Pak. J. Bot., 40(1): 151-160, 2008.

MAGNITUDE OF COMBINING ABILITY OF SUNFLOWER GENOTYPES IN DIFFERENT ENVIRONMENTS

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Abstract

Five cytoplasmic male sterile (CMS) lines and 5 restorers of sunflower were used, in a line x tester fashions at two locations over two years to determine the magnitude of combining ability and mode of gene action. The traits studied were days to 50% flowering, days to maturity, 1000-seed weight, seeds head^{-1}, oil content, and seed yield. The general combining ability (GCA) and specific combining ability (SCA) effects were significant for all parameters. The SCA effects were of greater magnitude than GCA effects, which showed greater manifestation of non-additive gene effects. The GCA:SCA ratio also revealed predominance of non-additive gene effects. Performance of TS-18 and TS-335 among the CMS and TR-5 and TR-13 among the restorers was better for most of the traits. CMS lines TS-4 and TS-335 and restorer TR-5 and TR-6023 were better general combiners for most of the traits at both locations. Not a single cross combination showed consistent promising results for all traits, however, the cross combinations TS-17 x TR-6, TS-18 x TR-5, TS-335 x TR-3 and TS-17 x TR-13 showed higher specific combining ability effects for seed yield at Peshawar. At Mansehra TS-11 x TR-6023, TS-17 x TR-6, TS-4 x TR-3 and TS-335 x TR-5 had higher specific combining ability effects for seed yield.

Introduction

Combining ability information is very important for plant breeders. Through the availability of this information, sunflower improvement program can be improved considerably. Combining ability is the ability of two parents to transmit favorable or unfavorable traits to their progeny. In biometrical genetics two types of combining abilities are considered i.e. general combining ability (*GCA*) and specific combining ability (*SCA*). General combining ability refers to the average performance of parental lines as reflected in its hybrid combinations and specific combining ability refers to the average performance of a particular cross. According to Sprague & Tatum (1942) general combining ability is due to the genes which are largely additive, while specific combining ability is due to genes showing non-additive effects. The importance of combining ability studies lies in the assessment of parental lines and their hybrids showing significant additive and non-additive effect with respect to certain traits. In a systematic breeding programme, it is essential to identify superior parents for hybridization and crosses to expand the genetic variability for selection of superior genotypes (Inamullah *et al*., 2006b). One crucial step in hybrid development is testing of inbred lines for their *GCA*. The line x tester analysis is one of the efficient methods of evaluating large number of inbreds as well as providing information on the relative importance of general combining ability and specific combining ability effects for interpreting the genetic basis of important plant traits.

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Bajaj *et al*., (1997) observed significant *GCA* and *SCA* variances and the additive gene effects were important in the inheritance of days to maturity, 1000-seed weight and oil content while seed yield per plant was predominantly under the control of non-additive gene effects. Generally crosses exhibited significant *SCA* effects. Hussain *et al*., (1998) and Radhika *et al*., (1999) found that *SCA* variances were higher than *GCA* variances for days to 50% flowering, days to maturity, 1000-seed weight, seeds head^{-1}, and seed yield which were generally controlled by non-additive gene action. However, substantial amounts of additive variance were detected for oil content. Shekar *et al*., (1998) observed non-additive gene action for days to 50% flowering, seed yield per plant and oil content whereas additive gene action was observed for 100-seed weight.

Naik *et al*., (1999) and Ashok *et al*., (2000) observed dominance gene action for days to 50% flowering, total yield per plant and harvest index and over dominance effects for 100-seed weight and oil content where as Inamullah *et al*., (2006a) have reported partial dominance with additive gene effects for 1000 grain weight in wheat. Kannababu & Karivaratharaju (2000) analysed the proportional contribution of lines, testers and lines x testers to the total variance for different seed physiological characters.

The present study of line x tester analysis involving 5 cytoplasmic male sterile lines and 5 fertility restorer lines is an attempt to develop sunflower hybrids with diverse genetic background for their potential in varying cross combinations for different plant characters. Main objectives of the study were to estimate general combining ability of lines and testers and specific combining ability of crosses for seed yield and its components and to evaluate lines, tester and their crosses over two environments for wide adaptability

Materials and Methods

Field experiments were carried out during 2001-2003 at the Agricultural Research Institute (ARI) Tarnab, Peshawar and Agricultural Research Station (ARS) Baffa, Mansehra. The experimental material comprised 5 cytoplasmic male sterile lines (CMS, female parents) of sunflower (*Helianthus annuus* L.) viz., TS-4, TS-11, TS-17, TS-18 and TS-335, 5 testers/restorers (male parents) viz., TR-3, TR-5, TR-6, TR-13 and TR-6023 and their 25 crosses, The parents of the developed CMS lines and restorers were selected on the basis of early maturity, head size, high yield and oil content. The five CMS lines were crossed with the 5 restorers/testers in a line x tester fashion during spring 2001 and 2002 to obtain sufficient seed for evaluation in the following season.

