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Research Article

Elucidation of gene action and estimation of combining ability effects for fruit yield attributes and biochemical traits in brinjal (*Solanum melongena* L.)

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Abstract
The present investigation was undertaken in brinjal (*Solanum melongena* L.) to estimate combining ability and gene action following a half diallel mating design using ten parents. The ratio of genetic variance components, $\sigma^2_{gca}/\sigma^2_{sca}$ and σ^2_D/σ^2_A, showed dominant gene action, indicating the presence of non-additive genetic variance for days to 50% flowering, fruit yield per plant, total phenol, antioxidant activity and total soluble sugar. The traits fruits per plant, fruit girth, and fruit weight showed additive genetic variance. Among the parental genotypes, AB 15-08, ABSR 2 and AB 20-13 were found to be good general combiners for fruit yield, fruits per plant, and total soluble solids. The three highest-ranking hybrids were AB 15-08 × AB 20-13, AB 15-08 × AB 20-03 and AB 20-07 × GP BRJ 224. The above hybrids would be rewarding for harnessing heterosis.

Keywords: Diallel cross, brinjal, combining ability, fruit yield, antioxidant activity

INTRODUCTION

Brinjal (*Solanum melongena* L.) is a predominant Indian solanaceous vegetable crop, also known as eggplant. This diploid plant, with 2n = 24 chromosomes, contributes to a total production of approximately 13.154 million tons from 0.758 million hectares, yielding 17.35 MT/ha (DAC and FW, 2021). The major brinjal producing states of India are West Bengal, Maharashtra, Bihar, and Gujarat. Despite the fact that it is a self-compatible and self-pollinating crop, cross pollination to the extent of 30-40% has been observed in Brinjal (Daskalov and Murtazo, 1957). In the context of breeding, selecting suitable parent plants for hybridization is a pivotal step. Insights into combining ability offer breeders a tool to choose superior parents and favourable crosses for a well-structured breeding program. Additionally, it provides a means to comprehend the genetic mechanisms underlying the transmission of specific traits. With these considerations, the current study was conducted to evaluate both the general and specific combining abilities of parents and hybrids, respectively. Furthermore, the study aimed to elucidate the genetic effects responsible for yield and its contributing characteristics.

MATERIALS AND METHODS

The material used for mating comprised of ten parents, *viz.,* AB 15-06, AB 20-09, AB 15-08, AB 15-18, AB 20-07, ABSR 2, AB 20-13, GP BRJ 224, GP BRJ 309 and AB 20-03 and their 45 hybrids developed by half diallel mating design (Method-II). The crossing programme was carried out in *Rabi* 2021-22 followed by an evaluation of all the experimental material along with 1 standard check (ABH 1) in *Kharif* 2022-23 at Main Vegetable Research Station, AAU, Anand. Every genotype was grown individually in a row measuring 4.80 meters in length, with 90 × 60 cm spacing.

All the suggested agronomical practices were adhered to in order to cultivate a thriving and robust crop. Observations on 12 morphological traits were recorded on five plants chosen at random for each treatment in each replication. The analysis of data for general and specific combining ability was carried out as per Griffing's (1956) Method II, Model I (Fixed model). Moreover, data were statistically analyzed in SPAR1 (Statistical Package for Agricultural Research) developed at IARI, New Delhi.

RESULTS AND DISCUSSION

In the past, improved eggplant varieties were developed through methods like extensive screening and selecting pure lines from landraces. However, it has become clear that solely relying on the performance of individual plants does not always yield the desired outcomes. To make effective use of available genetic resources, diverse breeding approaches are required to effectively incorporate favourable allelic combinations into the background of economically advanced high-yielding cultivated varieties (Anushma *et al.,* 2018). The assessment of combining ability variances is instrumental in deciphering the genetic mechanisms at play. Optimal outcomes are more likely when gca variances outweigh sca variances in early-generation genotype testing. This situation increases the likelihood of stabilizing superior genes. Conversely, if the reverse scenario exists, where sca variances are predominant, breeders are advised to conduct selection in later generations for more effective results.

The analysis of variance for combining ability for fruit yield and its contributing traits is presented in **Table 1**. The ANOVA outcomes indicated notable significance in the comparison between parents and hybrids across all characteristics, except total soluble solids. This disparity between parents and hybrids for various traits signifies the potential influence of non-additive gene effects. Similarly, the comparison between checks and hybrids displayed statistical significance for all traits except total soluble solids, fruit girth, days to 50% flowering and branches per plant. This observation establishes a suitable basis for evaluating heterotic expression.

