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DEVELOPMENT OF HIGH-YIELDING SESAME (*SESAMUM INDICUM* L.) GENOTYPES UNDER DROUGHT STRESS CONDITIONS

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SUMMARY

Ten drought-tolerant and six sensitive lines with their resultant crosses emerged from crossing in the Line × Tester mating design, then evaluated at the maturity stage in the field. Data recorded for morphological and physiological parameters took place, as well as, for drought tolerance and yield-related traits. Recorded data followed analysis to access the variability in germplasm and general and specific combining ability effects. Combining ability analysis exhibited variable direction and magnitude of specific combining ability effects among crosses and general combining effects among line and testers. Results showed the breeding material had genetic variability that can serve in developing drought-tolerant and high-yielding genotypes of *Sesamum indicum* L. The testers 93004 and 96019 and Lines 90005 and 96006 revealed the best general combiners under normal and drought stress. Results of SCA indicated that 95001 × 97005, 97007 × 97001, 95010 × 93004, TH-6 × 96019, and 90005 × 96014 exhibited to have positive significant specific combining ability effects for most of the traits under control and drought stress conditions that can undergo further evaluation for growing under drought conditions. The fresh and dry weight of seedlings and 1000-seed weight traits proved useful as selection criteria in developing drought-tolerant types in sesame.

Keywords: Sesame (*Sesamum indicum* L.), genetic variability, line-by-tester combining ability, drought stress conditions, yield-related traits

Key findings: Testers 93004 and 96019 and lines 90005 and 96006 displayed the best general combiners for most traits under normal and drought stress conditions. The hybrids, viz., 95001 × 97005, 97007 × 97001, 95010 × 93004, TH-6 × 96019, and 90005 × 96014, showed significant positive SCA effects for the majority of the drought tolerant related traits.

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INTRODUCTION

Sesame (*Sesamum indicum* L.), also named Til, is the world's most ancient oil seed crop. Essential food items include seeds and their oil. The Arabic word 'simsim' is where the name 'sesame' originated. Its wide cultivation covers tropical to temperate regions of the world. Given its resistance to oxidation and rancidity, it gained the 'Queen of Oilseeds' name (Aristya *et al*., 2017; Khuimphukhieo and Khaengkhan, 2018). Likewise, due to its high nutritional value, it plays a significant role as an industrial food crop. Sesame seeds generally contain

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25% protein and 40% to 63% oil content. According to Kiruthika *et al*. (2018), sesame seed oil has a long shelf life because it contains lignans (Sesamin, Sesamol, and Sesamolin), which have a remarkable antioxidant action and resist oxidation, as well as, a considerable amount of oleic and linoleic acids (Abate and Mekbib, 2015; Kouighat *et al*., 2020). Sesame seeds provide calcium, potassium, tryptophan, and methionine. Oleic acid (43%), linoleic acid (35%), palmitic acid (11%), and stearic acid (7%) comprised the fatty acids found in sesame oil, which also has the greatest antioxidant concentration (Yogranjan *et al*. 2015).

Plants' exposure to several biotic and abiotic stresses prevents their performance for full potential attainment and threatens their survival. Drought has been regarded as the most crucial and damaging abiotic constraint for global crop production. A meteorological word, drought, generally refers to a period of five years with insufficient precipitation (Jaleel *et al*., 2009; Arslan *et al*., 2018). Drought has varied influences on plant growth and yield, membrane reliability, pigment content, osmotic modification, water associations, and photosynthetic action in different plants (Benjamin and Nielsen, 2006; Praba *et al*., 2009; Harfi *et al*., 2021).

Although sesame has an excellent drought tolerance compared with many other crops, it is especially vulnerable to the effects of drought during the germination and seedling phases (Rani *et al*., 2015; Sabiel *et al*., 2015). It is essential for efforts to focus on creating sesame cultivars that can provide high yields in drought. Development of inbred lines having high general combining ability (GCA) and specific combining ability (SCA) for important yield traits remained a key objective of sesame hybrid breeding. Selection of parents and information about the magnitude and nature of gene action for economically important traits depends on combining ability analysis, hence regarded as a powerful tool for identification of the best combiner in sesame (Rajaravindran *et al*., 2000; Kouighat *et al*., 2020).

Obtaining gene effects for particular traits under selection can result from combining ability analysis. With this information, the breeder can choose the best strategy for desirable parent selection or breeding procedure, which can improve the desired trait performance in sesame (Praveenkumar, 2009). Many studies showed that GCA and SCA served vital for several traits in sesame (Banerjee and Kole, 2009; Joshi *et al.,* 2015; Dissanayake *et al*., 2020). Understanding the genetic heterogeneity in germplasm will make it simpler to choose for breeding high-yielding and better-quality cultivars that will increase productivity.

Understanding variability from a quantitative perspective requires research in genetic traits, including genotypic and phenotypic variances, heritability (i.e., broad sense), and genetic progress. Praveenkumar (2009) stated combining strong genetic progress and high heritability estimates is typically more useful in forecasting gain under selection than heritability estimates alone. It is crucial to choose the best parents with excellent combining skills for hybridization and superior combinations between them (Gangappa *et al*., 1997). Higher specific combining ability (SCA) effects, on the other hand, indicate dominant gene effects. Still, higher general combining ability (GCA) effects demonstrate additive gene effects. Epistatic effects were also possible because of the small magnitude of the GCA and SCA effects (Fehr, 1993).

Use of numerous analyses, such as, diallel, line by tester, and North Carolina, among others, determine the combining abilities. Limitations include the requirement for genetic presumptions in diallel and extended mating patterns. More flowers are required to make all possible combinations, like in North Carolina. The line-by-tester is a useful tool for determining how genotypes will affect the GCA and how crosses will affect the SCA (Kempthorne, 1957; Baghery *et al*., 2022). The individual distinctions within a population display through genetic diversity. It gauges how frequently a population's various genotypes diverge from one another. Breeding procedures have efficiently used the genotypes' genetic differences and similarities as a genetic resource (Safavi *et al*., 2010; Mukhtar *et al*., 2022). Knowledge of the type and degree of genetic variation present in a crop species is necessary to establish crop improvement and development programs and develop any desired features (Dabholkar, 1999). Finding the genetic diversity of the entries under drought stress and control conditions served as the aim of the study. This investigation also aimed to find potential parents and the best cross combinations under drought stress.

