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Combining ability and gene action studies for seed yield and its components in sesame (*Sesamum Indicum* L)

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Abstract
A line x tester analysis using two lines and ten testers was carried out to study the combining ability and gene action in sesame for seed yield and 14 quantitative traits. Analysis of variance for combining ability revealed significant differences among the mean squares due to lines were non significant for all the characters except days to 50% flowering and weight of capsules and in case of lines x testers it found significant for most of the character except days to 50% flowering, length of capsule, weight of capsule, number of capsule per leaf axil and oil content which indicated the existence of genetic diversity among the hybrids. General and specific combining ability variances showed the involvement of both type of gene actions in the inheritance of these characters. Among the lines G.Til-2 and among testers DS 21, RT 127, RT 346 and NIC 17274 were good general combiners for seed yield per plant and some of its contributing traits. The cross combination G.Til 3 × RT 127, G.Til 3 × DS 21, G.Til 3 × RT 346, G.Til 2 × RMT 175, G.Til 2 × HT 2, G.Til 2 × DS 10, G.Til 2 × RMT 166, G.Til 2 × RMT 186 and G.Til 3 × NIC 17274 showed significant and positive sca effect for seed yield per plant and involved poor x good, good x poor, poor x poor and good x good general combiners for majority of characters indicating the presence of dominance x additive and additive x additive type of gene interactions. These crosses have been identified as best hybrids for improving seed yield per plant and could be evaluated under different environment to confirm their superiority.

Keywords: Sesame, combining ability, gene action, line x tester analysis

Introduction
Sesame (*Sesamum indicum* L.) is one of the most ancient and important oilseed crop grown next to groundnut and mustard in India. The oilseed crops play important role in agriculture and industrial economy of our country. It is called as the "queen of oilseeds" in view of its oil and protein which are of very high quality. In India, sesame is cultivated on an area of 18.40 lakh ha with production of 6.23 lakh tonnes and productivity 338 kg/ha (Anon., 2015). However, the productivity is low in India as compared to other countries which need to be improved. The hybridization is one of the potent technique for yield enhancement. The choice of parents to be incorporated in hybridization programme is a crucial step for breeders, particularly if the aim is improvement of complex quantitative characters, such as yield and its components. Further, an understanding of the combining ability and gene action is a pre-requisite for any successful plant breeding programme. Testing the parents for their combining ability is very important because many times, the high yielding parents may not combine well to give good hybrids. Line x tester analysis helps in testing a large number of genotypes to assess the gene action and combining ability. The present experiment was, therefore planned to study combining ability and gene action in sesame.

Material and Methods
The present study on sesame was conducted at Cotton Research Station, Junagadh Agricultural University, Junagadh, Gujarat. Two diverse lines *viz.*, G.Til-2, G.Til-3 and ten testers *viz.*, DS 10, DS 21, RT 127, RMT 166, RT 346, HT 2, JLS 408-2, RMT 186, RMT 175 and NIC 17274. The selected 2 lines and 10 testers were crossed in a line x tester design during *summer* 2016 to produce 20 hybrids. The resulting 20 hybrids along with 12 parents and a check variety GJT-5 were evaluated during *summer* 2017 in a Randomized Block Design with three replications. Each plot was constructed with a row length of 3m and adopted a spacing of 30 x 10 cm. All need based agronomic practices were followed during the crop growth period to raise a good crop. Observations were recorded on randomly selected five plants in each entry for 14 quantitative traits viz., days to 50 % flowering, days to maturity, plant height (cm), height to first capsule (cm), number of branches per plant, number of internodes per plant, length of capsule (cm), weight of capsule (g), number of capsules per plant, number of capsules per leaf axil, number of seeds per capsule, 1000-seed weight (g), seed yield per plant (g) and oil content (%) for each replication. The mean values were used for the analysis of variance for experimental design. The data were statistically analyzed for combining ability in accordance with Kempthorne (1957) [4].

Results and Discussion
Analysis of variance for combining ability (Table 1)

Table 1: Analysis of variance for combining ability and variance components for different characters in sesame

