Website : www.asthafoundation.in
Frontiers in Crop Improvement
Vol 10 (2) : 134-140 (July-2022) Print ISSN : 2393-8234 Online ISSN : 2454-6011
Astha Foundation, Meerut (U.P.) India

Combining Ability Studies in F_2 Generation of Sesame (*Sesamum indicum* L.) Over Environments

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Abstract

F_2 population of a set of diallel crosses involving 9 parents was evaluated to estimate the combining ability and gene action for yield and yield contributing characters under fourdifferent environments during summer 2016?17. On pooled basis, parents AT 238, AT 345 and GT 10 in F_2 generation were found good general combiners for seed yield per plant as well as for some important yield attributes, possessed high concentration of favourable genes as indicated by significant and positive gca effects. Considering the overall performance of hybrids with respect to high and significant sca effects across the environments for seed yield per plant in F_2 generation, the best ten best hybrids were AT 238×GT 1, AT 164×AT 238, AT 255×Nesadi Selection, AT 345×GT 10, AT 282×GT 10, AT 255×China, AT 238×AT 345, Nesadi Selection×GT 1, China×GT 10 and AT 345×China, manifested significant and high sca effects in that order. These best hybrids also manifested the high and desirable sca effects for some of the important yield contributing characters. On the basis of significant positive sca effects for seed yield per plant on pooled basis, AT 238×GT 1 (1.84), AT 164×AT 238 (1.79) and AT 255×Nesadi Selection three hybrids were rated as the best since it possessed desirable performance based on *per se*, *sca* effects for most of the yield attributing characters and so these hybrids could be exploited for further crop improvement. Also these crosses can be utilized for pedigree breeding programme.

Key words : *Combining ability, F_2 generation, GCA, SCA, sesame.*

Introduction

Sesame (*Sesamum indicum* L. Family: Pedaliaceae) is one of the oldest oilseed crops grown throughout the tropical and sub-tropical region soft the world. India is considered tobe the major centre of genetic diversity even though the crop originated in Africa (1). Oilseeds crops serve as the second most economically important target group of the Indian agriculture next to cereals accounting for 19% of the global area with around 2.7% of global production (2). Sesame is diploid (2n+26) in nature and is commonly known as Til, Tilli, Gigelly, Ellu, sim-sim, Benni seed, nurvulu, Velvorrasi and sesame in different part of India and often referred as the epithet "The queen of oilseeds". Generally, the oil content in sesame ranges from 34 to 63 percent (3). Sesame oil is considered as the queen of high-quality vegetable oil (44-58% of dry seed weight) for human consumption as it contains high levels of unsaturated fatty acids and antioxidants e.g., sesamol, sesamin, sesamolin and sesaminol (4). The seed of sesame contains 40 to 63 percentoil which is rich in antioxidants and has significant amount of oleic and linoleic acids (5). Sesame is an important source of high-quality oil and protein (6). Sesame seed cake is a by-product of traditional oil processing (7). Sesame seed oil was found to be rich in tocopherols (8). Worldwide, it is cultivated in an area of 117 lakh ha with production of 60.16 lakh mt and productivity of 512 $kgha^{-1}$ (9). Hence, there is a need to augment the productivity of crop through crop improvement programme. Selection of parents based on per seperformance alone is not a better option because parents with superior phenotype can result in inferior or poor hybrids in later generations (10).

The success of any plant breeding programme mostly depends on the exact knowledge of the genetic architecture of the population, the basic genetic mechanisms involved in generating variability and the selection of parents together with the information regarding nature and magnitude of gene action controlling various characters of agronomic importance. Hence, selection for yield per se may not be effective unless the yield contributing characters are given due emphasis as there being no gene for yield per se (11). The use of the seeds for decoration on the surface of breads and cookies is most familiar to the Americans (12). The combining ability is an important tool for the selection of desirable parents together with the information regarding nature and magnitude of gene effects controlling quantitative traits (13).

Received : April-2022; Revised : May-2022; Accepted : May-2022

Table-1 : Analysis of variance (mean squares) for combining ability, estimates of component of variance and their ratio for differentcharacters pooled over environments in F_2 population of sesame.