MATERIALS AND METHODS

Ten drought-tolerant accessions (TH-6, TS-5, 95001, 96006, TS-3, 90005, 97007, 95010, 95013, and 93003) served as lines (female parents), with six drought-sensitive accessions (97005, 96019-2, 97001, 96014, 93004, and 96019) as testers (male parents). These achieved crossing via the line × tester breeding method through controlled pollinations. The Department of Plant Breeding and Genetics at the University of Agriculture, Faisalabad, Pakistan, provided the crosses, parents, and check varieties that were planted in the fields where the field experiment also took place. Faisalabad situates between 73°–06° E longitude and 31°-26° N latitude. The area is categorized as semi-arid and contains loamy soil. All field entries received factorial structured treatments with three replications, employing the randomized complete block design (RCBD). Plant and row spacing was maintained at 10 and 45 cm, respectively. Three different irrigation techniques and schedules proceeded:

T0: standard irrigations;
T1: alternate irrigation was skipped; and
T2: only one irrigation, excluding rain.

Data recording took place on days to 50% flowering, days to 50% maturity, leaf water content, stomatal conductance (mmol $m^{-2A}s^{-1}$), number of branches per plant, number of pods per plant, number of seeds per pod, seed yield per plant (g), 1000-seed weight (g), and plant height (cm) after tagging two plants of each entry in each replication.

Biometrical approaches

The recorded data attained analysis of variance following Steel *et al*. (1997). Combining abilities computation followed the line × tester analysis outlined by Kempthorne (1957).

RESULTS

Genetic variability

Table 1 presents the results for the analysis of variance that revealed significant differences for all the characteristics at the maturity stage for all the treatments among the entry, parents, parents vs. crosses, and crosses. Entries revealed relevant differences for all characteristics at T0 (normal circumstances), except for stomatal conductance at the maturity stage. Plant height, leaf water content, 1000-seed weight, and yield per plant exhibited significant variations between the parents. There occurred notable differences in plant height, leaf water content, number of pods and seeds per pod, the weight of 1000 seeds per pod, and yield per plant across crosses. Every attribute showed expressive variations between parents and crosses, except stomatal conductance and plant yield. At T0 (normal conditions), noteworthy differences between the lines in plant height, leaf water content, stomatal conductance, the number of pods per plant, the number of seeds per pod, and yield per plant appeared. Testers revealed suggestive differences in leaf water content, the number of pods per plant, and the weight of 1000 seeds, except for stomatal conductance and yield per plant. The line × tester demonstrated considerable variations for all attributes at T0 (normal circumstances).

At T1, there existed significant variations in the entries for the number of pods per plant, the number of seeds per pod, 1000-seed weight, and yield per plant. Parents had considerable variations in 1000-seed weight and plant yield. For plant height, the number of pods per plant, and yield per plant, meaningful differences showed between crossings, but for plant height, leaf water content, and yield per plant, differences resulted between parents and crosses. Tests revealed measurable variations for 1000-seed weight. The yield per plant varied greatly between lines. All characteristics, except plant height, leaf water content, stomatal conductance, and 1000-seed weight, showed a notable difference across the line × tester. All characteristics, except for leaf water content, the number of pods per plant, and the number of seeds per pod, exhibited significant variations between entries at T2.

Parents had considerable variations in 1000-seed weight and plant output. Every feature revealed significant variations among crosses, except for the leaf water content, stomatal conductance, the number of pods per plant, and 1000-seed weight. A little difference ensued between parents and crosses in plant height and leaf water content. Lines showed remarkable variability in the quantity of the number of seeds in each pod and the number of seeds produced per plant. Except for leaf water content, number of pods per plant, number of seeds per pod, and yield, the experiments showed considerable differences for the maximum attributes. Except for leaf water content, stomatal conductance, 1000-seed weight, and yield per plant, the interaction of line × tester substantially differed for all characteristics.

Table 1. Mean squares from analysis of variances in sesame accessions at maturity stage.

SOV	DF	PH	DFF	LWC	SC	NP/P	NS/P	1000SW	YPP
					T0				
Replications	2	254.92*	15.76	4.75	0.26**	66.93	14.97**	4.49**	19.43*
Entries	75	132.35**	41.78*	34.11**	10.02	75.42**	21.63**	4.58**	3.44*
Parents (P)	15	103.96**	101.98**	39.81**	0.01	43.40	32.24	8.34**	3.42*
Crosses (C)	59	114.08**	21.95	28.90**	0.3	48.58*	64.93**	3.19**	3.40*
P vs. C	1	370.91**	23.38	153.52**	1.003	21.15**	24.31**	11.99**	5.10
Lines (L)	9	764.50**	35.93	34.86**	2.05*	55.11**	16.18*	1.47	5.00*
Testers (T)	5	930.10	49.02	24.11**	4.03	64.48*	49.75	4.71**	2.97
L × T	45	240.80**	33.54	28.67**	1.02	37.89*	19.51**	3.23**	3.17
Error	28	360.63	14.48	6.78	4.42	20.47	4.02	0.67	4.69
					T1				
Replications	2	67.10	31.97*	90.03**	35.86	274.83*	80.72	97.99	5.281
Entries	75	90.81	15.91*	111.86	68.12	268.90*	38.52*	140.96*	51.012**
Parents (P)	15	96.21	66.23	164.79	49.41	135.15	11.66	232.46*	63.27**
Crosses (C)	59	76.58*	19.88	95.69	70.30	231.69*	48.03	110.47	22.4**
P vs. C	1	129.34*	53.55	95.67*	197.64	42.80	1.10	201.64	31.32**
Lines (L)	9	59.28	83.49	155.00	76.88	424.91	89.49*	62.82	5.51**
Testers (T)	5	75.56	49.60	78.82	43.52	170.23	38.00	61.33*	9.28
L × T	45	60.24	21.21*	87.20	74.34	205.34*	41.74*	129.82	72.7**
Error	28	111.82	6.29	8.36	8.31	15.17	0.48	2.47	0.98
					T2				
Replications	2	16.92*	98.95*	107.10	651.07*	1001.03**	23.06	51.80*	60.12
Entries	75	99.30*	52.12*	98.01	123.11*	99.06	48.02	32.10*	26.52*
Parents (P)	15	14.12	23.05	78.11	87.13	105.99	29.11	75.25*	9.66*
Crosses (C)	59	95.09**	108.01**	96.08	99.08	45.79*	25.37	13.49	68.03*
P vs. C	1	20.09*	13.04	89.34*	29.45	39.07	119.24	66.09	0.90
Lines (L)	9	99.88	145.88*	123.18	99.69	175.00	66.89*	39.01	79.39*
Testers (T)	5	99.07*	100.09*	85.06	189.50*	88.22	47.32	19.03*	28.00
L × T	45	108.15**	109.06**	89.04	111.01	89.10*	78.04*	23.04	22.04
Error	28	45.03	14.09	10.32	15.14	21.26	1.01	1.07	12.78

*, **: Significant at 0.05 and 0.01 probability levels, respectively
SOV: Sources of Variations, DF: Degree of Freedom, PH: Plant height, DFF: Days to 50% flowering, LWC: Leaf water content, SC: Stomatal conductance, NP/P: No. of pods per plant, NS/P: No. of seeds per pod, 1000SW: 1000-seed weight, YPP: Yield per plant.

