ESTIMATION OF SESAME YIELD AND ITS COMPONENT BASED ON TRIALLEL ANALYSIS

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Since antiquity, sesame has been used as a valuable oil crop. Its origin has been disputed for more than a century. Sesame seed, paste and oil are utilized in a very wide range of edible products. Seed yield is a polygenic trait; hence direct selection for this character may often be misleading. Information on gene action governing the inheritance of such quantitative traits is essential for planning and execution of breeding programme successfully. The majority of gene action molds that have been used extensively either in self or cross pollinated crops were mainly additive- dominance models' or only additive models. The epistatic (non-allelic interaction) were ignored to have simplified models for explaining genetic variations. However, Allard (1999) emphasized importance of epistasis in a self-pollinated crop (rice). For the trait grain number per panicle, the number of loci involved in two-locus trait expressions included a total of two loci located on 9 of the 12 rice chromosomes. Besides, he als0 mentioned that all four types of epistatic interactions, AA, AD, DA and DD were found among the 25 two-locus combinations. He added that this idea became more plausible when significant two-locus interactions revealed" weblike" relations among the interacting two-locus combinations. Triallel as well as quadrallel analyses provides information on all type of gene actions viz., additive, dominance and epistasis components besides giving information on order of parents in three-way cross combinations for obtaining superior trasgressive segregants (Ponnuswamy *et al*., 1974; Singh and Narayaanan, 2000). In this context, El-Shakhess *et al*. (2009) used the quadrallel to study the magnitude of the therr types of gene action in sesame. In the absence of reciprocal effects and maternal-paternal interactions, the three- way crosses (AB) C and (BA) C would represent the same three-way hybrid (Rawlings and Cockerham, 1962).Many investigators studied genetic components of variance in sesame. Attia *et al.* (2004) studied gene action for yield and its components by parent (P_1, P_2), hybrids (F_1, F_2) and back-crosses (BC_1 and BC_2). They reported the importance of dominance gene action for plant height, length of fruiting zone, number of branches/pl., number of capsules/pl. and seed yield/pl. In addition, they indicated that all combinations of epistatic gene effects were of significant magnitude reflecting their importance in the inheritance of studied traits. Mothilal and Manoharan (2005) revealed that plant height and number of branches showed

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additive gene action. Meanwhile, non-additive gene action was involved in the expression of number of capsules on branches, 1000-seed weight and seed yield per plant. Overdominance was observed for number of branches, number of capsules on main stem, number of capsules on branches, number of seeds per capsule and seed yield per plant. Kumar *et al.* (2006) indicated that seed yield was determined by dominance × dominance type of genetic system and over dominance was associated with duplicate epistasis of yield and its components. El-Shakhess *et al.* (2009) studied epistasis beside additive and dominance effects and genetic components of variance for sesame yield and its components using quadrallel analysis. Their results exhibited all types of epistatic types of gene action for all studied characters except for capsule length and seed index. Abd-Eleziz *et al.* (2010), Mandal *et al.* (2010) and Madhusudan *et al.* (2012) showed that the major contribution of non-additive gene action for all the characters. This study has been made to give provides information on additive, dominance and epistasis gene action controlling yield and important yield component characters by using triallel analysis.

MATERIALS AND METHODS

Thirty three-way cross hybrids were developed by crossing five sesame lines and varieties via, MGS16-1 (P_1), MGS20-1 (P_2), Toshka1 (P_3), Shandweel3 (P_4) and line 78 (P_5) in a triallel mating design as explained by Rawlings and Cockerham (1962). Hybrids and their parents were evaluated at Giza Research Station (ARC) during 2009, 2010 and 2011 seasons in a randomized complete block design (RCBD) with three replications. The parents used in the present study were unrelated and completely homozygous. Their origin and some of their traits are presented in Table (1).

Ten guarded plants were randomly selected per plot for recording the following traits: plant height (cm), length of fruiting zone (cm), number of branches/pl., number of capsule/pl., capsule length, seed yield/pl. and oil percentage. The triallel analysis was carried out according to Singh and Chaudhary (1985).

RESULTS AND DISCUSSION

The data in Table (2) revealed that the analysis of variance of yield and their component revealed highly significant differences among genotypes for all studied traits.

The magnitude of variance due to parents was higher than crosses for plant height, length of fruiting zone, number of branches/pl. and length of capsule. However, the crosses showed higher mean squares than parents for number of capsules/pl., seed yield/pl. and oil percentage. These results indicated that the parents had pronounced variance than crosses for plant height, length of fruiting zone, number of branches/pl. and length of capsule. Meanwhile, the crosses had wider variance than parents for number of capsules/pl., seed yield/pl. and oil percentage.