Source of variation	GCA	SCA	Environ_ ments (E)	GCA x Environ- ment	SCA x Environ- ment	Error	^{2}GCA	^{2}SCA	^{2}GCA / ^{2}SCA
df	**8**	**36**	**3**	**24**	**108**	**352**			
Days to flowering	32.94**	9.29**	66.47**	1.27	1.61**	1.27	0.72	2.01	0.36
Days to maturity	497.04**	30.63**	69.50**	3.28	3.23**	5.85	11.16	6.20	1.80
Plant height (cm)	75.80**	66.54**	317.42**	7.67	9.71**	6.20	1.58	15.09	0.10
Number of branches per plant	7.09**	0.80**	0.09**	0.09**	0.04**	0.02	0.16	0.19	0.83
Number of capsules per plant	752.48**	95.44**	330.39**	52.72**	22.60**	3.75	17.02	22.92	0.74
Height to first capsule (cm)	31.57**	31.09**	280.72**	1.21**	2.34**	0.41	0.71	7.67	0.09
Length of capsule (cm)	0.65**	0.07**	0.33**	0.02**	0.02	0.01	0.01	0.01	0.95
Width of capsule (cm)	0.04**	0.01**	0.10**	0.001	0.002	0.001	0.001	0.001	0.49
No. of capsules per leaf axil	2.55**	0.76**	0.004	0.01**	0.01**	0.005	0.06	0.19	0.31
Number of seeds per capsule	0.23**	0.20**	0.07**	0.01	0.005**	0.005	0.005	0.05	0.11
1000 seed weight (g)	311.79**	31.74**	177.32**	18.05**	8.55**	7.13	6.92	6.15	1.13
Seed yield per plant (g)	11.34**	4.02**	19.64**	0.18	0.18	0.12	0.25	0.97	0.26
Biological yield per plant (g)	78.58**	22.13**	17.27**	0.42	0.54**	0.30	1.78	5.46	0.33
Harvest index (%)	292.79**	137.91**	692.44**	5.31	8.16**	6.69	6.50	32.81	0.20
Oil content (%)	4.98**	2.62**	0.53	0.04	0.03	0.52	0.10	0.53	0.19

* and ** significant at 5% and 1% levels of significance, respectively.

Materials and Methods

Nine sesame genotypes and their 36 F_2s were evaluated in a Randomized Block Design with three replications in four different environments [two locations, Junagadh and Nana Kandhasar and two dates of sowing, February 20 and March 10, 2016 at Junagadh and February 22 and March 12, 2016 at Nana Kandhasar] during summer 2016 and 17. Each entry was sown in single row of 3.0 m length with a spacing of 45 cm between row and 15 cm between plants within the row. Five competitive plants per genotype in each replication in each environment were selected randomly for recording observations on different characters *viz*., plant height (cm), number of branches per plant, number of capsules per plant, height to first capsule (cm), length of capsule (cm), width of capsule (cm), number of capsules per leaf axil, number of seeds per capsule, 1000 seed weight (g), seed yield per plant (g), biological yield per plant (g), harvest index (%) and oil content (%). Characters, days to flowering and days to maturity were recorded on plot basis, The combining ability analysis for individual as well as pooled over environments was carried out according to Model-I (Fixed effect), Method-II (parents and one set of F_1s without reciprocals) of (14).

Results nd Discussion

Analysis of variance for combining ability pooled over environments (Table-1) revealed that mean squares due to general combining ability as well as specific combining ability were significant for all the fifteen characters in F_2 population. The significant difference of gca and sca indicated that both additive and non-additive gene effects played an important role in the genetic control of the traits under study. The results obtained in the present studies are in accordance with the findings of (13, 14). Similarly, The mean squares due to gca x environment interactions were significant for number of branches per plant, number of capsules per plant, height to first capsule, length of capsule, number of capsules per leaf axil and 1000 seed weight in F_2 population (Table-1). The mean squares due to sca x environment interactions were significant for all the fifteen characters, except for length of capsule, width of capsule, seed yield per plant and oil content. On pooled basis, the variance ratio of ^{2}GCA(^{2}SCA)$^{-1}$ was less than unity for all the characters, except for days to maturity and 1000 seed weight in F_2 generation indicates the preponderance of non-additive gene action for almost all the characters under investigation, which suggested that the best cross combinations might be selected on the basis of sca for further tangible advancement in sesame. The predominance of non-additive gene action for seed yield and its component traits were also reported by (13,15) in sesame.