General combining ability effects

Results of general combining ability effects for field traits under T0, T1, and T2 appear in Tables 2, 3, and 4. The study of GCA effects of lines and testers for various traits progressed to finding the most suitable parent for future hybrid development. Examining the GCA effects of 10 traits for most of the characteristics among lines showed 90005 under normal (T0) and drought stress conditions (T1 and T2) with the highest GCA for days to 50% flowering, days to 50% maturity, leaf water content, number of branches per plant, number of pods per plant, 1000-seed weight, and plant height. In contrast, 93004 had the highest GCA among testers for the majority of the qualities in the mature stage. For most characteristics, (T1) tester 96019 had the greatest GCA under drought stress conditions. Likewise, 96019-2 showed the highest GCA in T2 (drought stress conditions) among all traits. Under normal (T0) and drought stress circumstances (T1 and T2), 90005 showed the strongest GCA impacts for the most characteristics across all lines. Yet, among the testers, 96019-2, 96019, and 93004 had the highest GCA effects for most of the traits at the maturity stage.

Specific combining ability effects

Specific combining ability (SCA) effects of various yield attribute traits are presented in Table 5 under T0, Table 6 under T1, and Table 7 under T2. The SCA effects are essential for identifying certain cross combinations (hybrids) regarding selecting specific traits. Cross 97007 × 97001 had the highest SCA for most of the characteristics, i.e., days to 50% flowering, days to 50% maturity, leaf water content, stomatal conductance, number of branches per plant, number of pods per plant, seed yield per plant, 1000-seed weight, and plant height, at the maturity stage under normal conditions (T0), followed by 90005 × 96014, 95001 ×

97005, 95001 × 93004, TS-3 × 93004, and 95013 × 97001. Majority of the attributes at the maturity stage under the drought stress condition (T1), the cross 97007 × 97001 exhibited the highest SCA, followed by 95001 × 97005, 97007 × 97005, 95010 × 96019-2, TS-5 × 97001, and 950109 × 7001. Under drought stress circumstances, the cross 97007 × 97001 showed the highest level of SCA for most of the characteristics at the maturity stage, followed by 95001 × 97005, 97007 × 97005, TS-5 × 97001, 95001 × 93004, 90005 × 96014, and 96006 × 97005 at (T2). For the majority of the characteristics, the crosses 97007 × 97001 and 95001 × 97005 demonstrated the highest levels of SCA under the normal (T0) and drought stress environments (T1 and T2).

Table 2. General combining ability effects of lines and testers for field traits in sesame under normal conditions (T0).

Genotypes	DFF	DFM	LWC	SC	NB/P	NP/P	NS/P	SY/P	1000SW	PH
Lines										
TH-6	-8.02	-22.98	-0.71	0.06	-94.43	-10.27	-0.25	-0.61	-0.82	0.48
TS-5	-1.8	0.46	-0.41	0.02	-36.9	-17.94	-0.03	-0.3	-0.15	3.35
95001	8.89	12.93	0.61	0.03	35.6	8..49	0.14	0.43	0.21	2.7
96006	10.48	-14.34	2.14	0.05	50.57	7.53	0.24	0.04	0.07	-0.4
90005	35.37	30.65	0.8	-0.04	109.3	26.28	-0.16	-0.28	0.34	4.66
97007	-11.74	16.24	0.13	-0.04	11.77	17.06	0.48	0.29	0.48	-2.09
95010	-24.3	-10.03	-1.95	-0.05	-40.32	-22.66	0.19	0.87	0.09	-2
95013	-3.16	3.61	2.02	2.05	-2.6	-0.55	-1.16	0.95	0.27	3.56
93003	-0.12	0.01	4.94	1.29	-0.98	3.3	0.38	2.42	-1.28	-12.4
TS-3	0.67	-0.76	-1.21	-3.24	-2.26	1.35	-5.75	-0.56	-4.28	7.73
Standard Error	9.89	13.93	0.61	0.03	38.60	11.49	0.19	0.51	0.27	3.70
Testers										
97005	3.88	-3.41	-0.07	0.02	-26.2	23.92	0.48	0.001	-0.32	1.83
96019-2	18.96	9.86	1.58	0.02	30.77	3.81	-0.55	0.08	0.27	-0.91
97001	-20.92	-29.27	-1.95	0.04	-88.22	-26.11	-0.55	-0.66	-0.05	-6.23
96014	-1.07	-3.04	-0.28	-0.01	18.23	7.06	-0.09	-0.14	-0.12	-0.06
93004	-0.27	18.09	0.5	-0.07	-23.79	-6	0.69	0.6	0.08	4.82
96019	-0.58	7.77	0.22	-0.01	89.21	-2.69	0.01	0.12	0.15	0.55
Standard Error	9.89	13.93	0.61	0.03	38.60	11.49	0.19	0.51	0.27	3.55

DFF: Days to 50% flowering, DFM: Days to 50% maturity, LWC: Leaf water content, SC: stomatal conductance, NB/P: No. of branches per plant, NP/P: No. of pods per plant, NS/P: No. of seeds per pod, SY/P: Seed yield per plant, 1000SW: 1000-seed weight, PH: Plant height, SE: Standard error.

Table 3. General combining ability effects of lines and testers for field traits in sesame under drought conditions (T1).

Genotypes	DFF	DFM	LRWC	SC	NB/P	NP/P	NS/P	SY/P	1000SW	PH
Lines										
TH-6	-28.28	-42.8	-2.61	0.48	-14.42	8.5	-0.98	2.08	-1.54	-10.27
TS-5	-6.68	-4.56	-0.95	3.35	10.74	-2.88	0	2.28	4.47	-17.94
95001	13.65	13.56	1.73	2.7	13.65	12.56	23.73	1.7	13.65	8..49
96006	15.54	16.56	1.3	-0.4	-29.39	18.09	-3.11	3.89	-5.15	7.53
90005	8.49	2.14	3.77	4.66	16.78	5.04	3.83	-0.97	-2.81	26.28
97007	3.54	10.43	0.01	-2.09	-16.99	-9.66	-1.61	-0.27	3.54	17.06
95010	7.39	24.22	1.49	-2	33.28	7.09	4.69	-0.22	1.49	-22.66
95013	8.15	6.93	1.59	3.56	8.15	6.93	1.59	3.56	3.7	-0.55
93003	-76.84	-78.58	-13.85	-12.4	-76.84	-78.58	-13.85	-12.4	-76.84	3.3
TS-3	-1.71	12.62	-2.82	7.73	-1.71	12.62	-2.82	7.73	-1.71	-10.27
Standard Error	15.65	15.56	3.73	3.70	15.65	15.56	3.73	3.70	15.65	11.49
Testers										
97005	-52.67	-50.47	-6.09	-3.54	-27.09	12.9	-4.8	1.83	-5.21	0.48
96019-2	13.55	-22.64	-0.49	-3.7	9.9	3.13	1.48	-0.91	3.95	-0.55
97001	12.82	-26.14	-0.4	1.67	-31.05	-17.32	-4.98	-6.23	-4.76	-0.55
96014	-10.48	-17.76	-0.88	-1.45	27.2	-9.96	1.53	-0.06	-0.47	-0.09
93004	12.62	50.7	4.74	4.46	-8.43	0.3	1.32	4.82	-0.28	-1.42
96019	24.16	66.3	3.11	2.55	29.47	10.95	5.44	0.55	6.76	-2.92
Standard Error	13.83	13.09	2.79	3.55	13.83	13.09	2.79	3.55	5.21	8.54