Source	d. f.	Days to 50 % flowering	Days to maturity	Plant height (cm)	Height to first capsule (cm)	Number of branches per plant	Number of internodes per plant	Length of capsule (cm)
		1	2	3	4	5	6	7
Replications	2	4.20**	4.05*	28.43	1.01	1.07**	0.38	0.19
Lines	1	18.15**	11.26	68.62	1.98	0.86	8.81	0.16
Testers	9	2.07	4.85	28.48	1.36	0.09	3.22	0.19
Lines x Testers	9	0.74	3.00*	48.51**	7.59**	0.25**	5.77**	0.08
Error	38	0.44	1.03	16.24	1.37	0.07	0.30	0.07
Variance components								
σ^2l	-	0.59**	0.34	1.74	0.02	0.02	0.28	0.002
σ^2t	-	0.27	0.63	2.74	-0.01	0.01	0.48	0.018
σ^2lt	-	0.09	0.65*	10.75**	2.07**	0.05**	1.82**	0.002
σ^2gca	-	0.53**	0.39*	1.79	0.01	0.02	0.31	0.005*
σ^2sca	-	0.09	0.65*	10.75**	2.07**	0.05**	1.82**	0.002
σ^2gca / σ^2sca	-	5.8	0.6	0.16	0.004	0.4	0.17	2.5

Table 2: (*contd…*)

Source	d. f.	Weight of capsule (g)	Number of capsules per plant	Number of capsules per leaf axil	Number of seeds per capsule	1000-seed weight (g)	Seed yield per plant (g)	Oil content (%)
		8	9	10	11	12	13	14
Replications	2	1.26	23.91**	0.15	49.65**	0.09	14.86*	0.31*
Lines	1	2.65*	33.49	0.66	42.10	2.10	60.12	0.01
Testers	9	0.53	44.50	0.29	28.89	0.81	23.67	0.09
Lines x Testers	9	0.36	31.16**	0.34	27.76**	0.68**	13.44**	0.06
Error	38	0.46	3.25	0.06	6.77	0.03	3.10	0.05
Variance components								
σ^2l	-	0.07*	1.00	0.01	1.17	0.06	1.90	-0.001
σ^2t	-	0.01	6.87	0.03	3.68	0.13	3.42	0.005
σ^2lt	-	-0.03	9.30**	0.09**	6.99**	0.21**	3.44**	0.002
σ^2gca	-	0.06	1.98	0.02	1.59	0.07*	2.15*	-0.001
σ^2sca	-	-0.03	9.30**	0.09**	6.99**	0.21**	3.44**	0.002
σ^2gca / σ^2sca	-	-2.00	0.21	0.22	0.22	0.33	0.625	-0.500

*, ** Significant at 5 and 1 per cent levels, respectively

revealed significant differences among the mean squares due to lines were significant only for days to 50% flowering and weight of capsules and in case of lines x testers it found significant for most of the character except days to 50% flowering, length of capsule, weight of capsule, number of capsule per leaf axil and oil content which indicated the existence of genetic diversity among the hybrids. Estimates of genetic component of variance revealed that the variances due to testers (σ^2t) were higher than the variances due to lines (σ^2l) for all the characters except days to 50% flowering, height to first capsule, number of branches per plant and weight of capsule indicating the greater role of testers towards total additive genetic variance (σ^2gca). Higher magnitude of σ^2gca as compared to σ^2sca for three character *i.e*. days to 50% flowering, length of capsule and weight of capsule indicated the involvement of additive gene action. Higher magnitude of σ^2sca than σ^2gca observed for all the characters except days to 50% flowering, length of capsule and weight of capsule which indicated that the predominance of non-additive gene effect in the inheritance of these characters. The line G.Til-2 displayed high gca effect and good *per se* performance for seed yield per plant and some desirable traits. These parents possessed high concentration of favourable genes for more number of traits and should be utilized in multiple crossing programme. The findings of the present investigation for seed yield per plant and its attributing traits are in close conformity with the findings of Sakhare *et al*. (2000) [9], Mothilal and Manoharan (2004) [7], Mishra *et al.* (2009) [5], Paramesh warappa and Salimath (2010) [8] and vimla and Paramesh warappa (2017) [10]. An overall appraisal of gca effects

Table 3: General combining ability effects for different traits in sesame

Sr. No.	Parents	Days to 50% flowering	Days to maturity	Plant eight (cm)	Height to first capsule (cm)	Number of branches per plant	Number of internodes per plant	Length of capsule (cm)
		1	2	3	4	5	6	7
Lines								
1	G.Til-2	-0.550**	-0.433**	-1.070	0.182*	0.120	-0.383	-0.053
2	G.Til-3	0.550**	0.433**	1.070	-0.182*	-0.120	0.383	0.053
	SE(g_i)	0.122	0.185	0.735	0.214	0.048	0.010	0.051
	SE(g_i-g_j)	0.172	0.262	1.040	0.302	0.069	0.143	0.072
Testers								
1	DS 10	0.050	0.600**	1.310**	-0.640**	-0.020	-0.150**	0.212**