The parents vs crosses showed highly significant mean squares for all studied traits. This means that considerable heterosis was obtained by crosses comparing to parental genotypes.

Combining ability

The triallel analysis in Table (3) shows that general line effects of both first and second kind, two line specific effects of first and second kind as well as three line specific effects were significant for seed yield/pl. and oil percentage, thus suggesting the major role of all three types of epistatic components viz., additive x additive, additive x dominance, dominance x dominance, in addition to the additive and dominance gene actions in the expression of these traits. This implies that improvement of these traits will be possible using any breeding procedure which emphasizes epistatic gene effect such as selection in letter generations and/or by using reciprocal recurrent selection in the present of male sterile parents. The remaining traits lacked significance in one or two of aforementioned components. Additive as h_i effect of gene for plant height, length of fruiting zone and number of branches/pl. Dominance as (d_{ij}) for plant height, length of fruiting zone and number of capsules/pl. were insignificant. Also, the non-allelic interactions as dominant x dominant (t_{ijk}) were insignificant for plant height, length of fruiting zone, number of branches/pl., number of capsules/pl. and capsule length. In addition, additive x additive (as g_i) was detected for plant height, length of fruiting zone, number of branches/pl. and number of capsules/pl. Thus, the strategies for improving these traits should take this information into consideration before planning or deciding the effective selection method in segregating generations. Raghunaiah *et al.* (2008), El-Shakhess *et al.* (2009), Prajapati *et al.* (2009), Mandal *et al.* (2010) and Madhusudan *et al.* (2012). They reported that non-additive gene action was predominantly responsible for inheritance of yield and its components. Meanwhile, Kim *et al.* (2007), Gaikwad *et al.* (2009) and Parameshwarappa and Salimath (2010) showed major contribution of additive gene action for all the studied traits.

General combing ability

General line effect of first and second kind (h_i and g_i) for plant height and length of fruiting zone are shown in Table (4). Parent (P_1) recorded positively and highly significant by general line effects of both first kind (h_i) and second kind (g_i) for plant height and length of fruiting zone, indicating that this parent was a good general combiner parent for these traits when used both as a grand parents as well as immediate parent in any three way crosses.

Data in Table (5) show general line effect of first and second kind (h_i and g_i) for number of branches/plant and number of capsules/plant. Among parents, parent (P_4) exhibited positive and significantly general line effects of first kind (h_i = 0.39). Meanwhile, parent (P_5) showed positive and highly significant general lines effects of second kind (g_i = 0.74), indicating that the parent P_4 was a good general combiner for number of branches/plant when used as grand-parent. In contrast, parent (P_5) was good general combiner for this trait when used as immediate parent in the three-way crosses. With respect to number of capsules/plant, parent (P_4) recoded positive and highly significant general line effects of both first kind (h_i = 7.48) and second kind (g_i = 9.58). This revealed that this parent was a good general combiner for capsules/plant when used either as a parent as or grand-parent. The significant general line effect of first kind (h_i) for P_5 indicated that it could be used as grand-parent in the three-way crosses.

Data in Table (6) show estimates of general line effects for length of capsule and seed yield/ plant in sesame. The results indicated that (P_3) showed a positively and highly significantly of (h_i = 0.19) and a significant of (g_i). Regarding seed yield/plant, general line effect of first and second (h_i and g_i) kinds were positive and highly significant for (P_4) and (P_5) indicated that the P_4 and P_5 could be utilized as grand-parents which showed good general combining ability of both kinds whereas, (P_1) reflected a poor general combing ability as evident from negative (h_i) and (g_i) estimates. Line P_4 is better than line P_5 in grand- parent performance. Meanwhile, line P_5 performs better than P_4 in parental performance.

Estimates of general line effects for oil percentage are presented in Table (7). General line effect of first and second kind (h_i and g_i) indicated that the (P_2) could be utilized as grand- parents and immediate parent which showed good general combining ability of both kinds. The significant general line effect of first kind (h_i) for P_3 and P_5 suggested that it could be used as grand-parent in the three-way crosses. But, the significant general line effect of second kind (g_i) for P_4 suggested that it could be used as immediate parent in the three-way crosses.

Specific combing ability

Two lines specific effect: The two line specific of the thirty crosses for plant height and length of fruiting zone is presented in Table (4). Only one cross (P_1XP_4) showed desirable specific effects of first kind (d_{ij}) for plant height. The two line specific effect of second kind (S_{ij}) was positive and significant in (P_3XP_1), (P_3XP_2), (P_4XP_1) and (P_5XP_3). Considering length of fruiting zone, the cross (P_1Xp_3) had desirable specific effects of first kind (d_{ij}). The two line specific effect of second kind (S_{ij}) was positive and significant in five crosses via, (P_2XP_5), (P_3XP_1), (P_3XP_2), (P_4XP_1) and (P_5XP_2).

