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Combining ability analysis over environments for fruit yield and its attributing traits in brinjal (*Solanum melongena* L.)

Ujjval Solanki, Sunayan R Patel, Prakashsinh Rathva and Raval Kalpesh

Abstract
Brinjal (*Solanum melongena* L.) is an important and popular vegetable crop of the subtropics and tropics region and grown worldwide for its edible fruit that is botanically classified as a berry. It is a member of the Solanaceae family with diploid chromosome number 2n=2x=24 and belongs to the genus *Solanum*. The fruits of brinjal are widely consumed in various culinary preparations and are rich source of protective nutrients.

In the present investigation, information on the combining ability and its interactions with locations were obtained for fruit yield per plant and its related components following half diallel mating design involving nine parents of Brinjal. The nine parents and their 36 F_1s with one standard check were tested for thirteen characters under three environments *viz*., Navsari (E_1), Vanarasi (E_2) and Waghai (E_3) in a randomized block design with three replications. Among the parents; Pusa Upkar, Swarna Mani, GAOB-2 and GOB-1 were good general combiners for fruit yield per plant and most of the yield components. The cross GAOB-2 x JBGR-1, GOB-1 x PU, SM x GRB-5 and NBL-117 x GJLB-4 showed higher SCA effects for fruit yield and the majority of yield components. Expression of heterosis for fruit yield and its components were related to GCA effect of parents *viz*., Pusa Upkar, Swarna Mani, GAOB-2 and GOB-1. Combining ability analysis revealed that both additive and non-additive variances were significant for fruit yield per plant and its related traits indicating their involvement in the expression of various traits.

Keywords: General combining ability, specific combining ability, heterosis, heterobeltiosis additive gene action and non-additive gene action

Introduction
"Brinjal" one of the versatile vegetables belong to the family Solanaceae with diploid chromosomes (2n=24). Brinjal is usually self-pollinated, but the extent of cross-pollination has been reported as high as 48% and its varieties exhibit a varied range of fruit shapes and colours, ranging from oval or egg-shaped to long club-shaped and from white, yellow and green through a degree of purple pigmentation to almost black colour. The family Solanaceae contains 75 genera and over 2000 species, out of which, about 150-200 are tuber bearing and belong to section Tuberarium. Indian sub-continent and China are its primary centers of diversity.

There are two types of combining ability *viz*., general combining ability (GCA) and specific combining ability (SCA). Sprague and Tatum (1942) [21] defined GCA as the average performance of a line in series of hybrid combinations and specific combining ability as those cases in which certain combinations are relatively better or worse than would be expected on the basis of the GCA for the parents. In a hybrid breeding programme plant breeders aim to identify parental lines with GCA and crosses showing high SCA. From the genetic viewpoint, GCA measures additive gene effect and SCA measures non-additive gene effects, including dominance and epistasis. It may happen that a high yielding genotype may not be able to transmit its superiority in cross combination and vice versa. Therefore, a breeder is expected to know the genetic potential of the parents by estimating their combining ability. The combining ability analysis, besides its use in selection of parents, elucidates the nature and magnitude of various types of gene action involved in the expression of quantitative characters.

Materials and Methods
The present investigation was carried out to check combining ability performance of hybrids and their parents for fruit yield and its component characters in Brinjal.

The experimental materials used includes 36 F_1 crosses produced using 9 × 9 Half diallel cross mating design excluding reciprocals (method 2; model 1/half-diallel cross), their nine parents and one check. The complete set of 46 genotypes comprising of 36 F_1s, nine parents and one check were evaluated in a Randomized Block Design with three replications over three environments during rabi 2020- 21 at three locations *viz*., College Farm, N. M. College of Agriculture, Navsari Agriculture University, Navsari; Niger Research Station, N.A.U., Vanarasi and Hill Millet Research Station, N.A.U, Waghai.

Table 1: Details of parental lines used in hybridization program

Sr. No.	Parent	Pedigree	Source
1.	GAOB-2	(Gujrat Anand Oblong Brinjal - 2)	AAU, Anand
2.	GOB-1	(Gujrat Oblong Brinjal - 1)	AAU, Anand
3.	PS	(Punjab Sadabahar)	PAU, Punjab
4.	JBGR-1	(Junagadh Brinjal Green Round - 1)	JAU, Junagadh
5.	SM	(Swarna Mani)	ICAR, RCER, Bihar
6.	PU	(Pusa Upkar)	ICAR, New Delhi
7.	GRB-5	(Gujrat Round Brinjal - 5)	JAU, Junagadh
8.	NBL-117	(Navsari Brinjal Line-117)	NAU, Navsari
9.	GJLB-4	(Gujrat Junagadh Long brinjal - 4)	JAU, Junagadh
10	GABH-3(Check)*	(Gujrat Anand Brinjal Hybrid-3)	AAU, Anand

Observations were recorded on five randomly selected plants per each entry in each replication for thirteen distinct characteristics, *viz.*, days to flowering, branches per plant, plant height (cm), fruit length (cm), fruit girth (cm), fruit weight (g), fruits per plant, seeds per fruit, fruit yield per plant (g), total phenols content (mg/100g FW), total soluble sugar (%), shoot and fruit borer infestation (%) and little leaf incidence (%). The observations for studied characters were recorded on five randomly selected (tagged) competitive plants of each experimental unit in each replication for various characters as described below. Days to 50 per cent flowering was recorded on plot's population basis. For quality traits, the observations were recorded on randomly selected sample of fruits from each genotype. The mean values for various characters of each experimental unit were computed and subjected for different statistical approaches as given below.

