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Combining ability and gene action over environments in Sesame (*Sesamum indicum* L.)

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Abstract
Five lines and ten testers were crossed in line x tester manner to develop 50 F_1 hybrids. ANOVA showed significant differences among the environments and genotypes for all characters. Greater stability was observed in gca values for all the characters. σ^2GCA/ σ^2SCA ratio revealed preponderance of additive gene action for seed yield per plant, capsules per plant, capsule length and 1000-seed weight. The preponderance of non-additive gene action was recorded for the rest, suggesting the importance of both additive and non-additive gene actions for inheritance of component traits. The parent G.Til-3 was found good general combiner for all the traits except earliness characters where Phule Til 1 manifested good gca for days to 50% flowering and days to maturity. Among the male parents, JLS-116, AKT-101, JLS-9707-2 and JLS-110-12 were good general combiners for seed yield per plant as well as most of the yield components. The crosses G.Til-3 x AKT-64, Phule Til No.1 x JLS-116 and Patan-64 x AKT-101 manifested significant, higher and desirable sca effect for seed yield per plant as well as important yield components.
Key words: sesame, hybrid, combining ability, gene action.

Introduction

Sesame (*Sesamum indicum* L.) is one of the ancient oilseed crops cultivated in India. It is having the highest oil content (46-54%), dietary energy (6355 kcal/kg) along with rich source of protein (20-28%), calcium, phosphorous, oxalic acid contents etc. The excellent nutritional, medicinal, cosmetic and cooking qualities of this oil has made it queen of oils. The crop is cultivated in almost all parts of the country as sole or mixed crop during *kharif, semi- rabi, rabi* and *summer* seasons and raised over an area of about 16.78 lakh hectares with an annual production of about 7.14 lakh tones and productivity of 426 kg/ha, (Anonymous,2015). However, the average productivity is very low and stagnant, which evidently indicates the potentiality of this crop for improvement in yield through various breeding tools.

The varietal improvement of sesame during the past has been oriented towards development of pureline varieties through conventional breeding. During recent years developing hybrid varieties through heterosis breeding are being attempted (Duhoon,2004). However, heterosis is still an untapped resource for sesame improvement in terms of yield and its components. The success of heterosis breeding programme largely depends on the efficiency of choosing appropriate parents of good genetic potential. In the present investigation attempts have been made to evaluate 15 parents and 50 hybrids through line x tester analysis to determine gene action and the magnitude of the general and specific combining ability effects of parents and hybrids for different characters.

Material and Methods

The present investigation was conducted at N.M.College of Agriculture, NAU, Navsari during *summer* 2012 and *rabi* 2012-13. The experimental material for this study consisted of five lines *viz.,* Gujarat Til-1, Gujarat Til-2, Gujarat Til-3, Phule Til No.1, Patan-64 and ten testers *viz.,* JLT-7, JLS-116, JLS-206-10, JLS-110-12, JLS-9707-2, JLT-408, JLT-408-2, AKT-64, PKV-NT-11 and AKT-101. These five lines and ten testers were crossed in a line x tester manner resulting in 50 hybrids. Three complete sets of 65 entries comprising 15 parents and 50 hybrids were evaluated in Randomized Block Design replicated three times during *rabi* 2012-13 at three locations *viz.,* NMCA, Navsari, ARS, Achhalia and RSRS, Vyara in Gujarat state. The parents and F_1s were represented by a single row plot of 2.25 m length with a spacing of 45 cm between rows and 15 cm between plants in a row. Observations were recorded on five random, normal and competitive plants for nine parameters *viz.,* days to 50% flowering, plant height (cm.), branches per plant, capsules per plant, length of capsule, days to maturity, seed yield per plant (g), seeds per capsule and 1000-seed weight (g). Mean values were used for analysis of variance for each character in each environment as well as pooled over environments as per the procedure described by Panse and Sukhatme (1978).

The variation among hybrids was further partitioned into sources attributable to general and specific combining ability components in accordance with the procedure developed by Kempthorne (1957) for line x tester analysis. All

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the characters were analyzed separately for each environment. Further, in order to have information concerning the influence of genotype x environment interactions on combining ability estimates, pooled analysis of combining ability over the environments was conducted.