A perusal of results presented in Table-2 on gca effects for seed yield per plant revealed that gca effects for parents in F_2generation pooled over environments ranged from -0.78 (AT 164) to 0.74 (GT 10).Across the environments, parents GT 10 (0.74), AT 345 (0.69) and AT 238 (0.28) were found to be good general combiners for seed yield per plant, as they recorded significant

Table-2 : Estimates of general combining ability effects of parents for various characters pooled over environments in F_2 generation of sesame.

Sr. No.	Parents	Days to flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of capsules per plant	Height to first Capsule (cm)	Length of capsule (cm)	Width of capsule (cm)	Number of capsules per leaf axil	Number of seeds per capsule	1000 seed weight (g)	Seed yield per plant (g)	Biological yield per plant (g)	Harvest index (%)	Oil Content (%)
1.	AT 164	-0.28	-0.72*	-0.16	0.09**	-0.13	-0.36**	0.01	0.01	-0.14**	0.78*	0.06**	-0.78**	-1.03**	-2.83**	0.42**
2.	AT 238	0.37*	-0.41	-1.27**	-0.17**	-0.09	-0.38**	-0.01	0.03**	0.10**	3.01**	0.08**	0.28**	-0.04	1.76**	0.16
3.	AT 255	0.56**	0.08	-0.23	-0.10**	-0.52	0.43**	0.09**	0.02*	-0.10**	3.50**	0.04**	-0.02	-1.05**	2.40**	0.46**
4.	AT 282	-0.20	-1.71**	-1.26**	-0.13**	-2.65**	0.25**	-0.01	0.03**	-0.32**	-3.08**	0.03*	-0.11*	-1.29**	2.49**	-0.28**
5.	AT 345	-0.17	1.64**	1.38**	0.22**	4.34**	0.10	-0.01	0.01	0.13**	1.09**	-0.01	0.69**	0.86**	2.17**	-0.29**
6.	China	0.12	-0.47	0.65	-0.53**	-2.06**	0.03	0.27**	0.02*	0.37**	2.06**	-0.16**	-0.33**	0.90**	-4.44**	-0.47**
7.	Nesadi Selection	-1.70**	-4.57**	-1.99**	-0.19**	-4.80**	-0.07	-0.09**	-0.04**	0.26**	-2.25**	0.03*	-0.48**	-0.95**	-1.09**	-0.11
8.	GT 1	-0.26**	-1.60**	1.28**	-0.11**	-2.79**	-1.61**	-0.11**	-0.03**	0.02	-1.61**	0.01	0.02	-0.23**	1.28**	0.26*
9.	GT 10	1.56**	7.77**	1.61**	0.92**	8.69**	1.61**	-0.14**	-0.05**	-0.32**	-3.49**	-0.07**	0.74**	2.82**	-1.74**	-0.16
	S.E. ±	0.18	0.16	0.34	0.35	0.02	0.28	0.09	0.02	0.01	0.38	0.01	0.05	0.08	0.37	0.10

* and ** significant at 5% and 1% levels of significance, respectively.

positive gca effects across the environments in F_2 generation.It was evident from the Table-2 that GT 10 which was good general combiner for seed yield per plant was also good general combiners for some of its yield contributing characters like plant height, number of branches per plant, number of capsules per plant and biological yield per plant. The second-best general combiner AT 345 was also good general combiner for plant height, number of branches per plant, number of capsules per plant, number of capsules per leaf axil, number of seeds per capsule, biological yield per plant and harvest index. The third good general combine AT 238 was also good general combiner for width of capsule, number of capsules per leaf axil, number of seeds per capsule, 1000 seed weight and harvest index.