The combining ability analysis was carried out according to method II; model 1 (fixed effect) of Griffing (1956) [5]. In this model, experimental material was considered as population about which inferences was to be drawn and combining ability effects of parents could be compared when parents themselves are used as testers to identify good combiners. The GCA and SCA effects of ijkth observations were calculated by following formula:

Sum of square for GCA:

$$S_g = \frac{1}{P+2}\left[\sum_{i=1}^{P}(X_{i.} + X_{ii})^2 - \frac{4}{P}X^2..\right]$$

Sum of squares for SCA:

$$S_S = \sum_{i \leq} \sum_{j} X^2_{ij} - \frac{1}{P+2}\sum_{i}(X_{i.}+X_{ii})^2 + \frac{2}{(P+1)(P+2)}X^2..$$

Where

P = Number of parents, S_g = Sum of squares due to GCA

S_g = Sum of squares due to GCA S_s = Sum of squares due to SCA

X_{ij} = Value of cross between ith and jth parents

$X_{i.}$ = Total of ith (row) array in diallel table (Summed over j)

X. = Grand total of 'P' parents and P (P-1)/2 progenies of diallel table,

X_{ii} = Parental value of the ith parent

$X_{i\bullet} + X_{ii}$ = Total of ith array + mean value of parent i

$X_{\bullet j} + X_{jj}$ = Total of jth array + mean value of parent j

The estimation of standard error of GCA and SCA effects were obtained by following formula:

$$S.E._{\cdot g_i} = \left[\frac{p-1}{p(p+2)}\sigma_e^2\right]^{\frac{1}{2}}$$ (for testing individual GCA effect)

$$S.E._{\cdot s_{ij}} = \left[\frac{p^2+p+2}{(p+1)(p+2)}\sigma_e^2\right]^{\frac{1}{2}}$$ (for testing individual SCA effect)

$$S.E._{\cdot(g_i - g_j)} = \left[\frac{2}{(p+2)}\sigma_e^2\right]^{\frac{1}{2}}$$ (for testing differences between two GCA effects)

$$S.E._{\cdot(s_{ij} - s_{ik})} = \left[\frac{2(p+1)}{(p+2)}\sigma_e^2\right]^{\frac{1}{2}}$$ (for testing difference between SCA of the same array)

$$S.E._{\cdot(s_{ij} - s_{kl})} = \left[\frac{2p}{(p+2)}\sigma_e^2\right]^{\frac{1}{2}}$$ (for testing SCA of any two crosses)

Where

p = Number of parents, σ_e^2 = Error mean square (M_e)

The GCA and SCA effects were subjected to 't' test for testing of significance.

$$t\,(GCA) = g_i - 0 \Big/ S.E._{\cdot g_i} \quad t\,(SCA) = s_{ij} - 0 \Big/ S.E._{\cdot s_{ij}}$$

The test of significance of GCA and SCA for individual environment were carried out by comparing the calculated 't' values with the tabulated 't' values at 5 per cent (1.96) and 1 per cent (2.58) levels of significance.

Result and Discussion

Analysis of variance

Analysis of variance for combining ability, using half-diallel mating design in respect of nine parents and thirty-six crosses

for all the thirteen characters in individual environment and pooled over environments is presented in Table 02 to 08. The analysis of variance for combining ability indicated that the mean sum of squares due to GCA and SCA were highly significant for most of the traits which revealed importance of additive and non-additive variances in the expression of various characters. The analysis of variance in each environment revealed that mean squares due to GCA were significant for all the characters in all the three environments except for the characters shoot and fruit borer infestation in E_1 and E_2 environments as well as for little leaf incidence in E_1 and E_3. Because of non-significance of GCA mean square of these aforesaid characters, their further evaluation for pooled over combining analysis has not been deemed fit to be true and their further and SCA effect analysis has been avoided.

Mean squares due to SCA effects were significant for all the characters in all environments. Significant mean squares due GCA and SCA for the concern characters suggested difference among parents for GCA and among hybrids for SCA. Characters with significant mean squares due to GCA of parents and SCA of hybrids are indication that parents and hybrids differed significantly in their combining ability effects and importance of both additive as well as non-additive effects for their inheritance. [Patel *et al*. (2017)] [13]. Whereas, Significant mean squares only for GCA suggest importance of additive genetic effects only. while, Whereas, mean squares due to only SCA was found significant for shoot and fruit borer infestation in E_1 and E_2 environments as well as little leaf incidence in E_1 and E_3 suggesting importance of non-additive genetic effects only. The magnitude of variance due to SCA was higher in comparison to variance due to GCA for all the trait at individual location, indicating larger influence of non-additive genetic variance in comparison to additive genetic variance. [Patel *et al*. (2017)] [13].

In pooled analysis over environments, mean squares due to environments, GCA and SCA were significant for all the characters revealing varied environments effect for GCA and SCA, except for the trait total phenol content for which environment mean sum of square was non-significant. Similarly, mean squares due to GCA x E and SCA x E were significant for all characters except, characters *viz.*, total phenol content, fruit borer infestation and little leaf incidence had non-significant GCA x E while, characters *viz.*, total phenol content and total soluble sugars had non-significant SCA x E. Because of non-significance of GCA mean square of these aforesaid characters, their further evaluation for pooled over combining analysis has not been deemed fit to be true and their further GCA effect analysis has been avoided.

Analysis of variance for GCA source was highly significant and favoring high values for characters studied during the experimental programme at all the three individual locations as well as pooled over locations. Suggesting, parents have variation in their combining ability and hence can be classified into good, average and poor on the basis of their GCA effects. SCA source was also highly significant at all locations as well as pooled over locations, for most of the traits signifying that the hybrids are different from parents involved in any specific cross and hence, there are chances of isolating good hybrids. The magnitude of variance due to specific combining ability was higher in comparison to variance due to general combining ability for all the trait over environment, suggesting greater influence of non-additive genetic variance in comparison to its counterpart additive genetic variance.