An examination of the variance ratios, namely $\sigma^2_{gca}/\sigma^2_{sca}$ and σ^2_D/σ^2_A, indicated a prevailing influence of non-additive genetic variance. Additionally, there was a pronounced presence of variance attributed to specific combining ability (sca) in comparison to general combining ability (gca) for traits such as total phenol content, fruit yield per plant, days to 50% flowering, antioxidant activity, and total soluble sugar. This pattern is advantageous for harnessing heterosis in breeding efforts aimed at enhancing these traits. Furthermore, the prevalence of non-additive genetic variance suggested the prevalence of heterozygotes within the population. Given the nature of this type of variation, which is resistant to being stabilized, hybridization emerges as a more suitable approach for crop improvement.

However, the extent of variation caused by general combining ability was greater when contrasted with the variation resulting from specific combining capability for characters such as fruit girth, fruit weight, and fruits per plant. This reveals the role of additive genetic variation.

Table 1. Analysis of variance (mean square) for combining ability and estimates of components of variance for different characters in brinjal

Source of variation	df	DF	PH	BP	FP	FYP	FL	FG	FW	TSSs	TP	AA	TSS
GCA	9	45.39**	45.53**	0.22**	2552.90**	0.87**	0.16**	38.19**	261.95**	0.34**	2014.29**	0.16**	2.04**
SCA	44	19.89**	102.07**	0.34**	200.44**	0.20**	0.19**	2.78**	24.93**	0.35**	1118.97**	0.07**	0.89**
σ^2gca	-	2.12**	-	-	196.04**	0.06	-	2.95**	19.75**	-	74.61**	0.01**	0.10**
σ^2sca	-	19.17**	94.91**	0.31**	171.92**	0.16**	0.14**	2.45**	19.21**	0.34**	1113.87**	0.07**	0.89**
σ^2A	-	4.25	-	-	392.08	0.11	-	5.9	39.5	-	149.22	0.01	0.19
σ^2D	-	19.17	94.91	0.31	171.92	0.16	0.14	2.45	19.21	0.34	1113.87	0.07	0.89
σ^2gca/σ^2sca	-	0.11	-	-	1.14	0.35	-	1.2	1.03	-	0.07	0.1	0.11
Error	108	0.72	7.16	0.03	28.52	0.03	0.05	0.33	5.72	0.01	5.11	0.001	0.004
Average degree of dominance	-	2.12	-	-	0.66	1.2	-	0.64	0.7	-	2.73	2.24	2.15

"-" indicate negative estimate.

DF = Days to 50% flowering
PH = Plant height
BP = Branches per plant
FP = Fruits per plant
FYP = Fruit yield per plant
FL = Fruit length (cm)
FG = Fruit girth (cm)
FW = Fruit weight (g)
TSSs = Total soluble solids (ºbrix)
TP = Total phenol (mg/100g)
AA = Antioxidant activity
TSS = Total soluble sugar

Estimates of the gca effect for days to 50% flowering showed that three parents, *viz.,* AB 20-03, AB 20-09 and AB 15-08 were good combiners, and all three were statistically at par with each other (**Table 2**). These parents will be further exploited to develop promising early varieties. Two specific hybrids, AB 15-08 × GP BRJ 309 and AB 15-18 × AB 20-13 (**Table 3**) are in favourable direction. Hence, they were considered good cross combinations for exploiting earliness. Moreover, the ratio ($\sigma^2_{gca}/\sigma^2_{sca}$) falling below unity and the ratio σ^2_D/σ^2_A surpassing unity, as observed in this study, suggest the predominant influence of non-additive gene actions. These findings align with previous research conducted by Gadhiya *et al*. (2015), Gharge *et al.* (2016), Desai *et al.* (2017), Kumar *et al*. (2017), Timmareddygari *et al*. (2021) and Rajan *et al*. (2022).

The σ^2_{gca} was found to be negative for plant height. Hence, the combining ability effects of parents were not estimated. The best three hybrid combinations were AB 15-08 × AB 20-03, AB 15-08 × GP BRJ 224 and AB 20-09 × GP BRJ 309. In the present results, non-additive gene action was predominant and was in accordance with those obtained by Prasad *et al*. (2015), Gharge *et al.* (2016), Kumar and Arumugam (2016), Desai *et al.* (2017), Patel (2017), Siva *et al.* (2020) and Timmareddygari *et al*. (2021) and Rahul *et al.* (2023)

Combining ability effects of parents were not estimated for branches per plant as σ^2_{gca} was found to be negative. The cross ABSR 2 × GP BRJ 309 and AB 20-13 × AB 20-03 had the minimum and maximum sca effects, respectively. The top three hybrid combinations, characterized by substantial and highest positive specific combining ability (sca) effects, ranked as follows: AB 20-13 × AB 20-03, AB 20-09 × ABSR 2, and AB 15-08 × GP BRJ 224. Venkata *et al*. (2014), Kumar and Arumugam (2016), Desai *et al*. (2017), Kumar *et al*. (2017), Siva *et al*. (2020), Timmareddygari *et al.* (2021) and Rajan *et al.* (2022) also have reported the importance of non-additive gene action for this trait.