2	DS 21	0.383	1.100**	1.879**	-0.110*	0.247**	0.750*	-0.034
3	RT 127	-0.450	-0.400	0.512	0.990**	0.163**	-0.250**	-0.096**
4	RMT 166	-0.283	-1.233**	-1.622**	-0.477**	-0.020	-1.650**	0.286**
5	RT 346	-0.450	-0.733**	-0.078	0.026	-0.103**	0.050	-0.054
6	HT 2	-0.450	-0.400**	-3.055**	0.553**	-0.120**	-0.650**	0.179**
7	JLS 408-2	-0.283	0.600**	-1.912**	-0.285**	0.030	0.583**	-0.311**
8	RMT 186	-0.450	0.933**	-1.462**	0.010	-0.053	0.350**	-0.099**
9	RMT 175	1.217**	0.767**	4.412**	0.073	0.030	0.717**	0.006
10	NIC 17274	0.717**	-1.233*	0.015	-0.140	-0.153**	0.250**	-0.088**
	SE(g_j)	0.272	0.418	1.645	0.478	0.109	0.226	0.115
	SE(g_ig_j)	0.385	0.586	2.326	0.676	0.154	0.320	0.163

*, ** Significant at 5% and 1% levels, respectively

Table 3: (*contd…*)

Sr. No.	Parents	Weight of capsule (g)	Number of capsules per plant	Capsules per leaf axil	Number of seeds per capsule	1000-seed weight (g)	Seed yield per plant	Oil content
		8	9	10	11	12	13	14
Lines								
1	G.Til-2	-0.210	0.747	-0.105	0.838**	-0.188**	1.001**	0.010
2	G.Til-3	0.210	-0.747	0.105	-0.838**	0.188**	-1.001**	-0.010
	SE(g_i)	0.124	0.329	0.046	0.475	0.033	0.321	0.044
	SE(g_i-g_j)	0.176	0.465	0.065	0.672	0.046	0.455	0.063
Testers								
1	DS 10	0.265**	-4.278**	0.058*	2.029**	0.037**	-0.296*	-0.052**
2	DS 21	0.314**	-0.542**	0.358**	4.291**	0.469**	2.867**	0.026
3	RT 127	-0.350**	-2.359**	-0.208**	-0.888**	0.594**	2.387**	0.069**
4	RMT 166	0.290**	0.291*	-0.075*	-2.106**	0.265**	-0.246*	0.159**
5	RT 346	-0.377**	3.773**	-0.275**	0.062	-0.150**	1.069**	0.131**
6	HT 2	-0.050	2.353**	-0.075*	0.229	0.044**	-2.981**	0.096**
7	JLS 408-2	0.246**	3.491**	0.025	-2.104**	-0.597**	-0.580**	-0.199**
8	RMT 186	-0.417**	1.391**	-0.058*	-0.821**	-0.038*	-2.356**	-0.146**
9	RMT 175	0.187**	-1.793**	-0.142**	1.912**	-0.377**	-1.593**	0.053**
10	NIC 17274	-0.107*	-2.326**	0.392**	-2.604**	-0.247**	1.730**	-0.137**
	SE(g_j)	0.279	0.736	0.103	1.063	0.074	0.719	0.099
	SE(g_i-g_j)	0.394	1.041	0.146	1.503	0.104	1.017	0.140

*, ** Significant at 5% and 1% levels, respectively

Indicated that none of the parents was good general combiner for all the characters studied. Among the lines, G.Til 2 gave desirable gca effect for four characters *viz*., days to 50% flowering, days to maturity, number of seeds per capsule and seed yield per plant. Among the testers, DS 21 gave desirable gca effect simultaneously for nine characters *viz.*, plant height, height to first capsule, number of branches per plant, number of internodes per plant, weight of capsule, number of capsules per leaf axil, number of seeds per capsule, 1000-seed weight, seed yield per plant followed by RMT 166 for seven characters *viz*., days to maturity, height to first capsule, length of capsule, weight of capsule, number of capsule per plant, 1000-seed weight and oil content and DS 10 for seven characters *viz*., plant height, height to first capsule, length of capsule, weight of capsule, number of capsules per leaf axil, number of seeds per capsule and 1000-seed weight. These parents were identified as the best testers in the present study. The parents which are good general combiners simultaneously for more number of characters are considered as the potential parents and should be preferred in breeding programme in order to combine more number of characters by involving fewer numbers of parents in a crossing programme. The study also indicated that the parents showing good general combining ability had high per se performance for almost all the traits studied. This suggested that while selecting parents for hybridization programme in sesame, per se performance of the parents may be given due consideration. High general combining ability effects mostly contribute either additive gene effects or additive x additive interaction effect or both and represent fixable portion of genetic variation. Accordingly, G.Til 2, DS 21, RT 127, RT 346 and NIC 17274 offered the best possibilities of exploitation for the development of improved purelines with enhanced yielding ability. Further, this parents showing good general combining ability for particular components may be utilized in component breeding programme for improving specific trait of interest.

