Diallel Analysis of Combining Ability for Seed Yield and Attributing Traits in Sesame (*Sesamum indicum* L.) Across Diverse Environments

Sanjay Tukaram Rathod[1], Akshata Vivekanand Shinde[2], Shrikant Bhanudas Sarode[3], Arun Venkatrao Gutte[4]

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ABSTRACT

Background: To evaluate combining ability across 8 parental lines and their 56 F1 hybrids, an 8 × 8 diallel analysis was conducted focusing on seed yield and associated agronomic traits. Analysis of GCA effects revealed that TBS-105, V-29, TBS-10, TBS-3, TBS-7 and R-09 served as superior general combiners for the majority of characters, whereas V-29, TBS-12 and TBS-105 specifically excelled for oil content. Furthermore, several high-performing crosses were identified through SCA effects, stemming from various parental combinations (High × High, High × Low and Low × Low). Notably, the hybrids TBS-105 × R-09, TBS-7 × TBS-12 and TBS-12 × V-29 (among others) exhibited the most desirable SCA effects and mean values for seed yield per plant when pooled across environments.

Methods: The experimental material comprised eight sesame genotypes (TBS-03, TBS-07, TBS-10, TBS-12, TS-105, R-9, R-20 and V-29) and their 56 F1 hybrids, generated via an 8 × 8 full diallel mating design (including reciprocals) during *Kharif* 2019 at the Oilseed Research Station, Latur. For comparative evaluation, three standard checks (AKT-101, JLT-408 and GT-2) were included. The resulting hybrids were evaluated across four distinct environments: Parbhani and Ambajogai during both Summer 2020 (E1, E2) and *Kharif* 2020 (E3, E4). These trials were conducted under the aegis of Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani. Observations for ten agro-morphological traits were recorded from five randomly selected plants per treatment in each replication. Mean values were subsequently subjected to combining ability analysis for seed yield and its components following the Method I, Model I approach.

Result: The pooled analysis of variance revealed highly significant differences among genotypes for the majority of the traits studied, underscoring substantial genetic variability within the experimental material. This wide-ranging diversity justified further partitioning of the variance into its components. Estimates of general combining ability (GCA), specific combining ability (SCA) and reciprocal combining ability (RCA) effects, calculated from the data pooled across all four environments.

Key words: Combining ability, GCA, SCA, Sesame.

INTRODUCTION

In the Indian agricultural landscape, sesame ranks as the fourth most vital oilseed. During the 2019-20 season, national cultivation spanned 14.19 lakh hectares with a total output of 6.89 lakh tons, reflecting a productivity of 485 kg/ha (FAOSTAT, 2021). Major producing states include Uttar Pradesh, Rajasthan, Odisha and West Bengal, among others. In Maharashtra specifically, the 2020-21 season saw cultivation on 1.3 lakh hectares with a productivity of 217 kg/ha (Anonymous, 2021). The crop demonstrates significant seasonal versatility, being traditionally integrated into *Kharif*, semi-*Rabi* and Summer cropping systems as either a sole or intercropped component.

Despite its economic importance, sesame productivity in Maharashtra (217 kg/ha) remains significantly lower than the national average (485 kg/ha), primarily due to a lack of high-yielding, stable varieties adapted to local agro-climatic conditions. Developing superior hybrids requires a deep understanding of the genetic architecture and combining ability of potential parents. This study, utilizing an 8 × 8 diallel mating design across four distinct environments (E1 through E4), aims to identify "plus" combiners and promising F1 hybrids. By partitioning genetic variance into

[1]College of Agriculture, Ambajogai, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani-431 401, Maharashtra, India.
[2]College of Agriculture, Jirewadi-431 515, Maharashtra, India.
[3]College of Agriculture, Badnapur-431 203, Maharashtra, India.
[4]Regional Agriculture Extension Education Centre, Ambajogai, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani-431 401, Maharashtra, India.

