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RESEARCH ARTICLE

Heterosis in relation to combining ability studies in sesame (*Sesamum indicum* L.)

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Abstract

For the evaluation of combining ability and heterosis in the sesame Line x Tester design was used. The experiment was conducted during 2018 and 2019 at University of Agriculture Faisalabad (UAF). During 2018 a total of 21 crosses were developed by using seven lines and 3 testers and during 2019 seeds of parents and their twenty-one hybrids were sown in a randomized complete block design (RCBD) with three replications. Presence of variability among all the parents was observed. Highly significant differences among all the genotypes i.e. parents, crosses and parent vs. crosses were observed. Effects of both GCA and SCA were significant for all the studied parameters. Variances due to GCA and SCA were indicating the non-additive gene action for all the traits due to less value of GCA variances. The ratio of GCA / SCA was less than the unity for the seed yield reflecting the non-additive types of gene action, having the maximum influence environment on tradition of this trait. Two parents PB4 and PB10 were found to be best general combiners for seed yield. However, the cross PB4 × PB11 had the most desirable effects of SCA for the most of studied traits while PB6 × PB10 for seed yield. The cross PB6 × PB10 showed the maximum heterosis percentages for seed yield.

Keywords: Sesame, line × tester, combining ability, yield, heterosis

Introduction

Sesame (*Sesamum indicum* L.), a well-known as well as the most important oilseed crop, commonly known as 'til' in Pakistan, is one of the major and prehistoric crop which belonged to family Pedaliaceae (Ashri, 1998) of Tubeflorae order (Nayar, 1976). It was primarily cultivated in the Africa, after that evidences were reported from the tropical as well as the subtropical regions in the world. It has the unique feature about its cultivation that it can be easily grown in both (well-watered as well as in water stress) types of environment not only in Pakistan but also throughout the remaining world as an annual crop (Peter, 2004). Sesame offers the several benefits by the unique feature of faster development and growth rate, also as a short duration crop grown in any type of soil conditions. The potential of sesame cultivation is much higher in Pakistan. Although the production of oilseeds can be easily increased with the help of sesame but it fails due to its low level of productivity. This problem mainly caused by the differences in product's potential and its actual yield. Therefore, it is very essential to evaluate the local as well as the used germplasm of sesame in the crossing program aiming to expand and improve the seed yield. Different techniques including combining ability and heterosis are very helpful tools in the identification of desirable parents for the production of the best recombinants (Aye 2018). Many studies have been reported throughout the world on these techniques in sesame. Karande *et al*., (2018) reported significant and maximum percentage of heterosis among genotypes of sesame for yield related parameters. Heterosis is superiority of newly developed hybrid over both of the portents. Combining ability analysis is useful design with the plant breeders in the formulation of an effective breeding strategy to develop the superior and well-defined strains of the crops. Line × tester investigation is a significant breeding approach to get information of changed trails that are inherently organized and direct various essential characters. Bhalodiya *et al*., (2019) found two parental genotypes used in their experiment as the best general combiner and about eight cross combination as the specific combiners for seed yield. Deshmukh *et al.*, (2019) exhibited that a maternal genotype AT-231 and paternal genotype KMR-69 were observed as the best combiners for seed yield. Among crosses one cross RT-54 × KMR-69 showed as the best specific combiner. Navaneetha *et al*., (2019) reveald the presence of genetic variability in the sesame for the seed yield in significant manners and declared that these crosses and parental genotypes have the potentail to increase the total yield of the sesame seed. These genotypes could be a better option for the generation of new breeding palns and production of high quality seed for better yield of sesame. Till date in most part of the world varieties of to the fact that non avalability of CMS system. The objectives of this experimental study were to find out the best combiners regarding the general and specific means among different parents as well as crosses, second to estimate the value of heterosis percentages over relative as well as better parents as well as to identify the high heterotic hybrids and to determine the kind of gene action which triggered the yield related agronomic parameters.

Material and methods

This said study was conducted during successive crop seasons of 2018 and 2019 in the field area of Department of the Plant Breeding & Genetics, University of Agriculture, Faisalabad, Pakistan. Seven maternal genotypes (PB2, PB3, PB4, PB5, PB6, PB7 and PB8) and three paternal genotypes of sesame (PB9, PB10 and PB11) were exploited during this study. Seeds of ten different genotypes of sesame were sown in the field area, during the 1st year of the study. Crossing was done in line × tester mating design by selecting seven genotypes of sesame as lines and three as the testers through the process of manual emasculation and pollination. After harvesting, cross seed was collected and stored in normal environmental conditions for the next season sowing purpose. During the 2nd year of the study, stored cross seeds of twenty one hybrids along with their parent were sown in the field under RCBD in three replications. Proper managements regarding watering and normal field conditions were kept during the whole process of growth from the stage of germination up to maturation of the plants. At the maturity level, five well-guarded plant were selected randomly from each of the replication for the purpose of data recording of following agronomic parameters: Plant height, branches/plant (primary), capsules / plant, seed yield / plant, 100-seed weight, and total seed weight/plant.