Among the examined genotypes, AB 20-09 exhibited the lowest general combining ability (gca) effect for fruits per plant, while AB 20-13 demonstrated the highest gca effect. The parents, *viz.,* AB 20-13, ABSR-2 , AB 15-18 , and AB 15-08 were the best general combiner. The best three hybrids were AB 15-08 × AB 20-13, AB 15-06 × AB 20-13 and AB 20-09 × AB 15-18 . These findings align with previous research conducted by Choudhary and Didel (2014), Ansari and Singh (2014), Uddin *et al.* (2015), Kumar *et al*. (2017), Santhosha *et al*. (2017), Valadares *et al.* (2019), Datta *et al.* (2021) and Mondal *et al.* (2021).

The parents *viz.,* AB 20-13 , ABSR 2 and AB 15-08 had significant and positive estimates of gca effect for fruit yield per plant, out of which, parents ABSR 2 and AB 20-13 were the best general combiners. The best hybrid combinations having significant and maximum positive sca effects in order were AB 15-08 × AB 20-13 , AB 15-08 × AB 20-03 , AB 20-07 × GP BRJ 224 , ABSR 2 × GP BRJ 224 and AB 20-07 × AB 20-13 which were

Table 2. Estimation of general combining ability (gca) effects of parents for various characters in brinjal

Parents		DF	FP	FYP	FG	FW	TP	AA	TSS
AB 15-06		0.57*	0.65	-0.12*	-0.59**	-2.16**	-16.97**	-0.11**	0.23**
AB 20-09		-1.12**	-20.53**	-0.52**	1.10**	4.95**	-11.88**	0.09**	-0.64**
AB 15-08		-0.57*	4.16**	0.16**	-0.18	-0.60	19.67**	-0.09**	0.73**
AB 15-18		0.57*	10.55**	0.06	-1.05**	-4.62**	-9.36**	-0.15**	-0.26**
AB 20-07		0.99**	-18.33**	-0.14**	0.75**	6.73**	-10.61**	-0.10**	-0.54**
ABSR 2		1.21**	15.51**	0.34**	-0.67**	-3.00**	11.64**	0.10**	0.15**
AB 20-13		-0.29	23.43**	0.42**	-0.69**	-7.49**	1.74**	-0.02**	0.08**
GP BRJ 224		0.13	2.02	-0.05	0.21	-0.56	3.55**	-0.02**	-0.14**
GP BRJ 309		-0.29	-2.32	-0.03	0.40**	0.91	17.70**	0.12**	0.03
AB 20-03		-1.21**	-15.15**	-0.13*	0.72**	5.83**	-5.49**	0.19**	0.36**
Range	Min.	-1.21	-20.53	-0.52	-1.05	-7.49	-16.97	-0.15	-0.64
	Max.	1.21	23.43	0.42	1.10	6.73	19.67	0.19	0.73
Significant	Positive	4	4	3	4	3	5	4	5
	Negative	3	3	4	4	4	5	6	4
	Total	7	7	7	8	7	10	10	9
	S.E. ±	0.23	1.46	0.05	0.16	0.65	0.62	0.01	0.02
	C.D.	0.46	2.87	0.10	0.31	1.28	1.21	0.01	0.04
	S.E. of g_i-g_j	0.35	2.18	0.07	0.23	0.98	0.92	0.01	0.03
	C.D. of g_i-g_j	0.68	4.27	0.14	0.46	1.91	1.81	0.02	0.05

Table 3. Estimation of specific combining ability (sca) effects of hybrids for various characters in brinjal