The 25 crosses alongwith 10 parents were field evaluated at two locations (ARI, Tarnab, Peshawar and ARS, Baffa, Mansehra) for two consecutive seasons of spring 2002 and 2003. The two locations chosen have significant differences in soil type, temperature and rainfall. ARI, Tarnab is 358 m above sea level having clay-loam soil with pH of 8.4 while ARS Baffa is 950 m above sea level with clay-loam soil having pH of 7.2. Soil organic matter at Baffa was 0.5% while at Tarnab 0.8%. Air temperature at Peshawar during March to July of 2002 and 2003 ranged from 10.0 to 39.0 and 11.2 to 40.4°C respectively, with annual rainfall of 135 and 74mm. In contrast air temperature at Baffa ranged from 2.5 to 32.0 and 3.9 to 35.0°C with annual rainfall of 490 and 540mm during March to July of 2002 and 2003, respectively.

A randomized complete block design with 3 replications was used at each location. The plot consisted of 5 meter long two rows with row to row and plant to plant distances of 0.75 m and 0.25 m, respectively. Sowing was done by dibbling three seeds per hill to ensure uniform stand which was later thinned to one plant per hill at V2 stage as explained by Schneiter & Miller (1981). NPK was applied @ 90:58:38 Kg ha^{-1} at sowing time. Rainfall at

Mansehra was high and no artificial irrigation was applied in either year. However, at Peshawar irrigation was applied at (1) three to four leaf stage (2) flower initiation stage (3) seeds filling stage, and 4) seeds maturing stage. Identical standard cultural practices were used at each location during both years. Harvesting and threshing was done manually.

Data were taken on 10 randomly selected plants of each entry from each replication on the following traits. For days to flowering number of days were counted from planting to the day when last row (central whorl) of disc flower opened on 50% of the plants in a plot. Days to maturity were determined as the number of days from planting to the day when 50% of the plants in a plot reached physiological maturity i.e., R9 stage as explained by Schneiter & Miller (1981).

A sample of 1000-filled seeds (at 8% moisture content) was drawn at random from the bulked seed of 10 random plants and weighed with an electronic balance. Seeds head^{-1} were calculated using the formula of Hussain & Schneiter, (1990).

$$\text{Seeds head}^{-1} = \frac{\text{Seed weight from 10 plants}}{\text{1000-Seed weight x 10}} \text{ x } 1000$$

Oil content was determined by Nuclear Magnetic Resonance (NMR) Apparatus (New port 4000 NMR Analyser). Seed yield in kilograms ha^{-1} was calculated and converted from seed yield head^{-1}.

Statistical analysis

Data from each location across 2 years was analyzed for each trait according to Steel & Torrie (1980). Thereafter, estimates of combining ability were computed using "Line x Tester Analysis" method as given by Kempthorn (1957). The estimates of general combining ability and specific combining effects of parents and hybrids were obtained as under.

1. Estimation of *GCA* effects

$$\text{(a) Lines:} \quad g_i = \frac{X_i}{tr} - \frac{X_{...}}{ltr}$$

$$\text{(b) Testers:} \quad g_i = \frac{X_i}{lr} - \frac{X_{...}}{ltr}$$

where l = number of CMS lines (female parent)
t = number of testers (male parent)
r = number of replications
X_i = Total of the F_1 resulting from crossing ith lines with all the testers
$X_{.j}$ = Total of all crosses of jth tester with all the lines
$X_{...}$ = Total of all crosses

2. Estimation of *SCA* effects

$$S_{ij} = \frac{X_{ij}}{r} - \frac{X_{i.}}{tr} - \frac{X_{.j}}{lr} + \frac{X_{...}}{ltr}$$

where X_{ij} = Total of F_1 resulting from crossing ith lines with jth testers

Results and Discussion

The data pertaining to each location on different agronomic parameters were analyzed independently according to Steel & Torrie (1980) to confirm the differences among sunflower genotypes. Highly significant differences ($p \leq 0.01$) existed among sunflower genotypes for all phenological traits. The sum of squares of genotypes for these traits were further partitioned into sum of squares pertaining to parents, crosses and parents vs. crosses. There were highly significant ($p \leq 0.01$) differences among parents, crosses and parents vs. crosses (Table 1). Similarly the sums of squares for crosses were further partitioned into sum of squares for lines, testers and line x tester components. Highly significant differences existed among lines for all traits at each location. Highly significant differences were found among testers for all the traits except seed yield at Mansehra. However, line x tester interaction was highly significant ($p \leq 0.01$) for all the traits at both locations.