Similar finding in accordance to the above result has also been reported by Dharwad *et al.* (2011) [3], Sane *et al.* (2011) [16], Shinde *et al.* (2011) [11], Thangavel (2011) [23], Kumar and Arumugam (2013) [10], Mishra *et al.* (2013) [12], Hussain *et al.* (2017) [6], Patil *et al.* (2019) [14], Singh and Chaudhry (2018) [19], Kachouli *et al.* (2019) [7], Kumar *et al.* (2019) [9], Siva *et al.* (2020) [20].

Table 2: ANOVA for combining ability for days to 50 per cent flowering and branches per plant under individual environment and over environments

Sources	d.f.	Days to 50 per cent flowering				Branches per plant				Plant height			
		E_1	E_2	E_3	Pooled	E_1	E_2	E_3	Pooled	E_1	E_2	E_3	Pooled
		Navsari	Vanarasi	Waghai		Navsari	Vanarasi	Waghai		Navsari	Vanarasi	Waghai	
GCA	08	46.41**	33.56**	33.48**	107.29**	1.64**	0.52*	1.99**	3.13**	120.63**	59.04**	35.65**	144.69**
SCA	36	10.95**	13.09**	12.23**	32.04**	1.61**	1.51**	1.77**	4.11**	49.96**	31.16**	30.51**	68.52**
Environment (E)	02	-	-	-	244.53**	-	-	-	34.74**	-	-	-	144.80**
GCA x Environment	16	-	-	-	3.08**	-	-	-	0.51**	-	-	-	38.22**
SCA x Environment	72	-	-	-	2.12**	-	-	-	0.39**	-	-	-	20.91**
Error	264	0.94	0.76	1.39	1.03	0.19	0.17	0.15	0.17	5.76	5.20	4.24	5.07

* and ** indicate significance at 5% and 1% levels of probability, respectively

Table 3: ANOVA for combining ability for plant height and fruit length under individual environment and over environments

Sources	d.f.	Fruit length				Fruit girth				Fruit weight			
		E_1	E_2	E_3	Pooled	E_1	E_2	E_3	Pooled	E_1	E_2	E_3	Pooled
		Navsari	Vanarasi	Waghai		Navsari	Vanarasi	Waghai		Navsari	Vanarasi	Waghai	
GCA	08	11.34**	7.66**	11.90**	29.70**	29.81**	21.92**	28.55**	78.26**	552.56**	673.20**	468.62**	1656.26**
SCA	36	3.04**	3.10**	3.88**	9.27**	3.32**	4.52**	4.09**	9.72**	107.57**	176.73**	130.48**	334.29**
Environment (E)	02	-	-	-	2.99**	-	-	-	3.86**	-	-	-	3532.53**
GCA x Environment	16	-	-	-	0.62**	-	-	-	1.05*	-	-	-	19.07
SCA x Environment	72	-	-	-	0.38**	-	-	-	1.13**	-	-	-	40.25**
Error	264	0.14	0.17	0.13	0.15	0.44	0.57	0.46	0.49	25.11	20.31	16.25	20.56

* and ** indicate significance at 5% and 1% levels of probability, respectively

Table 4: ANOVA for combining ability for fruit girth and fruit weight under individual environment and over environments

Sources	d.f.	Fruits per plant				Total phenol content				Total soluble sugars			
		E_1	E_2	E_3	Pooled	E_1	E_2	E_3	Pooled	E_1	E_2	E_3	Pooled
		Navsari	Vanarasi	Waghai		Navsari	Vanarasi	Waghai		Navsari	Vanarasi	Waghai	
GCA	08	84.08**	70.11**	48.08**	194.79**	1.40**	1.37**	1.34**	4.11**	0.36**	0.45**	0.58**	1.37**
SCA	36	11.06**	14.06**	12.51**	29.95**	1.82**	1.76**	1.75**	5.32**	0.36**	0.42**	0.44	1.21**
Environment (E)	02	-	-	-	236.17**	-	-	-	0.01	-	-	-	0.03*
GCA x Environment	16	-	-	-	3.75	-	-	-	0.01	-	-	-	0.01*
SCA x Environment	72	-	-	-	3.84*	-	-	-	0.01	-	-	-	0.07
Error	264	2.69	2.68	2.54	2.64	0.01	0.01	0.01	0.01	0.01	0.01	0.11	0.07

* and ** indicate significance at 5% and 1% levels of probability, respectively

Table 5: ANOVA for combining ability for fruits per plants and seeds per fruit under individual environment and over environments

Sources	d.f.	Fruits per plant				Seeds per fruit			
		E_1	E_2	E_3	Pooled	E_1	E_2	E_3	Pooled
		Navsari	Vanarasi	Waghai		Navsari	Vanarasi	Waghai	
GCA	08	1113893.50**	770167.12**	505205.03**	2234751.12**	151695.45**	142718.89**	181955.03**	468948.96**
SCA	36	24417.01**	231189.87**	183122.96**	495440.19**	29973.50**	29483.87**	30852.17**	79307.35**
Environment (E)	2	-	-	-	7706283.56**	-	-	-	1275.36
GCA x Environment	16	-	-	-	77302.28**	-	-	-	3710.21
SCA x Environment	72	-	-	-	81644.49*	-	-	-	5501.10**
Error	264	48068.48	34172.98	20639.98**	34293.80	3108.62	2560.47	2072.43	2580.51