Corresponding Author: Sanjay Tukaram Rathod, College of Agriculture, Ambajogai, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani-431 401, Maharashtra, India.
Email: strathod1981@gmail.com
ORCID: 0009-0001-0502-6774

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GCA, SCA and reciprocal effects, this research provides a strategic framework for breeding programs focused on enhancing seed yield and oil content in the Marathwada region and beyond.

MATERIALS AND METHODS

The experimental material for this investigation comprised eight diverse sesame genotypes (TBS-03, TBS-07, TBS-10, TBS-12, TS-105, R-9, R-20 and V-29) along with their 56 F1 hybrids. These hybrids, including reciprocals, were generated using an 8 × 8 full diallel mating design during *Kharif* 2019 at the Oilseed Research Station, Latur. To benchmark performance, three standard cultivars AKT-101, JLT-408 and GT-2 were included.

The 56 F1 progenies were subsequently evaluated across four distinct environments (E): Summer 2020 at Parbhani (E1) and Ambajogai (E2) and *Kharif* 2020 at Parbhani (E3) and Ambajogai (E4). These multi-location trials were conducted at the Department of Agricultural Botany, VNMKV, Parbhani and the Oilseed Research Substation, Ambajogai.

Data were recorded for ten agro-morphological traits at various growth stages. Observations were taken from five randomly selected plants per treatment in each replication and their mean values were used for statistical computation. Combining ability analysis for seed yield and its components was performed following the Method I, Model I approach of Kempthorne (1957).

RESULTS AND DISCUSSION

Significant mean squares for most agro-morphological characters indicated a high degree of variability among the studied sesame genotypes (Table 1). Based on this significant variation, the genetic effects were further analyzed. The GCA effects and the combined SCA and RCA effects for the pooled data are summarized in Table 2 and 3, respectively.

In sesame breeding, negative combining ability effects are desirable for flowering and maturity, as they indicate a trend toward earliness. In the pooled analysis, parents R-20, V-29, TBS-3 and TBS-12 exhibited significant negative GCA effects, identifying them as superior general combiners for shorter crop cycles. These results align with the observations of Tripathy *et al*. (2016) and Praveenkumar *et al*. (2012).

Regarding specific combining ability, the hybrids TBS-3 × V-29 (-0.89), TBS-10 × TBS-105 (-0.61), R-09 × R-20 (-0.55) and TBS-3 × R-20 (-0.37) demonstrated desirable significant negative SCA effects for days to 50% flowering. Furthermore, the cross TBS-105 × R-20 (-2.21), along with TBS-3 × R-09 (-1.84) and TBS-7 × R-09 (-1.62), showed the strongest negative SCA effects for days to maturity, consistent with reports by Virani *et al*. (2018).

Significant reciprocal effects for earliness were most pronounced in V-29 × TBS-10 (-1.62) for flowering and TBS-105 × TBS-3 (-3.31) for maturity. Such reciprocal variations

Table 1: Analysis of variance for randomized block design for different characters pooled over environments in sesame.

Source of variation	d.f.	Days to 50% flowering	Days to maturity	Plant height (cm)	No of branches/ plant	Number of capsules/ plant	Length of capsule (cm)	Number of seeds/ capsule	1000 seed weight (g)	Seed yield/ plant (g)	Oil content (%)
Replication × Environments	3	2.29	11.85	3.54	0.07	14.67	0.01	9.33	0.0002	0.66	0.02
Genotypes (G)	66	11.20**	4.38**	579.68**	0.43**	1171.08**	0.44**	313.67**	1.05**	80.87**	122.70**
Environments (E)	3	471.51**	24.07**	23472.87**	1.18**	39173.85**	0.16**	103.27**	1.66**	64.39**	7.62**
G × E	198	2.92**	3.53	167.29**	0.09**	233.70**	0.01**	6.16*	0.03**	5.98**	3.57**
Error	462	4.69	9.13	178.14	0.10	214.17	0.01	0.01	0.03	5.86	3.35

*Significant at 5% level and **significant at 1% level.

suggest the presence of maternal influences, which typically become more evident in later segregating generations a phenomenon also noted by Salunkhe and Lokesha (2012).