Data in Table (5) showed two lines specific effect of first and second kinds for number of branches/plant and number of capsules/plant. With respect to number of branches/plant, two crosses (P_1XP_4) and (P_3XP_5) exhibited positive and significant two lines specific effect of first kind (dij) and eight crosses (P_1XP_5), (P_2XP_3), (P_2XP_4),(P_2XP_5), (P_3XP_1), (P_3XP_5), (P_4XP_1) and (P_5XP_4) reveled positive and significant specific effect of second kind (S_{ij}). Only one cross (P_3XP_4) had desirable specific effect of first kind (d_{ij}) for number of capsules/ plant. Whereas, six crosses (P_1XP_4), (P_2XP_1), (P_3XP_4), (P_4XP_3), (P_4XP_5) and (P_5XP_4) exhibited positive and significant two lines specific effect of second kind (S_{ij}).

The two lines specific effects of first and second kind for capsule length and seed yield/ plant are presented in Table (6). Four crosses (P_1XP_4), (P_1XP_5), (P_2XP_3) and (P_2XP_4) exhibited positive and significant two lines specific effects of first kind (d_{ij}) for capsule length. Eight crosses (P_1XP_3), (P_1XP_4), (P_2XP_1), (P_3XP_4), (P_4XP_2), (P_5XP_1), (P_5XP_2) and (P_5XP_3) exhibited desirable two lines specific effect of second kind (S_{ij}). Considering seed yield/plant, the positive and significant two line specific effect of first kind in four combinations via, (P_1XP_2), (P_3XP_4), (P_3XP_5) and (P_4XP_3) showed that they could produce significant effects in their order. These combiners were good specific combiners for seed yield/plant as grand-parents in three- way crosses. The two line specific effect of second kind (S_{ij}) was positive and significant for crosses (P_1XP_2), (P_1XP_5), (P_2XP_3), (P_3XP_4), and (P_4XP_5) indicating the usefulness of these cross combinations as good specific combiners for seed yield/plant. Such crosses that were identified as good specific combiners had reciprocal effect (S_{ji}) in crosses (P_2XP_1), (P_3XP_2), (P_4XP_3) and (P_5XP_4) pointing out the maternal effect and to the importance of the order effects of the parents in the three-way cross hybrids. The two line order effect is due to interaction between additive X dominance gene effects and all three factors or higher epistatic effects except the all dominance types as reported Rawlings and Cockerham (1962).

Data in Table (7) showed two line effects for oil percent in sesame. Two line specific of first kind was positively significant in five combinations among which the maximum effect was (1.84) in (P_1XP_2). The other combinations had highly significant two line specific effect viz., (P_3XP_5), (P_4XP_5), (P_2XP_4) and (P_1XP_3) suggesting their superiority as grand-parents in the three-way crosses. Reciprocal effect S_{ij} and S_{ji} kinds for crosses (P_1XP_2), (P_1XP_3), (P_2XP_4) and (P_4XP_5) had invariably reciprocal differences and were associated with order effects in three-way hybrids.

Three- line specific effects

The estimation of three line specific effect t_{ijk} of the thirty crosses for all studied traits are shown in Table (8).

Regarding plant height, the estimates of t_{ijk} were positive and highly significant in seven crosses. In the best performing triplet of ($P_1XP_4XP_3$).

The estimates of t_{ijk} for length of fruiting zone were found to be positive and highly significant in six crosses ($P_1XP_3XP_2$), ($P_1XP_3XP_4$), ($P_1XP_3XP_5$), ($P_2XP_4XP_3$), ($P_2XP_5XP_3$) and (P_3XP_5XP). Considering number of branches/plant, the t_{ijk} were found to be positive and highly significant in seven which the highest t_{ijk} was recorded by the triplet ($P_3XP_5XP_2$) followed by ($P_1XP_4XP_2$). The crosses ($P_1XP_3XP_2$), ($P_1XP_4XP_2$), ($P_2XP_5XP_1$), ($P_3XP_4XP_1$), ($P_3XP_4XP_2$), ($P_3XP_5XP_2$), ($P_4XP_5XP_1$) and ($P_4XP_5XP_2$) exhibited positive and highly significant t_{ijk} for number of capsules/plant. With respect to capsule length, five crosses (P1XP3XP5), ($P_1XP_4XP_5$), ($P_2XP_3XP_5$), ($P_2XP_4XP_5$) and ($P_3XP_4XP_5$) showed positive and highly significant t_{ijk}. Also, t_{ijk} was found to be highly significant and positive in eleven combinations for seed yield/plant. In the best performing triplet of ($P_4XP_5XP_1$) showed superior *per se* and significantly superior t_{ijk} effect. Whereas, P_4 and P_5 were good combiners, two line specific effect of the first kind was highly significant in cross (P_4XP_5) due to the presence of P_4 and P5 as grand-parents and the interaction of parents in that particular order. Hence one can conclude that the superiority of the triplets is mainly due to (1) two of three parent showing better general line effects (2) one cross showing better two line specific effect and/or (3) the interaction might be due to additive X additive and additive X dominance among the three lines used in making the triplet (Joshi and Sharma, 1984).