The sca effects for seed yield per plant in F_2 generation ranged from -1.63 (AT 164×AT 345) to 1.74 (AT 164×AT 238), -2.09 (AT 164×AT 345) to 2.50 (AT 238×GT 1), -1.56 (AT 164×AT 345) to 1.72 (AT 345×GT 10), -1.87 (AT 164×AT 345) to 1.99 (AT 164×AT 238) and -1.79 (AT 164×AT 345) to 1.84 (AT 238×GT 1) in E_1, E_2, E_3, E_4 and pooled over environments, respectively (Table 3). Out of 36 F_2crosses, 8, 10, 8, 12 and 12 crosses in F_2 generation noted significant and positive sca effects for seed yield per plant in E_1, E_2, E_3, E_4 and pooled over environments, respectively. In F_2 generation, three best crosses on the basis of significant and positive sca effects for seed yield per plant were AT 164 x AT 238 (1.74), AT 255 x China (1.73) and AT 238 x GT 1 (1.72) in E_1; AT 238 x GT 1 (2.50), AT 164 x AT 238 (2.47) and AT 238 x AT 345 (2.41) in E_2; AT 345 x GT 10 (1.72), AT 255 x Nesadi Selection (1.69) and AT 238 x GT 1 (1.55) in E_3; AT 164 x AT 238 (1.99), AT 238 x GT 1 (1.57) and AT 255 x Nesadi Selection (1.57) in E_4; and AT 238×GT 1 (1.84), AT 164×AT 238 (1.79) and AT 255×Nesadi Selection (1.78).

The estimates of sca effects in F_2 generation (Table-4) revealed that none of the hybrid was consistently superior for all the characters in F_2 generations. Considering the overall performance of hybrids with respect to high and significant sca effects across the environments for seed yield per plant in F_2 generation, the best ten best hybrids were AT 238×GT 1, AT 164×AT 238, AT 255×Nesadi Selection, AT 345×GT 10, AT 282×GT 10, AT 255×China, AT 238×AT 345, NesadiSelection×GT 1, China×GT 10 and AT 345×China, manifested significant and high sca effects in that order. These best hybrids of F_2 generations with high sca effects for seed yield per plant also manifested the high and desirable sca effects for some of the important yield contributing characters. Hence, the hybrids with high sca effects for seed yield per plant were also associated with high and desirable sca effects for some of the important yield contributing characters. Of these ten hybrids, AT 238×GT 1 (1.84), AT 164×AT 238 (1.79) and AT

Table-3 : Estimates of specific combining ability effects of F_2 crosses for seed yield per plant (g) in individual and pooled over environments in sesame.