S. No.	Hybrids	DF	PH	BP	FP	FYP	FL	FG	FW	TSSs	TP	AA	TSS
1	AB 15-06 × AB 20-09	3.08**	9.33**	0.08	-13.13**	0.24	0.29	1.83**	14.27**	-0.84**	-37.26**	-0.26**	-1.41**
2	AB 15-06 × AB 15-08	-0.14	-3.81	0.65**	4.18	-0.15	0.10	-0.59	-4.35	-0.15	-31.28**	-0.51**	-0.08
3	AB 15-06 × AB 15-18	0.06	10.17**	0.18	-13.74**	-0.43*	-0.01	0.06	-0.75	-0.40**	83.97**	-0.30**	-0.98**
4	AB 15-06 × AB 20-07	-0.69	1.39	0.48**	1.34	-0.05	0.51*	0.69	-1.76	0.97**	23.63**	0.05	1.02**
5	AB 15-06 × ABSR 2	1.42	8.82**	0.49**	-7.09	-0.04	-0.61**	-0.24	1.68	0.02	-1.71	0.23**	0.33**
6	AB 15-06 × AB 20-13	-0.08	-0.89	-0.25	25.95**	0.46**	-0.40	-0.49	-0.17	-1.47**	4.07	0.00	0.82**
7	AB 15-06 × GP BRJ 224	-0.17	-8.98**	0.53**	11.73*	0.15	-0.42*	-0.77	-5.15*	-0.38**	-1.38	0.04	-0.01
8	AB 15-06 × GP BRJ 309	-0.75	-0.88	-0.50**	8.47	0.07	0.02	-0.11	-4.56*	1.21**	22.27**	0.42**	-0.70**
9	AB 15-06 × AB 20-03	-1.50	-1.79	0.10	1.96	0.41*	0.22	0.93	4.09	0.48**	-25.95**	0.30**	0.54**
10	AB 20-09 × AB 15-08	0.56	-10.93**	-1.06**	-17.84**	-0.50**	-0.74**	0.66	2.86	0.47**	-21.05**	0.37**	-1.77**
11	AB 20-09 × AB 15-18	0.75	-9.68**	-0.20	25.37**	0.35*	0.90**	0.16	-9.50**	-0.45**	30.78**	0.04	1.26**
12	AB 20-09 × AB 20-07	-1.00	-2.53	-0.43**	1.45	-0.30	0.66**	-0.24	-3.51	0.39**	-12.95**	0.23**	-0.84**
13	AB 20-09 × ABSR 2	-0.22	13.10**	0.91**	-13.39**	-0.05	0.30	0.62	3.92	0.51**	40.36**	-0.44**	0.30**
14	AB 20-09 × AB 20-13	-0.72	-0.74	0.44**	14.09**	-0.06	0.09	-0.82	-6.15**	-0.05	-1.37	-0.18**	0.63**
15	AB 20-09 × GP BRJ 224	-1.47	0.10	0.69**	-11.23*	0.19	0.18	0.45	9.68**	-0.69**	-15.91**	-0.04	0.25**
16	AB 20-09 × GP BRJ 309	-1.39	19.80**	0.45**	-16.49**	-0.32	0.07	0.61	8.36**	-0.31**	18.94**	-0.08**	-0.54**
17	AB 20-09 × AB 20-03	0.19	-10.31**	-0.01	7.07	-0.34*	0.05	-1.27*	-12.43**	-0.17	-10.94**	-0.19**	1.84**
18	AB 15-08 × AB 15-18	0.19	1.05	0.64**	13.75**	0.31	0.46*	1.28**	-1.13	0.65**	3.93	-0.09**	1.31**
19	AB 15-08 × AB 20-07	-0.89	-5.27*	-0.13	-0.84	-0.06	0.15	0.83	0.26	0.08	48.73**	-0.16**	0.70**
20	AB 15-08 × ABSR 2	-0.78	-2.38	-0.45**	14.32**	0.30	0.51*	0.86	-1.66	-0.80**	18.63**	0.11**	0.27**
21	AB 15-08 × AB 20-13	-0.28	-8.08**	0.27	26.14**	0.83**	0.08	-0.47	-2.91	0.11	31.55**	-0.14**	0.76**
22	AB 15-08 × GP BRJ 224	-0.69	21.13**	0.72**	-17.79**	-0.40*	0.53*	1.06*	1.67	0.87**	5.31*	-0.02	0.12
23	AB 15-08 × GP BRJ 309	-2.28**	6.32*	0.02	3.02	0.24	-0.40	-0.81	0.56	0.12	-72.33**	0.06*	0.38**
24	AB 15-08 × AB 20-03	-1.03	22.12**	0.56**	8.25	0.75**	-0.43*	-1.66**	6.06**	-0.07	-37.74**	-0.45**	-2.14**
25	AB 15-18 × AB 20-07	-1.36	2.85	0.07	-6.16	0.05	-0.61**	-0.36	3.77	0.17	5.52**	-0.08**	-1.24**
26	AB 15-18 × ABSR 2	0.08	5.21*	-0.06	8.14	0.26	0.03	-0.47	0.87	0.08	-51.39**	-0.41**	0.19**
27	AB 15-18 × AB 20-13	-2.08*	-3.17	0.27	-5.25	0.06	-0.23	-0.64	2.01	0.06	-17.19**	-0.21**	-0.67**
28	AB 15-18 × GP BRJ 224	0.50	3.54	-0.15	17.69**	0.14	0.17	-0.17	-1.52	-0.25*	-31.67**	-0.24**	0.08

Table 3. Continued..

