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Gene action for morpho-biochemical traits of sesame (*Sesamum indicum*) in different environments

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ABSTRACT

Sesame (*Sesamum indicum* L.) is a drought tolerant oilseed crop with the highest oleic acid content, which is yet to be explored for its hybrid vigour. Therefore, present study was carried at Sri Karan Narendra Agriculture University, Jobner, Jaipur, Rajasthan during 2019–20 and 2020–21 to study the combining ability for 11 seed yield and its attributing traits in 10 parents and their 45 crosses in sesame. The effects of general combining ability and specific combining ability on morpo-biochemical attributes of cultivars were studied utilizing half-diallel cross. The experiment was conducted using randomized blocks design (RBD) with 3 replications under different environmental conditions. Significant variations were detected among parents for all of the recorded attributes and the F_1 generation also showed significant differences for all recorded attributes. The GCA (General Combining Ability)/SCA (Specialized Combining Ability) variance ratio was found to be less than one, indicating that non-additive gene action predominated for all tested attributes. The parents RT–346, TKG–22, RT–372 and RT–351 emerged as good general combiners for seed yield per plant and its attributes in all environmental conditions. The crosses RT–346 × RT–351, TKG–22 × RT–372, RT–372 × RT–351 and RT–103 × RT–351 emerged as good specific cross combinations for seed yield and oil content. Incorporating F_1 hybrids with a high SCA and parents with a high GCA into multiple crossings could also to be a beneficial strategy for improving seed production and oil content in sesame.

Keywords: Additive gene, Combining ability, Half diallel, Morpho-biochemical traits, Non-additive gene

Sesame (*Sesamum indicum* L.) is one of the oldest cultivated oilseed crops, with a production of 3150 metric tonnes and a productivity level of 535 kg/hectare (FAOSTAT 2020). It is considered the queen of high quality vegetable oil (44–58% dry seed weight) due to its high levels of unsaturated fatty acids and antioxidants e.g., sesamol, sesamin, sesamolin and sesaminol. The most significant hurdles to sesame production in India include low productivity in various states and a lack of farmer knowledge. Evaluation of native and exotic germplasm in cross-breeding efforts is essential to increase seed output, as low productivity among oilseed crops may be due to cultivation of low-yielding dehiscent varieties and lack of varietal replacement. Combining ability is used to identify desirable genotypes for producing the best recombination. Inter-population selection is the most effective breeding procedure, while hybrid programmes may be the better choice if additive gene action plays a major role in controlling quantitative traits.

Combining ability aids in the identification of suitable parents for superior recombinants in sesame (Singh *et al.* 2022). Anyanga *et al.* (2016) found that non-additive gene action was more important in the inheritance of days to 50% flowering, number of branches/plant, number of capsules/plant, 1000-seed weight and plant yield. This investigation aimed to estimate combining ability study in sesame to select better combining parents, which would produce more desirable recombinants. Diallel mating design was used to provide gene action and information on superior parents and crosses. Researchers studied the mode of gene action for 11 traits in sesame germplasm to identify the most efficient breeding procedure for achieving maximum genetic improvement in rainfed environmental conditions following Griffing's numerical approach (Griffing's 1956 method 2, model 1). This research could provide guidance for researchers to produce new genotypes to increase sesame production and increase oil percentage in India, with the goal of becoming one of the leading sesame seed producers in the world.

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MATERIALS AND METHODS

An experimental was conducted at research farm of Sri Karan Narendra Agriculture University, Jobner, Jaipur, Rajasthan during 2019–20 and 2020–21. A crossing block was constructed and direct F_1 crosses were produced following a half diallel mating design. Ten parents [RT–346 (P_1), TKG–22 (P_2), RT–372 (P_3), TC–25 (P_4), PRAGATI (P_5), RT–46 (P_6), RT–125 (P_7), RT–103 (P_8), GT–10 (P_9) and RT–351 (P_{10})] and 45 F_1's were planted based on a randomized complete block design with 3 replications under 3 different environments, viz. normal, late and very late; these environment were based on different date of sowing. Observations on all characters were recorded on randomly taken plants of each genotype under each environment, with 9 quantitative traits and 1 qualitative trait estimated. Oil content was determined using NMR.

