ESTIMATES OF HETEROISIS, COMBINING ABILITY AND TYPE OF GENE ACTION FOR YIELD AND ITS COMPONENTS IN SEVEN PARENT DIALLEL CROSSES OF SESAME (Sesamum indicum, L)
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ABSTRACT

A half diallel set of crosses involving seven parents were used to study heterosis and combining ability in the F₁ generation as well as the nature of gene action controlling seed yield and its contributing traits in both F₁ and F₂ generations. Results indicated that the expression of heterosis varied with the crosses as also with characters investigated. The maximum significant positive heterobeltiosis was observed for branches/plant (52.9%) followed by seed yield/plant (38.0%), capsules/plant (33.6%), capsule length (19.0%), 1000-seed weight (18.6%) and plant height (12.1%).

Analysis of variance for combining ability indicated that general (GCA) and specific (SCA) combining ability variances were highly significant for all studied traits, suggesting the presence of both additive and non-additive (dominance) gene effects involved in the expression of these traits. General and specific combining ability effects were frequently significant among parents and crosses for the investigated traits. Superior parents were identified for particular characters. None of the parents appeared to be good general combiner for all traits together. The good combiner parents for seed yield/plant were also high combiner for two or more of yield contributing characters. Estimates of GCA effects showed that EUL92 (P4) and EXM90 (P5) were the best general combiner parents for earliness and low position of the first capsule. However, the local cultivar Giza 32 (P1) and Mutant 48 (P3) were the best general combiner parents for seed yield and two or more yield components especially number of capsules per plant. Moreover, the favorable cross combinations that indicated highly significant positive SCA effects for seed yield and some of its main components were derived from the P1 and P3 parents.

Estimates of the type of gene action confirmed the importance of both additive and non-additive (dominance) gene effects in the inheritance of the studied characters in both F₁ and F₂ generations. However, the dominance components were larger in magnitude than additive ones for most investigated traits in the F₁ and vice versa in the F₂ generation. The mean degree of dominance as estimated by the ratio \((H₁/D)^{0.5}\) revealed the existence of overdominance for all traits in the F₁ except capsule length, and partial dominance in the F₂ generation except seed yield/plant. The negative and positive genes were unequally distributed in the parents for all traits in both generations. Heritability in narrow sense (Hn) was found to be low for all characters except capsule length in the F₁ generation. The presence of overdominance and low heritability estimates recorded for most traits in the F₁, suggested the possibility using of cross breeding. High values of heritability were recorded for all the investigated traits in the F₂ generation, indicating that the genetic variance associated with those traits was mostly due to additive effect of genes.
INTRODUCTION

Although sesame (Sesamum indicum, L) is largely self-pollinated crop, high level of heterosis have been reported for certain hybrid combinations from studies done in various countries (Ashri, 1998). The magnitude of heterosis varied in different crosses, but generally it was high in the hybrids from diverse origin (Tu, 1993). Heterosis of varying degree for seed yield and other contributing traits in sesame has been reported (Atta, 1990; Yadav and Mishra, 1991; Padmavathi et al, 1993; El-Shazly et al, 1993b; Mishra et al, 1994; Quijada and Layrisse, 1995; Mishra and Yadav, 1996; Murty, 1997 and Ganesh et al, 1999).

Production of hybrids in sesame is possible by crossing suitable inbred parents, with high specific combining ability. Once such inbreeds are found, hybrid seed can be produced by three ways: 1) Hand emasculation and pollination, 2) Male sterility mechanisms and hand pollination, and 3) Male sterility and honey bees or other insect pollinators.

Hand emasculation and pollination are useful for researchers but not for commercial production due to time-consuming and high cost of hybrid seeds. However, Manivannan et al (1993) reported that production of sesame hybrid seeds by hand emasculation and pollination at commercial scale is possible and an easy method in this concern was described in their study. On the other hand, various research workers reported that the farmers hybrid seeds must be produced on a large scale with lower cost which necessitates the use of male sterility (Brar, 1982; Rangaswamy and Rathiram, 1982; Li, 1997; Ashri, 1998 and Ganesh et al, 1999). So far, only genetic male sterility (GMS) has been found in sesame. A naturally occurring ms allele was found in Venezuela about 30 years ago. This is the one, which is being used in China now (Tu, 1993 and Li, 1997).

The commercial use of heterosis is, probably, the most important area of research and development for sesame in the near future, because it will lead to greater productivity and consequently to an increase in the total crop area and more efficient use of fertilizers (Quijada and Layrisse, 1995). It is also likely to result in better seed quality since hybrid seed would have to be purchased yearly, whereas seeds for the pure-line cultivars are usually multiplied and maintained by farmers themselves.