The fifteen out of thirty crosses showed positively and highly significant t_{ijk} for oil percent. The highest t_{ijk} effect was recorded by triplet ($P_1XP_2XP_3$) (2.09) followed by ($P_1XP_2XP_4$) (2.06). In the best performing triplet of ($P_1XP_2XP_3$), P_2 were good in their grand parental performance.

Components of genetic variance

Component of variance for studied traits are shown in Table (9). Component of variance for plant height and number of capsules/pl. indicated that dominance component was the highest in magnitude followed by the epistatic effect dominance x dominance and additive components. The additive x additive and additive x dominance epistatic effect were negative. The dominance was the highest component of variance for length of fruiting zone followed by additive and dominance x dominance components. The additive x additive and additive x dominance were negative. With respect to number of branches/pl., the component of variance revealed that the epistatic variance additive x additive was the highest in magnitude followed by dominance components. Meanwhile, additive, dominance x dominance and additive x dominance components were negative. Concerning capsule length, the additive x additive was the highest component of genetic variance. Components of genetic variance for seed yield/pl. exhibited that additive x additive was the highest (1457.6) followed by additive x dominance (480.7) components. Whereas, additive (-2022.7), dominance (-842.3) and dominance x dominance (-

1066.7) components were of negative magnitude. Thus predominance of epistatic components of genetic variance for seed yield/pl. has to be kept in mind while formulating breeding procedures for improvement of this trait. Oil percent indicated that additive x additive was the highest component of genetic variance followed by additive x dominance components. Meanwhile, additive, dominance and dominance x dominance components were negative. Similar results were obtained by El-Shakhess *et al*. (2009), Mandal *et al*. (2010) and Madhusudan *et al.* (2012). Thus, triallel analysis had clearly elucidated its advantages over diallel analysis by giving additional information on magnitude of all types of epistatic components and also on order of parents to be crossed in three way crosses for obtaining superior transgressive segregates.

SUMMARY

The main objective of this investigation was to give information on additive and non-additive (dominance and epistasis) gene actions for seed yield and its component. This information is very essential for deciding the effective selection method to be used in manipulating of segregation generations. Five parents were crossed in a triallel analysis mating design to obtain 30 three-way cross hybrids. Results revealed that the parents had pronounced variance than crosses for plant height, length of fruiting zone, number of branches/pl. and length of capsule. Meanwhile, the crosses had wider variance than parents for number of capsules/pl., seed yield/pl. and oil percentage. The parents had pronounced variance than crosses for plant height, length of fruiting zone, number of branches/pl. and length of capsule. Meanwhile, the crosses had wider variance than parents for number of capsules/pl., seed yield/pl. and oil percentage. Two line-specific effects of first and second kind as well as three line specific effects were significant for seed yield / pl. and oil percent, thus suggesting the major role of all the three types of epistatic components viz., additive x additive, additive x dominance, dominance x dominance, besides additive and dominance gene action in expression of these traits. The P_4 and P_5 could be utilized as grand-parents and immediately parent which showed good general combining ability of first kind (h_i) and second kind (g_i) for seed yield/ plant and number of capsules/plant. Whereas, (P_1) recorded positively and highly significantly general line effects of both first kind (h_i) and second kind (g_i) for plant height and length of fruiting zone. ($P_4XP_5XP_1$) showed superior *per se* and significantly superior t_{ijk} effects for yield/plant, number of capsules/plant and oil percent.

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Table (1): Origin, pedigree and characteristics of five parental sesame lines.

Parental line	Origin	Pedigree	Characteristic
MGS16-1 (P_1)	Egypt 1990	Selected line from line38x line 82	Tall, branched, creame seed, short capsule, 1-capsule/ aix.
MGS 20-1 (P_2)	Egypt 1990	Selected line from NA592 x Giza 32	Medium, branched, white seed, medium capsule, 3-capsules/ aix.
Toshka1 (P_3)	Egypt 1987	unknown	Short, non-branched, creamer seed, long capsule, 3-capsules/aix.
Shandweel3 (P_4)	Egypt 1987	Selected line from Giza32 x N.A130	Medium tall, non-branched, white seed, long capsule, 3- capsules/aix.
line 78 (P_5)	Egypt 1971	Selected line from S16-4x NA48	Tall, branched, red seed, short capsule, 1 capsule/aix.