* and ** indicate significance at 5% and 1% levels of probability, respectively

Table 8: ANOVA for combining ability for shoot and fruit borer infestation and little leaf incidence under individual environment and over environments

Sources	d.f.	Shoot and fruit borer infestation				Little leaf incidence			
		E_1	E_2	E_3	Pooled	E_1	E_2	E_3	Pooled
		Navsari	Vanarasi	Waghai		Navsari	Vanarasi	Waghai	
GCA	08	4.26	2.49	4.37**	-	10.65	14.43**	5.57	-
SCA	36	1.02**	5.57**	4.27**	6.92**	14.64**	9.25**	15.84**	14.37**
Environment (E)	2	-	-	-	23.54**	-	-	-	43.39**
GCA x Environment	16	-	-	-	-	-	-	-	-
SCA x Environment	72	-	-	-	6.49**	-	-	-	12.70**
Error	264	4.70	1.39	0.66	2.26	5.67	4.49	4.96	5.04

* and ** indicate significance at 5% and 1% levels of probability, respectively

Estimation of general combining ability effects and specific combing ability

The estimate of general combining ability (GCA) effects and of the parents for different characters for individual and pooled over environments are presented in Table 09. To Table 21. The salient features of the results of general combining ability effects of parents and specific combining ability effects for different characters are given below:

Days to 50% flowering

The GCA effects of parents ranged from -2.39 (NBL-117) to 4.69 (GJLB-4) at Navsari; -2.52 (NBL-117) to 2.84 (GJLB-4) at Vanarasi; -2.13 (Pusa Upkar) to 3.07 (GJLB-4) at Waghai and -2.32 (NBL-117) to 3.53 (GJLB-4) in pooled, environments respectively. Among the parents, GCA effects was significant and negative for parents *viz*., Panjab Sadabhar in E_1 (-1.39), E_2 (-0.67), E_3 (-0.77) and pooled (-0.94); Swarna Mani in E_1 (-1.09), E_2 (-1.46), E_3 (-1.22) and pooled (-1.26); Pusa Upkar in E_1 (-1.42), E_2 (-1.70), E_3 (-2.13) and pooled (-1.75) and NBL-117 in E_1 (-2.39), E_2 (-2.52), E_3 (-2.04) and pooled (-2.32). Hence, they were registered as good general combiners for earliness to flowering.

The estimates of SCA effects in hybrids varied from -6.76 (GAOB-2 x JBGR-1) to 5.39 (Pusa Upkar x NBL-117) at Navsari; -10.27 (GOB-1 x NBL-117) to 6.82 (GOB-1 x JBGR-1) at Vanarasi; -8.96 (GOB-1 x NBL-117) to 7.61 (GOB-1 x JBGR-1) at Waghai and -8.23 (GOB-1 x NBL-117) to 5.63 (GOB-1 x JBGR-1) on pooled environment basis, respectively for this character. The highest, significant and negative SCA effect was observed -6.76 (GAOB-2 x JBGR-1), -10.27 (GOB-1 x NBL-117), -8.96 (GOB-1 x NBL-117) and -8.23 (GOB-1 x NBL-117) in E_1, E_2, E_3 and pooled, respectively for days to 50 per cent flowering (Table 4.28). Among hybrids, six crosses namely, GAOB-2 x JBGR-1, GAOB-2 x GRB-5, GOB-1 x NBL-117, Punjab Sadabahar x Pusa Upkar, Punjab Sadabahar x NBL-117 and JBGR-1 x GRB-5 exhibited significant and desirable SCA effects in all the environments. Similar results were also reported by Dharwad *et al.* (2011) [3], Shinde *et al.* (2011) [11], Hussain *et al.* (2017) [6], Patil *et al.* (2019) [14] and Siva *et al.* (2020) [20].

Branches per plant

Total three parents in all environment and on pooled basis exhibited positive GCA effects out of which GRB-5 and Pusa Upkar had significant positive GCA effects over all environments for this character. The GCA effects of parents ranged from -0.51 (Punjab Sadabahar) to 0.58 (GAOB-2) at E_1; -0.35 (NBL-117) to 0.25 (GJLB-4) at E_2; -49 (Punjab Sadabhar) to 0.70 (Pusa Upkar) at E_3 and -0.37 (Punjab Sadabhar) to 0.44 (Pusa Upkar) on pooled basis, respectively.

Among the parents, GCA effects was significant and positive for parents mainly, GAOB-2 in E_1 (0.58), E_2 (0.21), E_3 (0.11) and pooled (-0.30); Pusa Upkar in E_1 (0.45), E_2 (0.17), E_3 (0.70) and pooled (0.44) and GRB-5 in E_1 (0.43), E_2 (0.29), E_3

(0.24) and pooled (0.32). Hence, they were registered as good general combiners for Branches per plant. In addition to the GCA effects the estimates of SCA effects in hybrids varied from -1.78 (GAOB-2 x Pusa Upkar) to 2.04 (Pusa Upkar x NBL-117) at Navsari; -1.60 (GOB-1 x NBL-117) to 2.73 (NBL-117 x GJLB-4) at Waghai; -1.88 (Punjab Sadabahar x GRB-5) to 3.34 (NBL-117 x GJLB-4) at Waghai and -1.59 (GAOB-2 x Pusa Upkar) to 2.62 (NBL-117 x GJLB-4) on pooled basis, respectively.