The combining ability and genetic component analysis provide fair understanding about the nature of gene action of quantitative characters and help in identifying parents and their derived crosses to be used for genetic improvement. Among the biometrical methods which have been developed, diallel cross analysis provides information on combining ability that helps the breeder in choosing the parents with high general combining ability (GCA) and hybrids with high specific combining ability (SCA) effects. Moreover, diallel analysis would present estimates for the genetic variance and the relative importance of additive and non-additive types of gene action which assist the breeder in selecting the most efficient breeding techniques leading to rapid genetic improvement.
In sesame, although studies in this aspect have been carried out (El-Shazly et al., 1993a; Reddy and Haripriya, 1993; Padmavathi et al., 1994; Macharo et al., 1995 and Yingzhong, 1999) more information about combining ability and type of gene action are needed. Hence, the present study was undertaken with the objective of determining the magnitude of heterosis, general and specific combining ability effects and nature of gene action for seed yield and its contributing traits in 21 hybrids derived from a diallel cross of 7 parental genotypes of sesame.

**MATERIALS AND METHODS**

**Field layout and recorded data**

Seven parental genotypes of sesame were selfed for two successive seasons before making diallel crosses. The seven parents were chosen on the basis of the presence of wide differences between them in respect to certain economic traits. These genotypes were: Giza 32 (local cultivar); Mut. 8, Mut. 48, EUL92 and TM90 (advanced mutant lines resulting from the mutation breeding program conducted at Agron. Dept., Fac. of Agric., Cairo Univ., Giza, Egypt); EXM90 [F7 hybrid population line derived from crossing between Margo201 (introduced line from USA) and Mut. 48] and EXL139 (exotic line from FAO world collection).

Field experiments were carried out at the Agric. Exp. and Res. Station, Fac. of Agric., Cairo Univ., Giza, Egypt during 1997, 1998 and 1999. In 1997 the parental genotypes were crossed in all possible combinations excluding reciprocals, to obtain a total of 21 F₁ hybrids using a half diallel mating system.

In 1998 selfed seeds from parents and their F₁’s were planted in a randomized complete blocks design (RCBD) with three replications. Each block contained 21 F₁’s and 7 parents, i.e. a total of 28 entries per block. Each (F1) was planted in a 2-rows/plot and the parents in 4-rows/plot. Each row was 4 m long and 60 cm wide. Seeds were sown in hills 20 cm apart. Thinning was done 30 days after sowing to secure 2 plants/hill. At maturity, data on 10 randomly guarded plants from each plot were recorded for plant height, stem height to the first capsule, no. of fruiting branches/plant, no. of capsules/plant, 1000- seed weight and seed yield/plant. Number of days from sowing to maturity was recorded on whole plot basis.

In 1999 the parents and their F₂ populations were evaluated in RCBD with four replications. Both parents and F₂’s were planted in a 3 rows/plot. Row length and spacing between and within rows were applied as in F₁ generation. At maturity, 10 random competitive plants per each entry were sampled to study the same characters mentioned before. Recommended agronomic practices were applied at the proper time in both generations.

**Statistical and genetic component analysis**

The collected data were tested for significance on the basis of the analysis of variance according to Snedecor and Cochran (1980). Heterosis and heterobeltiosis were estimated for all investigated traits as percentage of F₁ over mid- parents and better parent , respectively. Combining ability analysis was performed according to Griffing (1956) method 2 model 2. General and specific combining ability effects were also estimated.
To study the inheritance of mentioned traits, genetic parameters were computed according to diallel cross analysis proposed by Hayman (1954 a & b) in both $F_1$ and $F_2$ generations. These parameters and their ratios were as follows:

- **D**: The component of variation due to additive effect.
- **H_1**: The component of variation due to dominance effect.
- **H_2**: The component of variation due to dominance effect, correlated for gene distribution to positive and negative genes in the parents, when they are equal then $H_1 = H_2$.
- **F**: An indicator relative frequencies of dominant vs. recessive genes in all crosses.
- **h^2**: Dominance effect as algebraic sum over all loci in heterozygous phase in the parents.

- **E**: Environmental or non-heritable component of variation.
- $\left(\frac{H_1}{D}\right)^{0.5}$: Mean degree of dominance.
- $\frac{H_2}{4H_1}$: Proportion of positive and negative gene effects in the parents.
- **KD/KR**: Proportion of dominant and recessive genes in the parents where:
  
  $KD/KR = \frac{(4DH_1)^{0.5} + F}{(4DH_1)^{0.5} - F}$

Narrow sense heritability ($H_n$) was estimated according to formulas proposed by Mather and Jinks (1971) in the $F_1$ and by Verhalen and Murray (1969) in the $F_2$ generation. The validity of diallel analysis assumption made by Hayman (1954) was tested by $t^2$ following the formula suggested by Singh and Chaudhary (1977).

**RESULTS AND DISCUSSION**

**Heterotic effects**

The heterotic effects expressed as the percentage deviation of $F_1$ mean performance from the mid-parents (heterosis) and better parent (heterobeltiosis) are presented in Table 1. The direction and magnitude of heterotic effects differed owing to crosses and characters investigated.

Concerning days to maturity, 8 crosses showed desirable significant negative heterosis and 4 out of them recorded highly significant negative heterobeltiosis indicating the possibility of obtaining earlier maturing combinations than those of the parents. The values of significant negative heterosis ranged from $-2.2$ to $-13.4\%$, while the range of heterobeltiosis varied from $-5.3\%$ ($P_1 \times P_3$) to $-9.9\%$ ($P_1 \times P_6$). Significant negative heterosis for maturity was reported by Sasikumar and Sardana, 1990; Yadav and Mishra, 1991; El-Shazly et al, 1993b and Mishra and Yadav, 1996.