Table (2): Analysis of variance for yield and its component.

SOV	DF	Plant height (cm)	Length of fruiting zone (cm)	No. of branches/pl.	No. of capsules/pl.	Length of capsule(cm)	Seed yield/pl. (gm)	Oil %
Replication	2	5271.67**	3601.63**	9.04**	1082.22	0.13	498.28**	0.02
Genotypes (G)	34	1656.02**	1307.24**	11.41**	2918.45**	0.93**	563.78**	9.73**
Parents (P)	4	6689.17**	3266.67**	24.46**	854.93	0.77**	104.82	1.07**
Crosses (C)	29	589.78	797.52*	8.54**	1669.49	0.38**	600.25**	9.84**
P vs C	1	12444.44**	8251.43**	42.48**	47392.59**	17.43**	1341.74**	41.14**
Error	68	538.02	483.21	3.05	1177.57	0.13	68.74	0.01

*: significant at 5% **: significant at 1%

Table (3): Analysis of variance for seed yield and its components via triallel analysis.

SOV	DF	Mean squares						
		Plant height (cm)	Length of fruiting zone (cm)	No. of branches/pl.	No. of capsules/pl.	Length of capsule (cm)	Seed yield/pl. (gm)	Oil %
General line effect of first kind (h_i)	4	587.03ns	682.44ns	1.43ns	3693.44**	1.010**	493.13**	16.21**
General line effect of second kind (g_i)	4	560.85ns	749.34ns	6.71ns	1949.97ns	0.466**	279.65**	3.02**
Two line specific effects of the first kind (d_{ij})	11	631.00ns	486.19ns	18.73**	1930.48ns	0.329**	632.86**	4.25**
Two line specific effects of the second kind (S_{ij})	5	479.76ns	518.52ns	10.02**	146.07ns	0.414**	970.06**	12.06**
Three line specific effect (t_{ijk})	5	297.93ns	382.02ns	1.11ns	2174.27ns	0.013ns	246.85**	19.04**
Crosses	29	589.78ns	797.51ns	8.54**	1669.49ns	0.382**	563.78**	9.73**
Error	58	533.07	506.85	3.38	1224.17	0.129	68.75	0.01

ns: Not significant **: significant at 1%

Table (4): Estimates of general line effects and two-line specific effects for plant height and length of fruiting zone in sesame.

Lines	Plant height							Length of fruiting zone						
	General line effects		Two - line specific effect (d_{ij} , S_{ij})					General line effects		Two - line specific effect (d_{ij} , S_{ij})				
	of 1st kind (h_i)	of 2nd kind (g_i)	Lines					of 1st kind (h_i)	of 2nd kind (g_i)	Lines				
			1	2	3	4	5			1	2	3	4	5
P_1	6.31**	6.91**	------	-9.48** 7.26	4.58 -17.98	6.81** 1.59	3.27 1.34	8.24**	8.14**	---------	-4.31 5.41	13.41** -11.44**	-1.58 5.34	-1.41 -8.51**
P_2	-4.18	1.40	-9.48** 4.39	-------	2.32 -8.62**	6.13 2.57	2.08 0.08	-6.18	1.29	-4.31 6.76	-----	-4.22 -6.47	5.54 -9.68	3.96 7.93**
P_3	-1.31	-3.91	4.58 13.39**	2.32 7.95**	--------	-8.56** -15.47**	-1.27 -1.47	-3.27	-2.62	13.41** 23.38**	-4.22 16.47**	---------	-7.00 -27.36**	-4.16 -9.53
P_4	4.33	-2.00	6.81** 24.19**	6.13 2.21	-8.56** -8.91**	-------	-5.88 -15.25**	1.98	-4.37	-1.58 18.80**	5.54 -4.90	-7.00 -3.51	----------	-0.23 -5.48
P_5	-5.16*	-2.40	3.27 2.08	2.08 -8.49	-1.27 10.56**	-5.88 -1.45	-----------	-0.78	-2.44	-1.41 2.98	3.96 8.76**	-4.16 4.67	-0.23 3.87	---------