DFF: Days to 50% flowering, DFM: Days to 50% maturity, LWC: Leaf water content, SC: stomatal conductance, NB/P: No. of branches per plant, NP/P: No. of pods per plant, NS/P: No. of seeds per pod, SY/P: Seed yield per plant, 1000SW: 1000-Seed weight, PH: Plant height, SE: Standard error.

Table 4. General combining ability effects of lines and testers for field traits in sesame under drought conditions (T2).

Genotypes	DFF	DFM	LWC	SC	NB/P	NP/P	NS/P	SY/P	1000SW	PH
Lines										
TH-6	-3.23	-3.31	-0.74	-1.61	-0.07	-0.03	-0.03	0.04	0.53	2.08
TS-5	2.99	0.25	0.08	0.66	0.15	-0.1	0.07	0.07	0.26	2.28
95001	0.81	0.78	0.434	0.23	0.05	-0.02	0.04	0.03	1.11	1.7
96006	1.58	2.01	0.75	-0.44	0.13	0.22	-0.02	-0.08	-0.24	3.89
90005	-0.01	-0.07	0.52	0.62	-0.01	0.05	-0.01	2.9	2.4	-0.97
97007	1.51	1.19	-0.05	0.02	0.15	0.16	0.01	-0.25	0.14	-0.27
95010	0.73	0.72	-1.19	1.34	-0.42	-0.15	-0.12	0.75	-0.95	-0.22
95013	-1.3	2.56	1.26	2.09	-0.05	-0.14	0.03	-2.76	-0.56	3.56
93003	0.91	-2.29	0.82	-0.56	-0.13	0.1	-0.07	0	-0.27	-12.4
TS-3	-4.1	-1.95	-0.39	-1.17	0.09	-0.1	0.07	0.83	-0.43	7.73
Standard Error	0.91	0.88	0.44	0.30	0.15	0.03	0.06	1.41	1.12	3.70
Testers										
97005	3.88	-3.41	-0.07	0.02	-26.2	23.92	0.48	1.32	-2.08	1.83
96019-2	18.96	9.86	1.58	0.02	30.77	3.81	-0.55	1.11	-0.95	-0.91
97001	-20.92	-29.27	-1.95	0.04	-88.22	-26.11	-0.55	0.63	-1.49	-6.23
96014	-1.07	-3.04	-0.28	-0.01	18.23	7.06	-0.09	-0.45	1.88	-0.06
93004	2.1	-2.16	-2.04	2.14	4.23	-1.11	-1.42	2.01	1.88	4.82
96019	-2.72	2.56	-3.13	1.29	-1.55	-2.64	-2.92	3.45	0.09	0.55
S.E.	3.23	3..27	0.57	0.75	3.16	0.36	8.54	1.37	2.54	3.55

DFF: Days to 50% flowering, DFM: Days to 50% maturity, LWC: Leaf water content, SC: stomatal conductance, NB/P: No. of branches per plant, NP/P: No. of pods per plant, NS/P: No. of seeds per pod, SY/P: Seed yield per plant, 1000SW: 1000-seed weight, PH: Plant height, S.E.: Standard error.

DISCUSSION

Information on the combining ability effects of accessions and type of gene activity influencing various traits is needed for yield improvement and breeding for new types with drought tolerance. This knowledge makes it possible to investigate the trait-inheritance pattern, create superior cross-combinations, and identify potential parents (Dudley and Moll, 1969; Lippman and Zamir, 2007; Bi *et al*., 2015). One of the goals of this study aimed to choose the accessions for use as parents in crossing programs. The GCA effects estimations proved helpful in choosing better genotypes as parents for breeding operations. The resulting accessions can widely serve in hybridization programs to get traits of commercial value. Past studies also reported significant positive general combining ability effects for different traits in various crop plants (Cruz, 1986; Goksoy *et al*., 1999; Shekar *et al*., 2000; Sharma *et al*., 2003; Gvozdenovic *et al*., 2005; Joshi *et al*., 2015; Prajapati *et al*., 2006; Praveenkumar *et al*., 2012; Hladni *et al*., 2006; Mohanasundaram *et al*., 2012; Mukhtar *et al*., 2022).

High GCA effects imply that character is more tied to the genotype's basic genetic makeup and less affected by its mean, thus selection may lead to success in the first generations (Cruz and Regazzi, 1994; Roy *et al.,* 2002; Kenga *et al*., 2004; Mubashir *et al*., 2007). Low GCA impacts show that a parent's mean in crosses does not considerably depart from the overall mean of crosses (Marinkovic, 1993). Since the lines have a high GCA, a sign of additive effects, and wide adaptation, they have tremendous potential for use as parents in the creation of widely adapted hybrids with high seed output and resilience to drought stress (Kenga *et al*., 2004; Mubashir *et al*., 2007; Mukhtar *et al*., 2022). For the bulk of the features across all treatments, the lines TS3, 90005, and 95010, as well as, testers 93004 and 96019, exhibited strong GCA impacts and exhibited the best general combiners. These lines can serve as parents in hybridization initiative programs to improve qualities linked to seed production and drought tolerance.

Particularly, combinatorial results indicate non-additive gene activation. SCA effects alone lack importance for parental selection in breeding programs; hence they can be improved by GCA (Arslan *et al*., 2018). The crosses 97007 × 97005, 97007 × 97001, 95010 × 93004, TH-6 × 96019, and 95001 × 97005 revealed significant SCA effects for the majority of the traits under both normal and drought stress treatments. It is noteworthy that in cross combinations with high values, beneficial SCA effects, and at least one parent having high GCA, the frequency of favourable alleles would likely increase (Kenga *et al*., 2004; Mubashir *et al*., 2007). Combining high-high and high-low general combiners produced hybrids with significant SCA effects.

Interactions between dominant and recessive genes from poor and good combiners may lead to high SCA hybrids (Roy *et al*., 2002; Arslan *et al*., 2018).

According to research, the possibility of employing the available breeding stock to boost sesame seed production and drought resilience can proceed. The accessions 90005,

Table 5. Specific combining ability effects of crosses for field traits in sesame under normal conditions (T0).