Increased plant height is a target trait for maximizing biomass and capsule-bearing potential in sesame. Parents R-09 (3.18), TBS-105 (1.82) and TBS-3 (1.46) displayed significant positive GCA effects, marking them as preferred progenitors for height enhancement. Among the hybrids, TBS-3 × V-29 (9.81), TBS-12 × R-20 (8.84) and TBS-7 × V-29 (8.12) exhibited the most noteworthy positive SCA effects. These findings are in agreement with the results of Hassan and Sedeck (2015). Additionally, the reciprocal analysis revealed substantial positive RCA effects in R-09 × R-20 (7.81) and TBS-7 × TBS-12 (7.31).

In sesame, increasing the number of primary branches is a key breeding objective to enhance the total number of capsules and, consequently, the overall seed yield. In the pooled analysis, parents TBS-105 (0.12), R-09 (0.07) and TBS-3 (0.004) emerged as superior general combiners, exhibiting highly significant positive GCA effects for this trait. These results are corroborated by the findings of Hassan and Sedeck (2015); Virani *et al*. (2018) and Ibrahim *et al*. (2021).

Significant positive SCA effects were observed in several hybrids, most notably TBS-7 × TBS-105 (0.39), TBS-3 × R-20 (0.17), TBS-3 × R-09 (0.13) and TBS-12 × R-09 (0.12). These combinations are considered promising for the development of highly branched genotypes, aligning with earlier observations by Kumar and Kannan (2010).

The reciprocal analysis further identified substantial positive effects in the crosses R-09 × TBS-105 (0.30), R-20 × TBS-7 (0.22), TBS-12 × TBS-10 (0.21), TBS-105 × TBS-10 (0.17) and V-29 × TBS-7 (0.10). Similar significant reciprocal impacts for branch number were previously documented by Sharma and Chouhan (1985) and Salunkhe and Lokesha (2012).

For the number of capsules per plant, positive GCA and SCA values are highly desirable as they directly correlate with increased seed yield potential. Pooled analysis revealed that parents TBS-105 (4.54), V-29 (4.27) and R-09 (1.67) exhibited highly significant positive GCA effects, identifying them as excellent general combiners for this trait. These observations are consistent with previous reports by Hassan and Sedeck (2015) and Virani *et al*. (2018).

Notable positive SCA effects were recorded in several cross combinations, specifically TBS-7 × TBS-12 (13.25), TBS-10 × TBS-105 (10.5), TBS-7 × V-29 (7.29), TBS-105 × V-29 (6.64) and TBS-3 × R-09 (6.31). Similar significant positive SCA impacts on capsule number have been documented by Hassan and Sedeck (2015) and Tripathy *et al*. (2016).

Furthermore, highly significant positive reciprocal effects were displayed by the hybrids TBS-12 × TBS-7 (18.41), TBS-105 × TBS-7 (13.89), V-29 × TBS-10 (13.14),

Table 2: Estimates of general combining ability (GCA) of parents for different characters pooled over environments in sesame (*Sesamum indicum* L.).

Lines and testers	Days to 50% flowering	Days to maturity	Plant height (cm)	Number of branches per plant	Number of capsules per plant	Length of capsule (cm)	Number of seeds per capsule	1000 seed weight (g)	Seed yield per plant (g)	Oil content %
					Line					
TBS-02	-0.24**	-0.36**	1.46**	0.004**	-3.74**	-0.07**	-0.71**	0.14**	-0.57**	-1.99**
TBS-05	0.09**	-0.20**	0.84	0.02**	-1.60**	0.04**	0.004	0.09**	-0.32**	-1.15**
TBS-06	0.31**	0.67**	0.35	0.003**	1.10**	0.05**	-0.02	0.08**	0.22**	-2.58**
TBS-07	-0.06**	-0.12	0.49	-0.09	-4.63**	-0.03**	-2.33**	0.17**	-0.77**	2.04**
TS-11	0.26**	0.76**	1.82**	0.12**	4.54**	0.01**	-1.86**	0.20**	0.94**	0.63**
TS-13	1.06**	2.14**	3.18**	0.07**	1.67**	-0.04**	-0.73**	-0.29**	-0.26**	0.87**
TS-14	-0.85**	-1.24**	-3.73**	-0.09	-1.59**	-0.02**	0.27**	-0.16**	-0.78**	-0.87**
	-0.58**	-1.63**	-4.42**	-0.04	4.27	0.05**	5.38**	-0.23**	1.54**	3.06**
S.E.(Gi)	0.16	0.26	0.64	0.01	0.40	0.007	0.19	0.004	0.09	0.05
S.E.(Gi-Gj)	0.24	0.40	0.97	0.02	0.61	0.01	0.29	0.006	0.14	0.08