Estimates of heterosis for plant height showed significant positive values in 7 crosses ranging from 6.5 to 22.2%. However, significant positive heterobeltiosis was observed in 5 crosses and varied between 6.4% ($P_1 \times P_3$) to 12.1% ($P_2 \times P_4$). The remaining crosses possessed negative heterosis for this trait. These results are in harmony with those obtained by Shivprakash (1986), Singh et al (1986) and Yadav and Mishra (1991) who reported positive and/or negative heterosis for plant height.

Regarding the stem height to first capsule, as an important character to sesame breeder, the data in Table 1 indicated that most of...
cross combinations gave undesirable positive heterosis, and non of crosses showed negative heterosis for this trait. Mahdy and Bakheit (1988) found similar result. However, Ibrahim et al (1983a) and El-Shazly et al (1993b) reported favorable negative heterosis in other crosses.

Table (1): Heterosis (upper values) and heterobeltiosis (lower values) in a half diallel crosses of sesame in F₁ generation

<table>
<thead>
<tr>
<th>Crosses</th>
<th>Days to maturity</th>
<th>Plant height (cm)</th>
<th>Height to first capsule (cm)</th>
<th>Capsule length (cm)</th>
<th>Branches / plant</th>
<th>Capsulees / plant</th>
<th>1000-seed weight (gm)</th>
<th>Seed yield/plant (gm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. P1 x P2</td>
<td>-9.1**</td>
<td>22.2*</td>
<td>27.8**</td>
<td>3.1</td>
<td>31.6</td>
<td>26.2**</td>
<td>-16.6**</td>
<td>1.9</td>
</tr>
<tr>
<td>2. P1 x P3</td>
<td>-5.4**</td>
<td>21.5*</td>
<td>31.1**</td>
<td>-0.1</td>
<td>17.5</td>
<td>23.2**</td>
<td>-24.3**</td>
<td>2.2</td>
</tr>
<tr>
<td>3. P1 x P4</td>
<td>-5.2**</td>
<td>26.3**</td>
<td>45.7**</td>
<td>-5.3</td>
<td>-25.8</td>
<td>7.6</td>
<td>-11.9</td>
<td>2.9</td>
</tr>
<tr>
<td>4. P1 x P5</td>
<td>-5.4**</td>
<td>48.7**</td>
<td>157.4**</td>
<td>0.0</td>
<td>203.7**</td>
<td>25.9**</td>
<td>15.5*</td>
<td>0.7</td>
</tr>
<tr>
<td>5. P1 x P6</td>
<td>-4.9**</td>
<td>13.0**</td>
<td>54.9**</td>
<td>-5.3</td>
<td>62.9*</td>
<td>22.3*</td>
<td>15.1*</td>
<td>0.7</td>
</tr>
<tr>
<td>6. P1 x P7</td>
<td>-1.4</td>
<td>10.3**</td>
<td>13.6**</td>
<td>6.1**</td>
<td>86.4*</td>
<td>20.7</td>
<td>25.8**</td>
<td>41.4**</td>
</tr>
<tr>
<td>7. P2 x P3</td>
<td>-9.0</td>
<td>4.8</td>
<td>59.7**</td>
<td>-7.6**</td>
<td>15.3</td>
<td>9.3</td>
<td>8.0</td>
<td>-28.3</td>
</tr>
<tr>
<td>8. P2 x P4</td>
<td>-0.9</td>
<td>-10.2**</td>
<td>16.4</td>
<td>-4.6</td>
<td>52.0**</td>
<td>-31.2</td>
<td>-8.6</td>
<td>-29.7</td>
</tr>
<tr>
<td>9. P2 x P5</td>
<td>-6.2**</td>
<td>6.5**</td>
<td>9.5</td>
<td>1.7</td>
<td>36.6</td>
<td>10.8</td>
<td>38.8**</td>
<td>3.8</td>
</tr>
<tr>
<td>10. P2 x P6</td>
<td>-6.2**</td>
<td>9.5</td>
<td>18.2**</td>
<td>-3.4</td>
<td>36.6</td>
<td>10.8</td>
<td>38.8**</td>
<td>3.8</td>
</tr>
<tr>
<td>11. P2 x P7</td>
<td>1.2**</td>
<td>16.3**</td>
<td>24.1**</td>
<td>-6.0</td>
<td>109.0**</td>
<td>7.6</td>
<td>15.1**</td>
<td>1.0</td>
</tr>
<tr>
<td>12. P3 x P4</td>
<td>9.5**</td>
<td>15.0**</td>
<td>55.8**</td>
<td>-2.6</td>
<td>21.2</td>
<td>13.0</td>
<td>3.8</td>
<td>14.9</td>
</tr>
<tr>
<td>13. P3 x P5</td>
<td>4.3**</td>
<td>14.8**</td>
<td>26.5**</td>
<td>-3.4</td>
<td>20.7</td>
<td>1.4</td>
<td>-28.7</td>
<td>7.5</td>
</tr>
<tr>
<td>14. P3 x P6</td>
<td>0.9</td>
<td>9.5</td>
<td>26.0**</td>
<td>-8.7**</td>
<td>31.6</td>
<td>-18.9</td>
<td>4.7</td>
<td>27.6</td>
</tr>
<tr>
<td>15. P3 x P7</td>
<td>1.2**</td>
<td>16.4**</td>
<td>24.1**</td>
<td>18.0**</td>
<td>1.4</td>
<td>21.9</td>
<td>1.4</td>
<td>27.6</td>
</tr>
<tr>
<td>16. P4 x P5</td>
<td>10.8</td>
<td>16.8**</td>
<td>55.8**</td>
<td>-2.6</td>
<td>21.2</td>
<td>13.0</td>
<td>3.8</td>
<td>14.9</td>
</tr>
<tr>
<td>17. P4 x P6</td>
<td>11.3**</td>
<td>11.9**</td>
<td>24.1**</td>
<td>-6.0</td>
<td>109.0**</td>
<td>7.6</td>
<td>15.1**</td>
<td>1.0</td>
</tr>
<tr>
<td>18. P4 x P7</td>
<td>8.1</td>
<td>17.5**</td>
<td>27.5**</td>
<td>-6.9**</td>
<td>134.5**</td>
<td>47.4**</td>
<td>6.8</td>
<td>45.9**</td>
</tr>
<tr>
<td>19. P5 x P6</td>
<td>0.5</td>
<td>17.5**</td>
<td>11.5</td>
<td>-3.1</td>
<td>59.7</td>
<td>-37.8</td>
<td>12.7</td>
<td>-10.6</td>
</tr>
<tr>
<td>20. P5 x P7</td>
<td>7.1**</td>
<td>24.7**</td>
<td>49.7**</td>
<td>-23.3**</td>
<td>79.8**</td>
<td>-46.8**</td>
<td>5.0</td>
<td>-19.8</td>
</tr>
<tr>
<td>21. P6 x P7</td>
<td>2.2**</td>
<td>19.8**</td>
<td>12.5**</td>
<td>-3.1</td>
<td>59.7</td>
<td>-37.8</td>
<td>12.7</td>
<td>-10.6</td>
</tr>
</tbody>
</table>