Highly significant differences among sunflower genotypes, parents, crosses lines and tester for days to flowering, 1000-seed weight and oil contents were observed at Peshawar as well as at Mansehra (Table 1). Similar results were also obtained by Ashok *et al.* (2000).

Performance of sunflower genotypes (lines, testers and crosses): The sunflower genotypes i.e., cytoplasmic male sterile (CMS) lines, tester and their crosses used in the present study provided a wide range of expression for various characters at both locations. Parental lines, testers and their crosses took more days for flowering and maturity at Mansehra than Peshawar which may be due to low temperature and high rainfall at Mansehra. These results are in agreement with the findings of Ashok *et al*., (2000) who observed early flowering and maturity in sunflower. Similarly the parents and their crosses exhibited higher average mean values for 1000 seeds weight, seeds head^{-1}, seed and oil yield ha^{-1} at Peshawar than at Mansehra which may be due to high organic matter at Peshawar. Heavy rains at Mansehra also delayed cultural practices like weeding which may have resulted in low values for the above traits at Mansehra. However high oil contents were observed at Mansehra for these genotypes which may be due to more number of days taken for maturity at Mansehra. These results are in agreement with the findings of Ashok *et al*. (2000) who observed high degree of variations in seeds weight, seeds head^{-1}, oil content and seed yield in sunflower.

General combining ability effects: Variation in general combining ability effect was estimated among lines and tester for indicated plant traits to identify the best parent for subsequent hybrid development programme. The results of general combining ability effects of lines and testers are presented in Tables 2 and 3.

Farmers need short duration sunflower hybrids because it reduces the incidence of insect-pest and disease attack due to early maturity. Minimum number of days to 50% flowering are preferred to reduce the crop growth period. Negative *GCA* effect was exhibited by parents (lines) TS-11 for days to 50% flowering and TS-335 for early maturity at both locations. TS-335 having significant negative *GCA* effects can be considered for selection due to shorter number of days to maturity. Female parents TS-4, revealed positive and significant *GCA* effect for 1000 seeds weight, seeds head^{-1} and seed yield at both locations while TS-335 and TS-11 also depicted positive and significant *GCA* effect for these traits at both locations. Lines with high positive *GCA* estimates for seeds weight, seeds head^{-1}, and seed yield are good candidates to be used as parents for the development of desirable hybrids. These results are in accordance to Naik *et al.,* (1999) and Ashok *et al.,* (2000) who observed significant and positive *GCA* effects for these traits in their respective studies.

Among the testers TR-3 for days to flowering and days to maturity exhibited negative *GCA* effect at both locations and as such was desirable male parent for earliness. Male parents TR-5 demonstrated positive and significant *GCA* effect for seeds weight, seeds head^{-1} and seed yield while TR-6023 also revealed significant and positive *GCA* effect for seed weight, seeds head^{-1} and seed yield at both locations. Only TR-6 expressed positive *GCA* effect for % oil content at both locations. Restorers with high *GCA* effects for seeds weight, seeds head^{-1} and seed yield are good candidates to be used as parents in a population improvement programme.

Specific combining ability effects: The hybrids having negative and significant *SCA* effects for 50% flowering and maturity showed their ability to contribute genes for earliness. Out of top 5 hybrids exhibiting highest negative SCA effects for days to flowering and maturity at each location, none was found consistent in performance across both locations. Therefore, hybrids selected at one location for the above traits would not have similar performance at other location hence independent selection of hybrids for the above traits is necessary at each location. These results are in line with the finding of Ashok *et al.,* (2000) who found significant and negative *SCA* effects for maturity in sunflower hybrids.

For 1000-seed weight, significantly positive *SCA* effects were demonstrated by 11 crosses at Peshawar and 9 crosses at Mansehra. Cross combination TS-18xTR-5, TS-17xTR-13 and TS-335xTR-6023 revealed maximum positive and significant *SCA* effects for higher seed weight at both locations. The top 5 crosses with highest SCA effects for seed weight were found consistent in performance at both locations (Table 4). These results confirm the studies Kanababu & Kariraratharaju (2000). Similarly, potential crosses showing significantly high positive *SCA* effects for seeds head^{-1} were 12 at Peshawar and 13 at Mansehra. Among the top 5 crosses for seeds head^{-1}, only 3 (TS-4xTR-13, TS-11xTR-6023 and TS-17xTR-6) were consistent in performance at both locations. These findings are in line with Ashok *et al.,* (2000).