*and ** indicated significance at 5 and 1 percent level, respectively.

R-09 × TBS-10 (12.62), TBS-12 × TBS-10 (11.15) and TBS-105 × TBS-12 (10.68). The presence of these substantial reciprocal effects points toward maternal or cytoplasmic influences on capsule production. Such extranuclear genetic factors warrant further verification in subsequent segregating generations, a conclusion supported by the findings of Brindha and Sivasubramanian (1992) and Salunkhe and Lokesha (2012).

In sesame breeding, increased capsule length is a highly desirable trait, as it typically accommodates a greater number of seeds, thereby enhancing overall productivity. In the pooled analysis, parents V-29 (0.05), TBS-10 (0.05), TBS-7 (0.04) and TBS-105 (0.01) demonstrated significant positive GCA effects, identifying them as ideal progenitors for improving this character. These findings are corroborated by the work of Kumar and Kannan (2010); Praveenkumar *et al*. (2012); Hassan and Sedeck (2015) and Virani *et al*. (2018).

Analysis of specific combining ability revealed that the hybrids TBS-3 × V-29 (0.24), TBS-7 × R-09 (0.24), TBS-10 × R-09 (0.23) and TBS-7 × R-20 (0.22) exhibited significant positive SCA effects. Consequently, these crosses are considered promising for the development of long-capsule genotypes, aligning with results reported by Hassan and Sedeck (2015); Tripathy *et al*. (2016) and Ibrahim *et al*. (2021).

Furthermore, substantial positive reciprocal effects were observed in the crosses TBS-7 × TBS-3 (0.27), R-20 × TBS-3 (0.27), V-29 × TBS-10 (0.27) and V-29 × TBS-3 (0.17). These results concur with the findings of Brindha and Sivasubramanian (1992) and Salunkhe and Lokesha (2012), suggesting that maternal factors may also influence the inheritance of capsule length in these specific combinations.

A higher seed count per capsule is a pivotal yield attribute in sesame, as reflected by the desirability of positive combining ability estimates. Pooled analysis revealed that parents V-29 (5.38) and R-20 (0.27) exhibited substantial positive GCA effects, identifying them as superior general combiners for increasing seed density. These findings align with previous research by Pathirana (1999); Bharathi Kumar and Vivekanandan (2009); Kumar and Kannan (2010) and Virani *et al*. (2018).

Several hybrids demonstrated significant positive SCA effects, most notably TBS-12 × V-29 (6.06), R-20 × V-29 (4.1), TBS-7 × TBS-105 (3.68), TBS-3 × V-29 (3.67) and TBS-10 × R-09 (3.6). This outcome corroborates the conclusions of Kumar and Kannan (2010) and Tripathy *et al*. (2016).

Furthermore, pronounced positive reciprocal effects were observed in the crosses R-09 × TBS-7 (6.82), TBS-10 × TBS-3 (6.42), TBS-12 × TBS-7 (5.94), TBS-105 × TBS-3 (5.87) and TBS-10 × TBS-7 (5.13). These results, which suggest maternal influence, are consistent with the outcomes reported by Brindha and Sivasubramanian (1992) and Salunkhe and Lokesha (2012). Interestingly, the cross V-29 × R-09 (-8.60) exhibited a significant negative reciprocal effect specifically in environment E2, indicating a potential genotype-by-environment (G × E) interaction for maternal factors in that specific site.