P1=Giza 32, P2= Mut.8, P3=Mul.48, P4=EUL 92, P5=EXM90, P6=EXL 139, P7=TM 90

* and ** indicate significant at 5 % and 1 % levels of probability, respectively.

Significant positive heterosis was recorded for capsule length in 6 crosses, and 3 out of them exhibited significant positive heterobeltiosis with
values ranging from 8.7% (P3xP6) to 19.0% (P2xP7). El-Shazly et al (1993b) and Padmavathi et al (1993) reported significant positive heterosis for various cross combinations.

The maximum values of heterosis/heterobeltiosis were observed in number of fruiting branches. Significant positive heterosis was found in 6 crosses with values varied from 86.7% (P5xP7) to 203.7% (P1xP4), while only the cross (P1xP4) showed significant positive heterobeltiosis of 52.9%. On the other hand, significant negative heterobeltiosis of −54.2, -52.0 and –79.8% was recorded for crosses (P1xP6), (P2xP3) and P5xP6), respectively. The combinations showing significant positive values open the possibility of increasing the branches in hybrids. Sodani and Bhatnagar (1990) Mishra et al (1994) and Mishra and Yadav (1996) have reported positive heterosis for branches, but Ibrahim et al (1983a) and Jadon and Mehrotra (1988) found negative heterosis for this trait.

The most important yield component, number of capsules per plant, exhibited significant positive heterosis and heterobeltiosis in 4 crosses namely: (P1xP2), (P1xP4), (P1xP7) and (P3xP5) with values ranging from 25.9% to 47.4% for heterosis and from 21.7% to 33.6% for heterobeltiosis. Atta (1990), Sodani and Bhatnagar (1990), Mishra and Yadav (1996) and Ganesh et al (1999) have reported significant heterosis/heterobeltiosis in capsules/plant.

For seed index (1000 - seed weight), results obtained indicated that 6 crosses viz. (P1xP4), (P1xP5), (P2xP4), (P4xP6), (P5xP7) and (P6xP7) gave significant heterosis of 15.5, 25.8, 14.5, 18.5, 16.7 and 29.5%, respectively. However, significant heterobeltiosis of 18.6% was recorded for only one cross (P6xP7). The remaining crosses showed insignificant values with exception of (P1xP2) which gave negative heterosis. These results are in agreement with that obtained by Singh et al (1986), Ding et al (1987) and Mishra and Yadav (1996).

Regarding seed yield per plant, 3 crosses namely: (P1xP4), (P1xP5) and (P1xP7), having the local cultivar Giza 32 as a female parent, recorded significant positive heterobeltiosis of 38.0, 28.3 and 31.0%, respectively. Whereas (P3xP5) showed significant positive heterosis of 45.9%. The remaining crosses showed insignificant heterosis in both directions with the exception of cross (P6xP7) which exhibited negative heterosis. Many investigators, i.e. Yadav and Mishra (1991), Padmavathi et al (1993) Mishra et al (1994), Mishra and Yadav (1996) and Ganesh et al (1999) reported significant heterosis/heterobeltiosis for seed yield in other crosses.