Statistical analysis: Before proceeding with the biometrical analysis, differences among genotypes were tested by running the regular analysis of variance (Hayman 1954). The combining ability analysis for individual environment was worked out for all the 3 environments separately by the procedure postulated by Griffing's (1956) Method 2, Model I procedure using the software WINDOSTAT version 8.1. The following mathematical model was assumed:

$$x_{ijk} = \mu + g_i + g_j + s_{ij} + e_{ijk}/b$$

where μ = Population Mean; xijk = An observation of the phenotype of a cross involving i^{th} and j^{th} parents in the k^{th} block, = population mean; gi, General combining ability effect of i^{th} parent; gj, General combining ability effect of j^{th} parent; sij, Specific combining ability effect of the cross between i^{th} parent and jth parent; sij = sji; b = number of blocks; eijk, Environmental effects associated with ijk. Hayman's statistical analysis was also carried out.

RESULTS AND DISCUSSION

The analysis of variance: The mean squares due to GCA and SCA were significant for all of the characters, indicating that both additive and non-additive gene effects played a significant role in the genetic control of the phenotypes studied. The variation between GCA × Environment and SCA × Environment was also significant, indicating that the environment has a considerable impact on their expression.

The purpose of the combining ability analysis was to determine the nature and extent of gene action influencing the expression of various qualities. Combining ability analysis revealed sufficient diversity and potential for selection between tested parents and F_1 crosses, with GCA and SCA variances significant for all characters in all 3 environments reflecting the presence of both additive and non-additive gene effects in the inheritance of these traits (Table 1). Gami *et al.* (2020) found significant GCA and SCA variances for all traits except days to maturity for SCA variance, suggesting the importance of additive and non-additive types of gene action in the inheritance of traits.

Effects of general combining ability: The results showed that days to maturity are desirable traits in sesame, which was reflected by negative combining effects. For most characters, the genotype × environment interaction was significant and the effects of combining ability were estimated on the basis of a single environment. The parents TKG–22 and GTv10 for days to maturity demonstrated significant negative general combining ability effects in all environments, making them good general combiners. The parents of GT–10 and RT–351 were desirable for plant height, higher number of seeds/capsules and seed yield/plant and TKG–22 and RT–351 for higher number of capsules per plant in all 3 environments. Higher oil content is most desirable in sesame, and parent TKG–22 (except E1) followed by GT–10 revealed highly positive and significant GCA effects (Table 2, 3).

Combining ability analyses are essential for determining parental lines in self-pollinated crops where additive gene actions are predominant (Joshi and Dhawan 1966). Data shows the magnitudes of GCA impacts for parental genotypes for numerous individual features in various scenarios. The parents with consistent desirable GCA estimates in all 3 environments were TKG–22 for days to maturity, capsules per plant; RT–351 for plant height, capsules per plant, seeds per capsule and 1000-seed weight; RT–346 for oil content;

Table 1 Pooled ANOVA showing mean squares for combining ability for yield and its contributing attributes in sesame

Source of variation	Df	Character										
		DFF	DTM	PH (cm)	BPP	CPP	CL (cm)	SPC	1000-seed weight (g)	CG (cm)	SYPP (g)	Oil (%)
GCA	9	14.74**	33.00**	1325.34**	1.58**	595.76**	0.07**	177.78**	0.16**	0.07w	7.40**	12.19**
SCA	45	5.24**	11.27**	452.19**	0.32**	112.22**	0.05**	55.11**	0.07**	0.04**	1.07**	14.93**
Environments	2	603.70**	1951.27**	71229.40**	70.66**	18560.78**	5.67**	15098.81**	9.22**	15.90**	273.24**	393.12**
GCA × environments	18	3.05**	1.85**	158.14**	0.11**	98.01**	0.02**	25.15**	0.05**	0.01**	1.23**	3.83**
SCA × environments	90	3.35**	6.52**	289.63**	0.31**	89.63**	0.03**	52.37**	0.05**	0.04**	1.05**	4.44**
Error	324	0.5	0.88	27.41	0.02	6.17	0.01	2.79	0.02	0.01	0.06	1.05

DFF, Days to 50% flowering; DTM, Days to maturity; PH, Plant height; BPP, Branches per plant; CPP, Capsules per plant; CL, Capsule length; SPC, Seeds per capsule; CG, Capsule girth; SYPP, Seed yeild per plant.

and GT–10 for plant height, branches per plant, seeds per capsule, seed yield per plant and oil content (Azeez and Morakinyo 2014). The genotype at the stage of capsule formation and seed formation in varied environmental conditions influences sesame productivity. Due to self-pollinated nature of sesame good general combiners had fixable variance components such as additive and additive × additive epistasis components; hence, these parents offer the best utilization of potential for the development of improved high-yielding varieties in sesame (Elaziz and Ghareeb 2018 and Sikarwar *et al*. 2021).