Crosses	DFF	DFM	LWC	SC	NB/P	NP/P	NS/P	SY/P	1000SW	PH
TH-6 × 97005	20.63	20.01	-2.32	1.53	-9.45	22.05	-1.22	2.53	3.06	-14.6
TS-5 × 97005	-45.69	-23.09	-11.47	-0.52	-98.67	-25.14	-10.57	-0.52	-13.92	-152.41
95001 × 97005	35.3	42.03	28.2	14.46	50.16	100.61	28.3	28.46	9.42	77.49
96006 × 97005	30.02	-40.01	-11.07	-36.02	-19.48	-141.02	-12.33	28.54	4.46	30.08
90005 × 97005	29.5	52.55	-11.04	-7.82	-30.5	-41.31	-12.03	6.82	20.61	47.11
97007 × 97005	44.55	30.25	23.76	14.27	-107.92	-84.81	17.86	15.37	1.32	66.7
95010 × 97005	25.5	22.76	-13.14	3.73	18.85	22.78	-10.44	3.72	-3.35	29.12
95013 × 97005	-55.05	-40.99	-13.29	-12.22	-66.42	74.05	-12.19	13.52	20.41	102.59
93003 × 97005	51.04	11.55	-1.21	-6.56	34.56	9.8	-0.11	-7.56	9.18	53.39
TS-3 × 97005	11.05	35.51	19.39	11.01	5.47	-38.21	29.89	12.05	10	8.44
TH-6 × 96019-2	20.55	30.09	7.28	-2.64	23.79	30.06	7.27	-1.61	14.25	36.75
TS-5 × 96019-2	17.5	55.51	-19.03	8.91	-16.25	49.63	-14.44	6.91	-18.8	-25.1
95001 × 96019-2	49.05	22.91	2.82	4.5	33.66	65.9	1.86	5.9	-2.99	51.99
96006 × 96019-2	37.04	19.51	13.44	13.34	81.08	15.13	24.46	14.44	7.35	115.23
90005 × 96019-2	-39.014	-55.05	-35.04	-11.28	-99.44	87.08	26.94	-14.18	-7.49	153.61
97007 × 96019-2	48.03	-41.79	-17.9	-3.32	59.7	-72.82	-7.91	4.12	15.71	92.21
95010 × 96019-2	21.5	42.5	13.35	13.64	28.37	101.93	11.8	21.64	20.98	43.82
95013 × 96019-2	30.05	-49.09	-3.16	-12.61	16.03	-23.06	-3.26	13.66	-2.13	24.76
93003 × 96019-2	26.03	-43.83	8.96	-4.03	2.69	-38.07	7.95	24.03	21.38	4.15
TS-3 × 96019-2	41.55	-34.55	17.83	-15.9	40.23	-62.04	-7.83	14.93	-8.08	62.14
TH-6 × 97001	45.43	-23.99	-2.9	11.63	45.51	-28.87	-5.39	10.67	27.42	70.29
TS-5 × 97001	37.77	40.05	-8.04	13.73	62.56	134.86	8.34	24.83	-15.6	96.64
95001 × 97001	-11.05	-37.09	7.94	-13.25	-2.74	-60.95	-8.98	14.15	-20.8	-4.24
96006 × 97001	5.05	29.55	5.51	6.66	23.23	55.08	5.9	27.6	-4.32	35.88
90005 × 97001	-15.5	-24.71	1.3	-13.37	-26.08	-53.89	1.4	11.37	-10.66	40.29
97007 × 97001	45.23	25.99	14.01	34.72	95.57	166.89	15.03	33.82	35.96	147.62
95010 × 97001	35.44	32.69	6.98	-5.32	44.36	28.1	5.98	-6.22	24.71	68.53
95013 × 97001	32.59	30.71	-17.01	-1.13	46.33	82.52	-7.03	-1.23	34.93	71.57
93003 × 97001	-50.55	-25.9	-26.16	-13.4	-112.6	-136.07	-18.16	-14.9	32.17	73.93
TS-3 × 97001	-52.37	-31.01	3.76	-1.19	47.59	87.54	2.78	-0.1	-3.37	73.51
TH-6 × 96014	-20.17	-15.09	1.45	3.35	-19.66	-18.77	0.45	3.25	-1.33	30.36
TS-5 × 96014	10.99	-19.99	-7.3	-20.3	28.66	-20.79	-8.9	19.3	-0.92	44.27
95001 × 96014	30.09	22.5	8.16	2.83	15.85	-22.57	8.16	1.83	5.01	24.48
96006 × 96014	-59.03	31.63	-11.596	6.4	-35.2	34.7	-10.96	4.49	28.08	54.37
90005 × 96014	60.01	70.05	10.1	23.64	93.7	106.33	20.1	25.84	25.63	-144.73
97007 × 96014	-41.6	-71.09	-8.85	-16.11	83.35	-78.92	8.85	16.11	-10.32	128.75
95010 × 96014	40.55	55.19	9.27	11.16	42.94	42.69	10.24	10.16	9.73	66.33
95013 × 96014	-8.55	11.17	-1.22	1.5	-9.45	22.05	-1.22	2.53	1.78	-14.6
93003 × 96014	-50.11	-51.11	8.53	-1.43	-98.67	-25.14	10.57	-0.52	4.48	152.41
TS-3 × 96014	41.11	59.2	11.3	16.49	50.16	100.61	18.3	15.46	3.39	77.49
TH-6 × 93004	-15.99	-24.01	-16.34	27.53	-19.48	-141.02	-12.33	26.02	-0.92	30.08
TS-5 × 93004	-29.01	30.19	-16.03	-4.82	30.5	-41.31	12.03	-6.82	2.64	47.11
95001 × 93004	32.99	70.99	19.86	34.37	107.92	84.81	17.86	35.37	6.12	66.7
96006 × 93004	14.05	72.01	10.34	13.21	18.85	22.78	10.44	3.72	-10.18	29.12
90005 × 93004	-45.01	-75.05	-12.1	-12.52	-66.42	-74.05	-12.19	13.52	-20.04	-102.59
97007 × 93004	44.71	19.19	-1.11	7.41	34.56	9.8	-0.11	7.56	-6.17	53.39
95010 × 93004	40.4	80.01	20.88	10.04	5.47	-38.21	29.89	12.05	24.9	8.44
95013 × 93004	13.01	71.11	3.23	-11.61	23.79	30.06	7.27	-1.61	11.36	36.75
93003 × 93004	-17.05	65.71	-14.34	4.21	-16.25	49.63	-14.44	6.91	0.12	-25.1
TS-3 × 93004	33.09	69.11	1.93	3.94	39.66	75.9	1.86	5.9	30.41	51.99
TH-6 × 96019	35.6	10.09	14.36	11.34	81.08	15.13	24.46	14.44	10.49	-125.23
TS-5 × 96019	-44.11	-75.51	-16.94	11.28	-99.44	87.08	26.94	-14.18	-1.64	153.61
95001 × 96019	55.01	-82.05	-7.91	14.12	59.7	-72.82	-7.91	-4.12	-6.99	92.21
96006 × 96019	20.99	70.19	12.8	10.24	28.37	101.93	11.8	11.64	4.33	43.82
90005 × 96019	25.6	-30.15	-13.26	23.76	16.03	-23.06	-3.26	-13.66	2.05	24.76
97007 × 96019	11.99	29.61	17.95	-4.03	2.69	38.07	7.95	-4.03	8.2	4.15
95010 × 96019	-39.05	-83.19	-17.23	26.03	40.23	-62.04	-7.83	-14.93	3.49	62.14
95013 × 96019	36.92	60.03	-21.39	13.07	45.51	-28.87	-5.39	10.67	13.33	70.29
93003 × 96019	33.71	55.71	6.34	14.73	62.56	134.86	8.34	14.83	-11.22	-96.64
TS-3 × 96019	-30.03	-33.75	-4.75	-10.17	-2.74	-60.95	-8.98	-14.15	-17.82	-4.24
S.E.	31.59	22.08	1.78	20.90	36.64	68.31	19.89	27.91	20.33	26.46

