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Research Article

Genetic studies on yield and yield attributing traits in sesame (*Sesamum indicum* L.)

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Abstract
Six diverse parents were crossed in a half diallel fashion to study the heterosis and combining ability in sesame. Parents, 15 F_1s with one check was planted in RBD design at College Farm, NAU, Campus Bharuch during *kharif*-2021. The mean sum of squares due to genotypes and hybrids were significant for all the traits while, due to parents were significant for most of the traits. The mean sum of squares due to parents *vs.* hybrids were found to be significant for some traits. The *gca* and *sca* ratio was less than unity indicated that non-additive components play a greater role in the inheritance of most of the traits. Parents, Ingorala 5 and DC 4 had high *per se* and also good general combiner for seed yield and its traits, while hybrids AT 476 x Ingorala 5 and AT 332 x Ingorala 5 had the highest standard heterosis and *sca* effects for seed yield and some of its traits.

Keywords: Sesame, Heterosis, Combining ability, Gene action

INTRODUCTION

Sesame (*Sesamum indicum* L.) is an important and perhaps the most ancient oilseed crop grown in India. It is mainly a *Kharif* crop but is also grown in *Rabi* season. It belongs to the Tubiflorae order and Pedaliaceae family. Sesame is a diploid (2n=26) dicotyledon. Asia is rich in the diversity of cultivated sesame, while Africa is prosperous in wild relatives of sesame (Sharma *et al*., 2014). The genus sesame has about 36 species of which *Sesamum indicum* L. is the most dominant cultivated species.

Sesame is basically a short-day plant. Therefore, an intensity of light produces a significant morphogenic effect, influencing yield and oil content. The composition of sesame oil is quite unique as it contains both oil (57 to 63 per cent) and a good amount of protein (about 25.18 per cent) (Alege and Mustapha, 2013). Amino acids like methionine and tryptophan are missing in many vegetable proteins and sesame is rich in these amino acids, which enhance the quality of the crop (Quasem *et al*., 2009). Black varieties contain more oxalic acid, fibre and lower level of protein than white varieties. The sesame oil has a prolonged shelf life than the other oils as it consists of a high content of linoleic-oleic acid (Thakur *et al*., 2018). In the world, India occupies second place in terms of area and production of oilseed crops next to Myanmar. It occupies over 13.96 million ha area with a total world production of 6.80 million tones and average yield of 487.2 kg/ha (Anon., 2021). In India, sesame occupies an area of 1.52 million ha with a production of 0.658 million tones and 432.9 kg / ha of productivity (FAO, 2020).

The study of heterosis can give essential information concerning the breeding methodology to be used for varietal improvement. It additionally helps in rejecting a large number of crosses in the initial generation itself and selecting only those with high potential. The superiority of parents depends on their ability to combine well and additionally on the potentiality to throw transgressive segregants. In this context, combining ability analysis is helpful in isolating superior genotypes and in identifying gene action concerned with the inheritance of characters of economic importance.

MATERIALS AND METHODS

The crossing programme was carried out at College Farm, College of Agriculture, NAU, Campus Bharuch during summer-2021. A total of fifteen crosses were generated using six diverse parents *viz.,* AT 332, AT 456, AT 476, DC 4, Ingorala 5 and G. Til 4 of sesame hybridized in half diallel fashion. A complete set of 22 entries comprising of six parental genotypes, their 15 hybrids and one standard check variety (G. Til 6) were evaluated in Randomized Block Design (RBD) with three replications during *Kharif*-2021. Each entry was grown in a single row plot of 1.5 m length. Fifteen plants in each row were accommodated maintaining 10 cm inter-plant distance while inter-row distance was at 45 cm. Five plants were randomly selected and tagged excluding border plants from each replication and in each plot to minimize border effects. All the cultural and recommended packages of practices were followed Observations were recorded on the 13 characters *viz.,* days to 50% flowering, days to maturity, plant height (cm), branches per plant, capsules per plant, locules per capsule , capsule length (mm), seeds per capsule, seed yield per plant (g), 1000 seed weight (g), harvest index (%), oil content (%) and protein content (%). The analysis of variance was performed to test the significance of differences among the genotypes for all the characters following the fixed effect model as suggested by Panse and Sukhatme (1978). The heterotic effects were computed as the percentage increase or decrease of F_1 mean values over the better parent (heterobeltiosis) and standard check variety (standard heterosis) for all the characters and crosses following the standard formula. The variation among the hybrids was further partitioned into genetic components attributed to general combining ability (GCA) variances and specific combining ability (SCA) variances and effects were analysed by adopting Model-I, Method-2 of Griffing's (1956), since the present study includes parents and F_1s (without reciprocals).