Selection for high seed yield should result in favourable improvements in yield and yield attributing traits under diverse environmental circumstances. The findings of our study are in accordance with those of Dela *et al*. (2019) and Jeeva *et al*. (2020). Combining ability effects can create superior offspring when choosing parent plants in crop improvement programmes. The parents mentioned above have a high potential for perspective features and can be used to build a dynamic population with the majority of the accumulated beneficial genes.

Effects of specific combining ability (SCA): The analysis of SCA effects in individual environments revealed that crosses with high SCA effects could be developed for specific breeding conditions. The crosses $P_3 \times P_9$ and $P_3 \times P_{10}$ showed significant negative SCA effects, making them desirable for good specific combiners for early maturity. Over all evaluation in all the environments exhibited that 3 crosses for capsules per plant, 4 crosses for higher seeds per capsule showed significant positive SCA effects indicating highly desirable and emerged as good specific combiners (Tripathy *et al.* 2016 and Raikwar 2018). Evaluation of all

Table 2 GCA and SCA effects for yield and yield attributing characters in 3 environments in sesame

Parent/cross	DTM			PH (cm)			BPP			CPP		
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
GCA effect												
P_1	0.34	-1.26**	0.71*	-0.54	10.86**	2.18*	-0.15**	0.21**	-0.07*	2.74**	4.16**	-0.71
P_2	-0.99**	-1.12**	-1.71**	2.22	4.91**	5.02**	0.09	0.22**	0.07*	10.94**	6.20**	2.42**
P_3	-1.21**	0.38	-1.18**	2.23	-3.01*	3.81**	0.27**	-0.03	0.07*	2.64**	-4.50**	0.26
P_4	-0.24	0.71**	0.74*	-6.78**	-8.82**	2.96**	-0.02	-0.38**	0.06	-8.60**	-4.03**	-1.60**
P_5	1.18**	0.54*	0.18	-5.50**	-10.39**	-5.01**	-0.37**	-0.38**	-0.18**	-6.09**	-3.77**	-1.02**
P_6	1.09**	1.04**	1.35**	-8.77**	-5.78**	-6.60**	-0.34**	-0.17**	-0.18**	-1.41	-4.86**	-1.46**
P_7	0.34	0.57*	0.77*	-3.27	-2.44	-7.04**	-0.02	-0.11*	0.05	-5.47**	-1.23*	-1.12**
P_8	1.07**	-0.71**	1.32**	4.12*	5.53**	-6.49**	-0.02	0.36**	-0.21**	-4.11**	6.35**	-2.71**
P_9	-0.88**	-0.98**	-1.59**	5.89**	13.84**	6.35**	0.25**	0.26**	0.29**	6.48**	5.17**	2.62**
P_{10}	-0.71**	-1.97*	-0.59	10.40**	21.15**	4.82**	0.29**	0.77**	0.10**	2.88**	8.68**	3.32**
SE (gi)±	0.22	0.23	0.31	1.72	1.47	1.01	0.05	0.05	0.03	0.96	0.58	0.37
SE (gi–gj)±	0.33	0.34	0.46	2.57	2.20	1.51	0.07	0.07	0.05	1.43	0.87	0.55
SCA effect												
$P_1 \times P_2$	-3.43**	0.23	-3.44**	12.92*	1.83	7.11*	0.71**	0.20	0.28*	10.73**	4.17*	2.10
$P_1 \times P_3$	0.45	-0.94	0.36	-11.76*	0.69	9.13**	0.48**	0.11	0.11	10.02**	-3.99*	-3.14*
$P_1 \times P_4$	0.48	1.39	-2.55*	-1.81	5.03	-19.88**	0.22	-0.60**	-0.31**	3.20	-8.27**	5.38**
$P_1 \times P_5$	1.07	-1.77*	-2.00	-1.24	-5.94	12.53**	-0.43**	-0.07	0.43**	2.82	-2.33	5.47**
$P_1 \times P_6$	0.48	0.39	-0.83	-10.46	-12.14*	0.53	-0.76**	-0.35*	-0.14	-9.52**	-2.77	-8.76**
$P_1 \times P_7$	-2.43**	0.53	-0.58	-4.26	36.51**	1.51	-0.31	0.52**	-0.33**	6.61*	9.93**	-2.63*
$P_1 \times P_8$	-0.49	-2.19**	4.86**	23.68**	16.88**	-3.95	-0.41*	0.32*	-0.11	4.44	0.68	0.82
$P_1 \times P_9$	-3.88**	-2.24**	-0.89	20.51**	-9.29	14.68**	0.71**	0.16	0.26*	14.32**	12.33**	3.90**
$P_1 \times P_{10}$	1.29	-3.02**	2.11*	18.00**	17.26**	11.71**	0.38*	0.54**	0.15	4.45	9.99**	7.73**
$P_2 \times P_3$	2.45**	1.14	-3.22**	49.94**	8.32	9.59**	0.36*	0.35*	0.40**	17.42**	-13.43**	10.26**
$P_2 \times P_4$	-2.52**	0.81	1.53	-21.37**	-11.27*	13.06**	-0.79**	-0.86**	-0.45**	3.33	-11.11**	0.32
$P_2 \times P_5$	-3.60**	0.64	2.75**	-8.06	19.23**	-11.66**	0.53**	0.20	-0.24*	3.46	-3.10	-3.86**
$P_2 \times P_6$	-2.52**	0.48	-0.75	-3.19	-5.51	0.84	0.37*	-0.84**	0.32**	-2.86	-2.27	6.14**
$P_2 \times P_7$	0.57	3.62**	1.17	-11.68*	-13.39**	-11.37**	-0.55**	-1.14**	-0.51**	-6.19	-8.71**	-4.89**
$P_2 \times P_8$	0.51	-3.11**	2.28*	-3.41	15.31**	-2.01	-0.22	0.60**	0.31**	7.64*	14.84**	-5.64**