Statistical Analyses

All the recorded data were analyzed through the different statistical techniques i.e., analysis of variance (ANOVA) for the estimation of the mean performances of each entry (Steel *et al*., 1997), line × tester analysis (Kempthorne, 1957) for the detection of variances and effects due to general combining ability (GCA) along with the specific combining ability (SCA). Estimation of heterosis over the mid- as well as the better-parent was done by the deviation of hybrids expressed in percentage (Falconer *et al*., 1996).

Results and discussion

Analysis of variance indicated the existence of highly momentous variation in all genetically different genotypes of the sesame. The overall results obtained from the analysis of variance for the combining ability of ten diverse genotypes of sesame for all studied agronomic traits are shown in the Table 1. The results demonstrated the existence of highly significant differences among lines, testers (except primary branches) and line x tester interactions for all the agronomic parameters studied. The manifestation of highly significant differences in the variance for the interaction in line × tester, revealed the importance of the specific combining ability. On the other side, the assessments of the variances due to GCA and SCA were more useful for the understanding of gene action types as well as for getting knowledge about which one of the breeding method could be followed to improve the crop.
In this study, the calculated magnitude of GCA variances was very lower than SCA variances for all of the parameters and hence their GCA/SCA ratio was less than unity, which revealed the preponderance of the non-additive type of the gene action for all of the quantitative agronomic traits. Azeez and Morakinyo (2014) found non-additive gene action for all of the parameters studied especially for the seed yield in sesame. Hence, the improvement of the yield related agronomic parameters could be accomplished through the selection of the devoted generations. Since the lower GCA values attributed to the non-additive action of genes (Saxena and Bisen, 2017), the formation of hybrids plays an important role in the maintenance of breeding programs and improvement in the yield of the sesame.
Combining ability considered as the main pillar which provide information of both parents as well as the hybrids necessary for the selection of the breeding techniques (Dhillon, 1975).

Table 1: Analysis of variance for combining ability for some agronomic traits in sesame

Source of variation	DF	Plant height	No. of primary branches	No. of capsules /plant	No. of seeds in capsules	100-seeds weight	Seed yield/plant
Replication	2	0.4603	0.3284	4.0903	540.8700	0.00001	0.0026
Crosses	20	757.0133**	7.5572**	271.3331**	738161.5319**	0.0106**	6.0417**
Lines	6	555.2486**	13.6260**	335.0132**	1050414.3634**	0.0155**	7.5884**
Testers	2	529.9756**	0.4772	121.2569**	694120.9415**	0.0235**	9.6970**
L × T	12	895.7354**	5.7029**	264.5058**	589375.2146**	0.0060**	4.6592**
Error	40	0.9909	0.1784	2.6455	360.495	0.0001	0.0033
GCA	9	-3.6126	0.0483	0.1778	3874.6436	0.0001	0.036
SCA	20	298.2482	1.8415	87.2868	196338.24	0.002	1.5519
GCA/SCA		-0.012113	0.02623	0.00204	0.019735	0.05	0.0231974

* Significant at P = 0.05 ** Significant at P = 0.01 D.F = Degree of Freedom

Line PB4 and tester PB10 showed the maximum and highly significant value of GCA in positive manners for the most of the studied agronomic traits (Table 2). However, other maternal genotypes namely PB6, PB3 and PB8 exhibited the highest GCA values for the parameter of plant height also 100-seed weight and primary branches respectively. Paternal genotype (PB11) indicated highly significant results for the plant height as well as primary branches. Azeez and Morakinyo (2014) and Bhalodiya *et al.,* (2019) indicated the presence of positive and significant results regarding the above mentioned traits in sesame for their GCA effects.