In sesame breeding, a higher 1000-seed weight is a critical component for enhancing grain yield and oil recovery. In the pooled analysis, the genotypes TBS-105 (0.20), TBS-12 (0.17), TBS-3 (0.14), TBS-7 (0.09) and TBS-10 (0.08) emerged as superior general combiners. These parents consistently produced test weights exceeding 3.5 g and exhibited substantial positive GCA effects, identifying them as ideal donors for bold-seededness. These results corroborate the earlier findings of Kumar and Kannan (2010); Shekhat *et al*. (2011) and Ibrahim *et al*. (2021).

Specific combining ability (SCA) analysis identified several promising hybrids, most notably TBS-3 × R-09 (0.36), TBS-12 × TBS-105 (0.21), TBS-3 × R-20 (0.19), TBS-10 × V-29 (0.15) and TBS-10 × TBS-12 (0.14). The significant positive SCA estimates for these crosses are in agreement with the reports of Brindha and Sivasubramanian (1992) and Salunkhe and Lokesha (2012).

Furthermore, the reciprocal analysis revealed pronounced positive effects in the crosses R-09 × TBS-12 (0.45), R-09 × TBS-10 (0.28), V-29 x TBS-105 (0.26), TBS-12 × TBS-10 (0.24), TBS-105 × TBS-12 (0.24) and TBS-12 × TBS-7 (0.22). These significant reciprocal impacts (Table 3) suggest a degree of maternal influence on seed development and weight, a phenomenon previously documented by Brindha and Sivasubramanian (1992) and Salunkhe and Lokesha (2012).

As the ultimate objective of sesame breeding programs, high seed yield per plant is the most critical trait for commercial and agronomic success. In the pooled analysis, parents V-29 (1.54), TBS-105 (0.94) and TBS-10 (0.22) emerged as superior general combiners, exhibiting highly significant positive GCA effects. These genotypes serve as valuable genetic reservoirs for yield improvement, corroborating the findings of Hassan and Sedeck (2015), Tripathy *et al*. (2016) and Ibrahim *et al*. (2021).

Specific combining ability analysis identified several high-yielding hybrids with notable positive SCA estimates. The most promising combinations included TBS-3 × R-20 (3.11), TBS-7 × V-29 (2.63), TBS-10 × V-29 (2.37), TBS-3 × R-09 (2.06) and TBS-10 × TBS-105 (2.05). The superior performance of these crosses is consistent with reports by Virani *et al*. (2018) and Hassan and Sedeck (2015), highlighting their potential for commercial exploitation or further selection.

Furthermore, the reciprocal analysis revealed substantial positive effects in hybrids such as TBS-12 × TBS-7 (4.39), V-29 × TBS-105 (4.12), R-09 × TBS-105 (3.51), R-09 × TBS-12 (3.34) and TBS-10 × TBS-7 (3.18). These significant reciprocal impacts (Table 3) underscore the influence of maternal or cytoplasmic factors on final yield, a phenomenon echoed by the results of Dora and Kamla (1987) and Salunkhe and Lokesha (2012).

Table 3: Estimates of specific combining ability (SCA) for different characters pooled over environments in sesame (*Sesamum indicum* L.).