Results and Discussion

Analysis of variance showed significant differences among the environments and genotypes for all the nine characters *viz.,* days to 50% flowering, plant height, branches per plant, capsules per plant, length of capsules, days to maturity, seed yield per plant, seeds per capsule and 1000-seed weight (Table 1). Analysis of variance for combining ability over the environments revealed that the mean squares due to females and males were significant for all the characters suggesting that both the females and males had considerable general combining ability (gca) and contributed towards additive genetic variance. Highly significant mean squares due to females x males were also manifested by all the characters studied which reflects its significant contribution in favor of specific combining ability and non additive variance. Pooled analysis of variance further revealed non-significant interaction of females and males with environments for all the characters except 50% flowering suggesting that, in general, females as well as males were non sensitive to diverse environmental conditions and the estimates of general combining ability were less affected by environments. This was further endorsed by non significant estimates of σ^2 females x environments and σ^2 males x environments for all the characters. The interaction mean squares due to (females x males) x environments were significant for all characters except days to 50% flowering and 1000-seed weight indicating that estimates of specific combining ability variances were largely influenced by environments.

Combining ability analysis is a powerful tool to identify the parents having good potential to transmit desirable characteristics to their progenies and also to help in sorting out promising crosses for seed yield and its components. At the same time, it also elucidates the nature of gene action involved in the inheritance of characters. The general combining ability is attributed to additive genetic effects and it is theoretically fixable. On the other hand, specific combining ability is attributable to non-additive gene action, which may be due to dominance or epistasis or both and is non-fixable in nature. The presence of non-additive genetic variance is the primary justification for initiating the hybrid breeding programme (Cockerham, 1961). Therefore, non conventional breeding methods such a biparental mating and/or diallel selective mating which accumulates favorable genes in homozygous state or helps in breaking the linkage blocks are advisable in such situations. In the present study ratio of σ^2GCA/σ^2SCA ratio revealed preponderance of additive gene action for seed yield per plant, capsules per plant, capsule length and 1000-seed weight. The preponderance of non-additive gene action was evident for rest of the characters suggesting the importance of both additive and non additive gene actions for inheritance of these traits. Role of additive gene action for control of seed yield per plant was also reported by Pushpa *et al.*, (2002) and Ratna Babu *et al.*, (2004), while Patel *et al.*,(2013) and Sreeja and Chidambaram (2013) observed non additive gene action governing this character. The preponderance of additive gene action for control of capsules per plant, capsule length and 1000-seed weight was observed by Pushpa *et al.* (2002) and Rajput and Kute (2012). Presence of non additive gene action for control of earliness characters *viz.,* days to 50% flowering, days to maturity and seeds per capsule was observed by Sreeja and Chidambaram (2013) and Praveenkumar *et al.* (2012). While Sakila *et al.* (2000) and Vidhyavathi *et al.* (2005) observed its role for branches per plant and seeds per capsule.

Females and males recognized as good general combiners for days to 50% flowering were found to have good gca effects for days to maturity also (Table 2). Additionally, the male parent JLS-206-10 recorded maximum significant negative gca effect for maturity in pooled analysis over environments. The female parent G.Til-3 and male parents JLS-116, JLS-110-12, JLS-9707-2, AKT-101 were found to be a good general combiners for seed yield per plant across the environments by exhibiting significant positive gca effects. The female G.Til-3 and male JLS-116 exhibited significant positive gca effects for plant height, branches per plant, capsules per plant, capsule length, seeds per capsule and 1000-seed weight and can be treated as good general combiners. With respect to plant height and branches per plant Patan-64, JLS-206-10, AKT-101; while for capsule length and 1000-seed weight only AKT-101 additionally exhibited significant positive gca effects. Whereas, G.Til-2 exhibited poor general combining ability for most of the characters. Overall the female G.Til-3 and males JLS-116, JLS 110-12 and AKT-101 were found to be good general combiners for seed yield per plant as well as two or more important yield contributing traits thereby classifying these parents as sources of favorable genes for higher productivity.

The parents involved in present investigation were classified as good, average and poor combiners based on estimates of gca effects across the environments. None of the parent was observed to be good general combiner simultaneously for all

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the characters. It is desirable to seek for parental lines with high gca effects and low sensitivity to environmental variation in a crop improvement programme. In the present study, majority of the genotypes exhibited consistency in the magnitude and direction of the gca effects over the environments, thereby suggesting that such genotypes would be ideally suited for inclusion in population improvement programmes for developing hybrids and also for hybridization studies.

The sca is the deviation from the performance predicted on the basis of gca. The sca effect is an important criterion for the evaluation of hybrids. The crosses exhibiting significant desirable sca effects for various traits involved either good x good, good x poor or poor x good combining parents (Table 3). It reveals that the crosses involving high sca effects did not always involve the parents with high gca effect, thereby suggesting the importance of inter-allelic interaction. Corresponding to these findings Solanki and Gupta (2001) reported that it is an indication of involvement of non additive type of gene action which is non fixable. Nevertheless, it was observed that at least one good general combining parent was involved in desirable specific combination. From the present investigation the crosses, *viz.*, G.Til-3 x AKT-64, Phule Til No.1 x JLS-116 and Patan-64 x AKT-101 manifesting significant, higher and desirable sca effects for seed yield per plant and some of its important component traits might be exploited commercially. However, the stability of performance of these crosses across the environments is indispensable for making their commercial cultivation successful and beneficial.