RESULTS AND DISCUSSION

The result revealed that the mean squares due to genotypes and hybrids were highly significant for all the characters, while the mean squares for parents were non significant for plant height, locules per capsule and 1000 seed weight (**Table 1**). This indicated the existence of a considerable amount of genetic variability among genotypes, parents and hybrids for all the traits. The mean squares due to parents *vs*. hybrids was found to be significant for plant height, branches per plant, seed yield per plant, 1000 seed weight and protein content. This implied that the performance of parents was different

Table 1. Analysis of variance (mean sum of square) for various characters in sesame

Source of variation	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of capsules per plant	Number of locules per capsule	Capsules length (mm)
Replication	2	0.82	11.25	525.76*	0.02	27.50	0.06	0.24
Genotypes	20	7.11**	21.03**	308.68**	0.94**	78.12**	0.12**	9.35**
Parents	5	10.26**	28.18**	295.25	1.08**	88.77**	0.07	6.66**
Hybrids	14	6.31**	18.26**	294.42*	0.86**	79.89**	0.14**	10.75**
Parents vs. Hybrids	1	2.53	24.01	575.37*	1.25**	0.13	0.13	3.34
Error	40	2.12	6.43	129.47	0.10	23.94	0.04	1.75
Total	62	3.69	11.30	200.06	0.37	41.53	0.07	4.15

Table 1. Conintued..

Source of Variation	d.f.	Seeds per capsule	Seed yield per plant (g)	1000 seed weight (g)	Harvest index (%)	Oil content (%)	Protein content (%)
Replication	2	21.41	0.18	0.04	3.03	5.22	0.18
Genotypes	20	101.99**	11.76**	0.31**	44.96**	10.74**	8.08**
Parents	5	103.87*	4.95**	0.07	25.61**	7.47**	5.44**
Hybrids	14	98.43**	13.71**	0.37**	54.85**	12.68**	9.37**
Parents vs. Hybrids	1	142.47	18.57**	0.62**	3.20	0.01	3.20*
Error	40	38.10	0.64	0.04	6.29	2.10	0.52
Total	62	58.17	4.21	0.13	18.66	4.99	2.95

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than that of hybrids, which revealed the presence of mean heterosis for almost all the characters studied. Similar findings were noted by Hassan and Sedeck (2015), Virani *et al.* (2017), Vekariya and Dhaduk (2018), Dela and Sharma (2019) and Konate *et al.* (2021) in sesame.

A perusal of the mean value revealed that the parent Ingorala 5 recorded the highest seed yield per plant followed by DC 4 and G. Til 4. The hybrids, AT 476 x Ingorala 5, DC 4 x Ingorala 5 and AT 332 x Ingorala 5 were found to be superior for seed yield per plant among all hybrids tested. The parent AT 332 and Ingorala 5 were earlier for days to 50% flowering and the parent AT 456 was earlier in terms of days to maturity, whereas among hybrids AT 332 x Ingorala 5 were earlier in flowering and AT 456 x DC 4 were earlier in maturity. Parent Ingorala 5 and hybrid AT 456 x AT 476 were superior for plant height. Among parents, Ingorala 5 was superior for plant height, branches per plant, seeds per capsule, capsules per plant, capsule length and harvest index, whereas parents AT 476 and G. Til 4 were better for locules per capsule. In the case of hybrids, AT 456 x AT 476 was superior for plant height, AT 476 x Ingorala 5 was superior for branches per plant, seeds per capsule and capsules per plant. For capsule length DC 4 x Ingorala 5 was found better, AT 332 x Ingorala 5 was superior for harvest index and the hybrid Ingorala 5 x G. Til 4 was superior for locules per capsule. Among parents, DC 4 was superior for 1000 seed weight, oil content and protein content, whereas in the case of hybrids AT 332 x AT 476 and DC 4 x Ingorala 5 were superior for 1000 seed weight and oil content and protein content, respectively.