The specific combining ability is basically a fine aberration from the observed performance calculated from the values of general combining ability (Allard, 1960). Cross combination PB4 × PB11 showed the maximum and positive values of SCA effects in highly significant way for the most of the characters i.e., plant height, number of capsules and number of seeds, followed by PB5 × PB9 (primary branches), PB7 × PB11 (100-seed weight) and PB6 × PB10 (seed yield) (Table 3). Eswaran *et al*., (2019) and Wadikar *et al*., (2019) presented the results regarding the SCA effects of seed yield and other related characters in positive as well as significant manners. The crosses with positive and significant SCA effects could be used in the future heterotic breeding programs to obtain the desirable improvement in the various characters of sesame crop. The contribution of all of the parents as well as their hybrids concerning to the total variance is presented in the Table 4. From the values, it was concluded that the LxT interactions contributed the more towards the entire variance for all of the agronomic parameters studied except the number of the main (primary) branches and the weight of 100-seeds, where the rate of contribution of the maternal genotypes (female parent) was relatively higher. Out of 100%, line × tester interaction contributed more than 50 % for plant height (70.99%), number of capsules/plant (58.49%) while the participation of lines and testers for the plant height (22% and 7%), number of capsules (37.04% and 4.47%) respectively. The comparison among the parents indicated that the contribution of the maternal genotypes (lines) were greater for the plant height, primary branches, capsules/plant, seeds yield/pant, 100-seed weight and the total seed weight to the entire variance.

Table 2: General Combining Ability effects of parents for some agronomic traits in sesame

Sr. No.	Parents	Plant height (cm)	No. of primary branches	No. of capsules / plant	No. of seeds in capsules	100- seeds weight (g)	Seed yield/ plant
	Lines (females)						
1	PB2	-11.71**	-0.72 **	-6.49 **	-87.81 **	-0.01*	-0.31**
2	PB3	-3.95**	1.81 **	-1.08	-310.03 **	0.02**	-0.80**
3	PB4	5.66**	0.45 **	9.04 **	695.50 **	0.00	1.70**
4	PB5	-5.28**	0.45 **	-3.83 **	-303.81 **	-0.00	-0.81**
5	PB6	12.36**	-0.77 **	7.92 **	117.19 **	0.04**	0.76**
6	PB7	2.02**	-1.94 **	-4.44 **	-71.81 **	0.02**	-0.10**
7	PB8	0.89*	0.73 **	-1.13 *	-39.25 **	-0.09**	-0.43**
	S.E	0.3318	0.1408	0.5422	6.3289	0.0031	0.0193
	Testers (male)						
8	PB9	-5.75**	-0.13	-2.72 **	-207.52 **	-0.03 **	-0.72**
9	PB10	2.23**	-0.03	1.84 **	131.26 **	0.04 **	0.63**
10.	PB11	3.52**	0.16	0.88 *	76.26 **	-0.01 **	0.10**
	S.E	0.2172	0.0922	0.3549	4.1432	0.0021	0.0126

* Significant at P = 0.05 ** Significant at P = 0.0

Table 3: Specific combining ability effects of hybrids for some agronomic traits in sesame

Sr. No.	Crosses	Plant height (cm)	No. of primary branches	No. of capsules / plant	No. of seeds in capsules	100-seeds weight (g)	Seed yield/ plant (g)
1	PB2×PB9	4.62 **	-1.12 **	-1.87	96.63 **	0.01	0.33 **
2	PB2×PB10	3.53 **	-0.31	-2.34 *	-173.81 **	0.01	-0.47 **
3	PB2×PB11	-8.15 **	1.42 **	4.21 **	77.19 **	-0.02 **	0.15 **
4	PB3×PB9	4.03 **	1.19 **	4.38 **	298.18 **	-0.02 **	0.92 **
5	PB3×PB10	11.05 **	-1.00 **	3.33 **	-196.59 **	-0.02 **	-0.79 **
6	PB3×PB11	-15.08 **	-0.19	-7.71 **	-101.59 **	0.04 **	-0.14 **
7	PB4×PB9	-6.08 **	0.55 *	-12.14 **	-605.43 **	-0.01	-1.51 **
8	PB4×PB10	-30.07 **	-0.72 **	-3.54 **	-247.12 **	0.03 **	-0.23 **
9	PB4×PB11	36.15 **	0.17	15.68 **	852.55 **	-0.02 **	1.74 **
10	PB5×PB9	11.36 **	1.97 **	14.13 **	271.29 **	0.03 **	0.90 **
11	PB5×PB10	5.71 **	-1.39 **	-5.92 **	-82.48 **	-0.02 **	-0.45 **
12	PB5×PB11	-17.08 **	-0.58 *	-8.21 **	-188.81 **	-0.01 *	-0.45 **
13	PB6×PB9	-5.77 **	-1.14 **	-8.12 **	-334.71 **	-0.01 *	-1.21 **
14	PB6×PB10	0.24	1.92 **	11.08 **	676.19 **	0.02 **	2.36 **
15	PB6×PB11	5.53 **	-0.77 **	-2.96 **	-341.48 **	-0.01 *	-1.15 **
16	PB7×PB9	-12.94 **	0.02	-0.92	-48.04 **	-0.02 **	-0.18 **
17	PB7×PB10	12.24 **	-0.00	1.02	13.85	-0.07 **	-0.44 **
18	PB7×PB11	0.70	-0.02	-0.10	34.19 **	0.09 **	0.63 **
19	PB8×PB9	4.78 **	-1.48 **	4.52 **	322.07 **	0.02 **	0.77 **
20	PB8×PB10	-2.70 **	1.50 **	-3.62 **	9.96	0.04 **	0.02
21.	PB8×PB11	-2.08 **	-0.02	-0.90	-332.04 **	-0.06 **	-0.78 **
	S.E of SCA effects	0.5747	0.2438	0.9391	10.962	0.0054	0.0334