Sr. No.	Hybrid	E_1	E_2	E_3	E_4	Pooled
1.	AT 164 x AT 238	1.74**	2.47**	0.94**	1.99**	1.79**
2.	AT 164 x AT 255	-0.43	-0.92*	0.03	-0.61**	-0.48**
3.	AT 164 x AT 282	-0.48	-0.57	0.01	-0.66**	-0.43**
4.	AT 164 x AT 345	-1.63**	-2.09**	-1.56**	-1.87**	-1.79**
5.	AT 164 x China	-0.57*	-0.90*	-0.52	-0.61**	-0.65**
6.	AT 164 x Nesadi Selection	-0.60*	-0.29	0.05	0.17	-0.17
7.	AT 164 x GT 1	0.37	0.05	0.36	0.74**	0.38*
8.	AT 164 x GT 10	-0.59*	-0.58	-1.13**	-1.02**	-0.83**
9.	AT 238 x AT 255	-0.45	-0.56	-0.68*	-0.24	-0.48**
10.	AT 238 x AT 282	-0.45	-0.64	-1.27**	-0.22	-0.65**
11.	AT 238 x AT 345	0.67*	2.41**	0.73**	0.66**	1.12**
12.	AT 238 x China	-1.10**	-2.00**	-0.38	-1.46**	-1.24**
13.	AT 238 x Nesadi Selection	-0.43	-0.85*	-0.49	-0.44**	-0.55**
14.	AT 238 x GT 1	1.72**	2.50**	1.55**	1.57**	1.84**
15.	AT 238 x GT 10	0.26	-0.11	-0.08	0.22	0.08
16.	AT 255 x AT 282	-0.20	-0.84*	-0.48	0.12	-0.35*
17.	AT 255 x AT 345	-0.01	0.43	-0.89**	-0.32	-0.20
18.	AT 255 x China	1.73**	1.55**	1.27**	1.07**	1.40**
19.	AT 255 x Nesadi Selection	1.69**	2.17**	1.69**	1.57**	1.78**
20.	AT 255 x GT 1	0.39	0.33	0.23	0.84**	0.45**
21.	AT 255 x GT 10	-0.73**	-0.12	0.06	0.15	-0.16
22.	AT 282 x AT 345	-0.55	-0.55	-0.26	0.04	-0.33*
23.	AT 282 x China	-0.21	-0.20	-0.47	-0.58**	-0.36*
24.	AT 282 x Nesadi Selection	0.21	0.11	0.46	0.17	0.23
25.	AT 282 x GT 1	0.11	-0.01	-0.30	-0.33	-0.13
26.	AT 282 x GT 10	1.37**	2.05**	1.17**	1.25**	1.46**
27.	AT 345 x China	0.49	0.86*	-0.09	0.66**	0.48**
28.	AT 345 x Nesadi Selection	-0.79**	-1.20**	-1.35**	-1.17**	-1.13**
29.	AT 345 x GT 1	-0.99**	-1.50**	-1.11**	-1.08**	-1.17**
30.	AT 345 x GT 10	1.48**	1.55**	1.72**	1.51**	1.57**
31.	China x Nesadi Selection	0.08	-0.54	0.49	0.54**	0.14
32.	China x GT 1	0.25	0.78	-0.23	-0.04	0.19
33.	China x GT 10	0.55	1.35**	0.08	0.67**	0.66**
34.	Nesadi Selection x GT 1	0.75**	1.73**	0.77**	0.69**	0.98**
35.	Nesadi Selection x GT 10	-0.40	-1.08**	-0.79**	-1.09**	-0.84**
36.	GT 1 x GT 10	-0.96**	-1.13**	-0.44	-0.51**	-0.76**
	S.E. ±	0.28	0.41	0.28	0.15	0.16

* and ** significant at 5 and 1 per cent levels of significance, respectively.

255×Nesadi Selection (1.78) were the best three hybrids on the basis of the significant and desirable sca effects pooled over environments for seed yield per plant in F_2 population. Of these hybrids, AT 238×GT 1 exhibited significant and desirable sca effects for number of branches per plant, biological yield per plant and harvest index; AT 164×AT 238 for days to maturity, plant height, length of capsule, width of capsule, number of seeds per capsule, biological yield and harvest index; and AT 255×Nesadi Selection for height to first capsule, biological yield per plant and harvest index in F_2 generation. The crosses showing significant sca effects are expected through-off transgressive segregants in segregating generation and thus, such crosses could be exploited for the improvement of yield and specific yield contributing characters.

A perusal of the data presented in Table-5 showed a good agreement between best performing parents and best general combining parents for seed yield per plant and important yield components in F_2 generation. This

Table-4 : Top ten crosses based on significant SCA effects for seed yield per plant on pooled basis and its position to component traits with respect to sca effects in F_2 generation of sesame.