S. No.	Hybrids	DF	PH	BP	FP	FYP	FL	FG	FW	TSSs	TP	AA	TSS
29	AB 15-18 × GP BRJ 309	-0.08	-4.23	0.49**	-13.70**	-0.25	0.40	-0.10	1.51	-0.40**	10.67**	0.21**	-0.18**
30	AB 15-18 × AB 20-03	-0.83	2.73	-0.11	-0.28	0.31	0.01	0.24	3.42	-0.52**	15.09**	0.04	-0.67**
31	AB 20-07 × ABSR 2	-0.67	1.22	-0.29	6.82	0.31	-0.30	-0.47	-1.28	-1.08**	-39.84**	-0.40**	-0.04
32	AB 20-07 × AB 20-13	1.17	1.38	-0.36*	-11.57*	0.56**	-0.07	0.65	-0.08	0.56**	20.95**	-0.02	0.91**
33	AB 20-07 × GP BRJ 224	-1.25	17.49**	-0.05	9.91*	0.70**	0.18	0.90	3.43	-0.28**	-45.53**	-0.13**	-0.94**
34	AB 20-07 × GP BRJ 309	0.83	3.66	0.39*	-1.42	0.21	0.10	0.98*	7.41**	-0.56**	17.74**	-0.50**	-0.13*
35	AB 20-07 × AB 20-03	0.75	-13.92**	0.52**	9.01	0.18	0.01	-1.42**	1.25	-0.28**	29.51**	0.04	0.07
36	ABSR 2 × AB 20-13	-0.06	-14.25**	-0.03	7.66	-0.20	-0.36	0.02	-0.26	0.68**	37.48**	0.26**	0.65**
37	ABSR 2 × GP BRJ 224	-0.14	-7.28**	0.16	17.20**	0.61**	-0.20	-0.43	-0.94	-0.16	10.89**	0.07**	-1.24**
38	ABSR 2 × GP BRJ 309	1.28	-7.45**	-1.48**	-13.93**	-0.44**	-0.18	-0.02	-1.40	-0.44**	64.22**	-0.02	1.56**
39	ABSR 2 × AB 20-03	0.19	-3.49	0.00	1.90	0.46**	1.02**	0.75	3.44	0.57**	-8.64**	0.18**	0.06
40	AB 20-13 × GP BRJ 224	1.03	-10.18**	-0.71**	-6.65	-0.42*	0.47*	1.03*	-1.35	-0.12	-22.96**	0.14**	-0.43**
41	AB 20-13 × GP BRJ 309	-1.56	-1.22	0.72**	14.56**	0.15	0.09	0.36	-2.00	1.00**	-5.89**	0.02	0.25**
42	AB 20-13 × AB 20-03	-0.31	17.87**	0.92**	5.18	0.13	0.22	1.19*	-0.64	-0.19	-2.79	-0.17**	0.69**
43	GP BRJ 224 × GP BRJ 309	-1.31	12.62**	-0.03	-7.84	-0.14	-0.13	-0.26	-0.30	-0.24*	15.06**	0.19**	-0.36**
44	GP BRJ 224 × AB 20-03	-1.06	-4.15	0.17	-15.21**	-0.61**	-0.51*	-1.33**	-1.84	0.50**	-11.53**	0.20**	-0.30**
45	GP BRJ 309 × AB 20-03	-0.97	2.88	-0.86**	-0.47	0.26	0.48*	1.37**	4.38*	0.28**	-16.93**	0.07**	-0.90**
Range	Min.	-2.28	-14.25	-1.48	-17.84	-0.61	-0.74	-1.66	-12.43	-1.47	-72.33	-0.51	-2.14
	Max.	3.08	22.12	0.92	26.14	0.83	1.02	1.83	14.27	1.21	83.97	0.42	1.84
No. of significant crosses	Positive	1	12	16	11	9	9	7	6	14	20	15	20
	Negative	2	11	8	11	7	6	4	5	17	19	19	18
	Total	3	23	24	22	16	15	11	11	31	39	34	38
	S. E. ±	0.78	2.46	0.16	4.92	0.17	0.21	0.53	2.20	0.10	2.08	0.03	0.06
	C.D.	1.53	4.83	0.32	9.64	0.33	0.41	1.04	4.32	0.19	4.08	0.05	0.12
	S.E. of S_{ij}-S_{ik}	1.15	3.62	0.24	7.23	0.24	0.31	0.78	3.24	0.14	3.06	0.04	0.09
	C.D. of S_{ij}-S_{ik}	2.25	7.10	0.47	14.17	0.48	0.61	1.52	6.35	0.28	6.00	0.07	0.18

statistically superior to rest of the hybrids. The crosses AB 15-08 × AB 20-13 and ABSR 2 × GP BRJ 224 had G × G and G × A parental combinations, indicating additive × additive type of epistasis that can be exploited in future heterosis breeding programme. The present results are in congruency with the studies of Gharge *et al.* (2016), Kumar and Arumugam (2016), Desai *et al.* (2017), Patel (2017), Santhosha *et al*. (2017), Siva *et al*. (2020), Datta *et al.* (2021), Mondal *et al*. (2021), Timmareddygari *et al*. (2021) and Rajan *et al*. (2022), Mishra *et al.* (2023) and Thota and Delvadiya (2024).