Crosses	Days to 50% flowering		Days to maturity		Plant height (cm)		Number of branches per plant		Number of capsules per plant	
	Cross	REC	Cross	REC	Cross	REC	Cross	REC	Cross	REC
TBS-3 × TBS-7	-0.13	0.25*	1.50**	-2.81**	-8.01*	-2.54	-0.13	0.09**	-7.11**	7.93**
TBS-3 × TBS-10	0.70**	0.68**	0.74	-2.31**	-3.86	4.16*	-0.07	-0.03	-11.05**	7.66*
TBS-3 × TBS-12	0.33	-0.43**	0.61	-1.75**	-0.78	4.38*	0.09**	0.01**	1.81	3.91**
TBS-3 × TBS-105	0.13	-0.18	0.52	-3.31**	3.06	-2.18	-0.15	-0.12	4.27**	0.68
TBS-3 × R-09	-0.09	-0.75**	-1.84**	-1.81**	0.11	-0.22	0.13**	-0.18	6.31**	3.68**
TBS-3 × R-20	-0.37	0.43**	0.29	-1.68**	2.89	4.33*	0.17**	-0.03	4.93**	2.00**
TBS-3 × V-29	-0.89**	0.06	-1.31*	-1.68**	9.81**	-9.17**	-0.04	0.07**	4.87**	-7.65**
TBS-7 × TBS-10	0.11	-0.31**	-1.28*	-2.31**	2.55	0.01	-0.09	0.06**	-0.76	5.55**
TBS-7 × TBS-12	-0.19	-0.75**	-0.16	-2.12**	-1.44	7.31**	-0.04	-0.04	13.25**	18.41**
TBS-7 × TBS-105	0.22	-0.12	1.05	-2.25**	-1.43	-5.10**	0.39**	0.07**	-0.82	13.89**
TBS-7 × R-09	0.68**	0.25*	-1.62**	-1.43**	0.76	-1.89	-0.14	0.07**	-5.96**	-2.58**
TBS-7 × R-20	0.72**	0.50**	1.45**	-2.25**	2.43	2.95	0.001	0.22**	-0.43	8.10**
TBS-7 × V-29	-0.30	0.37**	0.52	-0.93**	8.12**	-0.49	-0.05	0.10**	10.20**	9.30**
TBS-10 × TBS-12	-0.09	0.18	0.95	-0.50	1.03	-0.52	-0.03	0.21**	2.99*	11.15**
TBS-10 × TBS-105	-0.61**	-0.50**	1.11*	-0.43	-0.12	1.32	-0.007	-0.19	10.50**	1.10
TBS-10 × R-09	0.46*	-0.50**	0.05	-0.12	-4.13	-2.31	-0.009	0.12**	4.77**	12.62**
TBS-10 × R-20	0.25	0.37**	0.94	-0.25	4.59	4.37**	0.006**	0.07**	6.00**	9.75**
TBS-10 × V-29	0.60**	-1.62**	0.58	-2.12**	3.49	0.75	0.001	0.07**	2.19	13.14**
TBS-12 × TBS-105	0.20	-0.06	1.41*	-0.81**	-3.98	-2.50	0.06**	0.17**	-3.38**	10.68**
TBS-12 × R-09	0.34	-0.12	0.66	-0.43	2.49	4.63**	0.12**	-0.03	-0.72	7.36**
TBS-12 × R-20	0.07	0.81**	-1.12*	0.25	8.84**	2.99	-0.04	0.03**	-0.90	-0.1
TBS-12 × V-29	0.98**	1.25**	-0.86	0.25	-5.07	4.08*	-0.02	-0.11	-7.63**	-2.41**
TBS-105 × R-09	-0.16	-0.06	-0.22	-0.18	-7.28*	6.38**	0.06**	0.30**	2.77*	9.27**
TBS-105 × R-20	0.86**	2.06**	-2.21**	0.68*	6.43*	-0.54	0.06**	0.06**	4.26**	2.79**
TBS-105 × V-29	-0.09	0.37**	-0.26	1.37**	5.88	-0.96	-0.07	0.03**	6.64**	10.04**
R-09 × R-20	-0.55**	1.31**	2.09**	3.25**	2.36	7.81**	0.12**	0.02**	0.70	1.14
R-09 × V-29	-0.01	1.00**	0.73	4.25**	-0.98	6.43**	0.04**	0.06**	4.83**	9.43**
R-20 × V-29	-0.03	-0.43**	-0.05	0.93**	-0.79	-2.79	0.12**	0.0006	2.97*	-2.35**
SE (sii)	0.60		1.01		2.40		0.07		1.52	

Table 3: Continue.....

Table 3: Continue.....