Among the hybrids, GAOB-2 x GOB-1, GOB-1 x Swarna Mani, GOB-1 x Pusa Upkar, Pusa Upkar x GJLB-4 and NBL-117 x GJLB-4 had positive and significantly desirable SCA effects over environments studied. The hybrids *viz.*, GAOB-2 x Pusa Upkar, GOB-1 x GJLB-4, GOB-1 x NBL-117, Punjab Sadabahar x JBGR-1, PS x GRB-5, Punjab Sadabahar x GJLB-4, Swarna Mani x GRB-5 and GRB-5 x GJLB-4 showed significant and negative SCA effects for branches per plant over the environments. These findings are in conformity with Kumar and Arumugam (2013) [10], Hussain *et al*. (2017) [6], Patel *et al*. (2017) [13], Patil *et al*. (2019) [14] and Siva *et al.* (2020) [20].

Plant height

The GCA effects of parents ranged from -7.33 (Swarna Mani) to 3.87 (GJLB-4) at E_1; -1.70 (Swarna Mani) to 3.74 (Pusa Upkar) at E_2; -1.70 (Swarna Mani) to 3.74 (Pusa Upkar) at E_3 and -4.63 (Swarna Mani) to 2.46 (GJLB-4) on pooled environment basis, respectively for plant height. Among the parents, GCA effects were significant and negative for GAOB-2 (-1.62), Swarna Mani (-7.33), Pusa Upkar (-0.78) and GRB-5 (-0.31) E_1; GAOB-2 (-0.44), JBGR-1 (-2.13) and Swarna Mani (-4.86) in E_2 GAOB-2 (-0.83), Punjab Sadabhar (-0.91), JBGR-1 (-1.50), GRB-5 (-1.39) and Swarna Mani (-1.70) in E_3; and GAOB-2 (-0.96), JBGR-1 (-1.18) and Swarna Mani (-4.63) on pooled basis. In addition to which, parents *viz*., GOB-1, NBL-117 and GJLB-4 recorded positive GCA effects in all environments and on pooled basis. (Table 4.31). Hence, they were registered as good general combiners for plant height.

Furthermore, Hybrids varied in their SCA effects from -11.52 (GOB-1 x NBL-117) to 10.61 (JBGR-1 x GRB-5) in Navsari; -8.21 (GAOB-2 x NBL-117) to 11.78 (GOB-1 x Swarna Mani) at Vanarasi; -11.64 (JBGR-1 x GJLB-4) to 11.00 (Punjab Sadabahar x Swarna Mani) for Waghai and -6.97 (JBGR-1 x GJLB-4) to 8.33 (GOB-1 x Swarna Mani) on pooled basis, respectively. While, GOB-1 x NBL-117 and Punjab Sadabahar x GJLB-4 hybrids recorded significant and negative SCA effects for dwarfness in plant height over all the three environments. The estimates of GCA and SCA effects for plant height is given in Table 4.31. The results were in correspondence to the findings of Similar results had also been reported by Kumar and Arumugam (2013) [10], Patel *et al*. (2017) [13], Hussain *et al*. (2017) [6], Patil *et al*. (2019) [14], Singh and Chaudhry (2018) [19] and Siva *et al.* (2020) [20].

Fruit length

GCA effects was significant and positive for GAOB-2 in E_1 (0.45), E_3 (0.18) and pooled (0.16); Punjab Sadabahar in E_1 (2.12), E_2 (1.88), E_3 (2.38) and pooled (2.12); JBGR-1 in E_1 (0.30), E_2 (0.45), E_3 (0.69) and pooled (0.48); while, GJLB-1 had positive and significant GCA effect in E_1 (0.57), E_2 (0.40) and pooled (0.30).Further comparison across the environments indicated that the parents *viz*., GOB-1 in E_1 (-0.34), E_2 (-0.56), E_3 (-0.56) and pooled (-0.49); Pusa Upkar in E_1 (-0.46), E_2 (-0.49), E_3 (-0.70) and pooled (-0.55); GRB-5 in E_1 (-1.08), E_2 (-0.63), E_3 (-0.66) and pooled (-0.79); NBL-117 in E_1 (-1.21), E_2 (-0.82), E_3 (-1.9) and pooled (-1.04) basis recorded significant and negative GCA effects. (Table 4.32).

The estimates of SCA effects in hybrids varied from -3.50 (GAOB-2 x Punjab Sadabahar) to 3.08 (Punjab Sadabahar x GJLB-4 and GAOB-2 x GRB-5); -3.97 (GAOB-2 x Punjab Sadabahar) to 3.83 (GAOB-2 x GRB-5); -4.93 (GAOB-2 x Punjab Sadabahar) to 4.05 (GAOB-2 x GRB-5) and -4.13 (GAOB-2 x Punjab Sadabahar) to 3.65 (GAOB-2 x GRB-5) in E_1, E_2, E_3 and on pooled, respectively. Out of 36 crosses, 14 crosses in E_1, 13 crosses in E_2 and 12 crosses E_3 exhibited significant and positive SCA effects for fruit length. Among these, GAOB-2 x GOB-1, GAOB-2 x Swarna Mani, GAOB-2 x Pusa Upkar, GAOB-2 x GRB-5, GAOB-2 x NBL-117, GOB-1 x Pusa Upkar, Punjab Sadabahar x Pusa Upkar, Punjab Sadabahar x GJLB-4 and NBL-117 x GJLB-4 had positive and significant SCA effects in the desired direction for this trait across the environments. While, 15 hybrids in E_1; 12 hybrids in E_2; and 16 hybrids in E_3 exhibited significant and positive SCA effects for Fruit length of which GAOB-2 x Punjab Sadabahar, GAOB-2 x GJLB-4, GOB-1 x Punjab Sadabahar, GOB-1 x NBL-117, GOB-1 x GJLB-4, JBGR-1 x Pusa Upkar, Swarna Mani x Pusa Upkar and GRB-5 x GJLB-4 cross combinations had negative and significant SCA effect over all environments.