For fruit length, the σ^2_{gca} was found to be negative. Therefore, combining ability effects of parents were not estimated. Only sca variance was found to be significant suggesting fruit length was under control of non-additive gene action as reported by Deshmukh *et al*. (2014), Venkata *et al*. (2014), Gadhiya *et al*. (2015), Uddin *et al.* (2015), Gharge *et al.* (2016), Kumar and Arumugam (2016), Desai *et al.* (2017), Timmareddygari *et al*. (2021), and Rajan *et al*. (2022).

Analysis of the gca effects on fruit girth revealed that four parent plants, namely AB 20-09 , AB 20-07 , AB 20-03 , and GP BRJ 309 were good general combiners. The best three F_1s were AB 15-06 × AB 20-09 , GP BRJ 309 × AB 20-03 and AB 15-08 × AB 15-18 . The ratio of $\sigma^2_{gca}/\sigma^2_{sca}$ and σ^2_D/σ^2_A were above unity and less than one, suggesting the predominant role of additive gene action. The present reports are in accordance with the observations of Shinde *et al*. (2011), Choudhary and Didel (2014), Prasad *et al*. (2015), Patel (2017), Kachouli *et al*. (2019), Datta *et al*. (2021) and Mondal *et al*. (2021).

The minimum and maximum gca effects for fruit weight were recorded in the genotypes AB 20-13 and AB 20-07 , respectively. The parents, *viz.,* AB 20-07 , AB 20-03 and AB 20-09 (**Table 2**) were the best general combiners. Maximum sca effect was observed in the cross AB 15-06 × AB 20-09 AB 20-09 × GP BRJ 224 and AB 20-09 × GP BRJ 309 hence considered as best specific combiners. The predominance of additive gene action for fruit weight were supported by Shinde *et al*. (2011), Reddy and Patel (2014), Patel (2017), Santhosha *et al*. (2017), Kachouli *et al*. (2019), Datta *et al*. (2021) and Mondal *et al*. (2021).

The content of total soluble solids exhibits a strong positive association with sugar content. This characteristic is widely acknowledged as a fundamental quality attribute of fruits. For total soluble solids, the σ^2_{gca} was found negative. Therefore, combining ability effects of parents were not estimated. The hybrid AB 15-06 × GP BRJ 309 had the highest significant sca effect so it was considered as best specific combiner. The leading three hybrid combinations were AB 15-06 × GP BRJ 309 , AB 20-13 × GP BRJ 309 and AB 15-06 × AB 20-07 . Only sca variance is significant suggesting the predominant role of non-additive gene action. The researchers Suneetha *et al*. (2008), Sao and Mehta (2010), Gadhiya *et al*. (2015), and Desai *et al*. (2017) are in agreement with findings of present study.

The major phenolic compounds in eggplant fruits can help to protect cell membranes and boost the brain's memory function. Negative combining ability effects are desirable for total phenol content. The parent AB 15-06 was the best general combiner, while AB 20-09, AB 20-07, AB 15-18 and AB 20-03 are good general combiners. The high-ranked hybrid combinations having significant and maximum negative sca effects in order were AB 15-08 × GP BRJ 309 ,AB 15-18 × ABSR 2 and AB 20-07 × GP BRJ 224 The ($\sigma^2_{gca}/\sigma^2_{sca}$) ratio below unity and σ^2_D/σ^2_A ratio above unity implied that non-additive genetic mechanisms were playing a role in determining the trait. These findings align with previous research conducted by Tha *et al*. (2006), Ajjappalavara (2006), Suneetha *et al*. (2008), Gadhiya *et al*. (2015), Kumar and Arumugam (2016), Desai *et al.* (2017), Siva *et al*. (2020), Timmareddygari *et al*. (2021) and Rajan *et al*. (2022).