DFF: Days to 50% flowering, DFM: Days to 50% maturity, LWC: Leaf water content, SC: stomatal conductance, NB/P: No. of branches per plant, NP/P: No. of pods per plant, NS/P: No. of seeds per pod, SY/P: Seed yield per plant, 1000SW: 1000-seed weight, PH: Plant height, S.E.: Standard error.

Table 6. Specific combining ability effects of crosses for field traits in sesame under drought conditions (T1).

Crosses	DFF	DFM	LWC	SC	NB/P	NP/P	NS/P	SY/P	1000SW	PH
TH-6 × 97005	-12.01	29.97	-1.43	2.22	-11.06	25.79	-1.07	2.96	39.58	34.06
TS-5 × 97005	99.91	-30.15	12.37	-0.45	-115.41	-29.41	-29.27	-0.6	-16.28	-38.84
95001 × 97005	59.65	116.68	21.41	13.56	58.67	117.68	16.05	18.08	61.02	155.4
96006 × 97005	27.71	135.49	-14.42	-22.82	-22.78	-164.94	-10.82	30.43	45.21	-217.82
90005 × 97005	-31.57	-58.13	14.07	-5.98	-35.67	48.31	-10.55	7.98	24.1	63.8
97007 × 97005	41.05	97.35	20.89	13.48	126.23	99.19	25.67	17.97	1.55	131
95010 × 97005	17.11	62.56	-12.21	3.26	22.05	26.65	-9.16	4.35	35.92	35.19
95013 × 97005	-59.09	81.26	-14.25	19.86	-77.68	-86.62	-10.69	-15.81	-23.87	114.3
93003 × 97005	52.01	10.99	-0.13	-6.63	40.43	11.46	-0.1	8.84	10.74	15.14
TS-3 × 97005	15.09	-47.4	34.96	10.57	6.39	44.7	26.22	14.1	37.7	-59.03
TH-6 × 96019-2	29.05	40.6	8.5	-0.81	27.82	35.16	6.38	-1.89	-16.66	46.43
TS-5 × 96019-2	-27.91	60.09	-16.89	3.48	-19.01	58.05	-12.66	8.08	21.99	76.66
95001 × 96019-2	54.85	74.18	2.17	2.97	39.37	77.08	1.63	6.9	3.5	101.79
96006 × 96019-2	55.9	20.71	28.61	7.26	94.83	17.7	30.46	-16.89	8.59	23.37
90005 × 96019-2	-70.73	-99.81	-31.51	-7.13	-116.31	-101.85	-23.63	16.58	8.76	134.5
97007 × 96019-2	-61.71	-58.2	-9.25	-2.07	-69.82	-85.18	-6.94	-4.82	-18.38	-112.48
95010 × 96019-2	35.62	111.25	13.81	5.85	33.18	119.22	10.36	13.61	44.54	157.4
95013 × 96019-2	27.09	-30.65	-3.81	16.87	18.75	26.97	32.86	15.98	-2.49	35.62
93003 × 96019-2	22.11	49.35	9.3	-2.03	3.14	44.53	6.98	-4.72	25.01	58.8
TS-3 × 96019-2	45.91	62.65	-9.16	17.51	-47.06	-72.56	-6.23	17.46	-9.45	95.8
TH-6 × 97001	-35.11	-15.71	-6.3	5.37	-53.23	-33.77	-24.28	12.48	32.07	-44.6
TS-5 × 97001	77.11	140.99	9.76	-17.46	73.18	57.74	6.64	17.34	-18.25	208.3
95001 × 97001	-29.99	-70.11	-10.51	-7.11	-3.21	71.29	27.14	-16.55	-24.33	-94.15
96006 × 97001	10.19	70.41	6.9	3.82	27.17	64.43	4.69	8.89	-5.06	85.08
90005 × 97001	-39.17	60.19	1.64	15.72	-30.51	-63.04	1.11	13.3	-12.47	83.25
97007 × 97001	39.01	150.15	17.58	17.01	111.78	95.2	31.95	39.56	42.06	77.79
95010 × 97001	45.85	35.81	7	-3.13	51.89	32.87	4.76	7.27	-28.9	43.41
95013 × 97001	55.92	91.6	-8.23	-0.62	54.19	96.52	-5.59	-1.44	40.86	127.4
93003 × 97001	31.01	-120.11	-21.24	-7.49	-131.71	-159.15	-14.44	7.42	-37.62	210.1
TS-3 × 97001	33.91	160.31	3.25	-0.05	55.66	-102.39	2.21	-0.12	-3.94	-135.22
TH-6 × 96014	-21.99	33.91	0.52	1.63	-22.99	-21.96	30.36	3.8	-1.56	28.99
TS-5 × 96014	31.25	-27.08	-10.41	-9.71	33.52	24.31	-7.08	-22.57	-1.07	-32.11
95001 × 96014	19.45	-62.21	9.55	0.92	18.54	26.4	6.49	2.14	5.86	-34.86
96006 × 96014	-44.11	43.28	-12.82	2.26	41.17	40.58	-8.72	5.25	-21.14	53.6
90005 × 96014	99.05	121.38	23.51	10.55	109.59	124.37	15.99	30.22	40.97	64.25
97007 × 96014	95.9	-70.91	-10.35	-12.81	-97.49	92.3	-7.04	-18.84	-12.07	-121.9
95010 × 96014	52.32	47.71	11.97	8.08	50.23	49.94	8.14	11.88	11.38	65.95
95013 × 96014	-7.09	23.97	-1.43	2.01	-11.06	25.79	30.97	2.96	2.08	34.06
93003 × 96014	116.02	-25.4	12.37	-0.41	-115.41	-29.41	-8.41	-0.6	7.43	-38.84
TS-3 × 96014	50.01	119.87	21.41	12.29	58.67	117.68	14.56	18.08	3.97	155.4
TH-6 × 93004	11.07	161.49	-14.42	-20.69	-22.78	-164.94	-9.81	30.43	-1.07	-217.8
TS-5 × 93004	53.01	41.35	-14.07	-5.42	-35.67	-48.31	-9.57	-7.98	3.09	-63.8
95001 × 93004	122.44	93.35	20.89	12.22	126.23	99.19	14.21	17.97	7.15	131
96006 × 93004	21,30	36.45	-12.21	2.96	22.05	26.65	-8.3	4.35	-11.91	35.19
90005 × 93004	73.86	84.26	-14.25	-10.75	77.68	-86.62	-9.69	15.81	-23.44	-114.39
97007 × 93004	42.34	12.64	-0.13	-6.01	40.43	11.46	-0.09	-8.84	-7.22	15.14
95010 × 93004	57.97	55.07	34.96	9.59	6.39	-44.7	33.78	14.1	29.12	-59.03
95013 × 93004	25.28	40.61	8.5	-1.28	27.82	35.16	5.78	-1.89	13.28	46.43
93003 × 93004	-17.02	54.09	-16.89	5.5	-19.01	58.05	-11.48	8.08	0.14	76.66
TS-3 × 93004	40.37	70.01	12.17	4.69	39.37	77.08	11.48	6.9	0.48	101.7
TH-6 × 96019	49.38	19.8	28.61	11.48	94.83	17.7	39.46	16.89	12.27	23.37
TS-5 × 96019	58.41	-90.58	-31.51	14.49	116.31	-101.85	27.42	16.58	-1.91	-134.5
95001 × 96019	-71.72	-80.81	9.25	-3.28	69.82	-85.18	-6.29	-4.82	-8.17	-112.4
96006 × 96019	44.81	101.3	13.81	9.26	33.18	119.22	9.39	13.61	-5.07	157.4
90005 × 96019	21.57	29.79	-3.81	-10.87	18.75	-26.97	24.59	15.98	2.4	-35.62
97007 × 96019	5.15	55.35	9.3	-3.21	3.14	-44.53	6.32	-4.72	9.59	-58.8
95010 × 96019	41.06	-27.65	-9.16	-11.87	47.06	-72.56	-6.23	-17.46	4.09	-95.82
95013 × 96019	-43.27	39.67	-6.3	18.49	-53.23	-33.77	-4.28	12.48	15.59	-44.6
93003 × 96019	70.81	142.47	9.76	-14.79	73.18	157.74	6.64	17.34	-13.13	-208.3
TS-3 × 96019	-5.2	-20.59	-10.51	-11.25	-3.21	-71.29	-7.14	16.55	-20.84	94.15
S.E.	30.19	13.08	2.18	14.39	27.15	23.67	24.05	7.21	35.33	63.41