Sr. No.	Crosses	Seed yield per plant (g)	Days to flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of capsules per plant	Height to first capsule (cm)	Length of capsule (cm)	Width of capsule (cm)	Number of capsules per leaf axil	Number of seeds per capsule	1000 seed weight (g)	Biological yield per plant (g)	Harvest index (%)	Oil content (%)
1.	AT 238 x GT 1	1.84**	-0.59	1.55	1.47	0.36**	0.00	4.77**	-0.09	-0.05*	-0.44**	0.82	0.05	2.90**	3.73**	0.26
2.	AT 282 x GT 10	1.79**	-1.33**	1.21	4.71**	-0.44**	-1.70	1.77**	0.17**	0.11**	-0.31**	3.57**	-0.05	2.67**	5.31**	0.28
3.	AT 164 x AT 238	1.78**	0.47	0.92	-4.74**	-0.06	-3.49**	-3.85**	-0.19**	-0.05*	-0.51**	-3.21**	-0.22**	2.21**	6.76**	0.36
4.	AT 238 x AT 345	1.57**	-0.59	-1.68	-6.59**	-0.21**	4.37**	1.81**	-0.10	-0.05*	-0.16**	-0.85	-0.23**	-0.04	8.84**	0.03
5.	AT 255 x Nesadi Selection	1.46**	-0.78	-2.76**	6.50**	-0.22**	8.12**	-0.68**	0.11*	-0.02	0.29**	2.23	-0.20**	3.90**	-0.18	-0.43
6.	Nesadi Selection x GT 1	1.40**	0.25	-0.86	-1.21	0.78**	1.75*	0.00	-0.10	0.03	-0.62**	1.49	0.31**	1.85**	4.30**	0.44
7.	AT 345 x China	1.12**	0.78	-3.17**	4.75**	-0.33**	-6.49**	-4.22**	0.27**	0.00	0.22**	0.85	-0.11**	4.10**	-2.67*	0.60
8.	AT 255 x China	0.98**	2.01**	1.10	3.24**	0.09	0.74	1.59**	-0.10	0.00	0.10**	-0.15	-0.02	-0.09	7.06**	-0.81*
9.	AT 238 x GT 10	0.66**	0.45	-3.84**	-7.92**	0.15*	-6.60**	-2.50**	-0.10	-0.01	-0.40**	-1.48	0.33**	0.65**	3.15**	-0.68*
10.	AT 255 x GT 1	0.48**	-0.28	-0.99	0.43	-0.50**	-1.23	2.23**	-0.03	0.02	0.32**	-1.19	0.16**	1.65**	-0.20	0.51

*, ** Indicates significance at P = 0.05 and P = 0.01 levels, respectively.

indicating that, while selecting the parents for hybridization programme, *per se* performance of parents should also be given due weightage along with combining ability of parents. Such parallel behaviour of *per se* performance and general combining ability was also reported by (16). Also the similar good agreement was observed between best performing cross combinations and best specific combining cross combinations for seed yield per plant and important yield components in F_2 generation. This indicating that, in self-pollinated crops like sesame, sca effects have relatively less applicability, as they are consequences of non-additive gene effects excepting those arising from complementary gene action or linkage effects and cannot be fixed in the end product i.e. pure line. (17) emphasized that the superiority of the hybrids might not indicate their ability to yield transgressive segregants, rather sca would provide satisfactory criteria. However, if a cross combination exhibiting high sca as well as high *per se* performance having at least one parent as good general combiner for a specific trait, it is expected that this cross combination may provide desirable transgressive segregants in later generations.

A perusal of the data given in Table-5 further revealed that the three best performing hybrids for different characters also possessed high heterotic response in desired direction over their respective better parents as well as over standard check and desired sca effects. It can be concluded that *per se* performance of parents and hybrids was related with gca effects of parents and heterotic response of the hybrids, respectively. Thus, the potentiality of a strain to be used as a parent in hybridization programme or a cross to be used as a commercial hybrid may be judged by comparing *per se* performance of parents and hybrids along with gca of parents and heterotic response of hybrids. The crosses exhibiting high *per se* performance, high heterosis and significant desirable sca effect for various traits involved either good x good or good x average or average x good or poor x poor combining parents (Table-5). Thus, the crosses exhibiting high sca effect did not always involve the parents with high gca effects. The results, thus, suggested that interallelic interaction were also important for these characters.