Table 3: Sca effects for various characters of best selected crosses on the basis of seed yield per plant

Characters	Hybrids								
	G.Til 3 × RT 127	G.Til 3 × DS 21	G.Til 3 × RT 346	G.Til 2 × RMT 175	G.Til 2 × HT 2	G.Til 2 × DS 10	G.Til 2 × RMT 166	G.Til 2 × RMT 186	G.Til 3 × NIC 17274
Days to 50% flowering	0.12	0.28	0.12	0.88*	-0.11	0.05	-0.28	0.21	-0.05
Days to maturity	0.40**	-0.43**	0.40	-0.57**	-1.07**	0.60**	-0.23**	0.27**	-1.43*
Plant height (cm)	-0.70	3.76**	-1.66*	3.87**	0.93*	-3.22**	3.89**	-2.19**	2.86**
Height to first capsule(cm)	2.12**	-0.73**	-1.37**	-0.38**	1.55**	-0.63**	0.35**	-0.32**	-0.47**
Number of branches per plant	0.09**	0.33**	-0.18	-0.02	0.16**	0.03	0.30**	-0.03	0.30**
Number of internodes per plant	-0.65**	1.15**	1.45**	0.81**	0.52**	1.15**	-0.35**	-0.02	-1.02**
Length of capsule (cm)	-0.05	-0.01	0.04	0.01	-0.31**	0.03	-0.02	0.09**	-0.11**
Weight of capsule (g)	-0.37**	0.29**	-0.31**	0.13	0.10	-0.09	-0.33**	0.07	0.03
Number of capsules per plant	-1.07**	5.51**	1.53**	2.04**	2.02**	1.71**	-0.41*	-0.58*	-1.07**
Number of capsules per leaf axil	-0.23**	0.40**	-0.11**	-0.03	0.11**	-0.16**	-0.02	0.05	0.29**
Number of seeds per capsule	-0.14	5.00**	1.90**	0.45	-0.04	1.90**	0.76*	2.38**	-1.66**
1000-seed weight (g)	0.06*	-0.01	-0.45**	-0.31**	0.24**	0.12**	0.07*	-0.63**	0.30**
Seed yield per plant (g)	2.21**	2.08**	1.69**	1.52**	1.47**	1.12**	0.90**	0.76**	0.32*
Oil content (%)	-0.09**	-0.13**	0.04	-0.06*	-0.11**	-0.06*	0.13**	0.04	-0.08**

***Significantat5%and1%levels, respectively

The sca effect of the crosses indicated that nine hybrids manifested significant and positive sca effect for seed yield per plant *viz.*, G.Til 3 × RT 127, G.Til 3 × DS 21, G.Til 3 × RT 346, G.Til 2 × RMT 175, G.Til 2 × HT 2, G.Til 2 × DS 10, G.Til 2 × RMT 166, G.Til 2 × RMT 186 and G.Til 3 × NIC 17274. These crosses also showed desirable sca effect for important yield contributing traits. The crosses exhibiting high sca effect involved poor x good, good x poor, poor x poor and good x good general combiners for majority of characters indicating the presence of dominance x additive and additive x additive type of gene interactions. The use of recurrent selection or biparental mating followed by pedigree selection may prove to be effective in simultaneous exploitation of both the type of gene actions for improvement of seed yield and its attributes in sesame. The good general combiners when crossed may not always produce the best hybrid. Marked negative effects in crosses between good x good were noteworthy, which could be attributed due to the lack of complementation between favourable alleles of the parents involved. Marked positive sca effects in crosses between good x poor and poor x poor could be ascribed for better complementation between favourable alleles of parents involved. These findings are in agreement with the earlier findings of Sakhare *et al.* (2000) [9], Arulmozhi *et al.* (2001) [2], Kar *et al.* (2002) [3], Mothilal *et al*. (2003) [6] and Mothilal and Manoharan (2004) [7]. Crosses *viz.*, G.Til 3 × DS 21, G.Til 2 × RMT 175, G.Til 2 × HT 2, G.Til 2 × RMT 166 and G.Til 3 × NIC 17274 are favourable for earliness while G.Til 3 × RT 127, G.Til 2 × HT 2, G.Til 2 × DS 10, G.Til 2 × RMT 166 and G.Til 3 × NIC 17274 are suitable for bold seed and only one cross G.Til 2 × RMT 166 is consider for improvement of oil content.

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