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Concept of heterotic groups and reciprocal recurrent selection in hybrid breeding

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Abstract

Heterotic groups and heterotic patterns form an integral part of hybrid breeding and help breeders to utilize their germplasm in a more efficient manner avoids unnecessary crosses to be made. The approaches for establishing vary depending on type of germplasm. When a small number of populations are available the heterotic groups can established based on complete diallel together with parental populations. If already established heterotic patterns are available selected elite genotypes from established heterotic pattern can be used as testers for production and evaluation of the germplasm to be classified. Different methods like sca effects of grain yield, Heterotic Group Specific and General Combining ability (HSGCA) and Heterotic grouping based on GCA of multiple traits (HGCAMT) can be followed for grouping germplasm into heterotic groups. The established heterotic groups can be further improved by following reciprocal recurrent selection schemes. A modified approach of reciprocal recurrent selection is reviewed.

Keywords: Heterotic groups, heterotic patterns, sca effects of grain yield, heterotic group specific and general combining ability (HSGCA), heterotic grouping based on GCA of multiple traits (HGCAMT), reciprocal recurrent selection

Introduction

Successful exploitation of heterosis has been instrumental in quantum jump in productivity of maize, cotton and many other crops. The genetic basis of heterosis given as $HF_1 = dy^2$ highlights the importance of enhancing genetic diversity for maximizing the heterosis (Falconer, 1981). Mere increase in genetic diversity doesn't increase the heterosis the combining ability of the lines has to be routinely checked. So development of hybrid oriented heterotic populations (genetically diverse populations) and application of schemes for improving combining ability is an integral part of hybrid breeding. In this regard the concept of heterotic grouping includes the subdivision of the germplasm available into divergent populations. The heterotic groups (hybrid oriented populations) so formed can be improved by inter population selection methods (reciprocal recurrent selection scheme). Crosses involving representatives of different heterotic groups exhibit high heterosis than within group.

A heterotic group is group of related or unrelated genotypes from the same or different populations, which display a similar combining ability when crossed with genotypes from other germplasm groups. A heterotic pattern is specific pair of heterotic groups, which may be populations or lines that express in their crosses high heterosis and consequently high hybrid performance (Melchinger and Gumber, 1998) [3].

1. Importance of heterotic groups and reciprocal recurrent selection in hybrid breeding:

Heterotic grouping leads to a reduced specific combining ability (SCA) variance and a lower ratio of SCA to general combining ability (GCA) variance. Thus early testing becomes more effective and superior hybrids can be identified and selected mainly based on their prediction from GCA effects. Assigning lines to heterotic groups would avoid the development and evaluation of crosses that should be discarded, allowing maximum heterosis to be exploited by crossing inbred lines belonging to different heterotic groups. Heterotic grouping help in effective management of available germplasm (Melchinger and Gumber, 1998) [3]. Reciprocal recurrent selection helps to improve the combining ability of the inbred line and simultaneously increases the genetic diversity between the inbreds of the opposite populations (Patil and Patil, 2003) [4].

2. Approaches for establishing heterotic patterns

When a small number of populations are available the heterotic groups can established based on complete diallel together with parental populations. Parental populations of cross combination with high performance are selected as potential heterotic groups and patterns. In the case of large number of accessions it is not feasible to make diallel. Multistage stage procedure to identify heterotic groups suggested by Melchinger and Gumber, 1998 [3] consists of following steps:

- Grouping germplasm based on genetic similarity;
- Selection of representative genotypes from each subgroup for producing diallel crosses;
- Evaluation of diallel crosses among the subgroups together with the parents in replicated trials; and
- Selection of most promising cross combinations as potential heterotic patterns.

If already established heterotic patterns are available selected elite genotypes from established heterotic pattern can be used as testers for production and evaluation of the germplasm to be classified. Based on the testcross performance, lines having similar combining ability and heterotic response could be merged to constitute a new independent heterotic group, if they have similar behaviour. If their behaviour is similar to existing heterotic group, they could be merged with it to enlarge its genetic base.

3. Classification of inbreds into heterotic groups:

The inbred lines can be classified into already established heterotic groups based on *sca* effects of the inbred lines with representative tester from each heterotic group. The lines with positive high *GCA* effects and high per-se performance with testers alone can be used to develop pools because such a pool will have accumulated desirable genes in high frequency. The lines with negative *GCA* effects are discarded. Inbred lines showing positive *sca* effect with tester A but having negative *sca* effects with tester B were placed into the heterotic A group. Similarly, inbred lines displaying positive *sca* effect with tester B but having negative *sca* effects with tester A were put into the heterotic B group (Riboniesa and Efren, 2008).