From the above results it is clear that the expression of heterosis varied with crosses and characters. The maximum significant positive heterobeltiosis was observed for number of fruiting branches/plant (52.9%) followed by seed yield/plant (38.0%), capsules/plant (33.6%), capsule length (19.0%), 1000- seed weight (18.6%) and plant height (12.1%).

Combining ability
Analysis of variance for combining ability was employed for all investigated characters in the F₁ generation (Table 2). The mean square (variance) of general (GCA) and specific (SCA) combining ability were highly
significant for all studied traits, suggesting the presence of both additive and non-additive (dominance) gene effects involved in the expression of these traits. Several investigations revealed the importance of both additive and dominance gene effects in the genetic control of seed yield and its contributing characters in sesame (Ibrahim et al., 1983b; El-Shazly et al., 1993a; Padmavathi et al., 1994; Mcharo et al., 1995 and Yingzhong, 1999).

However, non-additive gene action was found to be important for days to maturity, plant height, branches/plant, capsules/plant, 1000-seed weight and seed yield/plant as indicated by additive/dominance ratio being less than one. On the contrary, the ratio was more than one for stem height to first capsule and capsule length, indicating that additive component was more important in controlling these characters.

**General combining ability effects**

Estimates of general combining ability (GCA) effects of individual parents for each trait in the F1 generation are illustrated in Table 3. GCA effects were found to be either significant or highly significant in some cases. Highly positive values would be of interest for all studied traits except days to maturity and stem height to first capsule where the reverse situation is desirable, i.e. high negative values would be useful from the breeder’s point of view. In this respect, P2 (Mut. 8) appeared to be good general combiner for earliness, whereas P4 (EUL92) and P5 (EXM90) were good combiners for both earliness and stem height to first capsule.

Estimates of GCA effects for seed yield and its components indicated that the P1 (local cultivar Giza 32) and P3 (Mut. 48) were the best general combiner parents for seed yield/plant due to their highly significant positive values of GCA effects. Such parents were also exhibited significant or highly significant positive GCA effects for two or more yield components especially number of capsules/plant. Other parents viz. P5 (EXM90) showed to be good combiner for capsule length. P6 (EXL139) was good combiner for seed weight, while P7 (TM90) proved to be good combiner for number of branches. However, the three later parents (P5, P6 and P7) were poor general combiner for seed yield itself. These findings are in harmony with those reported by El-Shazly et al., 1993a; Mcharo et al., 1995; Mishra and Yadav, 1997 and Yingzhong, 1999.

Thus, it is worth noting that the parental genotypes, which showed high GCA effects in seed yield, might be also good combiner in two or more of the traits contributing to yield. Therefore, it is suggested to use these genotypes in a multiple crossing program for isolating high yielding varieties. On the other hand, the genotypes containing high GCA effects for particular yield components such as capsule length, seed weight and no. of branches may not be good combiners for seed yield, but it may be utilized for improving such traits by using its best combiner parent.

**Table (2): Estimates of variance (mean square) for general (GCA) and specific (SCA) combining ability from a half diallel crosses of sesame in F1 generation**

<table>
<thead>
<tr>
<th>Source of</th>
<th>Days to Maturity</th>
<th>Plant Height</th>
<th>Capsules/Branch</th>
<th>Capsules/Plant</th>
<th>1000-Seed Weight</th>
<th>Seed Yield</th>
</tr>
</thead>
</table>

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<table>
<thead>
<tr>
<th>variation</th>
<th>df</th>
<th>Matu-</th>
<th>height</th>
<th>to first</th>
<th>ule</th>
<th>plant</th>
<th>seed</th>
<th>yield/</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.C.A</td>
<td>6</td>
<td>82.05**</td>
<td>2932.3***</td>
<td>889.40**</td>
<td>0.996**</td>
<td>1.416**</td>
<td>1561.4**</td>
<td>0.384**</td>
</tr>
<tr>
<td>S.C.A</td>
<td>21</td>
<td>30.25**</td>
<td>848.93**</td>
<td>159.06**</td>
<td>0.041**</td>
<td>0.491**</td>
<td>796.3**</td>
<td>0.158**</td>
</tr>
<tr>
<td>Error</td>
<td>54</td>
<td>0.71</td>
<td>22.35</td>
<td>10.59</td>
<td>0.004</td>
<td>0.173</td>
<td>184.2</td>
<td>0.039</td>
</tr>
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</table>

Variance components

<p>| | | | | | | | | | |</p>
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<tr>
<th></th>
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<tbody>
<tr>
<td>Additive</td>
<td>11.51</td>
<td>507.42</td>
<td>162.30</td>
<td>0.21</td>
<td>0.21</td>
<td>170.0</td>
<td>0.05</td>
<td>5.93</td>
<td></td>
</tr>
<tr>
<td>Dominance</td>
<td>29.54</td>
<td>626.58</td>
<td>148.48</td>
<td>0.04</td>
<td>0.32</td>
<td>612.1</td>
<td>0.12</td>
<td>15.97</td>
<td></td>
</tr>
<tr>
<td>Add./Dom.</td>
<td>0.39</td>
<td>0.81</td>
<td>1.09</td>
<td>5.25</td>
<td>0.66</td>
<td>0.28</td>
<td>0.42</td>
<td>0.37</td>
<td></td>
</tr>
</tbody>
</table>