In the present study, seed yield per plant showed a wide range of variation in heterotic response over better parent and standard check and it was found that the hybrids, AT 476 x Ingorala 5, DC 4 x Ingorala 5 and AT 332 x Ingorala 5 were showing significant and desirable standard heterosis for seed yield per plant. They also exhibited significant and desirable heterosis for other traits like, capsules per plant, seeds per capsule, 1000 seed weight, branches per plant, harvest index and days to 50% flowering (**Table 2**). Similar findings was reported by earlier workers like Jatothu *et al.* (2013), Virani *et al.* (2017), Aye *et al.* (2018), Vekariya and Dhaduk (2018), Chauhan *et al.* (2019), Dela and Sharma (2019), Ismail *et al.* (2020), Jeeva *et al.* (2020), Ozahely *et al.* (2020), Nehra *et al.* (2021) and Parameshwarappa *et al.* (2021).

The analysis of variance for combining ability for different characters revealed that mean squares due to general combining ability (GCA) were significant for all the characters except days to maturity and specific combining ability (SCA) was significant for all the characters except plant height, capsules per plant and seeds per capsule (**Table 3**). This indicated that both additive and non-additive types of gene effects imparting a vital role in the inheritance of most of the traits under study. The results in general, were in accordance with the findings of Azeez and Morakinyo (2014), Ramesh *et al.* (2014),

Table 2. Estimates of heterosis over better parent and standard check for different characters in sesame

S. No	Crosses	Days to 50% flowering		Days to maturity		Plant height (cm)		Number of branches per plant	
		BH (%)	SH (%)	BH (%)	SH (%)	BH (%)	SH (%)	BH (%)	SH (%)
1	AT 332 x AT 456	2.14	-3.38	-4.60**	-1.97	-0.74	-1.64	13.56*	-2.42
2	AT 332 x AT 476	-8.50**	-5.41*	-1.53	1.18	-6.54**	-2.67**	-1.76	3.06
3	AT 332 x DC 4	-0.71	-5.41*	-6.51**	-3.94**	-5.35**	-6.98**	-9.08	-11.46*
4	AT 332 x Ingorala 5	-1.44	-7.43**	-6.13**	-3.54**	-8.93**	-1.20	4.16	11.52*
5	AT 332 x G. Til 4	-3.45	-5.41*	-6.90**	-4.33**	-7.37**	-8.97**	12.55*	4.46
6	AT 456 x AT 476	-4.58	-1.35	7.00**	2.36	2.88**	7.15**	-4.00	0.70
7	AT 456 x DC 4	1.42	-3.38	-0.41	-5.12**	2.86**	1.92**	-12.81*	-15.09*
8	AT 456 x Ingorala 5	3.57	-2.03	4.88**	1.57	-2.00**	6.32**	3.98	11.33*
9	AT 456 x G. Til 4	2.76	0.68	1.96	2.36	-6.59**	-7.44**	-7.82	-14.45*
10	AT 476 x DC 4	-1.96	1.35	5.76**	1.18	-17.90**	-14.50**	-9.59	-5.16
11	AT 476 x Ingorala 5	-6.54**	-3.38	4.07**	0.79	-4.54**	3.57**	10.46*	18.27*
12	AT 476 x G. Til 4	-6.54**	-3.38	1.57	1.97	-7.90**	-4.08**	4.37	9.48
13	DC 4 x Ingorala 5	6.38**	1.35	5.69**	2.36	-5.13**	2.93**	4.64	12.03*
14	DC 4 x G.Til 4	4.83	2.70	-3.92**	-3.54**	2.77**	-5.16**	-1.76	-4.33
15	Ingorala 5 x G.Til 4	-0.69	-2.70	1.96	2.36	-15.04**	-7.82**	-1.07	5.92
	S.E.(d) ±	1.205	1.205	2.054	2.054	9.240	9.240	0.265	0.265

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

BH = Heterobeltiosis and SH = Standard Heterosis

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Table 2. Continue...