Crosses	Length of capsule (cm)		Number of seeds per capsule		1000 seed weight (g)		Seed yield per plant (g)		Oil content %	
	Cross	REC	Cross	REC	Cross	REC	Cross	REC	Cross	REC
TBS-3 × TBS-7	-0.15**	0.27**	-1.44**	-1.39**	-0.07**	-0.11**	-1.16**	0.93**	-0.14**	1.17**
TBS-3 × TBS-10	-0.12**	0.14**	-1.36**	6.42**	-0.08**	0.02**	-3.00**	0.67**	0.18**	3.66**
TBS-3 × TBS-12	0.11**	-0.15**	2.08**	3.01**	-0.06**	0.08**	-0.37**	1.80**	-0.90**	0.99**
TBS-3 × TBS-105	-0.08**	-0.05**	-1.83**	5.87**	-0.12**	-0.10**	0.76**	2.26**	-2.71**	0.04**
TBS-3 × R-09	0.005**	0.04**	-0.009	-2.03**	0.36**	0.17**	2.06**	0.91**	-1.04**	-1.43**
TBS-3 × R-20	-0.05**	0.27**	0.55**	1.79**	0.19**	-0.02**	3.11**	-1.13**	1.19**	-1.61**
TBS-3 × V-29	0.24**	0.17**	3.67**	-6.52**	-0.12**	0.08**	1.76**	-2.29**	2.45**	-0.18**
TBS-7 × TBS-10	-0.25**	0.15**	-2.49**	5.13**	-0.04**	0.03**	-0.43**	3.18**	-1.44**	2.73**
TBS-7 × TBS-12	-0.04**	-0.07**	0.51	5.94**	0.09**	0.22**	1.94**	4.39**	-0.34**	4.59**
TBS-7 × TBS-105	0.14**	0.05**	3.68**	-1.64**	-0.02**	-0.006**	-0.29**	1.87**	0.82**	-0.12**
TBS-7 × R-09	0.24**	-0.07**	1.83**	6.82**	-0.08**	-0.14**	0.56**	0.53**	-1.10**	-1.51**
TBS-7 × R-20	0.22**	-0.0006**	3.12**	-0.95**	-0.01**	0.12**	0.31**	2.05**	-1.47**	-1.61**
TBS-7 × V-29	0.15**	-0.07**	1.02**	-2.74**	0.05**	-0.05**	2.63**	1.72**	1.13**	1.15**
TBS-10 × TBS-12	0.13**	0.007**	2.74**	0.33*	0.14**	0.24**	0.41**	2.27**	0.88**	-0.96**
TBS-10 × TBS-105	-0.02**	0.10**	2.11**	1.46**	-0.13**	-0.27**	2.50**	-0.52**	-0.81**	0.98**
TBS-10 × R-09	0.23**	0.10**	3.60**	0.45**	-0.02**	0.28**	0.75**	2.18**	0.001	1.89**
TBS-10 × R-20	0.04**	0.12**	2.20**	-0.61**	0.05**	0.21**	1.58**	2.17**	-0.22**	2.33**
TBS-10 × V-29	-0.16**	0.27**	-0.14	3.20**	0.15**	0.06**	2.37**	2.25**	2.48**	-1.16**
TBS-12 × TBS-105	0.02**	0.05**	1.32**	-5.65**	0.21**	0.24**	0.31**	1.99**	-2.30**	0.15**
TBS-12 × R-09	-0.07**	-0.30**	3.28**	-2.97**	-0.24**	0.45**	1.40**	3.34**	4.56**	-3.77**
TBS-12 × R-20	0.04**	0.03**	-11.07**	3.25**	-0.13**	0.11**	-1.73**	0.24**	3.15**	-0.48**
TBS-12 × V-29	-0.17**	-0.09**	6.06**	-0.68**	0.01**	0.16**	0.36**	-1.17**	-5.88**	3.75**
TBS-105 × R-09	0.12**	-0.20**	3.21**	3.16**	-0.09**	-0.007**	0.95**	3.51**	-0.44**	4.28**
TBS-105 × R-20	0.10	-0.05**	1.27**	4.53**	-0.09**	-0.13**	-0.007	-0.64**	-1.61**	-0.47**
TBS-105 × V-29	0.04**	0.01**	-4.45**	2.25**	0.01**	0.26**	0.90**	4.12**	1.60**	2.56**
R-09 × R-20	-0.11**	-0.30**	-0.15	2.19**	0.11**	-0.09**	-0.85**	0.73**	1.22**	-0.22**
R-09 × V-29	-0.21**	0.003**	-4.49**	-5.89**	-0.19**	0.20**	-0.98**	1.80**	-1.78**	-2.23**
R-20 × V-29	0.01**	0.02**	4.10**	3.54**	-0.08**	-0.10**	0.35**	-0.03	1.30**	-1.35**
SE (sii)	0.02		0.71		0.01		0.35		0.21	

*and ** indicated significance at 5 and 1 percent level, respectively.