SE (h_i) = 4.35	SE (h_i-g_i) =5.33	SE (d_{ij}-d_{kl})=7.70	SE (S_{ij}-S_{kl})=9.43	SE (h_i) =4.25	SE (h_i-g_i)=5.20	SE (d_{ij}-d_{kl})=7.50	SE (S_{ij}-S_{kl})=9.19
SE (g_i) = 5.33	SE (d_{ij}) =6.67	SE (S_{ij}-S_{ji})=10.07	SE (d_{ij}-(S_{ij}-S_{ji})/2) =4.71	SE (g_i)=5.20	SE (d_{ij})=6.50	SE (S_{ij}-S_{ji})=10.07	SE (d_{ij}-(S_{ij}-S_{ji})/2) =4.60
SE (h_i-h_j) =6.88	SE (S_{ij}) =7.74	SE (S_{ij}-S_{ik})=12.65	SE (d_{ij}-S_{ij}) =9.43	SE (h_i-h_j) =6.71	SE (S_{ij})=7.55	SE (S_{ij}-S_{ik}) =12.33	SE (d_{ij}-S_{ij}) =9.19
SE (g_i-g_j)=8.43	SE (d_{ij}-d_{ik}) =10.88	SE (S_{ij}-S_{ki})=20.65		SE (g_i-g_j) =8.22	SE (d_{ij}-d_{ik})=10.61	SE (S_{ij}-S_{ki}) =20.14	

Table (5): Estimates of general line effects and two-line specific effects for number of branches/ pl. and number of capsules/pl. in sesame.

Lines	No. of branches/pl.							No. of capsules/pl.						
	General line effects		Two - line specific effect (d_{ij} , S_{ij})					General line effects		Two - line specific effect (d_{ij} , S_{ij})				
	of 1st kind (h_i)	of 2nd kind (g_i)	Lines					of 1st kind (h_i)	of 2nd kind (g_i)	Lines				
			1	2	3	4	5			1	2	3	4	5
P_1	- 0.26	- 0.37	----	- 0.19 - 0.16	- 1.18** - 1.96**	1.30** - 0.35	-0.21 2.90**	-7.59*	- 4.33	----	4.05 - 7.03	4.11 -0.97	0.30 15.17**	-11.70 - 2.30
P_2	0.09	- 0.29	- 0.19 - 0.97**	-------	0.39 1.14**	0.25 0.97**	- 0.67** 0.83**	-18.57**	-11.27	4.05 22.97**	-------	- 11.98 - 0.92	-10.32 -10.19	9.79 0.82
P_3	- 0.12	- 0.29	-1.18** 1.60**	0.39 -0.54	------	-1.13** 0.45	1.70** 2.92**	5.89	4.50	4.11 - 9.47	-11.98** - 14.75**	--------	12.70** 20.81**	- 1.45 - 1.65
P_4	0.39**	0.21	1.30** 0.89**	0.25 - 001	-1.13** - 0.84**	------	-0.27 - 0.27	7.48**	9.58**	0.30 -12.72	-10.32** - 43.48**	12.70** 32.58**	-----	4.51 12.85**
P_5	- 0.10	0.74**	- 0.21 - 0.70**	-0.66** -1.11	1.70** - 0.17	-0.27 1.15**	------	12.79**	1.52	- 11.70** - 28.35**	9.97 - 6.60	-1.45 - 2.02	4.51 35.25**	-----------

SE (h_i) = 0.35 SE (g_i) = 0.42 SE (h_i-h_j) =0.55 SE (g_i-g_j)=0.67	SE (h_i-g_i) = 0.42 SE (d_{ij}) =0.53 SE (S_{ij}) =0.62 SE (d_{ij}-d_{ik}) =0.87	SE (d_{ij}-d_{kl})=0.61 SE (S_{ij}-S_{ji})=0.82 SE (S_{ij}-S_{ik})=1.01 SE (S_{ij}-S_{ki})=1.64	SE (S_{ij}-S_{kl})=0.75 SE (d_{ij}-(S_{ij}-S_{ji})/2) =0.38 SE (d_{ij}-S_{ij}) =0.75	SE (h_i) =6.60 SE (g_i)= 8.08 SE (h_i-h_j) =10.43 SE (g_i-g_j) =12.78	SE (h_i-g_i)=8.08 SE (d_{ij})=10.10 SE (S_{ij})=11.74 SE (d_{ij}-d_{ik})=16.49	SE (d_{ij}-d_{kl})=11.66 SE (S_{ij}-S_{ji})=15.65 SE (S_{ij}-S_{ik}) =19.16 SE (S_{ij}-S_{ki}) =31.29	SE (S_{ij}-S_{kl})=14.28 SE (d_{ij}-(S_{ij}-S_{ji})/2) =7.14 SE (d_{ij}-S_{ij}) =14.28

Table (6): Estimates of general line effects and two-line specific effects for length of capsule and seed yield/pl. in sesame.