Classification of inbreds into heterotic groups based on SCA effects of grain yield is influenced by interaction between two inbred lines and the interaction between the hybrid and environment. This leads to classification of same inbred into different heterotic groups in different studies. Classification of inbreds into heterotic groups based on Heterotic Group Specific and General Combining ability (HSGCA) could resolve the problem. Computation of Heterotic Group Specific and General Combining ability can be done using following formula as suggested by Fan *et al.* 2009 [2]:

SCA = Cross mean (Xij) – Line mean (X.j) – Tester mean (Xi.) + Overall mean (X.)
GCA = Line mean (X.j) – Overall mean (X.)
HSGCA = Cross mean Xij – Tester mean (Xi.)
= GCA+SCA

Where Xij is the mean yield of the cross between i^{th} tester and j^{th} line, Xj. is the mean yield of the i^{th} tester and X.j is the mean yield of j^{th} line.

Procedure for classifying inbreds into known heterotic groups via HSGCA method involves the following steps (Fan *et al.* 2009) Fan [2]:

- In the first step, place all inbred lines with negative HSGCA effects into the same heterotic groups as their tester. At this step, a line might be assigned to more than one heterotic group.
- In the second step, if an inbred line was assigned to more than one heterotic group in step 1, we kept the line in the heterotic group if its HSGCA had the smallest value (or largest negative value) and removed it from other heterotic groups.
- In the final step, if a line had a positive HSGCA effect with all representative testers, we were cautious to assign that line to any heterotic group because the line might belong to a heterotic group different from the four testers.

Both HSGCA and SCA-GY are primarily based on one trait *i.e.* grain yield. Grain yield has low heritability under stress. Heterotic grouping based on GCA of multiple traits (HGCAMT) method was suggested by Badu-Apraku *et al.* 2015 [1] this method use multiple traits of inbreds with significant *GCA* effects across contrasting environments

There is a need for comparison of breeding efficiency of each of the classification method. Breeding efficiency may be defined as percentage of superior high yielding hybrids obtained across the total number of inters heterotic crosses. The procedure consisted of dividing the total number of hybrids into two major group's i.e. inter-group and intra group crosses. The best classification method is the one in which inter group crosses produce superior hybrids than within group crosses (Fan *et al.* 2009) [2] Fan.

4. Heterotic groups and patterns in various crops

Crop	Heterotic group	Heterotic pattern	Country	Reference
Maize	U. S. dent lines, European flint lines	U. S. dent lines x European flint lines	Europe	Schnell *et al.* 1992
	Lancaster sure crop(LSC), Reid yellow dent(RYD)	Lancaster sure crop(LSC) x Reid yellow dent(RYD)	USA	Li *et al.*2004
	Stiff stalk(SS) and Non-stiff stalk(NSS)	Stiff stalk(SS) x Non stiff stalk(NSS)	U.S. corn belt and Cannada	Duvick *et al.* 2004
Rice	Early season indica from south china and late season indica from south eastern asia	Early season indica from south china x late season indica from south eastern asia	China	Yuan, 1977
Cotton	Compact, Robust, RGR and Stay Green	Compact x Robust RGR x Stay green	India	Patil *et al.* 2011 [6]