The best three hybrids for seed yield per plant on the basis of *per se* performance, *viz.,* AT 238×AT 345 (good x good), AT 282×GT 10 (average×average) and AT 238×GT 1 (good×poor) had significant desired sca effects, significant and desirable heterotic response over better parents and desirable standard heterosis for seed yield per plant (AT 238×AT 315 manifested significant standard heterosis). These high yielding hybrids also possessed desirable sca effects, high heterosis as well as high *per se* performance for some of its important yield

Table-5 : Summary of three best performing parents, best general combining parents and best performing hybrids along with their sca effects and per cent heterosis over better parent (BP) and standard check (SC) for various traits on pooled basis in F_2 generation of sesame.

Sr. No.	Characters	Best performing parents	Best general combiners	Best performing F_2	Sca effect	Best specific F_2 cross combination	Sca effect	Heterosis of best performing cross combination over	
								BP	SC
1.	Days to flowering	Nesad Selection	Nesadi Selection	AT 238 x Nesadi Selection	-0.14	AT 238 x AT 255	-1.45**	-5.87	-8.17*
		China	GT 1	AT 164 x Nesadi Selection	0.53	AT 164 x AT 238	-1.33**	-3.30	-6.31
		GT 1	-	AT 164 x AT 282	-0.95	AT 238 x GT 10	-1.00	-3.96	-6.31
2.	Days to maturity	Nesadi Selection	Nesadi Selection	AT 164 x GT 1	-3.98**	AT 164 x GT 1	-3.98**	2.27	-2.45
		GT 1	AT 282	AT 238 x Nesadi Selection	-1.30	China x GT 10	-3.84**	9.13*	9.13*
		AT 282	GT 1	AT 164 x Nesadi Selection	-0.46	AT 255 x AT 345	-3.60**	-5.88	-2.51
3.	Plant height (cm)	GT 10	GT 10	AT 282 x GT 10	6.50**	AT 282 x GT 10	6.50**	-8.53	4.43
		AT 345	AT 345	China x GT 1	4.31**	AT 238 x AT 345	4.75**	-0.91	5.89
		China	GT 1	AT 238 x AT 345	4.75**	AT 164 x AT 238	4.71**	21.03**	10.58*
4.	Number of branches per plant	GT 10	GT 10	AT 345 x GT 10	-0.21**	AT 255 x China	0.78**	41.67**	-3.59
		AT 164	AT 345	AT 238 x GT 10	0.04	AT 238 x GT 1	0.36**	10.17	-11.08
		AT 345	AT 164	AT 255 x GT 10	-0.22**	AT 255 x AT 345	0.35**	-17.21**	7.19
5.	Number of capsules per plant	AT 345	GT 10	AT 345 x GT 10	4.37**	AT 282 x GT 10	8.12**	10.08	38.96**
		GT 10	AT 345	AT 282 x GT 10	8.12**	AT 345 x GT 10	4.37**	-9.40	22.58**
		AT 164	-	AT 255 x GT 10	2.54**	AT 238 x China	3.59**	2.18	-5.40
6.	Height to first capsule (cm)	Nesadi Selection	GT 1	AT 255 x GT 1	-3.65**	AT 238 x AT 345	-4.22**	-26.00**	-38.56**
		GT 1	AT 238	China x GT 1	-3.20**	AT 164 x GT 10	-3.94**	36.66**	34.55**
		AT 238	AT 164	AT 238 x AT 345	-4.22**	AT 255 x Nesadi Selection	-3.85**	35.67**	-5.77
7.	Length of capsule (cm)	China	China	China x Nesadi Selection	0.17**	AT 238 x AT 345	0.22*	27.97**	7.90
		AT 255	AT 255	AT 164 x AT 255	0.16**	China x Nesadi Selection	0.17**	-7.82	3.37
		AT 282	-	AT 164 x China	-0.01	AT 255 x AT 345	0.17**	2.64	-1.17
8.	Width of capsule (cm)	AT 255	AT 238	AT 164 x AT 238	0.11**	AT 164 x AT 238	0.11**	23.19**	9.53
		AT 282	AT 282	AT 238 x AT 282	0.05*	AT 238 x China	0.06**	18.82**	5.64
		AT 345	AT 255	AT 238 x China	0.06**	AT 238 x AT 282	0.05*	0.19	0.97
9	Number of capsules per leaf axil	China	China	AT 345 x China	0.32**	AT 345 x China	0.32**	-61.78**	0.00
		Nesadi Selection	Nesadi Selection	AT 238 x China	0.29**	AT 282 x GT 10	0.29**	0.00	0.00