Lines	Length of capsule (cm)							Seed yield/pl. (gm)						
	General line effects		Two - line specific effect (d_{ij}, S_{ij})					General line effects		Two - line specific effect (d_{ij}, S_{ij})				
	of 1st kind (h_i)	of 2nd kind (g_i)	Lines					of 1st kind (h_i)	of 2nd kind (g_i)	Lines				
			1	2	3	4	5			1	2	3	4	5
P_1	0.10*	- 0.00	-------	- 0.21** 0.00	- 0.10** 0.15**	0.17** 0.23**	0.13** - 0.38**	- 1.92*	- 3.77**	-----	15.17** 11.30**	-12.98** - 16.37**	- 3.18* - 11.15**	- 1.84 20.46**
P_2	0.04	0.09*	- 0.21** 0.14**	--------	0.20** 0.08	0.12** - 0.06	- 0.04 - 0.26**	- 5.27**	-2.71	15.17** 4.43**	----------	2.23 4.87**	- 8.89** - 0.78	- 10.55** - 5.45**
P_3	0.19**	0.07*	-0.10** 0.00	0.20** - 0.05	------	- 0.02 0.19**	- 0.02 - 0.23**	-2.25**	1.19	- 12.98** - 21.52**	2.23 5.08**	----------	5.34** 15.99**	6.30** - 0.90
P_4	0.04	0.05	0.17** 0.03	0.12** 0.46**	-0.02 0.00	-----------	- 0.23** - 0.49**	6.53**	2.21**	- 3.18** - 4.93**	- 8.89** - 20.68**	5.34** 17.65**	----------	8.39** 5.47**
P_5	- 0.36	- 0.21**	0.13** 0.14**	-0.04 0.19**	-0.02 0.22**	- 0.23** - 0.02	---------	2.91**	3.07**	- 1.84 - 2.00	- 10.55** -12.98**	6.30** 1.45	8.39** 10.06**	----------

SE (h_i) = 0.07 SE (g_i) = 0.08 SE (h_i-h_j) =0.11 SE (g_i-g_j)=0.13	SE (h_i-g_i) =0.08 SE (d_{ij}) =0.10 SE (S_{ij}) =0.12 SE (d_{ij}-d_{ik}) =0.17	SE (d_{ij}-d_{kl})=0.12 SE (S_{ij}-S_{ji})=0.16 SE (S_{ij}-S_{ik})=0.20 SE (S_{ij}-S_{ki})=0.32	SE (S_{ij}-S_{kl})=0.15 SE (d_{ij}-(S_{ij}-S_{ji})/2) =0.07 SE (d_{ij}-S_{ij}) =0.15	SE (h_i) =1.68 SE (g_i)= 2.06 SE (h_i-h_j) =2.66 SE (g_i-g_j) =3.26	SE (h_i-g_i)=2.06 SE (d_{ij})=2.58 SE (S_{ij})=2.99 SE (d_{ij}-d_{ik})=4.21	SE (d_{ij}-d_{kl})=2.98 SE (S_{ij}-S_{ji})=3.99 SE (S_{ij}-S_{ik}) =4.89 SE (S_{ij}-S_{ki}) =7.98	SE (S_{ij}-S_{kl})=3.64 SE (d_{ij}-(S_{ij}-S_{ji})/2) =1.82 SE (d_{ij}-S_{ij}) =3.64

Table (7): Estimates of general line effects and two-line specific effects for oil percent in sesame.

Lines	Oil percent						
	General line effects		Two - line specific effect (d_{ij} , S_{ij})				
	of 1st kind (h_i)	of 2nd kind (g_i)	Lines				
			1	2	3	4	5
P_1	-0.56**	-0.32**	-----	1.84** 1.00**	0.14** 1.10**	-0.76** -0.88**	-1.46** -0.86
P_2	0.08**	0.49**	1.83** 0.15**	----------	-1.27** -0.95**	0.37** 1.06**	-0.58** -0.81**
P_3	0.22**	-0.12**	0.14** 0.57**	-1.27** -0.26**	----------	-0.19** -0.04**	1.23** -0.13**
P_4	-0.99**	0.13**	-0.76** -1.30**	0.37** 0.65**	-0.19** -0.16**	----------	0.68** 0.66**
P_5	1.24**	-0.18**	-1.46** -1.46**	-0.58** 1.71**	1.23** -0.75**	0.68** 0.70**	--------
SE (h_i) = 0.02 SE (g_i) = 0.02 SE (h_i-h_j) =0.03 SE (g_i-g_j)=0.03		SE (h_i-g_i) =0.02 SE (d_{ij}) =0.03 SE (S_{ij}) =0.03 SE (d_{ij}-d_{ik}) =0.04		SE (d_{ij}-d_{kl})=0.03 SE (S_{ij}-S_{ji})=0.04 SE (S_{ij}-S_{ik})=0.05 SE (S_{ij}-S_{ki})=0.08		SE (S_{ij}-S_{kl})=0.04 SE (d_{ij}-(S_{ij}-S_{ji})/2) =0.02 SE (d_{ij}-S_{ij}) =0.04	

Table (8): Three-line specific effects (tijk) for studied traits.