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Table 1. Analysis of variance for combining ability pooled over environments for different characters in sesame

Source of Variation	d.f.	Characters								
		Days to 50% flowering	Plant height	Branches per plant	Capsules per plant	Capsule length	Days to maturity	Seed yield per plant	Seeds per capsule	1000-seed weight
Environments	2	662.57**	2198.32**	16.628**	3926.44**	0.379**	749.64**	63.64**	1248.60**	4.698**
Replications/Environments	6	4.37	33.26	0.051	10.24	0.015	7.73	0.58	30.70	0.006
Females (F)	4	44.71*	985.08**	1.466**	1224.53**	0.732**	79.02**	112.22**	504.19**	2.413**
Males (M)	9	34.94*	593.07**	1.203**	415.24**	0.339**	70.54**	21.65**	398.33**	0.634**
Females x Males (F x M)	36	12.72**	129.45**	0.329**	111.39**	0.081**	18.36**	6.52**	104.19**	0.169**
Females x Environments	8	9.74**	34.93	0.208	48.85	0.024	14.96	1.59	37.55	0.085
Males x Environments	18	8.72**	37.18	0.080	46.76	0.023	12.76	0.94	23.61	0.174
(F x M) x Environments	72	3.43	60.88**	0.127**	55.91**	0.032**	9.60*	1.66**	36.18**	0.106
Pooled Error	294	3.84	14.31	0.036	11.75	0.014	6.79	0.27	13.77	0.015
Variance components										
σ^2 Environments		3.38	11.20	0.085	20.08	0.002	3.81	0.33	6.32	0.024
σ^2 Females		0.45	10.79	0.016	13.49	0.008	0.80	1.24	5.43	0.027
σ^2 Males		0.69	12.87	0.026	8.99	0.007	1.42	0.48	8.51	0.014
σ^2 GCA		0.53	11.49	0.019	11.99	0.008	1.01	0.99	6.46	0.022
σ^2 SCA		0.96	12.86	0.033	11.17	0.007	1.30	0.70	9.87	0.017
σ^2 GCA/σ^2SCA		0.55	0.89	0.58	1.07	1.042	0.78	1.42	0.65	1.31
σ^2 Females x Environments		0.19	0.71	0.005	1.27	0.000	0.28	0.04	0.74	0.002
σ^2 Males x Environments		0.31	1.57	0.003	2.39	0.001	0.40	0.05	0.55	0.011
σ^2 GCA x Environments		0.23	0.99	0.005	1.64	0.000	0.32	0.05	0.67	0.005
σ^2 SCA x Environments		-0.22	15.73	0.031	15.02	0.006	0.97	0.47	6.93	0.030

* and ** = Significant at 5% and 1% levels of probability, respectively.

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Table 2. Estimates general combining ability of parents pooled over environments for different characters in sesame

Parents	Days to 50% flowering	Plant height	Branches per plant	Capsules per plant	Capsule length	Days to maturity	Seed yield per plant	Seeds per capsule	1000-seed weight
Females									
G. Til-1	1.25**	-1.01*	-0.16**	-1.53**	-0.02	1.45**	-0.39**	-2.20**	-0.01
G. Til-2	-0.20	-5.04**	-0.07**	-1.56**	-0.10**	0.03	-0.67**	-1.39**	-0.22**
G. Til-3	-0.34	2.64**	0.16**	6.50**	0.15**	-0.27	1.98**	3.94**	0.24**
Ph. Til No.1	-0.48*	0.19	-0.02	-2.59**	-0.01	-1.16**	-0.58**	-0.33	0.00
Patan- 64	-0.22	3.22**	0.09**	-0.82*	-0.02	-0.05	-0.34**	-0.01	-0.02
S.E.(gi)	0.21	0.39	0.02	0.35	0.01	0.27	0.05	0.41	0.01
Males									
JLT-7	-0.01	-0.28	-0.04	-0.59	-0.02	-0.36	-0.02	-0.82	-0.04*
JLS-116	1.20**	7.32**	0.40**	7.68**	0.06*	0.52	0.92**	7.07**	0.28**
JLS-206-10	-0.21	2.57**	-0.13**	-1.05*	0.01	-2.01**	0.06	0.22	-0.09**
JLS-110-12	-1.91**	-0.01	0.02	0.54	0.01	0.19	0.31**	0.51	0.09**
JLS-9707-2	-0.74*	-0.75	0.05	0.05	0.01	-0.52	0.38**	0.70	-0.08**
JLT-408	0.01	-6.11**	-0.04	-0.57	-0.03	-0.25	-0.08	-0.95	-0.11**
JLT-408-2	-0.01	-0.89	-0.10**	-2.53**	-0.19*	3.01**	-1.75**	-1.52**	-0.05**
AKT-64	1.05**	0.57	-0.07**	-0.35	-0.01	-0.43	-0.24**	-0.66	-0.05**
PKV-NT-11	0.23	-4.08**	-0.19**	-3.88**	-0.01	-0.16	0.05	-4.94**	-0.01
AKT-101	0.39	1.66**	0.10**	0.70	0.17**	0.01	0.36**	0.39	0.05**
S.E.(g_j)	0.30	0.55	0.03	0.49	0.02	0.39	0.07	0.58	0.02