DFF: Days to 50% flowering, DFM: Days to 50% maturity, LWC: Leaf water content, SC: stomatal conductance, NB/P: No. of branches per plant, NP/P: No. of pods per plant, NS/P: No. of seeds per pod, SY/P: Seed yield per plant, 1000SW: 1000-seed weight, PH: Plant height, S.E.: Standard error.

Table 7. Specific combining ability effects of crosses for field traits in sesame under drought conditions (T2).

Crosses	DFF	DFM	LWC	SC	NB/P	NP/P	NS/P	SY/P	1000SW	PH
TH-6 × 97005	-5.53	3.61	1.28	3.91	-14.6	34.06	-1.89	2.66	-4.72	25.79
TS-5 × 97005	57.71	-4.12	0.99	-0.8	-152.41	-38.84	16.33	-0.54	21.5	-29.41
95001 × 97005	29.34	16.47	1.71	23.87	77.49	155.41	28.27	16.23	-14.55	117.6
96006 × 97005	-11.39	23.09	1.15	40.19	30.08	-217.82	19.05	27.33	6.89	-164.9
90005 × 97005	-17.84	-6.76	1.13	-10.54	47.11	63.8	18.58	-7.16	31.83	48.31
97007 × 97005	63.12	13.89	1.67	23.74	66.7	131	27.59	16.14	2.04	99.19
95010 × 97005	11.02	3.73	0.98	5.74	29.12	35.19	16.12	3.91	-5.17	26.65
95013 × 97005	38.84	22.13	1.14	-20.88	102.59	114.39	18.82	-14.2	-31.52	-86.62
93003 × 97005	20.21	1.6	-0.01	-11.68	53.39	15.14	-0.17	17.94	14.19	11.46
TS-3 × 97005	3.2	16.26	2.8	18.61	8.44	-59.03	46.17	12.66	15.45	44.7
TH-6 × 96019-2	13.91	4.92	0.68	-2.49	36.75	46.43	11.23	-1.69	-22.01	35.16
TS-5 × 96019-2	-9.5	8.13	1.35	10.67	-25.1	76.66	22.3	17.26	29.05	58.05
95001 × 96019-2	19.68	10.79	0.17	9.12	51.99	101.79	2.87	6.2	-4.62	77.08
96006 × 96019-2	47.42	2.48	2.29	22.3	115.23	23.37	37.78	15.16	11.35	17.7
90005 × 96019-2	58.16	-14.26	-2.52	21.9	153.61	134.51	41.61	15.89	-11.57	-101.8
97007 × 96019-2	-34.91	17.92	-0.74	-6.37	92.21	-112.48	-12.21	-4.33	-24.27	-85.18
95010 × 96019-2	16.59	16.69	1.1	17.97	43.82	157.45	18.23	12.22	32.4	119
95013 × 96019-2	9.37	23.78	-0.3	21.11	24.76	35.62	-5.03	-14.35	-3.29	26.97
93003 × 96019-2	1.57	-6.23	0.74	-6.23	4.15	58.8	12.28	-4.24	33.03	44.53
TS-3 × 96019-2	-23.53	10.16	-0.73	23.06	62.14	95.82	-12.09	15.68	-12.47	-72.56
TH-6 × 97001	36.61	4.73	-0.5	16.49	70.29	-44.6	-8.32	11.21	42.35	-33.77
TS-5 × 97001	36.59	22.08	0.79	22.91	96.64	208.31	12.89	15.58	-24.1	57.74
95001 × 97001	-1.6	-9.98	0.84	21.85	-4.24	-94.15	-13.87	-14.86	32.13	71.29
96006 × 97001	13.58	9.02	0.55	11.75	35.88	85.08	9.12	7.99	-6.68	64.43
90005 × 97001	-15.25	-8.83	0.13	-17.56	40.29	83.25	2.16	-11.94	-16.47	-63.04
97007 × 97001	55.89	27.33	1.41	52.25	147.62	77.79	23.22	35.53	15.55	95.2
95010 × 97001	25.94	4.6	0.56	-9.6	68.53	43.41	9.24	-6.53	38.16	32.87
95013 × 97001	27.1	13.51	-0.66	-1.9	71.57	127.47	-10.86	-1.29	53.96	96.52
93003 × 97001	65.85	22.28	1.7	-23.01	73.93	210.18	-28.04	-15.65	-49.69	-159
TS-3 × 97001	-27.83	14.33	0.26	-0.16	73.51	-135.22	4.29	-0.11	-5.21	-102.
TH-6 × 96014	-11.5	3.07	0.04	5.02	30.36	28.99	0.69	3.41	-2.06	-21.96
TS-5 × 96014	16.76	3.4	0.83	29.81	44.27	-32.11	-13.75	-20.27	-1.42	24.31
95001 × 96014	9.27	-3.7	0.76	2.82	24.48	-34.86	12.61	1.92	7.73	26.4
96006 × 96014	-20.59	5.68	-1.03	6.94	54.37	53.6	-16.94	4.72	-27.92	40.58
90005 × 96014	54.8	-17.41	1.88	39.91	-144.73	64.25	31.05	27.14	39.58	124.3
97007 × 96014	48.75	-12.92	-0.83	24.88	128.75	-121.9	-13.67	-16.92	-15.93	92.3
95010 × 96014	25.11	6.99	0.96	15.69	66.33	65.95	15.81	10.67	15.03	49.94
95013 × 96014	-5.53	3.61	-0.11	3.91	-14.6	34.06	-1.89	2.66	2.75	25.79
93003 × 96014	57.71	-4.12	-0.99	-0.8	152.41	-38.84	-16.33	-0.54	4.35	-29.41
TS-3 × 96014	29.34	16.47	-1.71	23.87	77.49	155.41	28.27	16.23	5.24	117.
TH-6 × 93004	-11.39	23.09	-1.15	40.19	30.08	-217.82	-19.05	-27.33	-1.42	-164.
TS-5 × 93004	-17.84	-6.76	-1.13	-10.54	47.11	-63.8	-18.58	-7.16	4.08	-48.31
95001 × 93004	63.12	13.89	1.67	23.74	66.7	131	27.59	16.14	9.45	99.19
96006 × 93004	11.02	3.73	-0.98	5.74	29.12	35.19	-16.12	3.91	15.73	26.65