Table (3): Estimates of general combining ability effects for each parent in F1 generation

<table>
<thead>
<tr>
<th>Parents</th>
<th>Days to Maturity</th>
<th>Plant Height</th>
<th>Height to first capsule</th>
<th>Capsule length</th>
<th>Branches/plant</th>
<th>Capsules/plant</th>
<th>1000-seed weight</th>
<th>Seed yield/ plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1 (Giza 32)</td>
<td>0.090</td>
<td>39.252**</td>
<td>16.354**</td>
<td>0.145**</td>
<td>0.017</td>
<td>10.913**</td>
<td>0.375**</td>
<td>2.934**</td>
</tr>
<tr>
<td>P2 (Mut. 8)</td>
<td>-0.873**</td>
<td>-3.966**</td>
<td>1.336</td>
<td>-0.166**</td>
<td>0.159</td>
<td>2.247</td>
<td>-0.115</td>
<td>-0.076</td>
</tr>
<tr>
<td>P3 (Mut. 48)</td>
<td>3.275**</td>
<td>3.523**</td>
<td>2.156**</td>
<td>0.245**</td>
<td>0.390**</td>
<td>21.484**</td>
<td>-0.204**</td>
<td>3.875**</td>
</tr>
<tr>
<td>P4 (EUL92)</td>
<td>-1.947**</td>
<td>-10.351**</td>
<td>-12.883**</td>
<td>-0.087**</td>
<td>-0.394**</td>
<td>1.035</td>
<td>-0.048</td>
<td>-0.769</td>
</tr>
<tr>
<td>P5 (EXM90)</td>
<td>-5.132**</td>
<td>-11.274**</td>
<td>-11.731**</td>
<td>0.689**</td>
<td>-0.687**</td>
<td>-7.916</td>
<td>-0.049</td>
<td>-0.584</td>
</tr>
<tr>
<td>P6 (EXL139)</td>
<td>1.164**</td>
<td>3.716**</td>
<td>3.817**</td>
<td>-0.262**</td>
<td>0.202</td>
<td>-15.624**</td>
<td>0.187**</td>
<td>-2.726**</td>
</tr>
<tr>
<td>P7 (ITM 96)</td>
<td>3.423**</td>
<td>-10.018**</td>
<td>0.947</td>
<td>0.073**</td>
<td>0.313**</td>
<td>-12.238**</td>
<td>-0.146**</td>
<td>-2.013**</td>
</tr>
<tr>
<td>SE (gi)</td>
<td>0.260</td>
<td>1.469</td>
<td>1.004</td>
<td>0.020</td>
<td>0.129</td>
<td>4.189</td>
<td>0.061</td>
<td>0.780</td>
</tr>
<tr>
<td>SE (gi - gj)</td>
<td>0.398</td>
<td>2.229</td>
<td>1.534</td>
<td>0.031</td>
<td>0.196</td>
<td>6.398</td>
<td>0.093</td>
<td>1.191</td>
</tr>
</tbody>
</table>

* and ** indicate significant at 5 % and 1 % levels of probability, respectively.

Specific combining ability effects

In order to detect the potentiality of crossing between specific parents to produce promising hybrids, specific combining ability (SCA) effects were calculated for the investigated characters in F1 generation (Table 4). Significant positive or negative SCA effects were noted for each character.

Highly significant negative SCA value as a desirable effects towards earliness were observed for eight cross combinations viz. (P1 x P2), (P1 x P3), (P1 x P5), (P1 x P7), (P2 x P4), (P2 x P5) and (P6 x P7), while (P5 x P7) exhibited significant negative values. In other crosses, EL-Shazly et al (1993a) and Mishra et al (1994) reported also significant negative SCA effects for this trait.

Table (4): Estimates of specific combining ability effects from a half diallel crosses of sesame in F1 generation

<table>
<thead>
<tr>
<th>Crosses</th>
<th>Days to maturity</th>
<th>Plant height (cm)</th>
<th>Height to first capsule (cm)</th>
<th>Capsule Length (cm)</th>
<th>Branches/plant</th>
<th>Capsules/plant</th>
<th>1000-seed weight (gm)</th>
<th>Seed Yield/ plant (gm)</th>
</tr>
</thead>
</table>

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Concerning seed yield per plant, five crosses namely; (P1 x P4), (P1 x P5), (P1 x P7), (P3 x P5) and (P3 x P6) recorded highly significant positive SCA effects. These crosses possessed also highly significant or significant SCA effects for two or more characters contributing to seed yield, i.e. capsule length, branches/plant, capsules/plant and 1000-seed weight. Also, non of these favorable crosses gave significant negative SCA effects for any of the yield components. Therefore, such cross combinations being promising for varietal improvement purpose as it showed high SCA effects and involved one of the parents as good gene combiner (Tables 3 & 4). The trend of SCA effects for seed yield and its components were more or less in agreement with that reported in the literature (EL-Shazly et al. (1993a), Mishra et al. (1994) and Mishra and Yadav (1997).