High oil content is a critical quality parameter in sesame and positive combining ability estimates are sought after to maximize total oil yield per unit area. In the pooled analysis, parents V-29 (3.06), TBS-12 (2.04), R-09 (0.87) and TBS-105 (0.63) exhibited the most pronounced positive GCA effects, distinguishing them as superior general combiners for oil percentage. These results align with the findings of Aladji Abatchoua *et al*. (2015) and Tripathy *et al*. (2016).

Regarding specific combining ability, several hybrids demonstrated highly significant positive SCA effects, notably TBS-12 × R-09 (4.56), TBS-12 × R-20 (3.15), TBS-10 × V-29 (2.48), TBS-3 × V-29 (2.45) and TBS-105 × V-29 (1.6). The identification of these superior combinations for oil enrichment is consistent with research reported by Aladji Abatchoua *et al*. (2015); Tripathy *et al*. (2016) and Ibrahim *et al*. (2021).

Furthermore, substantial positive reciprocal effects were identified in the crosses TBS-12 × TBS-7 (4.59), R-09 × TBS-105 (4.28), V-29 × TBS-12 (3.75) and TBS-10 × TBS-3 (3.66). These noteworthy reciprocal impacts suggest that maternal genotype plays a significant role in determining seed oil composition. Similar reciprocal influences have been documented previously by Brindha and Sivasubramanian (1992) and Salunkhe and Lokesha (2012).

Estimates of general combining ability (GCA) represent the fixable component of genetic variance, largely governed by additive gene action. In contrast, Specific Combining Ability (SCA) is attributed to non-additive gene effects including dominance and various epistatic interactions (additive × dominance or dominance × dominance) which are generally non-fixable. The presence of significant non-additive genetic variance serves as the primary justification for initiating a hybrid development program.

Depending on the predominant type of gene action identified, the parental material can be strategically utilized either to develop superior F1 hybrids or to accumulate favorable fixable genes through recurrent selection. The analysis of combining ability across ten distinct agro-morphological traits (Table 1) revealed highly significant parental variance for every character, validating the selection of these genotypes for the diallel study. The high GCA effects observed in the desired direction for seed yield and its components suggest that these elite lines possess a strong potential to transmit favorable traits to their progeny, facilitating the development of superior sesame varieties.

CONCLUSION

Based on General Combining Ability (GCA) effects, the genotypes TBS-105, V-29, TBS-10, TBS-3, TBS-7 and R-09 emerged as superior general combiners for the majority of the traits studied. Specifically for oil content, V-29, TBS-12 and TBS-105 demonstrated high GCA estimates, marking them as elite progenitors for quality improvement. These parents, characterized by significant positive GCA effects, are ideal candidates for yield enhancement through pedigree breeding, as their performance is primarily governed by fixable additive gene action.

Furthermore, several superior cross combinations were identified based on Specific Combining Ability (SCA) effects, involving various parental GCA combinations (High × High, High × Low and Low × Low). Hybrids such as TBS-105 × R-09, TBS-7 × TBS-12, TBS-12 × V-29, TBS-10 × V-29, TBS-12 × R-09, TBS-3 × R-20, TBS-10 × R-09 and TBS-105 × V-29 exhibited desirable SCA effects and high mean values for seed yield per plant across all environments. To maximize the genetic potential of these crosses, breeding strategies such as biparental mating, reciprocal recurrent selection, or the direct exploitation of heterosis through hybrid variety development are recommended.

Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest. The research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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