* and ** = Significant at 5% and 1% levels of probability, respectively.

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Table 3. Estimates specific combining ability effect of hybrids pooled over environments for different characters in sesame

Sr. No.	Crosses	Days to 50% flowering	Plant height (cm)	Branches per plant	Capsules per plant	Capsule length (cm)	Days to maturity	Seed yield per plant	Seeds per capsule	1000-seed weight
1	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	G.Til-1 x JLT-7	-0.84	2.28	0.19**	2.61*	0.07	-0.09	0.58**	3.22**	0.10*
2	G.Til-1 x JLS-116	0.12	0.77	0.14*	1.62	0.05	-0.20	0.13	1.74	0.07
3	G.Til-1 x JLS-206-10	0.69	1.84	-0.13*	0.08	-0.05	1.22	-0.03	-1.18	-0.08
4	G. Til-1 x JLS-110-12	0.12	-0.41	-0.04	-2.25*	-0.04	-1.42	-0.37*	-0.00	-0.09*
5	G.Til-1 x JLS-9707-2	0.12	-3.67**	-0.26**	-3.13**	-0.14**	-0.38	-0.94**	-4.08**	-0.14**
6	G.Til-1 x JLT-408	0.14	0.16	-0.12	-2.70*	-0.01	-0.42	-0.45**	-2.03	-0.02
7	G.Til-1 x JLT-408-2	-0.83	1.87	0.18**	4.38**	0.11**	1.98*	0.65**	3.36**	0.17**
8	G.Til-1 x AKT-64	0.11	-6.12**	-0.05	-1.05	-0.05	1.09	0.02	-3.30**	-0.04
9	G.Til-1 x PKV-NT-11	0.03	0.23	-0.01	-2.15	-0.02	-2.29**	-0.10	-0.89	-0.07
10	G.Til-1 x AKT-101	0.32	3.07*	0.11	2.60*	0.07	0.53	0.51**	3.16*	0.10*
11	G.Til-2 x JLT-7	0.50	1.20	-0.04	1.76	-0.02	1.10	-0.06	0.06	-0.04
12	G.Til-2 x JLS-116	-0.87	6.96**	0.22**	4.54**	0.14**	-3.67**	0.80**	3.85**	0.09*
13	G.Til-2 x JLS-206-10	-0.18	0.76	0.16*	2.12	0.07	-0.53	0.47**	0.90	0.08*
14	G.Til-2 x JLS-110-12	0.90	3.58**	0.27**	5.93**	0.14**	1.99*	1.14**	4.88**	0.31**
15	G.Til-2 x JLS-9707-2	-0.76	-4.03**	-0.23**	-4.35**	-0.09*	-0.30	-0.54**	-3.64**	-0.12**
16	G.Til-2 x JLT-408	-0.63	-1.42	0.04	-0.03	0.01	-2.23*	0.17	1.68	-0.05
17	G.Til-2 x JLT-408-2	-0.27	-0.01	-0.12	-0.31	-0.01	0.84	0.21	-0.94	-0.10*
18	G.Til-2 x AKT-64	-0.05	0.47	-0.27**	-1.41	-0.11**	0.84	0.03	-2.01	-0.07
19	G.Til-2 x PKV-NT-11	0.70	-2.53*	0.06	-0.32	-0.01	2.46**	-0.63**	1.33	0.02
20	G.Til-2 x AKT-101	0.66	-4.97**	-0.11	-7.93**	-0.14**	-0.50	-1.57**	-6.11**	-0.11**
21	G.Til-3 x JLT-7	-0.19	-4.24**	-0.08	-1.90	-0.05	-1.15	-0.48**	-1.92	-0.08
22	G.Til-3 x JLS-116	0.65	-5.28**	-0.33**	-4.78**	-0.16**	1.51	-1.22**	-6.02**	-0.28**
23	G.Til-3 x JLS-206-10	-2.99**	-2.83*	0.03	-0.04	-0.02	-0.45	-0.08	0.29	0.12**
24	G.Til-3 x JLS-110-12	1.43*	-4.32**	-0.35**	-5.11**	-0.16**	0.29	-1.12**	-4.43**	-0.18**
25	G.Til-3 x JLS-9707-2	-0.01	2.06	0.04	0.10	0.05	1.00	0.07	-0.19	0.00
26	G.Til-3 x JLT-408	0.45	1.22	0.12	0.78	0.02	1.18	0.23	0.68	0.01
27	G.Til-3 x JLT-408-2	0.37	0.73	0.14*	0.36	-0.01	-0.75	-0.62**	0.83	0.02
28	G.Til-3 x AKT-64	-0.02	3.22*	0.32**	5.12**	0.17**	-0.31	1.73**	5.97**	0.15**