These results are similar to the findings of Shinde *et al.* (2011) [11], Mishra *et al*. (2013) [12], Hussain *et al*. (2017) [6], Patel *et al*. (2017) [13], Patil *et al*. (2019) [14] Singh and Chaudhry (2018) [19], Kachouli *et al.* (2019) [7], Kumar *et al.* (2019) [9] and Siva *et al.* (2020) [20].

Fruit girth

The GCA effects of parents ranged from -3.05 (GJLB-4) to 2.08 (GAOB-2) at Navsari; -2.49 (GJLB-4) to 1.58 (Swarna Mani) at Vanarasi; -3.32 (GJLB-4) to 1.95 (GAOB-2) at Waghai and -2.95 (GJLB-4) to 1.81 (GAOB-2.) on pooled basis, respectively. GCA effects was significant and positive for GAOB-2 (2.08), GOB-1. (0.65), Swarna Mani (1.64), Pusa Upkar (0.64) and GRB-5 (0.40) in E_1; GAOB-2 (1.40), GOB-1 (0.65), JBGR-1 (0.66), Pusa Upkar (0.67) and Swarna Mani (1.58) in E_2; GAOB-2 (1.95), GOB-1 (0.49), JBGR-01 (0.55), Swarna Mani (1.09), Pusa Upkar (0.73), and GRB-5 (0.79) in E_3 and GAOB-2 (1.81), GOB-1 (0.60), JBGR-1 (0.52), Swarna Mani (1.43), Pusa Upkar (0.68) and GRB-5 (0.35) on pooled basis. Hence, they were registered as good general combiners for fruit girth.

The estimates of SCA effects in hybrids ranged from -2.89 (Swarna Mani x NBL-117) to 3.02 (GAOB-2 x GOB-1) at E_1; -3.69 (Swarna Mani x NBL-117) to 3.42 (Swarna Mani x GRB-5) at E_2; -3.44 (GOB-1 x NBL-117) to 2.79 (GAOB-2 x GOB-1) at E_3 and -3.22 (Swarna Mani x NBL-117) to 2.81 (GAOB-2 x GOB-1) on pooled environment basis, respectively. Significant SCA effects in the desired direction were observed for 11 hybrids in E_1; 12 hybrids in E_2; and eight hybrids for E_3. Of these, GAOB-2 x GOB-1, GOB-1 x Swarna Mani, Punjab Sadabahar x GRB-5, Punjab Sadabahar x GJLB-4 and NBL-117 x GJLB-4 exhibited significant and positive SCA effects for the fruit girth in all the environments. The cross combinations *viz.*, GOB-1 x Swarna Mani, GOB-1 x NBL-117, JBGR-1 x Pusa Upkar, JBGR-1 x GJLB-4, Swarna Mani x NBL-117 and Swarna Mani x GJLB-4

showed significant and negative SCA effects at all environments. The results were corroborative to the reports of Aswani and Khandelwal (2005) [1], Kamalakkannan *et al.* (2007) [8], Thangavel (2011) [23], Patel *et al.* (2017) [13] and Siva *et al.* (2020) [20].

Fruit weight

The range of GCA effects of parents varied from -6.78 (JBGR-1) to 9.11 (Pusa Upkar) for Navsari; -9.67 (JBGR-1) to 10.79 (Pusa Upkar) at Vanarasi; -6.85 (JBGR-1) to 8.71 (Pusa Upkar) at Waghai and -7.77 (JBGR-1) to 9.54 (Pusa Upkar) for pooled environment basis, respectively. Four parents in E_1, E_2, E_3 and on pooled basis exhibiting significant and positive GCA effects. Significant and positive GCA effects were observed for GAOB-2 (8.42), Swarna Mani (8.10), GOB-1 (2.85) and Pusa Upkar (9.11) in E_1; GAOB-2 (8.87), Swarna Mani (7.79), GOB-1 (4.07) and Pusa Upkar (10.79) in E_2; GAOB-2 (6.77), Swarna Mani (5.38), GOB-1 (6.01) and Pusa Upkar (8.79) in E_3 and GAOB-2 (8.02), GOB-1 (4.31) Swarna Mani (7.09) and Pusa Upkar (9.54) on pooled basis. Hence, they were registered as good general combiners for fruit weight.

The estimates of SCA effects in hybrids ranged from -13.80 (JBGR-1 x GJLB-4) to 17.91 (GOB-1 x Pusa Upkar) in E_1; -23.95 (Punjab Sadabahar x GRB-5) to 22.21 (GOB-1 x Pusa Upkar) in E_2; -22.95 (GOB-1 x GRB-5) at E_3 to 18.31 (GOB-1 x Pusa Upkar) and -19.58 (GOB-1 x GRB-5) to 19.48 (GOB-1 x Pusa Upkar) on pooled basis, respectively. Hybrids, GAOB-2 x GOB-1, GAOB-2 x Swarna Mani, GOB-1 x Pusa Upkar, Swarna Mani x GRB-5, Pusa Upkar x GRB-5, and NBL-117 x GJLB-4 exhibited significant and desirable SCA effects in all three environments. The cross combinations GOB-1 x GRB-5, Punjab Sadabahar x Pusa Upkar, JBGR-1 x GJLB-4 and Swarna Mani x NBL-117 showed significant and negative SCA effects in all three locations. Similar finding to the one reported in present condition have also been reported by Dharwad *et al.* (2011) [3], Shinde *et al.* (2011) [11], Thangavel (2011) [23], Hussain *et al.* (2017) [6], Patel *et al.* (2017) [13], Patil *et al.* (2019) [14], Kachouli *et al.* (2019) [7], Kumar *et al.* (2019) [9], Siva *et al.* (2020) [20].