S. No.	Crosses	Number of capsules per plant		Number of locules per capsule		Capsules length (mm)		Number of seeds per capsule	
		BH (%)	SH (%)	BH (%)	SH (%)	BH (%)	SH (%)	BH (%)	SH (%)
1	AT 332 x AT 456	9.06**	-9.12**	7.58*	9.23*	-8.38*	-3.97	1.44	-9.28**
2	AT 332 x AT 476	-14.10**	-14.45**	-2.90	3.08	8.41*	11.63**	-12.51**	-9.37**
3	AT 332 x DC 4	-16.29**	-17.06**	7.58*	9.23*	-6.11	0.35	1.29	0.92
4	AT 332 x Ingorala 5	6.00**	7.08**	4.41	9.23*	-6.31	2.61	4.62**	10.39**
5	AT 332 x G. Til 4	-4.16	-8.11**	-10.14*	-4.62	-5.93	-3.13	-8.27**	-6.25**
6	AT 456 x AT 476	5.90**	5.48**	-1.45	4.62	-1.81	2.91	-10.38**	-7.17**
7	AT 456 x DC 4	-11.75**	-12.56**	7.81*	6.15	4.68	11.89**	4.06	3.68
8	AT 456 x Ingorala 5	3.66	4.71	0.00	4.62	2.79	12.57**	2.44	8.09**
9	AT 456 x G. Til 4	-8.00**	-11.79**	-8.70*	-3.08	2.58	7.52	-8.36**	-6.34**
10	AT 476 x DC 4	-13.40**	-13.75**	-4.35	1.54	-9.61*	-3.39	3.28	6.99**
11	AT 476 x Ingorala 5	6.62**	7.70**	-1.45	4.62	-2.08	7.24	6.27**	12.13**
12	AT 476 x G. Til 4	-10.54**	-10.90**	-7.25*	-1.54	12.57**	12.38**	-11.98**	-8.82**
13	DC 4 x Ingorala 5	2.17	3.21	-2.94	1.54	7.58*	17.81**	4.27**	10.02**
14	DC 4 x G.Til 4	-2.22	-3.12	-10.14*	-4.62	-7.99*	-1.66	-0.90	1.29
15	Ingorala 5 x G.Til 4	3.75	4.81	4.35	10.77*	-4.22	4.90	-2.09	3.31
	S.E.(d) ±	4.016	4.016	0.155	0.155	1.098	1.098	4.963	4.963

*, ** Significant at 5 per cent and 1 per cent levels of probability, respectively
BH = Heterobeltiosis and SH = Standard Heterosis

Table 2. Continue….

S. No.	Crosses	Seed yield per plant (g)		1000 seed weight (g)		Harvest index (%)		Oil content (%)		Protein content (%)	
		BH (%)	SH (%)	BH (%)	SH (%)	BH (%)	SH (%)	BH (%)	SH (%)	BH (%)	SH (%)
1	AT 332 x AT 456	-0.09	-25.45*	6.25	-1.64	-7.62	-13.75**	-2.02	-4.50	-5.55	-15.67**
2	AT 332 x AT 476	4.86	-11.03	30.00*	20.35*	-4.89	-11.20**	-0.12	-3.26	-4.33	-14.58**
3	AT 332 x DC 4	-9.37	-10.75	-4.85	-7.33	-5.55	-2.94	-2.37	0.39	-6.98*	-4.55
4	AT 332 x Ingorala 5	15.50*	24.83*	8.33	0.29	9.27**	18.02**	-1.67	0.42	2.49	-4.78
5	AT 332 x G. Til 4	-22.47*	-26.77*	-7.50	-14.37*	-8.85	-14.89**	-2.95	-1.46	-1.90	-4.12
6	AT 456 x AT 476	3.15	-12.48	2.30	-5.59	-7.62	-15.24**	-0.73	-3.24	-4.99	-16.22**
7	AT 456 x DC 4	-12.46	-13.80*	0.00	-2.60	-20.30**	-18.10**	-4.59	-1.90	-10.49*	-8.15*
8	AT 456 x Ingorala 5	5.90	14.46*	3.24	-4.73	-16.58**	-9.90**	-4.32	-2.28	-3.81	-10.64*
9	AT 456 x G. Til 4	-14.54	-19.28*	-14.00*	-20.64*	-1.63	-9.74**	-3.72	-2.24	-5.30	-7.45*
10	AT 476 x DC 4	13.03	11.30	16.04*	13.02*	-16.98	-14.69**	-3.40	-0.67	-6.96*	-4.54
11	AT 476 x Ingorala 5	37.02**	48.09**	21.35*	11.28*	8.25	16.92**	-10.96**	-9.07**	4.78	-2.65
12	AT 476 x G. Til 4	-13.62	-18.41*	11.64	-6.56	-0.59	-12.28**	-2.22	-0.72	-1.77	-4.00
13	DC 4 x Ingorala 5	19.19*	28.81*	1.29	-1.35	8.83**	17.54**	5.00*	7.96**	6.42*	9.20*
14	DC 4 x G.Til 4	6.73	5.10	0.59	-2.03	7.58	10.55**	-1.73	1.05	5.51*	8.26*
15	Ingorala 5 x G.Til 4	3.82	12.21	6.73	-2.12	-5.78	1.77	5.53*	7.78**	10.23*	7.73*
	S.E.(d) ±	0.656	0.656	0.171	0.171	2.034	2.034	1.198	1.198	0.593	0.593