Table 4. Classification of parents with respect to general combining ability (gca) effect for various traits in brinjal

S. No.	Parents	DF	FP	FYP	FG	FW	TP	AA	TSS
1	AB 15-06	P	A	P	P	P	G	P	G
2	AB 20-09	G	P	P	G	G	G	G	P
3	AB 15-08	G	G	G	A	A	P	P	G
4	AB 15-18	P	G	A	P	P	G	P	P
5	AB 20-07	P	P	P	G	G	G	P	P
6	ABSR 2	P	G	G	P	P	P	G	G
7	AB 20-13	A	G	G	P	P	P	P	G
8	GP BRJ 224	A	A	A	A	A	P	P	P
9	GP BRJ 309	A	A	A	G	A	P	G	A
10	AB 20-03	G	P	P	G	G	G	G	G

Table 5. Summary of three best performing parents, best general combining parents and best performing hybrids based on *per se* performance and sca effects for various traits in brinjal

S. No.	Characters	Best *per se* performing parents	Best general combiners	Best *per se* performing hybrids	Best hybrids for sca effects
1	Days to 50% flowering	AB 20-09	AB 20-03	AB 15-08 × GP BRJ 309	AB 15-08 × GP BRJ 309 (G × A)
		AB 20-03	AB 20-09	AB 20-09 × GP BRJ 309	AB 15-18 × AB 20-13 (P × A)
		AB 15-06	AB 15-08	AB 15-08 × AB 20-03	-
2	Plant height	AB 20-13	AB 15-06	AB 15-08 × AB 20-03	AB 15-08 × AB 20-03
		ABSR 2	AB 15-08	AB 15-08 × GP BRJ 224	AB 15-08 × GP BRJ 224
		AB 15-06	AB 20-07	AB 20-09 × GP BRJ 309	AB 20-09 × GP BRJ 309
3	Branches per plant	GP BRJ 309	GP BRJ 309	AB 20-13 × GP BRJ 309	AB 20-13 × AB 20-03
		ABSR 2	AB 15-08	AB 20-13 × AB 20-03	AB 20-09 × ABSR 2
		AB 20-07	AB 20-13	AB 15-06 × AB 15-08	AB 15-08 × GP BRJ 224
4	Fruits per plant	ABSR 2	AB 20-13	AB 15-08 × AB 20-13	AB 15-08 × AB 20-13 (G × G)
		AB 20-13	ABSR-2	AB 15-06 × AB 20-13	AB 15-06 × AB 20-13 (A × G)
		GP BRJ 309	AB 15-18	ABSR 2 × AB 20-13	AB 20-09 × AB 15-18 (P × G)
5	Fruit yield per plant	AB 20-13	AB 20-13	AB 15-08 × AB 20-13	AB 15-08 × AB 20-13 (G × G)
		ABSR 2	ABSR 2	ABSR 2 × GP BRJ 224	AB 15-08 × AB 20-03 (G × P)
		GP BRJ 309	AB 15-08	AB 20-07 × AB 20-13	AB 20-07 × GP BRJ 224 (P × A)
6	Fruit length	AB 20-13	AB 20-13	ABSR 2 × AB 20-03	ABSR 2 × AB 20-03
		AB 15-06	-	AB 20-09 × AB 15-18	AB 20-09 × AB 15-18
		ABSR 2	-	AB 20-13 × GP BRJ 224	AB 20-09 × AB 20-07
7	Fruit girth	AB 20-03	AB 20-09	GP BRJ 309 × AB 20-03	AB 15-06 × AB 20-09 (P × G)
		AB 20-09	AB 20-07	AB 15-06 × AB 20-09	GP BRJ 309 × AB 20-03 (G × G)
		AB 20-07	AB 20-03	AB 20-07 × GP BRJ 309	AB 15-08 × AB 15-18 (A × P)
8	Fruit weight	AB 20-07	AB 20-07	AB 15-06 × AB 20-09	AB 15-06 × AB 20-09 (P × G)
		AB 20-03	AB 20-03	AB 20-07 × GP BRJ 309	AB 20-09 × GP BRJ 224 (G × A)
		AB 20-09	AB 20-09	AB 20-09 × GP BRJ 309	AB 20-09 × GP BRJ 309 (G × A)
9	Total soluble solids	AB 20-09	AB 20-09	AB 15-08 × GP BRJ 224	AB 15-06 × GP BRJ 309
		AB 15-18	ABSR 2	AB 20-09 × ABSR 2	AB 20-13 × GP BRJ 309
		GP BRJ 224	GP BRJ 224	ABSR 2 × AB 20-13	AB 15-06 × AB 20-07
10	Total phenol	AB 15-06	AB 15-06	AB 15-06 × AB 20-09	AB 15-08 × GP BRJ 309 (P × P)
		AB 20-07	AB 20-09	AB 20-07 × GP BRJ 224	AB 15-18 × ABSR 2 (G × P)
		AB 15-18	AB 20-07	AB 15-18 × ABSR 2	AB 20-07 × GP BRJ 224 (G × P)
11	Antioxidant activity	AB 20-09	AB 20-03	ABSR 2 × AB 20-03	AB 15-06 × GP BRJ 309 (P × G)
		ABSR 2	GP BRJ 309	AB 15-06 × GP BRJ 309	AB 20-09 × AB 15-08 (G × P)
		AB 20-03	ABSR 2	AB 15-06 × AB 20-03	AB 15-06 × AB 20-03 (P × G)
12	Total soluble sugar	AB 15-08	AB 15-08	AB 15-08 × AB 15-18	AB 20-09 × AB 20-03 (P × G)
		GP BRJ 224	AB 20-03	ABSR 2 × GP BRJ 309	ABSR 2 × GP BRJ 309 (G × A)
		AB 20-03	AB 15-06	AB 20-09 × AB 20-03	AB 15-08 × AB 15-18 (G × P)