* Significant at P = 0.05 ** Significant at P = 0.01

Table 4: Proportional contribution of sesame lines, testers and their interactions to total variance

Characters	Contribution (%)		
	Line (L)	**Tester (T)**	**L × T**
Plant height	22	7	70.99
Number of primary branches	54.09	0.63	45.28
Number of capsule	37.04	4.47	58.49
Number of seed	42.69	9.4	47.91
100-seed weight	43.84	22.25	33.9
Total seed weight	37.68	16.05	46.27

Heterosis considered as the technique which enhance the yield of the cross as well as the self-pollinated crops. Results obtained from the heterotic study among the crosses over the relative (mid) as well as the heterobeltiosis (better parent) for all of the studied parameters presented in the Tables 5. It was clearly noticed that all crosses showed a great variation in values ranging from negative to positive but in highly significant manners over both types of the heterosis. In case of heterosis and heterobeltiosis, ranges from for plant height -23.21 to 27.20% and -29.75 to 25.70% , for number of the primary branches (-55.00 to 74.31% and -61.86 to 50.00%), number of the capsules (-75.87 to 122.82% and -81.25 to 47.12%), number of the seeds (-93.33 to 79.52% and -93.66 to 32.88%), 100-seed weight (-53.95 to 45.10 and -53.95 to 44.16%), seed yield (-94.49 to 146.69% and -95.05 to 93.78%), respectively.

Out of twenty one crosses 15 hybrids identified (RH) as significantly negative for seed yield per plant whereas four hybrids identified as significantly expressing hybrid for high seed yield per plant. Out of twenty one crosses 18 hybrids identified (Hb) as significantly negative for seed yield per plant whereas three hybrids identified as significantly expressing hybrid for high seed yield per plant .The crosses namely PB4 × PB11 and PB6 × PB10 showed the maximum percentage of the heterosis for the plant height and yield of seed respectively. Therefore, the results obtained from these crosses indicated they have the ability to produce high yielding components and can become the best option in future for the improvement and production of high yielding sesame genotypes. Heterotic effects of sesame for the different parameters in positive and significant manners have been submitted by the Petal *et al.,* (2016) and Aye (2018) related to the seed yield. Bhalodiya *et al.,* (2019) recorded -39.76% to 68.28% heterobeltiosis for seed yield. Although Gangappa *et al.,* (2006) found comparatively the low heterotic values for the some related components. This may be due to the variations in the genetic composition of both of the parental genotypes used by them in their experiments which also transfer to the resulting hybrids.

Here we would like to emphasis that the results of the research revealed higher chances of producing heterotic sesame hybrids that combined good for the highest yield per plant, number of capsules, 100-seed weight and for number of seeds suggests that heterosis breeding and/or hybridization could be one of the breeding methods in sesame to produce high heterotic hybrids that combine well with the traits to develop potential recombinant pure lines from segregating generations.

Conclusion

The non-additive gene action appeared with major role in the inheritance of all the studied agronomic parameters in sesame. Most of the hybrids showed higher mean values as compared to their parents for the most studied characters. Parent line PB4 could be considered as the best general combiner for the seed yield. However, the cross PB6 × PB10 exhibited the desirable effects of SCA for the seed yield as well as the highest heterosis percentage. It is recommended that the cross could be advanced in order to produce desirable plant type in the segregating generation. These can be the best approach for future breeding plans for the high yielding varieties of sesame. The production of such new hybrid seeds providing the positive hope to the sesame breeders for the profitable improvements in the sesame varieties and increase production. Also the identified high heterotic hybrids could be advanced either by single seed decent menthod or by line to progeny method to produce the desirable plant type in the sesame.