Contd.

Table 2 (*Concluded*)

Parent/cross	DTM			PH (cm)			BPP			CPP		
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
$P_2 \times P_9$	2.45**	-2.16**	-1.80	4.82	10.67*	10.84**	-0.03	0.50**	0.22	3.98	10.23**	2.70*
$P_2 \times P_{10}$	2.29**	1.34	-3.14**	-18.96**	21.21**	6.29	-0.10	0.65**	0.27*	3.45	-0.81	3.20*
$P_3 \times P_4$	-0.96	0.67	-1.00	5.88	-23.05**	-0.62	-0.06	-0.47**	-0.46**	-8.71**	-0.88	-0.06
$P_3 \times P_5$	0.95	1.17	2.22*	-5.81	-5.55	-0.65	0.52**	-0.80**	-0.08	-0.08	0.12	0.10
$P_3 \times P_6$	-1.63*	0.34	-0.61	-6.60	-1.89	-11.72**	-0.34*	-1.15**	0.12	-12.56**	-2.78	0.07
$P_3 \times P_7$	1.12	-3.19**	0.97	-3.83	-7.90	-1.28	-0.06	0.86**	-0.04	2.04	-9.62**	-0.93
$P_3 \times P_8$	0.73	-2.91**	0.42	-13.89*	-6.07	-0.90	-0.06	0.56**	-0.25*	-1.59	10.40**	0.38
$P_3 \times P_9$	-4.99**	-2.97**	-2.66*	-18.87**	12.42*	12.67**	0.33*	0.29	0.31**	6.94*	10.85**	5.39**
$P_3 \times P_{10}$	-4.16**	-4.49**	-3.00**	-3.57	-22.26**	6.83*	0.36*	-0.42**	0.30**	7.61*	-8.64**	5.22**
$P_4 \times P_5$	-0.68	-0.99	-1.03	-20.93**	34.31**	-0.14	0.31	0.18	0.20	1.99	7.49**	0.36
$P_4 \times P_6$	-0.93	-1.16	1.81	34.35**	20.90**	-0.28	-0.38*	1.17**	-0.04	20.31**	14.26**	1.86
$P_4 \times P_7$	-2.52**	-0.36	-1.61	19.92**	-33.51**	-1.97	0.16	-0.49**	0.57**	-13.86**	-7.04**	-3.21*
$P_4 \times P_8$	-0.24	1.26	-3.50**	-3.48	-4.81	-0.99	-0.44**	-0.36*	0.49**	13.38**	6.17**	2.84*
$P_4 \times P_9$	-0.63	-0.13	-0.58	-3.51	5.68	7.78*	0.15	-0.19	0.16	-11.55**	-7.11**	-3.08*
$P_4 \times P_{10}$	-1.46	-0.33	-1.91	-19.36**	-6.75	10.31**	0.25	0.16	-0.08	-8.35*	4.02*	-3.52**
$P_5 \times P_6$	-1.35	-0.16	-1.97	16.19**	20.77**	4.96	0.50**	0.05	0.04	2.31	2.72	1.22