5. Reciprocal recurrent selection for improving combining ability

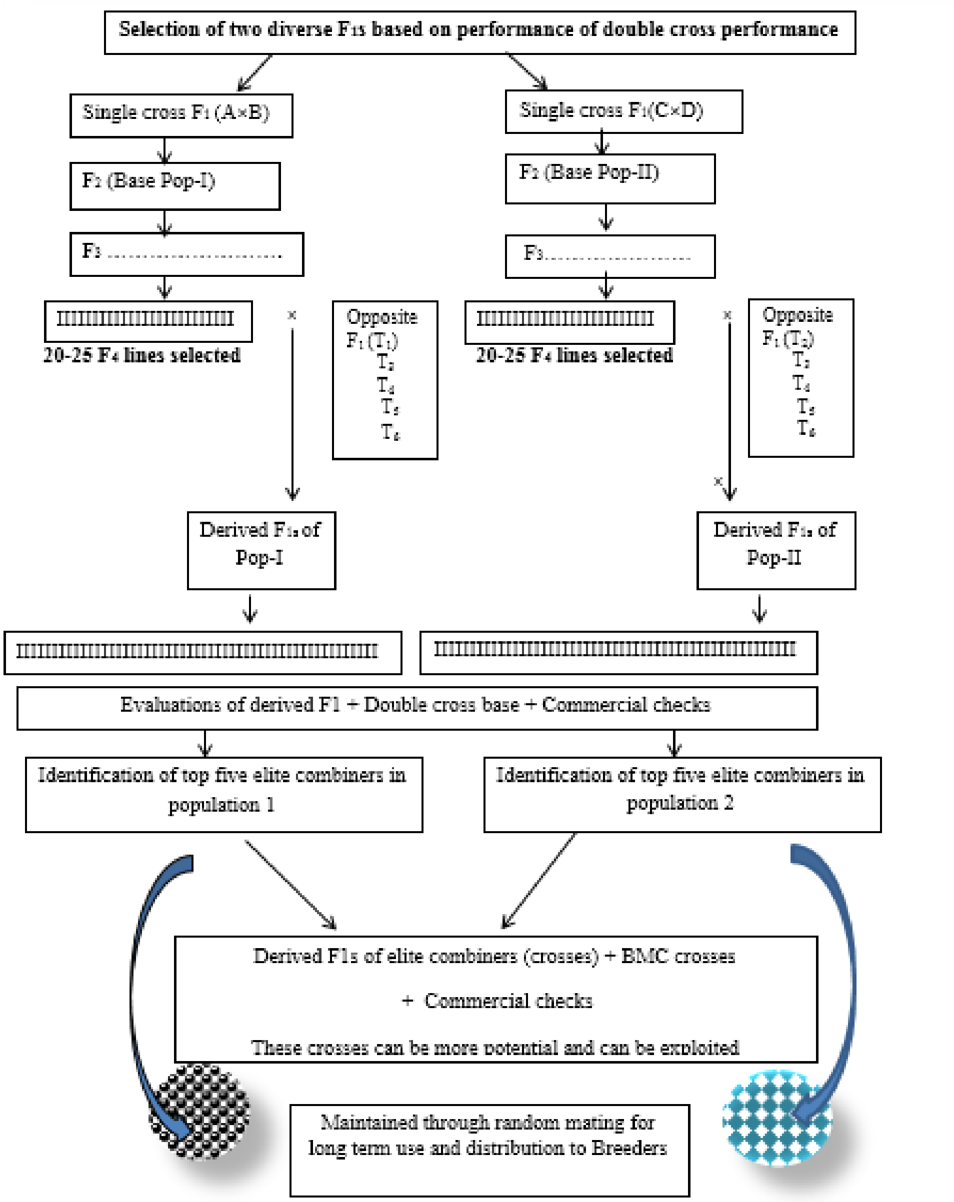
In cross pollinated crops like maize, hybrid breeding programmes are supplemented by regular systematic programmes aimed at improving combining ability. Population improvement schemes have led to the development of maize lines with improved combining ability resulting in the isolation of superior hybrid combinations. Schemes of improving combining ability by following the recurrent selection schemes can be very well followed in often cross pollinated crops with some modifications in tune with mating system of these crops. Procedural difference of following reciprocal selection in maize and a crop like cotton is diverse base populations (random mating) are identified in maize and reciprocal recurrent selection is followed between these populations. In often cross pollinated crops like cotton diverse F_1s have been identified as base populations and these F_1s are advanced through pedigree method up to an appropriate generation and then reciprocal selection for combining ability is followed.

A modified approach of improving combining ability were tested in cotton (Patil and Patil, 2003) [4] Practicing reciprocal selection for combining ability based on double cross performance These approaches involves evaluation of large number of single crosses and predict the double cross performance. Alternatively single cross F_1s can be used to make double crosses and based on the actual double cross performance diverse single crosses can be identified. The highest predicted/actual double cross performance indicates that the single crosses concerned are genetically diverse with respect to dominant favourable alleles present in them.

Since the segregating lines in different generations can be easily obtained in cotton without any inbreeding depression (unlike in maize), the process of assessing variability for combining ability can be initiated in any generation in the opposite populations (Patil and Patil, 2003) [4]. Twenty to twenty five random F_4 lines from each cross were selected for use in assessing the variability for combining ability. The selected lines were crossed reciprocally to the opposite F_1s to assess the variability for combining ability of the F_4 lines. The crosses involving F_4 lines and testers are termed as derived F_1,s (d F_1,s). Additionally the F_4 lines from the two populations were crossed to four common testers to test broader potentiality (breeding value) of the new lines for use in hybrid breeding. Elite combiners are identified based on derived F_1,s performance in both the populations. The F_1,s between these elite combiners from opposite populations could be more potential and can be exploited. Elite combiners from each population can be maintained through random mating for long term use and distribution to breeders.

7. Conclusion

Systematic exploitation of heterosis demands the characterisation of available germplasm for heterotic pattern and establishing heterotic groups. The heterotic groups so established should be broaden regularly by addition of the new lines based on *sca* effects of grain yield or HSGCA and SCA-GY. Simultaneously the combining ability of these heterotic groups can be improved by reciprocal recurrent selection schemes. The reciprocal recurrent selection schemes discussed above is modified approach proposed by Patil and Patil, 2003 [4] to suit the mating system of often cross pollinated crops. The adoption this could improve the combining ability of lines therefore help in successful exploitation of heterosis in often cross pollinated crops



Schematic presentation for following reciprocal recurrent selection (Patil and Patil, 2003)

T1 = Single cross F1(C×D)
T2 = Single cross F1 (A×B)

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