Crosses	Traits						
	Plant height	Length of fruiting zone	No. of branches/pl.	No. of capsules/pl.	Length of capsule	Seed yield/pl.	Oil %
1X2X3	-7.41*	-9.57**	0.90**	6.15	-0.22**	13.23**	2.09**
1X2X4	-6.08*	7.98*	-1.23**	-18.03**	-0.44**	10.14**	2.06**
1X2X5	-5.60*	-0.72	-0.98**	6.49	0.14*	14.86**	1.55**
1X3X2	6.61*	18.19**	-0.37	30.72**	-0.56**	-7.10**	0.45**
1X3X4	0.10	15.75**	-1.00**	-13.39*	-0.05	-11.16**	-1.53**
1X3X5	10.41**	12.50**	-2.91**	-4.81	0.38**	-23.57**	1.01**
1X4X2	-2.29	-14.69**	3.22**	28.19**	0.10*	7.15**	-2.13**
1X4X3	21.03**	8.98*	1.11**	-21.70**	-0.24**	-9.42**	-0.40**
1X4X5	7.22*	5.21	-0.61*	0.30	0.70**	-9.01**	0.04**
1X5X2	-3.77	-7.40*	-0.83**	8.90*	0.06	2.06*	-3.26**
1X5X3	6.72*	3.90	1.00**	-17.24**	0.11*	1.55	-1.09**
1X5X4	11.92**	5.70*	-0.39	-29.92**	-0.02	-9.92**	-0.61**
2X3X1	-14.99**	-24.17**	1.34**	-7.39	0.14*	14.14**	-1.96**
2X3X4	13.61**	5.52*	0.57*	-28.71**	-0.10*	-5.54**	-0.74**
2X3X5	5.51*	4.49	-1.37**	-7.47	0.69**	-3.61*	-0.68**
2X4X1	-7.10	-8.84*	0.74*	1.94	-0.00	-1.39	0.63**
2X4X3	11.50**	14.13**	1.62**	-16.27**	-0.04	-5.57**	0.33**
2X4X5	13.31**	7.86*	-1.70**	-18.53**	0.57**	-20.26**	0.84**
2X5X1	-12.49**	-14.68**	0.50*	28.97**	0.05	-3.91**	1.55**
2X5X3	18.52**	16.38**	-1.09**	-6.57	-0.39**	-17.51**	-0.40**
2X5X4	-0.90	8.81*	-0.90**	-3.99	0.07	-9.83**	-2.53**
3X4X1	-21.30**	-23.37**	0.24	22.94**	-0.02	10.83**	2.04**
3X4X2	-11.69**	-8.23*	-1.57**	26.97**	-0.22**	7.70**	-2.17**
3X4X5	0.65	2.75	-2.13**	4.01	0.31**	1.32	-042**
3X5X1	-21.36**	-17.79**	1.98**	7.91	-0.04	12.01**	1.83**
3X5X2	-6.17*	-13.95**	3.38**	26.15**	-0.02	14.45**	-010**
3X5X4	7.61*	13.57**	0.24	-31.64**	-0.17**	-2.76*	1.62**
4X5X1	-22.47**	-18.13**	0.11	2.40**	-0.12*	17.75**	0.14**
4X5X2	-1.07	9.17*	-0.06	27.02**	-0.60**	11.32**	0.84**
4X5X3	0.96	0.60	0.22	-3.41	-0.15**	2.04	1.01
t_{ijk} t_{ijk}-t_{ikj}	5.44 9.43	5.31 9.19	0,43 0.75	8.25 14.28	0.08 0.15	2.10 3.64	0.02 0.04

Table (9): Additive and non-additive (dominance and epistasis).

Traits	Genetic variance				
	σ^2A	σ^2D	σ^2AA	σ^2AD	σ^2 DD
Plant height	1306.8	2440.7	-1728.0	-2538.6	1542.1
Length of fruiting zone	795.9	1677.1	-1447.3	-1468.7	774.3
Number of branches/pl.	-15.6	3.2	8.0	-15.5	-4.4
Number of capsules/pl.	3052.8	6406.6	-4723.6	-3242.0	3366.7
Capsule length	-0.52	-0.12	0.32	-0.56	-0.27
Seed yield/pl.	-2022.7	-842.3	1457.6	480.7	-1066.7
Oil percent	-19.1	-13.1	14.3	7.5	-11.1