90005 × 93004	38.84	-12.13	-1.14	20.88	-102.59	-114.39	-18.82	-14.2	30.95	-86.62
97007 × 93004	20.21	1.6	-0.01	-11.68	53.39	15.14	-0.17	-7.94	-9.53	11.46
95010 × 93004	29.4	16.26	2.8	18.61	8.44	-59.03	46.17	12.66	38.46	-44.7
95013 × 93004	13.91	4.92	0.68	-2.49	36.75	46.43	11.23	-1.69	17.54	35.16
93003 × 93004	-9.5	8.13	1.35	10.67	-25.1	76.66	-22.3	17.26	0.19	58.05
TS-3 × 93004	19.68	30.79	10.17	19.12	51.99	101.79	2.87	6.2	20.64	77.08
TH-6 × 96019	47.42	2.48	2.29	22.3	-125.23	23.37	37.78	15.26	16.21	17.7
TS-5 × 96019	58.16	-14.26	2.52	21.9	153.61	-134.51	-41.61	-14.89	-2.53	-101
95001 × 96019	-34.91	-11.92	-0.74	-6.37	92.21	-112.48	-12.21	-4.33	-10.8	-85.18
96006 × 96019	16.59	16.69	1.1	18.97	43.82	157.45	18.23	12.22	-6.7	119
90005 × 96019	9.37	-3.78	-0.3	21.11	24.76	-35.62	-5.03	-14.35	3.17	-26.97
97007 × 96019	1.57	16.23	0.74	-6.23	4.15	-58.8	12.28	-4.24	12.66	-44.53
95010 × 96019	-23.53	-10.16	-0.73	23.06	62.14	-95.82	-12.09	15.68	5.4	-72.56
95013 × 96019	-26.59	-4.73	-0.5	16.49	70.29	-44.6	-8.32	11.21	20.59	-33.77
93003 × 96019	36.59	22.08	0.88	22.91	-96.64	-208.31	12.89	15.18	17.33	157.7
TS-3 × 96019	-1.6	-9.98	0.84	21.85	-4.24	94.15	-13.87	-14.86	-27.52	-71.29
S.E.	35.69	16.08	0.78	18.4	26.46	63.41	14.53	15.21	13.33	23.67

DFF: Days to 50% flowering, DFM: Days to 50% maturity, LWC: Leaf water content, SC: stomatal conductance, NB/P: No. of branches per plant, NP/P: No. of pods per plant, NS/P: No. of seeds per pod, SY/P: Seed yield per plant, 1000SW: 1000-seed weight, PH: Plant height, S.E. Standard error.

96006, 93004, and 96019 may serve as parents in a hybridization scheme. Specific combining ability impacts indicate non-additive gene activities. The performance of the cross combinations 97007 × 97005, TS-3 × 93004, and 97007 × 97001 under diverse agroecological settings requires further investigation. SCA effects need combination with other characteristics, such as, the GCA of the respective parents, as SCA effects alone have minimal relevance for parental selection in breeding programs (Arslan *et al*., 2018). Under normal and drought stress treatments, the crosses 97007 × 97005, 97007 × 97001, 95010 × 93004, TH-6 × 96019, and 95001 × 97005, demonstrated substantial and favorable SCA effects for the majority of the characteristics.

The frequency of advantageous alleles would tend to grow in cross combinations with high values, favorable SCA effects, including at least one parent with high GCA (Kenga *et al*., 2004; Mubashir *et al*., 2007; Harfi *et al*., 2021; Baghery *et al*., 2022), which is a notable condition. High-high and high-low general combiners, crossed to create hybrids, exhibited strong SCA effects. High SCA hybrids may result from interactions between dominant and recessive genes from both poor and good combiners (Roy *et al*., 2002). Research findings suggested that current breeding material can help to increase sesame seed output and drought resistance. In a hybridization program, the accessions, 90005, 96006, 93004, and 96019, can serve as parents. The performance of the cross combinations, 97007 × 97005, TS-3 × 93004, and 97007 × 97001, under various agroecological situations, needs further assessment.

CONCLUSIONS

Based on the results, testers 93004 and 96019 and lines 90005 and 96006 showed the most successful general combiners for most of the traits under normal and drought stress conditions. The hybrids, viz., 95001 × 97005, 97007 × 97001, 95010 × 93004, TH-6 × 96019, and 90005 × 96014 exhibited significant positive SCA effects for most traits. The results suggested that the newly developed material can serve in the breeding program under drought stress for seed yield increase in sesame.

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