the emergence of superior genotypes in populations. Superior genotypes have been created using this method in crops like cotton, brown mustard, and sorghum. This method has assisted in the creation of early cotton materials and the improvement of seed oil content.

Main Features

- This approach can be used to improve the genetics of both self- and cross-pollinated species.
- Because this strategy also includes selecting and combining superior plants in a population that is segregating, it might be seen as a type of recurrent selection.
- The directional selection is different from this. Directional selection improves mean performance while disruptive selection does not affect mean performance of a population since plants are only chosen from one extreme and interbred for further selection.

Procedure

- The result of a cross between two distinct types, F1, was cultivated, and F2 seed was gathered.
- Extremely early and extremely late for maturity plants, for example, are chosen in F2 plants and crossed to complete one cycle of selection and mating.
- The crossing seed is cultivated, and the second round of selection is finished. To accomplish the required improvement in the qualities under consideration, numerous selection and mating cycles are conducted. The best descendants from the chosen plants are eventually grown and chosen.

Merits of disruptive selection

- Breaking unwanted genetic links, releasing genetic variability, producing variety, and improving plant population response are all possible through the use of disruptive selection as a breeding technique.
- This approach breaks repulsion phase links by using wild material in the breeding program.

Demerits of disruptive selection

- Repeated crossings must result in the improvement of a specific trait.
- This approach can only handle populations of specific crossings at once.

F. Biparental mating

It describes crossing F2 plants that were chosen at random or the clearly defined generation after a cross.

- Comstock and Robinson were responsible for developing the idea of biparental mating (1948, 1952).
- It is a crucial technique for concentrating advantageous genes in a population.
- The desired enhancement can only be attained after three to four cycles of biparental mating.

Merits of biparental mating

- It is very effective in breaking undesirable linkages. Mating of randomly selected plants in segregating provides greater opportunities of recombination between linked genes.
- This approach results in a population with a huge genetic diversity for different economic features.
- This technique can be used to improve the genetics of both self- and cross-pollinated species.
- This is a quick and efficient way to boost the population.

Demerits of biparental mating

- Large segregating population (F_1 or F_2) has to be grown for selection and intermating to achieve desired improvement.
- Repeated biparental mating has to be made for 3-4 generations.
- It permits handling of limited segregating population at a time.

G. Diallel Selective Mating System (DSM)

This is a useful technique for enhancing difficult-to-cross and low-seed-per-cross self-pollinated plants. Jensen (1970) created the idea of diallel selective mating for wheat genetic improvement.

Procedure for Diallel Selective Mating System (DSM)

The breeding procedure of DSM consists of three major steps, viz. (1) parental diallel series. (2) F, diallel series, and (3) selective mating series. These are briefly discussed below:

1. **Parental Diallel Series**: The breeding goals are taken into consideration when choosing the parental lines. Diallel crosses are made between the chosen parents to produce F_1 seeds. When there are six or fewer parents, complete diallel is employed. When there are more than seven parents, a partial diallel cross is created. P1 stands for the parental diallel series.

2. **F, Diallel Series**: The aforementioned F_1 crosses are utilized in two different ways, namely to create F_2 populations and to create F_1 diallel series. The F_2 population is being advanced through mass selection. The diallel crossing of the chosen F_1 crossings is used (upto 7 complete diallel and above 7 partial diallel). Due to the fact that each cross in the F_1 diallel series involves four parents, it is also known as multiple parent crosses. The P_2 designation applies to the F_1 diallel series.

3. **Selective Mating Series**: The F_2 population is created by selfing the F_{1s} from the many crossings. Two processes involve the use of the F_2 population: (1) mass selection to create the F_3 population, and (2) intermating chosen F_2 plants to create the first selective mating series (P_3). Three different uses are made of the F_1 hybrids produced by selective mating. Others are crossed with new parents (germplasm lines) not present in the initial diallel, and some are chosen for intermarriage to create the second selective mating series (P_3). This aids in enhancing breeding populations' genetic diversity. To create an F_2 population, some plants are selfed. To accomplish the desired breeding purpose, numerous such cycles can be constructed.

Merits of DSM

- By including many parents (germplasm lines) in the breeding cycle, DSM is incredibly helpful in extending the genetic basis of populations.
- Because it allows for the interbreeding of chosen plants in segregating generations, this technique is particularly effective at removing unwanted linkage blocks. More potential for extra gene recombinations are presented by interbreeding in segregating populations. To put it another way, DSM speeds up DNA recombination.
- This approach also produces a huge genetic diversity for different economic features. This is made possible by including numerous parents into the breeding program and mixing populations that are segregated.
- This approach has reportedly been particularly successful in creating new cultivars of minor grain crops (Jensen, 1978).

Demerits of DSM

- In this approach, numerous crosses must be made in order to produce an adequate number of crossed seeds. Without the aid of male sterility, this is a challenging task.
- This approach involves mixing segregated populations and managing material by mass selection, which takes more labour and space.
- Characters with poor heredity respond less favourably to this technique for improvement.
- This approach has not yet attracted much attention and is rarely employed in crop development.

III. CONCLUSION

Population improvement is an essential part to create genetic variability among population. The various breeding methods of population improvement can be employed in breeding programmes as to increase the frequency of desirable alleles in the population. As a result, the phenotype of the population would be favourably changed.

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