In general, it is of interest to mention that the local cultivar Giza 32 (P1) and Mut. 48 (P3) showed highly significant positive GCA effects for seed yield and two or more of its components (Table 3). Moreover the favorable cross combinations, that performed highly significant positive SCA effects of seed yield and some of its main components (Table 4), were derived from these two parents. Therefore, such parents and their derived crosses could be utilized for both hybrid sesame production and/or varietal improvement purpose in terms of the probability of isolating desirable segregates for yield and some of its components.

Performance of the crosses was compared on the basis of mean yield, desirable heterotic response, and SCA effects of hybrids and GCA effects of the parents. The best four crosses selected on the basis of these parameters are presented in Table 5. The first three crosses involving the local cultivar Giza 32, i.e. (P1xP4), (P1xP5) and (P1xP7) showed high means of seed yield/plant with values ranging from 32.2 to 34.6 g. These crosses exhibited also positive significant heterobeltiosis coupled with

<table>
<thead>
<tr>
<th>Cross</th>
<th>Mean Yield (g)</th>
<th>Desirable Heterotic Response</th>
<th>SCA Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P1 x P4)</td>
<td>32.2</td>
<td>1.05</td>
<td>0.082</td>
</tr>
<tr>
<td>(P1 x P5)</td>
<td>34.6</td>
<td>1.12</td>
<td>0.050</td>
</tr>
<tr>
<td>(P1 x P7)</td>
<td>34.0</td>
<td>1.17</td>
<td>0.078</td>
</tr>
</tbody>
</table>

6635
significant or highly significant SCA effects. The fourth cross (P3xP5) showed the highest mean yield (38.6 g) and positive significant heterosis along with highly significant SCA effects.

Table (5): Best four crosses selected for seed yield on the basis of heterotic response and SCA effects along with GCA effects of the parents involved

<table>
<thead>
<tr>
<th>Crosses</th>
<th>Yield/ plant (gm)</th>
<th>Heterosis %</th>
<th>Heterobeltiosis %</th>
<th>SCA effects</th>
<th>GCA effects</th>
<th>Desirable+ heterosis for other traits</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1 x P4</td>
<td>34.60</td>
<td>41.9**</td>
<td>38.0**</td>
<td>6.622**</td>
<td>2.294**</td>
<td>-0.769 b, d, e, f</td>
</tr>
<tr>
<td>P1 x P5</td>
<td>32.17</td>
<td>41.4**</td>
<td>28.3*</td>
<td>4.005*</td>
<td>2.294**</td>
<td>-0.584 a, d, f</td>
</tr>
<tr>
<td>P1 x P7</td>
<td>32.83</td>
<td>38.8**</td>
<td>31.0*</td>
<td>6.100**</td>
<td>2.294**</td>
<td>-2.013** a, c, e</td>
</tr>
<tr>
<td>P3 x P5</td>
<td>38.56</td>
<td>45.9**</td>
<td>18.9</td>
<td>8.817**</td>
<td>3.875**</td>
<td>-0.584 b, d, e</td>
</tr>
</tbody>
</table>

+ a = Days to maturity, b = Plant height, c = Capsule length
    d = Branches/plant, e = Capsules/plant, f = 1000- seed weight

Results demonstrated also that the best four crosses which recorded significant positive heterosis/heterobeltiosis for seed yield and high SCA effects were also involving at least one parent as a good general combiner for this trait. Moreover, heterosis for seed yield in these crosses was accompanied by heterosis for two or more of yield components. Out of the best 4 crosses, 2 combinations (P1xP5 and P1xP7) recorded also significant negative heterosis for maturity indicating the possibility of obtaining high yield coupled with earlier maturing combinations than those of the parents.

Normally SCA effects do not contribute much to the improvement of self-pollinated crops like sesame. However, when SCA effects are observed in the crosses having at least one good general combiner parent, the possibility of their exploitation in practical breeding increases (Goyal and Kumar, 1988). In the present study, it may be concluded that on the basis of heterosis, combining ability and per se performance, the aforementioned 4 crosses are the most promising to be used in a breeding program aiming to improve seed yield and its components.

Type of gene action and heritability

The analysis of variance revealed significant differences between entries for all studied characters in both F₁ and F₂ generations. The genetic components of variance and their standard error estimated from the diallel analysis together with the ratios of the genetic parameters, heritability and $t^2$ values are given in Table 6. The values of $t^2$ were found to be not significant for all studied traits in both generations, indicating that the additive-dominance model was adequate to explain the present variation.

The results of Table 6 showed that the estimates of additive genetic component (D) were significant for days to maturity, plant height, stem height to first capsule, capsule length, branches/plant, 1000- seed weight in both F₁ and F₂ generations and for capsules/plant in the F₂ only, suggesting the importance of (D) component in the inheritance of such characters.