Positive and significant *SCA* effects for oil percentage were recorded in 12 crosses at Peshawar and 13 crosses at Mansehra. One, out of the top 5 hybrids was stable for higher oil content at both locations. These results are in line with the findings of Bajaj *et al.*, (1997) and Naik *et al.*, (1999).

Higher seed yield is an ultimate objective of sunflower breeding and hybrid development programmes. Positive and highly significant specific combining ability effects for seed yield were revealed by 13 crosses at Peshawar and 15 crosses at Mansehra. Among the top 5 crosses exhibiting highest SCA effects only one cross (TS-17 x TR-6) was consistent for higher seed yield at both locations which may be suggested for higher seed yield at both locations. Naik *et al.,* (1999) also reported significant SCA effects for seed yield in sunflower hybrids.

Variances due to *GCA* and *SCA*: Variance due to general and specific combining ability (δ_{gca} and δ_{sca}), ratio of *GCA*: *SCA* variances, additive variance (δ^2_A), dominance variance (δ^2_D) and degree of dominance ($\sqrt{\delta^2_D/\delta^2_A}$) for different traits at two locations are presented in Table 5. It is evident from the table that the hybrids in general were superior to parents for all the indicated traits studied during the investigation.

Table 5 also depicts that variance due to specific combining ability was more important than the variance due to general combining ability as well as the additive variance for all traits. It is evident from the Table that the variance due to *SCA* wherein dominance variance was more important for most of the plant traits. Preponderance of dominance gene action is declared by the degree of dominance greater than I for days to flowering and maturity, seed weight, seeds head^{-1}, oil content and seed yield. The preponderance of dominance gene action for these traits is also clear from the *GCA*: *SCA* ratio and lesser than one degree of additive variance. At the experimental site Peshawar days to flowering gave *GCA*: *SCA* ratio higher than unity with predominantly dominant gene action. These results have the support of Naik *et al.,* (1999) who reported over dominance effects for days to flowering, seed weight, seeds head^{-1} and oil content. Hussain *et al.,* (1998) observed in their study that *SCA* variances were higher than *GCA* variances for yield and yield components which were generally controlled by non-additive gene action.

Proportional contribution of lines, testers and their interaction to the total variance: A line x tester analysis of sunflower with 5 cytoplasmic male sterile lines and 5 restorer lines as tester were carried out to obtain the proportional contribution of lines, testers and lines x testers to the total variance for different plant traits (Table 6). The contribution of maternal and paternal interaction (line x tester) was very high for all traits. It revealed preponderance of paternal and maternal interaction (line x tester) influence for all these traits. These results are partially in agreement with Kannababu & Karivaratharaju (2000).

Conclusions and recommendation: Among the lines, TS-11 and TS-4 were best combiner for days to flowering and oil content respectively at both locations while TS-4 also performed best for seeds head^{-1} and seed yield at Peshawar. Lines TS-11 and TS-4 were the best general combiner for early maturity at Peshawar and Mansehra, respectively. TS-11 was the best line for seed weight at Peshawar and TS-335 at Mansehra. At Mansehra the best line for seeds head^{-1} and seed yield was TS-335.

Among testers, TR-6023 was the best general combiner for early flowering at Peshawar. Restorer TR-13 was best for days to flowering at Mansehra. Restorer TR-5 was the best general combiner for seed weight, seeds head^{-1} and seed yield at both locations and for early maturity at Mansehra. For oil content TR-6 was found the best general combiner.

In terms of specific combining ability effects, the best sunflower hybrids were TS-18 x TR-13 for early flowering and maturity, and TS-17 x TR-6 for seed yield at Peshawar and Mansehra. At Mansehra the best cross combinations were TS-18 x TR-3 for early flowering, TS-11 x TR-3 for early maturity, TS-11 x TR-6023 for seeds head^{-1} and TS-335 x TR-5 for oil content while cross combinations TS-18xTR-5 for seed weight, revealed best specific combining ability effects at both locations.

The dominance gene action was predominant for days to flowering and maturity, seed weight, seeds head^{-1}, oil content, and seed yield. The relative contribution of line x tester interaction was found more important for all characters under study.

Parental lines with high *GCA* effects for yield and yield components may result in hybrids with better performance for yield and its components. High *SCA* effects resulting from crosses between higher general combiners can be improved through early selection. High *SCA* effects resulting from low *GCA* combiners suggests that such crosses may be utilized for further improvement through single plant selection in the later generations. Higher *SCA* variances than *GCA* variances show that the characters were under the control of Dominance gene action.

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(Received for publication 15 May 2007)