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Table 3 contd….

1	2	3	4	5	6	7	8	9	10	11
29	G.Til-3 x PKV-NT-11	0.23	7.15**	0.15*	3.13**	0.08*	-0.69	1.11**	3.72**	0.18**
30	G.Til-3 x AKT-101	0.08	2.29	-0.04	2.35*	0.07	-0.64	0.36*	1.06	0.05
31	PT-1 x JLT-7	0.39	1.56	-0.07	-0.19	0.02	-0.60	0.08	0.15	0.01
32	PT-1 x JLS-116	-0.66	2.78*	0.19**	2.68*	0.12**	0.51	1.43**	4.29**	0.26**
33	PT-1 x JLS-206-10	-0.86	4.96**	0.06	2.01	0.03	-0.34	0.53**	2.00	-0.04
34	PT-1 x JLS-110-12	1.34*	-0.88	-0.04	0.15	-0.01	0.29	0.07	-2.32	-0.07
35	PT-1 x JLS-9707-2	0.57	2.70*	0.19**	3.62**	0.08	0.45	0.70**	4.19**	0.06
36	PT-1 x JLT-408	-0.30	-2.37	-0.01	-0.73	-0.02	0.63	-0.08	-0.37	0.03
37	PT-1 x JLT-408-2	0.17	-3.94**	-0.17**	-4.19**	-0.07	-2.09*	-0.39*	-2.03	-0.08
38	PT-1 x AKT-64	-0.67	2.09	0.10	-2.31*	0.03	0.58	-1.79**	0.02	-0.04
39	PT-1 x PKV-NT-11	0.03	-2.52*	-0.03	0.85	-0.06	0.87	-0.07	-2.65*	0.04
40	PT-1 x AKT-101	-0.01	-4.38**	-0.22**	-1.89	-0.11**	-0.31	-0.49**	-3.30**	-0.18 **
41	Patan-64 x JLT-7	0.13	-0.79	-0.01	-2.27*	-0.03	0.74	-0.12	-1.51	0.01
42	Patan-64 x JLS-116	0.75	-5.23**	-0.21**	-4.06**	-0.14**	1.85*	-1.13**	-3.86**	-0.14**
43	Patan-64 x JLS-206-10	3.33**	-4.73**	-0.12	-4.16**	-0.04	0.10	-0.89**	-2.01	-0.08*
44	Patan-64 x JLS-110-12	-3.80**	2.04	0.17**	1.28	0.07	-1.15	0.28	1.86	0.03
45	Patan-64 x JLS-9707-2	0.09	2.95*	0.25**	3.77**	0.10*	-0.77	0.71**	3.71**	0.19**
46	Patan-64 x JLT-408	0.33	2.42	-0.03	2.68*	0.00	0.85	0.13	0.04	0.03
47	Patan-64 x JLT-408-2	0.58	1.34	-0.04	-0.23	-0.03	0.03	0.14	-1.23	-0.01
48	Patan-64 x AKT-64	0.63	0.34	-0.10	-0.36	-0.04	-2.20*	0.01	-0.69	-0.01
49	Patan-64 x PKV-NT-11	-1.00	-2.34	-0.17**	-1.51	0.00	-0.35	-0.32	-1.52	-0.17**
50	Patan-64 x AKT-101	-1.05	4.00**	0.26**	4.86**	0.10*	0.91	1.19**	5.19**	0.15**
	S.E. (S_{ij})	0.65	1.26	0.06	1.14	0.040	0.87	0.17	1.24	0.04