$P_5 \times P_7$	-4.60**	-0.69	-1.39	12.83*	28.30**	9.67**	0.51**	0.59**	0.01	-10.90**	5.48**	0.82
$P_5 \times P_8$	-1.32	0.92	-2.28*	16.30**	6.00	9.98**	-0.19	0.59**	0.07	6.94*	-9.97**	8.33**
$P_5 \times P_9$	0.29	0.20	-0.03	0.19	11.36*	-9.78**	-0.10	0.29	-0.29*	6.14	-3.92*	-3.72**
$P_5 \times P_{10}$	0.79	-0.99	-0.03	13.09*	12.54*	-3.12	-0.07	-0.21	-0.24*	4.55	3.06	-3.56**
$P_6 \times P_7$	-0.85	-1.86*	-2.89**	6.30	-23.47**	4.86	0.55**	-0.48**	-0.25*	20.09**	17.69**	0.52
$P_6 \times P_8$	-2.24**	1.42	-1.44	-6.76	5.56	3.71	0.55**	0.19	-0.13	-8.41*	-2.49	1.90
$P_6 \times P_9$	-0.30	0.37	-0.53	1.60	-0.74	-3.59	-0.12	0.43**	0.17	7.53*	-15.04**	-2.35
$P_6 \times P_{10}$	-0.13	-0.69	0.14	-1.04	0.32	-7.73*	-0.16	-0.62**	-0.24*	10.40**	-8.48**	6.21**
$P_7 \times P_8$	-3.16**	0.59	-2.86**	-10.86	3.62	-4.38	0.53**	0.41**	-0.23	-5.61	0.40	-1.43
$P_7 \times P_9$	1.79*	0.20	0.06	15.64**	13.92**	-12.68**	-0.18	0.38*	0.21	-2.14	1.58	7.24**
$P_7 \times P_{10}$	1.62*	0.06	0.39	12.73*	22.35**	-2.69	0.65**	-0.09	0.20	2.73	-7.23**	-4.53**
$P_8 \times P_9$	1.07	0.34	0.17	13.31*	16.97**	-4.17	-0.25	0.22	-0.34**	3.06	0.62	-1.24
$P_8 \times P_{10}$	0.23	-1.38	0.50	11.74*	10.67*	-5.97	-0.22	-0.05	-0.01	-12.17**	6.70**	-2.41
$P_9 \times P_{10}$	-1.16	0.23	-2.58*	25.50**	1.47	3.86	0.51**	0.05	0.29*	8.17*	0.58	1.47
SE (Sij)±	0.74	0.77	1.04	5.80	4.96	3.40	0.16	0.15	0.11	3.22	1.95	1.24
SE (Sij-Sik)±	1.09	1.14	1.54	8.52	7.29	5.00	0.23	0.23	0.17	4.73	2.87	1.83
SE (Sij-Ski)±	1.04	1.08	1.46	8.12	6.95	4.77	0.22	0.22	0.16	4.51	2.74	1.74

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

DTM, Days to maturity; PH, Plant height; BPP, Branches per plant; CPP, Capsules per plant.