Fruits per Plant

The parents possessing significant and positive GCA effects were GAOB-2 (1.76), GOB-1 (1.60), JBGR-1 (1.35) and GRB-5 (3.53) in E_1; JBGR-1 (2.12) and GRB-5 (3.84) in E_2; JBGR-1 (1.73) and GRB-5 (3.19) in E_3; and GAOB-2 (1.02), GOB-1 (0.79), JBGR-1 (1.73) and GRB-5 (3.52) on pooled basis. Additionally, the estimates of SCA effects in hybrids varied from -6.04 (GAOB-2 x Punjab Sadabahar) to 5.88 (Swarna Mani x GRB-5); -7.74 (GAOB-2 x Punjab Sadabahar) to 7.18 (GJB-3 x JB-12-06); -8.04 (GAOB-2 x Punjab Sadabahar) to 6.06 (GOB-1 x Pusa Upkar) and -7.27 (GAOB-2 x Punjab Sadabahar) to 5.21 (GAOB-2 x GOB-1) in E_1, E_2, E_3 and on pooled, respectively.

Significant and positive SCA effects for a greater number of fruits per plant were observed for six hybrids in E_1; eight hybrids in E_2; and seven hybrids for E_3 for respective locations. Hybrids *viz*., GAOB-2 x GOB-1 (5.55), GAOB-2 x GJLB-4 (2.76), Swarna Mani x Pusa Upkar (3.62), Swarna Mani x GRB-5 (5.88), NBL-117 x GJLB-4 (2.85) had positive and significant SCA in Navsari location, in addition to which GAOB-2 x GOB-1 (5.41), GAOB-2 x NBL-117 (4.49), JBGR-1 x Swarna Mani (2.72), JBGR-1 x Pusa Upkar (5.97), JBGR-1 x GRB-5 (6.35), Swarna Mani x Pusa Upkar (7.18), Swarna Mani x GRB-5 (4.91) and Pusa Upkar x NBL-117 (3.33) had positive and significant SCA at Vanarasi location, and Hybrid *viz*., GAOB-2 x GOB-1 (4.66), GAOB-2 x JBGR-1 (3.80), GOB-1 x Pusa Upkar (6.06), Punjab Sadabahar x Swarna Mani (3.32), Punjab Sadabahar x Pusa Upkar (2.83), Punjab Sadabahar x GJLB-4 (3.18), JBGR-1 x GRB-5 (5.80) and GRB-5 x NBL-117 (3.07) had positive and significant SCA in Waghai location. Hybrids particularly GAOB-2 x GOB-1, Swarna Mani x Pusa Upkar and Swarna Mani x GRB-5 exhibited significant SCA effects in the desired direction for the trait over the environments.

On contrary, cross combinations GAOB-2 x Punjab Sadabahar. JBGR-1 x NBL-117 and Pusa Upkar x GJLB-1 exhibited significant and negative SCA effects over all three environments. Similar finding to the one found for above trait have also been reported by Mishra *et al*. (2013) [12], Hussain *et al*. (2017) [6], Patel *et al.* (2017) [13], Patil *et al*. (2019) [14], Kumar *et al.* (2019) [9], Siva *et al.* (2020) [20], Datta *et al.* (2021) [2] and Rajan *et al.* (2022) [15].

Fruit yield per plant

The GCA effects of parents for fruit yield per plant varied from -579.50 (GJLB-4) to 314.80 (GAOB-2) for Navsari location; -401.11 (GJLB-4) to 343.63 (Pusa Upkar) in Vanarasi location; -333.00 (GJLB-4) to 228.47 (Swarna Mani) Waghai location and -437.87 (GJLB-4) to 241.81 (Pusa Upkar) on pooled environment basis, respectively. Among the parents, GCA effect was significant and positive for GAOB-2 (314.80), GOB-1 (163.19), Swarna Mani (272.83), Pusa Upkar (191.01) and GRB-5 (181.24) in E_1; GAOB-2 (221.71), GOB-1 (126.78), Swarna Mani (117.03) and Pusa Upkar (343.63) in E_2; GAOB-2 (160.53), GOB-1(144.83), Swarna Mani (228.47) and Pusa Upkar (190.80) in E_3 and GAOB-2 (232.35), GOB-1 (144.94), Swarna Mani (26.11) and Pusa Upkar (241.81) on pooled basis. Hence, they were registered as good general combiners for fruit yield per plant.

Furthermore, the estimates of SCA effects in hybrids varied from -917.59 (JBGR-1 x GJLB-4) to 763.89 (GOB-1 x Pusa Upkar) at Navsari; -910.68 (Pusa Upkar x GJLB-4) to 855.28 (GAOB-2 x GOB-1) at Vanarasi; -763.05 (Pusa Upkar x GJLB-4) to 944.32 (Pusa Upkar x GRB-5) for Waghai environment and -759.62 (Pusa Upkar x GJLB-4) to 689.13 (GOB-1 x Pusa Upkar) on pooled environment basis, respectively. Significant and positive SCA effects for higher fruit yield per plant were observed for nine hybrids at Navsari *viz*., GAOB-2 x JBGR-1 (673.42), GAOB-2 x Swarna Mani (373.97), GAOB-2 x GJLB-4 (640.59), GOB-1 x Punjab Sadabahar (369.18), GOB-1 x Pusa Upkar (763.89), Swarna Mani x GRB-5 (580.55), Pusa Upkar x NBL-117 (581.01), GRB-5 x NBL-117 (616.85) and NBL-117 x GJLB-4 (641.85). In addition to which 12 hybrids in Vanarasi location *viz.*, GAOB-2 x GOB-1 (855.28), GAOB-2 x JBGR-1 (541.29), GAOB-2 x NBL-117 (375.44), GOB-1 x Pusa Upkar (604.00), Punjab Sadabahar x Swarna Mani (304.92), Punjab Sadabahar x GJLB-4 (588.21), Swarna Mani x Pusa Upkar (516.25), Swarna Mani x GRB-5 (660.02), Pusa Upkar x GRB-5 (356.67), Pusa Upkar x NBL-117 (703.63) and NBL-117 x GJLB-4 (498.22) had positive and significant SCA effect for fruit yield per plant. Furthermore 10 hybrids in Waghai location *viz.*, GAOB-2 x GOB-1 (548.31), GAOB-2 x JBGR-1 (458.18), GAOB-2 x Swarna Mani (248.88), GOB-1