*, ** Significant at 5 per cent and 1 per cent levels of probability, respectively
BH = Heterobeltiosis and SH = Standard Heterosis

Joshi *et al.* (2015), Kumari *et al.* (2015), Pawar *et al.* (2016), Abd- Elsaber *et al.* (2019), Dela *et al.* (2019), Ismail *et al.* (2020), Pramitha(2020) and Kumar *et al.* (2021).

The magnitude of GCA and SCA variances revealed that the SCA variances were higher than their respective GCA variances for all traits. The GCA and SCA ratio (σ^2GCA/σ^2SCA) was less than unity for most of the traits indicating that non-additive components play a relatively greater role in the inheritance of these traits (**Table 3**). The predominance of non-additive gene action for seed yield per plant and its component traits were also reported by Azeez and Morakinyo (2014), Hassan and Sedeck (2015), Kumari *et al.* (2015), Reddy *et al*. (2015), Tripathy *et al.* (2016), Khuimphukhieo and Khaengkhan (2018), Abd- Elsaber *et al.* (2019), Dela *et al.* (2019), Ismail *et al.* (2020), Pramitha (2020) and Kumar *et al.* (2021).

The GCA effects of the parents revealed that none of the parents were found to be a good general combiner for all the traits. An overall appraisal of GCA effect revealed that its parents, Ingorala 5 and DC 4 were good general combiners for seed yield per plant and some of its components, whereas AT 456, AT 332 and G. Til 4 were poor combiners for seed yield per plant. The parent Ingorala 5 ranked first in the GCA effect for seed yield per plant, plant height, branches per plant, capsules per plant, locules per capsule, capsule length, seeds per capsule and harvest index, second position in days to 50% flowering and oil content and the third position in respect of 1000 seed weight and protein content. The parent DC 4 secured second position in the GCA effect for seeds per capsule, seed yield per plant and harvest index but secured first position in respect of the GCA effect for days to maturity, oil content and protein content (**Table 4**). Thus, Ingorala 5 and DC 4 were good general combiners for seed yield and its components, and they may be utilized in crossing programme to generate high genetic variability for implied selection to develop high yielding varieties of sesame. These results are in accordance with the findings of Azeez and Morakinyo (2014), Kumari *et al.* (2015), Reddy *et al*. (2015), Tripathy *et al.* (2016), Dela *et al.* (2019), Ismail *et al.* (2020), Pramitha (2020) and Sikarwar *et al.* (2021).

In the case of specific combining ability effects, none of the hybrids collectively exhibited a favourable SCA effect for all the traits. In the present study, positive specific combining ability is desirable for all the characters except for days to 50% flowering and days to maturity (**Table 5)**. Significant specific combining ability in a favourable direction was observed in many crosses for days to flowering (1 cross), days to maturity (1 cross), branches per plant (3 crosses), capsules per plant (2 crosses), locules per capsule (4 crosses), capsules length (4 crosses), seeds per capsule (1 cross), seed yield per plant (3 crosses), 1000 seed weight (5 crosses), harvest index (3 crosses), oil content (2 crosses) and protein content (3 crosses). These results are supported by the findings of Kumari *et al.* (2015), Reddy *et al*. (2015), Tripathy *et al.* (2016), Dela *et al.* (2019), Ismail *et al.* (2020), Pramitha (2020) and Sikarwar *et al.* (2021).