Table 3 GCA and SCA effects for yield and yield attributing characters in 3 environments in sesame

Parent/cross	SPC			1000-seed weight (g)			SYPP (g)			oil (%)		
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
GCA effect												
P_1	-0.13	0.97**	1.28**	0.12**	0.05*	0.02	-0.17	0.65**	-0.14**	0.84**	0.38	0.64*
P_2	2.65**	-1.45**	-0.49	0.13**	0.03	0.06**	1.09**	0.23**	0.27**	-0.36	0.69*	1.31**

Contd.

Table 3 (*Contd.*)

Parent/cross	SPC			1000-seed weight (g)			SYPP (g)			oil (%)		
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
P_3	1.36*	1.4**	-0.06	0.13**	0.08**	0.09**	0.88**	-0.22**	0.30**	0.54*	-0.67*	0.47
P_4	-0.89	-2.54**	-0.45	-0.09**	-0.1**	-0.06**	0.29**	-0.34**	-0.09**	-0.76**	-0.93**	-1.45**
P_5	-4.14**	-5.12**	-0.16	-0.21**	-0.03	0.01	-1.01**	-0.31**	-0.34**	0.01	-0.11	-0.43
P_6	-2.89**	1.54**	-2.99**	-0.11**	0.03	-0.12**	-0.73**	-0.41**	-0.27**	0.7**	-0.09	-1.12**
P_7	-1.30*	-1.48**	-1.79**	-0.09**	-0.07**	-0.01	-0.77**	-0.11	-0.22**	-0.94**	-0.02	-0.70*
P_8	-2.8**	1.22**	-1.12**	-0.01	-0.02	-0.08**	-0.84**	0.28**	-0.06	-0.86**	0.06	-0.38
P_9	4.07**	3.86**	2.96**	0.07**	-0.02	0.03	0.68**	0.34**	0.26**	0.05	0.68*	1.11**
P_{10}	4.05**	6.81**	2.83**	0.08**	0.24**	0.07**	0.57**	1.27**	0.27**	0.78**	0.13	0.55*
SE (gi)±	0.61	0.37	0.35	0.02	0.02	0.02	0.09	0.07	0.03	0.22	0.33	0.28
SE (gi–gj)±	0.90	0.55	0.53	0.03	0.03	0.02	0.14	0.10	0.05	0.33	0.49	0.41
SCA effect												
$P_1 \times P_2$	3.75	11.23**	7.68**	0.18*	0.16*	0.11*	1.08**	-0.72**	0.31**	3.52**	3.15**	0.23
$P_1 \times P_3$	-1.56	-3.65**	-2.49*	0.04	-0.09	0.05	0.17	-0.71**	-0.20	1.84*	-1.05	0.01
$P_1 \times P_4$	-1.51	2.02	-2.63*	0.07	0.02	-0.13*	0.23	-0.18	0.25*	-0.31	-3.96**	3.91**
$P_1 \times P_5$	2.81	-3.67**	6.78**	-0.56**	-0.14	-0.23**	-0.36	-0.41	0.11	-0.41	-1.39	-5.83**
$P_1 \times P_6$	4.49*	-2.99*	-0.35	0.34**	-0.11	-0.01	0.55	0.63**	0.07	-1.45	-6.12**	4.24**
$P_1 \times P_7$	7.44**	-0.23	-0.75	-0.34**	-0.07	0.12*	0.37	1.16**	0.37**	-3.55**	3.88**	-1.72
$P_1 \times P_8$	3.47	2.00	-1.69	-0.05	0.25**	0.02	-0.11	-0.12	0.31**	-2.08**	3.58**	0.55
$P_1 \times P_9$	4.20*	-0.34	3.49**	0.16*	-0.25**	0.17**	1.14**	0.29	0.16	3.01**	3.33**	1.81
$P_1 \times P_{10}$	5.29*	14.23**	4.16**	0.25**	0.22**	0.12*	0.60	0.86**	-0.53**	1.91*	1.54	3.00**
$P_2 \times P_3$	-4.81*	-3.28**	-0.98	0.26**	0.14	0.22**	0.83*	1.05**	0.4**	-0.63	-0.42	3.54**
$P_2 \times P_4$	7.04**	0.39	-6.79**	-0.08	-0.08	0.03	1.69**	0.37	-0.48**	-0.16	-4.50**	-3.97**