The presence of dominance effect was substantiated by the significant values of $H_1$ for all studied characters in both generations.
However, the values of $H_1$ were higher in magnitude as compared to the (D) component for all traits except capsule length in the $F_1$ and vice versa for all studied characters in the $F_2$ generation. These results suggested that since the non-additive gene action was predominant in the $F_1$, therefore, heterosis breeding in sesame could be used. Yadav and Mishra (1991), Mishra et al. (1994), Mishra and Yadav (1996) and Ganesh et al. (1999) also reported similar conclusion. However, the additive gene effect was the main component of the total genetic variance for most traits in the $F_2$ generation, suggesting the possibility of improving such traits by means of selection of superior segregates in early generations.

Estimates of dominant component ($H_2$) were smaller than ($H_1$) for all studied characters in both generations, indicating that the frequencies of positive and negative genes at the loci governing these characters were not equal in proportion in the parents.

The distribution of dominant versus recessive genes (F) was positive and significant for days to maturity and capsule length in the $F_1$ and for branches/plant in both $F_1$ and $F_2$ generations, indicating an excess of dominant genes in the parents of these traits.

The overall dominance effects of heterozygous loci ($h^2$) were positive and significant for stem height to first capsule, branches/plant and 1000-seed weight in the $F_1$ and for plant height and seed yield/plant in the $F_2$ generation. This enhancing that dominant gene effects was mainly attributed to heterozygosity and dominance seems to be acting in positive direction (unidirectional) for such traits. The remaining characters showed insignificant values of $h^2$, indicating that dominance effect for the character was ambi-directional; i.e. both dominance and recessive genes were involved at various loci.

The environmental component of variance (E) was significant only for plant height in the $F_2$ and for branches/plant and capsules/plant in both $F_1$ and $F_2$ generations, reflecting the large effect of environmental factors on these traits.

The mean degree of dominance over all loci, as estimated by the ratio ($H_1/D)^{0.5}$ was found to be more than unity for all traits in the $F_1$ generation, revealing the role of overdominance gene effects in the inheritance of the traits. However, the ratio was less than unity for all traits in the $F_2$ generation (with two exceptions), suggesting the presence of partial dominance in controlling such traits.

The ratio of $H_2/4H_1$, which measure the average frequency of negative vs. positive genes in the parents, was less than its maximum theoretical value (0.25) in both generations, confirming that genes having positive and negative effects were not equally distributed in the parents.

**Table (6):** Estimates of genetic and environmental variance components and their derived ratios of $F_1$'s and $F_2$'s from diallel crosses of sesame for seed yield and its attributes

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Days to maturity</th>
<th>Plant height (cm)</th>
<th>Height to first capsule (cm)</th>
<th>Capsule length (cm)</th>
<th>Branches/plant</th>
<th>Capsules/plant</th>
<th>1000-seed weight</th>
<th>Seed yield/plant</th>
</tr>
</thead>
</table>

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The ratio of dominant to recessive genes (K₀/Kₐ) in the parents was greater than one for all traits in both F₁ and F₂ generations, suggesting an excess of dominant genes in the parents for each trait.

Heritability in narrow sense (Hn) estimated from F₁ data was found to be low for the studied characters, except capsule length, with values ranging from 32.24 to 59.27%, indicating that the genetic variance associated with those characters was mostly due to dominance gene effects. However, heritability (Hn) on the basis of the F₂ data recorded high

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estimates for all characters, except seed yield/plant, with values ranging between 60.5 and 93.3%, confirming that the additive gene effects was more prevalent. These results are in line with that obtained by Taha (1995) and Shrief (1997).

From the previous results it is evident that the estimates of genetic variance and its ratios indicated the importance of both additive and non-additive (dominance) gene effects in the inheritance of the investigated characters in both F1 and F2 generations. But the predominant role of non-additive component for most traits in the F1 generation which were confirmed by the genetic parameters; Hr, (Hr/D)0.5 and Hn and consistent with results from the combining ability analysis, suggested the possibility using of heterosis breeding in sesame. However, the predominance of additive genetic variance for most of the investigated characters in the F2 generation that confirmed by the significant and high magnitude of the parameters; D and Hn can be exploited by selection based on progeny performance. Thus, it is also apparent in the present materials that there are good chance of improvement seed yield and its components along with early maturity. In addition, the incorporation of desirable characters from sources other than the present ones can be fully exploited for further improvement.

REFERENCES


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Giza 32, Mut. 8, EUL92, EXM90, ELX139, TM90

بالنسبة للحقل الأول (1997-1998)، تم قياس سرعة أشعة الشمس والظروف المحيطة، وتم قياس سرعة أشعة الشمس والتغذية، وتم قياس سرعة أشعة الشمس والتغذية، وتم قياس سرعة أشعة الشمس والتغذية، وتم قياس سرعة أشعة الشمس والتغذية، وتم قياس سرعة أشعة الشمس والتغذية، وتم قياس سرعة أشعة الشمس والتغذية، وتم قياس سرعة أشعة الشمس والتغذية، وتم قياس سرعة أشعة الشمس والتغذية، وتم قياس سرعة أشعة الشمس والتغذية، وتم قياس سرعة أشعة الشمس والتغذية، وتم قياس سرعة أشعة الشمس والتغذية، وتم قياس سرعة أشعة الشمس والتغذية، وتم قياس سرعة A.A. 6642