Among the three crosses that registered significant and positive SCA effects for seed yield per plant, two hybrids recorded significant and positive SCA effects for harvest index and 1000 seed weight, 1 for capsules per plant,

Table 3. Mean squares due to general and specific combining ability for different characters in sesame

Character	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of capsules per plant	Number of locules per capsule
GCA (5 d.f.)	4.45**	4.37	280.47**	0.84**	51.95**	0.04*
SCA (14 d.f.)	1.65*	7.46**	49.54	0.15**	15.13	0.05**
Error (40 d.f.)	0.73	2.11	42.69	0.04	8.06	0.01
σ^2 g	0.07	0.22	4.44	0.004	0.84	0.001
σ^2 s	0.57	1.65	33.54	0.028	6.33	0.009
GCA/SCA ratio	0.50	0.05	4.33	0.91	0.77	0.08

Character	Capsules length (mm)	Number of seeds per capsule	Seed yield per plant (g)	1000 seed weight (g)	Harvest index (%)	Oil content (%)	Protein content (%)
GCA (5 d.f.)	3.46**	85.97**	10.21**	0.16**	34.25**	7.78**	8.44**
SCA (14 d.f.)	3.11**	15.34	1.78**	0.11**	8.12**	2.11**	0.78**
Error (40 d.f.)	0.60	12.32	0.22	0.01	2.07	0.72	0.18
σ^2 g	0.06	1.28	0.022	0.002	0.21	0.075	0.018
σ^2 s	0.47	9.67	0.169	0.011	1.62	0.56	0.138
GCA/SCA ratio	0.14	3.04	0.79	0.20	0.66	0.63	1.70

Table 4. Estimates of GCA effects of parents for various characters in sesame

S. No.	Parents	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of capsules per plant	Number of locules per capsule
1	AT 332	-1.22**	-0.03	-1.74	-0.13*	-2.83**	0.04
2	AT 456	-0.06	-0.44	4.19*	-0.40**	-1.53	-0.05
3	AT 476	0.86**	0.60	2.83	0.26**	0.60	0.02
4	DC 4	0.40	-1.24**	-4.22*	-0.17**	-0.70	-0.06
5	Ingorala 5	-0.43	0.43	7.48**	0.50**	4.61**	0.10**
6	G. Til 4	0.44	0.68	-8.54**	-0.06	-0.15	-0.06
	S. E. (gi) ±	2.20	3.75	16.87	0.48	7.33	0.28
	S. E. (gi - gj) ±	0.42	0.72	3.26	0.09	1.42	0.05

S. No.	Parents	Capsules length (mm)	Number of seeds per capsule	Seed yield per plant (g)	1000 seed weight (g)	Harvest index (%)	Oil content (%)	Protein content (%)
1	AT 332	-0.65**	-3.76**	-0.97**	0.05	-0.36	-0.74**	-0.73**
2	AT 456	0.28	-2.77*	-1.07**	-0.09*	-2.18**	-0.84**	-1.18**
3	AT 476	-0.50*	0.23	0.08	0.12**	-1.36**	-1.09**	-0.83**
4	DC 4	0.22	2.15	0.45**	0.10*	1.08*	1.06**	1.19**
5	Ingorala 5	1.09**	5.13**	1.97**	0.07	3.59**	0.85**	0.62**
6	G. Til 4	-0.44	-0.98	-0.47**	-0.24**	-0.77	0.76**	0.93**
	S. E. (gi) ±	2.00	9.06	1.19	0.31	3.71	2.18	1.08
	S. E. (gi - gj) ±	0.38	1.75	0.23	0.06	0.71	0.42	0.21