		AT 255	AT 345	China x Nesadi Selection	0.07*	AT 238 x China	0.29**	-36.94**	65.00**
10	Number of seeds per capsule	AT 255	AT 255	AT 164 x AT 255	3.33**	AT 164 x AT 282	3.70**	-5.62	-4.20
		AT 238	AT 238	AT 238 x China	2.45*	AT 164 x AT 238	3.57**	-9.44**	-5.91
		China	China	AT 164 x AT 238	3.57**	AT 164 x AT 255	3.33**	-8.45*	-4.60
11.	1000 seed weight (g	AT 282	AT 238	AT 255 x China	0.31**	China x GT 10	0.33**	-3.23	-17.81**
		AT 345	AT 164	AT 164 x China	0.27**	AT 255 x China	0.31**	-8.51**	-14.5**
		GT 1	AT 255	AT 345 x Nesadi Selection	0.15**	AT 164 x China	0.27**	-13.31**	-17.89**
12.	Seed yield per plant (g)	AT 345	GT 10	AT 345 x GT 10	1.57**	AT 238 x GT 1	1.84**	94.43**	6.56
		GT 10	AT 345	AT 238 x GT 1	1.84**	AT 164 x AT 238	1.79**	83.30**	0.46
		AT 282	AT 238	AT 238 x AT 345	1.12**	AT 255 x Nesadi Selection	1.78**	94.24**	-8.40
13.	Biological yield per plant (g)	GT 10	GT 10	China x GT 1	6.53**	China x GT 1	6.53**	86.34**	29.32**
		AT 345	China	AT 282 x GT 10	3.90**	AT 238 x AT 345	4.10**	32.30**	18.73**
		AT 282	AT 345	AT 238 x AT 345	4.10**	AT 282 x GT 10	3.90**	13.91**	19.74**
14.	Harvest index (%)	AT 345	AT 282	AT 345 x GT 10	8.84**	AT 345 x GT 10	8.84**	-10.48	-16.42**
		AT 164	AT 255	AT 255 x Nesadi Selection	6.76**	Nesadi Selection x GT 1	7.06**	27.70**	-4.37
		AT 282	AT 345	AT 282 x AT 345	3.36**	AT 255 x Nesadi Selection	6.76**	21.25**	-6.32
15.	Oil content (%)	GT 1	AT 255	AT 255 x AT 282	0.86**	AT 238 x China	1.30**	1.48	1.57
		AT 255	AT 164	AT 238 x China	1.30**	AT 255 x AT 282	0.86**	0.00	2.35
		GT 10	GT 1	AT 164 x AT 238	0.28	AT 282 x Nesadi Selection	0.79*	-1.02	-0.42

*, ** significant at 5% and 1% levels of significance, respectively.

contributing characters. This appeared appropriate as yield being a complex character depends on number of traits. Significant positive sca effects for seed yield and its important yield component traits have also been reported by (14,18). The information regarding three best performing parents, best general combiners, best performing hybrids in F_2generation along with their per cent heterosis over better parent as well as standard check, GT 3 and sca effect for different traits based on pooled analysis in F_2 generation (Table 5) revealed that parents with good *per se* performance were, in general, good general combiners. However, good general combiners may not necessarily always produce good specific combinations for different traits. In many cases, it was observed that at least one good general combining ability parent was involved in heterotic hybrids having desirable sca effects. This was true for most of the traits studied.

Conclusions

Considering the overall performance of hybrids with respect to high and significant sca effects across the environments for seed yield per plant in F_2 generation, the best five best hybrids were AT 238×GT 1, AT 164×AT 238, AT 255×Nesadi Selection, AT 345×GT 10 and AT 282×GT 10, manifested significant and high sca effects in that order. These crosses could be exploited through heterosis breeding hence, it would be worthwhile to use them for improvement in seed yield per se in sesame.

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