$P_2 \times P_5$	1.09	-7.84**	-5.91**	-0.07	-0.08	-0.28**	0.29	0.52*	-0.03	0.11	-2.10	1.58
$P_2 \times P_6$	7.04**	-2.09	-3.92**	-0.10	0.32**	-0.09	-0.13	-1.39**	0.09	-2.49**	3.72**	-1.96*
$P_2 \times P_7$	-9.08**	-10.20**	-0.98	-0.32**	-0.15	-0.09	-1.94**	-0.88**	0.03	-1.16	-0.75	0.66
$P_2 \times P_8$	3.09	5.56**	0.08	-0.13	-0.06	0.04	0.14	0.19	-0.32**	-0.59	4.33**	-2.06*
$P_2 \times P_9$	5.29*	3.99**	5.20**	0.29**	-0.22**	0.28**	0.57	0.00	0.4**	2.01**	-1.05	2.54**
$P_2 \times P_{10}$	5.17*	-0.86	5.86**	0.28**	0.32**	0.09	1.15**	0.03	0.51**	1.91*	-7.10**	2.49**
$P_3 \times P_4$	11.67**	-5.22**	5.65**	-0.09	-0.03	0.02	1.35**	-0.18	-0.28**	-1.56*	1.45	-1.04
$P_3 \times P_5$	-7.75**	-7.42**	-1.84	0.04	-0.26**	-0.11	0.39	-0.52*	-0.02	-0.66	0.05	0.09
$P_3 \times P_6$	-6.73**	9.26**	1.52	-0.07	-0.06	-0.05	0.37	-1.27**	-0.26*	0.26	1.36	0.53
$P_3 \times P_7$	2.54	-7.71**	1.39	0.35**	-0.33**	0.15**	-0.31	-0.11	-0.27*	0.64	-0.31	0.10
$P_3 \times P_8$	3.85	-12.02**	-6.09**	-0.14	0.19*	-0.35**	0.75*	1.26**	0.00	-0.16	1.61	-0.48
$P_3 \times P_9$	5.04*	-3.59**	4.37**	0.10	0.03	0.13*	-0.38	1.31**	0.43**	3.17**	3.30**	2.43*
$P_3 \times P_{10}$	5.93**	0.23	5.7**	0.31**	0.15*	0.13*	0.91**	0.36	0.53**	-1.67*	4.06**	-2.53**
$P_4 \times P_5$	0.10	2.54*	-1.18	0.12	-0.01	-0.05	0.06	0.82**	0.13	-0.08	2.31*	0.59
$P_4 \times P_6$	-3.08	-3.05*	1.11	0.02	-0.01	-0.03	0.08	0.44*	0.63**	-0.91	0.65	3.35**
$P_4 \times P_7$	-4.87*	9.71**	0.98	0.36**	-0.01	0.33**	-0.28	-0.03	0.35**	1.71*	-0.31	1.29
$P_4 \times P_8$	0.60	5.14**	-3.82**	0.02	0.14	0.06	0.88**	-0.91**	0.35**	-0.31	2.92**	0.09
$P_4 \times P_9$	6.16**	3.57**	5.16**	-0.09	0.15	-0.11*	0.67*	-0.35	-0.8**	1.67*	-2.33*	1.24
$P_4 \times P_{10}$	7.92**	5.41**	5.56**	0.04	0.07	-0.05	-2.82**	0.63**	-0.19	1.92*	-1.38	-2.17*
$P_5 \times P_6$	7.97**	1.15	0.56	0.15*	0.03	0.07	0.31	0.30	-0.19	-1.61*	7.99**	-1.61
$P_5 \times P_7$	7.64**	-1.36	0.63	0.32**	-0.27**	0.30**	1.29**	0.28	0.33**	7.50**	0.90	7.36**
$P_5 \times P_8$	-1.99	-1.99	-0.25	0.17*	0.42**	0.06	-1.38**	-0.30	0.46**	0.13	-2.63*	0.03
$P_5 \times P_9$	0.34	-2.50*	4.61**	-0.01	0.16*	0.15**	-1.61**	-0.21	-0.05	-3.92**	2.40*	-4.91**
$P_5 \times P_{10}$	1.73	2.66*	6.07**	-0.15*	0.04	0.15**	1.9**	0.08	0.08	1.28	-2.29*	1.28
$P_6 \times P_7$	6.99**	-4.58**	2.99*	0.15	0.49**	0.02	1.06**	0.26	-0.06	-0.67	-0.55	0.91
$P_6 \times P_8$	2.43	1.38	1.78	0.07	-0.08	0.22**	-0.18	0.00	0.39**	0.35	0.70	0.07
$P_6 \times P_9$	-1.97	0.08	-3.37**	-0.16*	0.10	-0.16**	1.2**	0.17	0.20	-1.19	-1.75	1.90*