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

Table 5. Estimates of SCA effects of hybrids for various characters in sesame

S. No.	Crosses	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of capsules per plant	Number of locules per capsule
1	AT 332 x AT 456	0.97	-0.37	-1.35	0.43*	2.03	0.27**
2	AT 332 x AT 476	-0.94	1.26	-1.64	0.05	-3.13	-0.06
3	AT 332 x DC 4	-0.48	-1.24	-1.55	-0.28	-3.31	0.28**
4	AT 332 x Ingorala 5	-0.64	-2.58	-3.92	0.26	5.12*	0.12
5	AT 332 x G. Til 4	-0.52	-3.49**	-0.45	0.45**	1.23	-0.31**
6	AT 456 x AT 476	-0.10	2.67*	8.27	0.20	6.91**	0.10
7	AT 456 x DC 4	-0.64	-1.83	6.89	-0.20	-2.05	0.24*
8	AT 456 x Ingorala 5	0.85	2.17	2.29	0.52**	2.47	0.01
9	AT 456 x G. Til 4	1.30	2.59*	-3.90	-0.27	-2.17	-0.15
10	AT 476 x DC 4	0.76	2.46	-18.26**	-0.33*	-4.86	-0.03
11	AT 476 x Ingorala 5	-0.73	0.46	-0.80	0.22	2.03	-0.05
12	AT 476 x G. Til 4	-1.60*	1.21	2.87	0.33	-3.79	-0.15
13	DC 4 x Ingorala 5	2.05*	3.63**	5.23	0.32	0.79	-0.11
14	DC 4 x G. Til 4	1.85*	-1.62	8.19	0.03	1.94	-0.21*
15	Ingorala 5 x G. Til 4	0.01	1.71	-7.81	-0.10	1.14	0.30**
	S.E.(sij) ±	2.880	4.910	22.087	0.633	9.599	0.372
	S.E.(sij-sik) ±	1.127	1.921	8.643	0.248	3.756	0.145
	S.E.(sij-skl) ±	1.043	1.779	8.002	0.229	3.478	0.135

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

Table 5. Continue...

S. No.	Crosses	Capsules length (mm)	Number of seeds per capsule	Seed yield per plant (g)	1000 seed weight (g)	Harvest index (%)	Oil content (%)	Protein content (%)
1	AT 332 x AT 456	-1.98**	-0.04	-0.15	0.13	-0.55	-0.22	-0.31
2	AT 332 x AT 476	3.06**	-3.11	0.09	0.67**	-0.55	0.62	-0.42
3	AT 332 x DC 4	-0.74	2.43	-0.25	-0.26*	-0.33	0.22	-0.26
4	AT 332 x Ingorala 5	-0.99	6.33*	1.65**	0.04	3.90**	0.44	0.26
5	AT 332 x G. Til 4	-1.04	0.37	-0.87*	-0.16	-2.33	-0.37	0.09
6	AT 456 x AT 476	-0.25	-2.49	0.05	-0.08	-0.03	0.73	-0.33
7	AT 456 x DC 4	1.49*	3.45	-0.44	0.05	-3.39**	-0.77	-0.59
8	AT 456 x Ingorala 5	0.81	3.68	0.75	0.01	-3.26*	-0.75	-0.57
9	AT 456 x G. Til 4	0.95	-0.68	-0.05	-0.23*	1.15	-0.64	-0.18
10	AT 476 x DC 4	-1.92**	2.85	0.83*	0.37**	-3.12*	0.06	-0.16
11	AT 476 x Ingorala 5	0.12	3.61	2.84**	0.34**	4.54**	-3.77**	0.82*
12	AT 476 x G. Til 4	3.05**	-5.48	-1.12**	0.04	-0.49	0.33	0.22
13	DC 4 x Ingorala 5	2.30**	0.15	0.62	-0.07	2.30	2.26**	1.38**
14	DC 4 x G. Til 4	-1.50*	-0.07	0.78	0.22*	4.41**	-0.96	0.87*
15	Ingorala 5 x G. Til 4	-0.58	-1.58	-0.06	0.25*	-0.92	2.48**	1.32**
	S.E.(sij) ±	2.624	11.864	1.569	0.409	4.863	2.865	1.418
	S.E.(sij-sik) ±	1.027	4.643	0.614	0.160	1.903	1.121	0.555
	S.E.(sij-skl) ±	0.951	4.298	0.568	0.148	1.762	1.038	0.514

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

seeds per capsule and protein content. Hence, hybrids with high SCA effects for seed yield per plant also exhibited high SCA effects for one or more yield contributing traits. This suggested the role of yield attributing traits towards high yield. This experiment revealed that parents, Ingorala 5 and DC 4 had high *per se* and also good general combiner for seed yield and its traits, while hybrids AT 476 x Ingorala 5 and AT 332 x Ingorala 5 had the highest standard heterosis and *sca* effects for seed yield and some of its traits. So, these parents and crosses can be used for further breeding programme.

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