Antioxidant activity in brinjal plays a key role in human health as these antioxidants provide protection against damage caused by free radicals, which is responsible for the development of many chronic diseases, including cardiovascular diseases, aging, heart diseases, anemia, cancer, etc. Estimates of gca effect revealed that AB 20-03 was the best general combiner, while GP BRJ 309, ABSR 2 and AB 20-09 were good general combiners. Out of 34 sca effects, 15 hybrids showed significant and positive sca effects and 19 F_1s had negative sca effects. Among these, the three best cross combinations were AB 15-06 × GP BRJ 309 , AB 20-09 × AB 15-08 and AB 15-06 × AB 20-03 . The ($\sigma^2_{gca}/\sigma^2_{sca}$) ratio below unity and the average degree of dominance above unity for this trait in the present investigation suggested the prevailing influence of non-additive genetic mechanisms. These

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findings disagree with previous research conducted by Datta *et al.* (2021) as they reported a preponderance of additive gene effect. Although eggplant represents an essential source of nutraceuticals and pharmaceuticals, limited research has been conducted to investigate the antioxidant activity in eggplant.

Estimates of gca effect for total soluble sugar revealed that five parents, AB 15-08 , AB 20-03, AB 15-06 , ABSR-2 and AB 20-13 had significant and positive estimates of gca effect and were considered as best general combiners. The high-ranked hybrid combinations were AB 20-09 × AB 20-03 , ABSR 2 × GP BRJ 309 and AB 15-08 × AB 15-18 . The ($\sigma^2_{gca}/\sigma^2_{sca}$) ratio below unity and σ^2_D/σ^2_A ratio above unity suggested the predominant role of non-additive gene action. These findings align with previous research conducted by Ajjappalavara (2006), Tha *et al.* (2006), Suneetha *et al*. (2008), and Patel (2017).

In a crossbreeding scenario, favourable offspring with desired traits can emerge in subsequent generations if there is a substantial estimation of specific combining ability (sca) effects combined with strong individual performance, especially if one parent demonstrates notable general combining ability (gca) effects for a specific trait. This occurrence signifies a positive interaction between parents with differing general combining abilities. In contrast, hybrids displaying high sca effects originating from less proficient × less proficient general combiners may result from dominance × dominance interactions and are therefore not stabilizable.

The aforementioned outcomes demonstrate a substantial and beneficial transmission of genes from parents to their offspring. Specifically, three parents – AB 15-08, ABSR 2, and AB 20-13 – displayed commendable general combining abilities concerning fruit yield and its associated attributes, including fruits per plant and total soluble solids. As a result, these parents are considered valuable sources of advantageous genes for augmenting fruit yield through diverse contributing characteristics. The genotypes AB 20-03 and AB 20-09 were found to be good general combiners for ancillary traits *viz.,* days to 50% flowering, fruit girth, fruit weight, total phenol, antioxidant activity, and total soluble sugar. Hence, these parents would be used for the improvement of these traits. The evaluations of specific combining ability effects revealed that no single cross exhibited superiority across all traits. Nevertheless, the top three hybrids were AB 15-08 × AB 20-13, AB 15-08 × AB 20-03, and AB 20-07 × GP BRJ 224. These hybrids also demonstrated substantial and desirable specific combining ability effects for fruits per plant, total soluble sugar, branches per plant, fruit weight, and total phenol. This alignment seems appropriate given that fruit yield, which was multifaceted character, is deviated by a number of component characteristics. It is anticipated that such hybrids could yield promising transgressive segregants in subsequent resulting progenies if the additive genetic component prevailing in good general combiners collaborates with the complementary epistatic effects in F_1 to maximize desirable plant attributes. If these crosses lead to a significant leap in brinjal fruit production, they may be considered for commercialization.

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