Contd.

Table 3 (*Concluded*)

Parent/cross	SPC			1000-seed weight (g)			SYPP (g)			oil (%)		
	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3	E_1	E_2	E_3
$P_6 \times P_{10}$	-6.65**	1.70	-1.63	-0.28**	0.14	0.17**	-0.78*	-0.16	-0.08	-2.09**	1.41	-1.37
$P_7 \times P_8$	1.77	-3.81**	3.31**	0.22**	-0.08	0.11*	1.08**	-0.5*	-0.17	2.25**	-0.61	4.29**
$P_7 \times P_9$	0.44	4.89**	-4.03**	-0.11	-0.01	0.10	-0.85**	-0.46*	-0.44**	-2.15**	-2.18	-1.80
$P_7 \times P_{10}$	0.19	9.99**	-2.83*	-0.26**	-0.08	0.10	0.18	-0.24	-0.36**	-2.84**	-1.58	-0.61
$P_8 \times P_9$	2.01	-2.22	6.90**	0.33**	0.33**	-0.16**	1.07**	-1.89**	-0.04	-1.01	1.49	-1.43
$P_8 \times P_{10}$	1.43	4.18**	-3.24**	0.05	-0.25**	-0.03	0.85**	1.59**	-0.65**	2.40**	-2.28*	1.22
$P_9 \times P_{10}$	1.29	0.37	2.85*	0.01	0.02	0.02	0.59	0.07	0.61**	2.09**	0.33	2.12*
SE (Sij)±	2.04	1.24	1.19	0.08	0.08	0.05	0.32	0.22	0.10	0.75	1.11	0.93
SE (Sij-Sik)±	2.99	1.83	1.74	0.11	0.11	0.08	0.47	0.33	0.15	1.10	1.64	1.37
SE (Sij-Ski)±	2.85	1.74	1.66	0.11	0.11	0.08	0.45	0.31	0.15	1.05	1.56	1.31

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

SPC, Seeds per capsule; SYPP, Seed yeild per plant.

the crosses across the environments exhibited that the cross $P_2 \times P_3$ for seed yield per plant and $P_3 \times P_9$ for high oil content showed significant positive SCA effects indicating highly desirable and emerged as good specific combiner for these traits (Table 2, 3).

Distinctive combining ability effects explain why certain crosses had the most important SCA effects across environments of wide-ranging magnitudes, but none consistently demonstrated high SCA impacts for all characters. These parents gave the best potential for developing high-yielding lines in various environmental conditions. If both parents are powerful general combiners, the high SCA could be attributable to the accumulation of both parents' dominant alleles. Diallel selective mating or biparental mating may be an effective alternative approach for further enhancement in seed yield and oil content of sesame.

These findings suggest that both additive and non-additive factors have a role in these traits. An overall review showed that the RT–346, TKG–22, RT–372, RT–103, GT–10 and RT–351 emerged as good general combiners for seed yield per plant and some associated features based on GCA impacts in all 3 environment. Hybridization can increase sesame production by creating desirable lines with desirable features. In the E_1 environment, the crosses $P_1 \times P_2$, $P_1 \times P_9$, $P_2 \times P_3$, $P_5 \times P_7$, $P_9 \times P_{10}$, $P_1 \times P_{10}$, $P_3 \times P_8$, $P_3 \times P_9$ and $P_4 \times P_5$ have a lot of potential for sesame improvement and can be used in a variety of crossing programmes. The crosses involving good general combiners may be utilized to develop a pure line.

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