Table 5. Heterosis over the relative (RH) and heterobeltosis (Hb) for yield and yield related parameters in sesame

Sr. No.	Crosses	Plant height		No. of primary branches		No. of capsules / plant		100-seeds weight		Seed yield/plant		No. of seeds in capsules	
		RH	Hb	RH	Hb	RH	Hb	RH	Hb	RH	RH	Hb	Hb
1	PB2 × PB9	-15.58**	-18.42**	-55.00**	-61.86**	-75.87**	-80.10**	-22.34**	-29.81**	-80.11**	-72.51**	-75.00**	-80.99**
2	PB2 × PB10	-9.53**	-13.74**	-31.29**	-52.54**	-48.13**	-67.28**	0.55	-7.07**	-47.74**	-57.08**	-69.19**	-60.82**
3	PB2 × PB11	-18.35**	-20.79**	-11.24*	-33.05**	-50.90**	-52.00**	-18.44**	-29.81**	-68.95**	-63.97**	-71.63**	-77.76**
4	PB3 × PB9	-9.65**	-11.87**	53.73**	25.61**	-2.48	-12.90*	8.05**	-5.05	-74.49**	-77.99**	-78.82**	-75.11**
5	PB3 × PB10	2.36**	-1.50*	60.82**	50.00**	74.92**	32.31**	27.15**	26.32**	-74.55**	-80.41**	-85.04**	-79.86**
6	PB3 × PB11	-16.94**	-18.66**	60.71**	50.00**	-61.68**	-71.50**	-26.80**	-31.73**	-81.36**	-72.36**	-78.58**	-84.84**
7	PB4 × PB9	-9.15**	-10.56**	5.33	-3.66	-41.10**	-43.95**	7.94**	3.03	1.68	-5.28**	-38.79**	-34.64**
8	PB4 × PB10	-19.49**	-21.83**	15.04*	-4.41	83.33**	32.59**	-12.05**	-18.89**	26.44**	51.00**	20.83**	-7.30**
9	PB4 × PB11	27.20**	25.70**	21.87**	14.71*	65.38**	29.00**	-18.41**	-21.15**	-70.28**	-64.75**	-73.77**	-78.77**
10	PB5 × PB9	-2.55**	-2.97**	57.38**	17.07**	36.99**	20.97**	-12.24**	-13.13**	-51.72**	-51.63**	-53.61**	-53.11**
11	PB5 × PB10	0.56	-0.43	34.12**	26.67**	-21.38*	-40.00**	-14.45**	-23.71**	-91.03**	-89.97**	-92.74**	-92.93**
12	PB5 × PB11	-16.87**	-17.55**	38.00**	15.00*	-74.58**	-81.25**	-7.87**	-21.15**	-94.49**	-93.33**	-93.66**	-95.05**
13	PB6 × PB9	-4.82**	-6.94**	-39.73**	-46.34**	-37.86**	-44.23**	29.48**	13.13**	146.69**	79.52**	32.88**	93.78**
14	PB6 × PB10	6.57**	2.78**	50.46**	28.12**	122.82**	47.12**	17.33**	15.79**	-58.90**	-67.46**	-67.69**	-60.28**
15	PB6 × PB11	9.38**	7.35**	-16.13*	-18.75**	-21.63**	-30.25**	-18.23**	-28.85**	-84.85**	-76.53**	-82.84**	-89.79**
16	PB7 × PB9	-23.21**	-29.75**	-34.33**	-46.34**	-48.51**	-54.84**	-10.23**	-20.20**	7.56*	18.20**	10.47**	-5.11
17	PB7 × PB10	-0.08	-9.75**	-7.22	-13.46	32.40**	1.60	45.10**	44.16**	9.18**	-29.03**	-49.49**	-19.86**
18	PB7 × PB11	-8.43**	-15.93**	-16.07*	-21.67**	-43.78**	-58.75**	-42.22**	-50.00**	-66.74**	-41.85**	-42.65**	-71.28**
19	PB8 × PB9	-7.87**	-12.06**	-20.55**	-29.27**	-19.48**	-25.43**	-9.71**	-20.20**	-20.62**	-20.85**	-39.95**	-35.47**
20	PB8 × PB10	-6.28**	-11.73**	74.31**	48.44**	-11.00	-40.21**	-53.95**	-53.95**	-91.20**	-80.64**	-81.21**	-91.29**
21	PB8 × PB11	-6.55**	-10.46**	27.42**	23.44**	-43.56**	-51.25**	-53.95**	-53.95**	-91.20**	-80.64**	-81.21**	-91.29**

* Significant at P = 0.05   ** Significant at P = 0.01

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