x JBGR-1 (547.25), GOB-1 x Pusa Upkar (699.51), Punjab Sadabahar x Swarna Mani (335.50), Swarna Mani x GRB-5 (293.72), Pusa Upkar x GRB-5 (944.32), GRB-5 x NBL-117 (287.95) and NBL-117 x GJLB-4 (695.56) had positive and significant SCA effect for fruit yield per plant.

The cross combinations GAOB-2 x JBGR-1, GOB-1 x Pusa Upkar, Swarna Mani x GRB-5 and NBL-117 x GJLB-4 consistently showed significant and positive SCA effects at all three locations. The hybrids GAOB-2 x Swarna Mani, GOB-1 x Punjab Sadabahar, GAOB-2 x JBGR-1, GOB-1 x Pusa Upkar and GAOB-2 x GOB-1 having high SCA effects for fruit yield per plant also registered high and desirable SCA effects for fruit length, fruit girth, fruit weight, fruits per plant. All the parents involved in these crosses had good or average gca effects. Hence, their hybrids are also expected to throw-off transgressive recombinants in segregating generations, combining favourable traits into one genotype for development as improved varieties. Similar finding in accordance to the above result has also been reported by Dharwad *et al.* (2011) [3], Sane *et al.* (2011) [16], Shinde *et al.* (2011) [11], Thangavel (2011) [23], Kumar and Arumugam (2013) [10], Mishra *et al.* (2013) [12], Hussain *et al.* (2017) [6], Patel *et al.* (2017) [13], Patil *et al.* (2019) [14], Singh and Chaudhry (2018) [19], Kachouli *et al.* (2019) [7], Kumar *et al.* (2019) [9], Siva *et al.* (2020) [20], Datta *et al.* (2021) [2] and Rajan *et al.* (2022) [15].

Seeds per fruit

The GCA effects of parents ranged from -173.48 (Punjab Sadabahar) to (137.26) Pusa Upkar; -185.99 (Punjab Sadabahar) to 142.81 (JBGR-1); -205.43 (Punjab Sadabahar) to 145.32 (JBGR-1) and -188.30 (Punjab Sadabahar) to 132.84 (JBGR-1) in E_1, E_2, E_3 and on pooled, respectively. Among the parents, GCA effect was significant and negative for Punjab Sadabahar (-173.48), NBL-117 (-102.01) and GJLB-4 (-151.87) in E_1; Punjab Sadabahar (-185.99), NBL-117 (-86.62) and GJLB-4 (-139.97) in E_2; Punjab Sadabahar (-205.43), NBL-117 (-91.45) and GJLB-4 (-176.53) in E_3; and Punjab Sadabahar (-188.30) NBL-117 (-93.36) and GJLB-4 (-156.12) on pooled basis. Hence, they were registered as good general combiners for seeds per fruit.

The spectrum of variation for SCA effects in hybrids ranged from -405.89 (Swarna Mani x GJLB-4) to 314.04 (Punjab Sadabahar x GJLB-4); -297.48 (Punjab Sadabahar x Pusa Upkar) to 364.42 (Punjab Sadabahar x GJLB-4); -464.51 (Swarna Mani x GJLB-4.) to 252.17 (Swarna Mani x NBL-117); and -379.04 (Swarna Mani x GJLB-4) to 198.28 (Swarna Mani x NBL-117) in E_1, E_2, E_3 and on pooled, respectively.

Significant and negative SCA effects were observed for 12 hybrids in E_1; 11 hybrids in E_2; and 10 hybrids in E_3. Of these, GAOB-2 x JBGR-1, GAOB-2 x Swarna Mani, Punjab Sadabahar x JBGR-1, Punjab Sadabahar x Pusa Upkar, Swarna Mani x NBL-117, Swarna Mani x GJLB-4, Pusa Upkar x GJLB-4 and GRB-5 x GJLB-4 recorded significant and negative desirable SCA effects for this trait in all the environments. The derived results were in conformity with Makani *et al.* (2013) [11] and Patel *et al.* (2017) [13].

Total phenol content

The GCA effects of parents varied from -0.57 (Swarna Mani) to 0.51 (GAOB-2) at Navsari; -0.54 (Swarna Mani) to 0.49 (GAOB-2) at Vanarasi; -0.53 (Swarna Mani) to 0.49 (GAOB-2) at Waghai and -0.34 (GRB-5) to 0.50 (GAOB-2) on pooled basis, respectively. Among the parents, GCA effect was significant and positive for GAOB-2 (0.51), GOB-1 (0.05), Punjab Sadabahar (0.14), JBGR-1 (0.49) in E_1; GAOB-2 (0.49), GOB-1 (0.05), Punjab Sadabahar (0.16), JBGR-1 (0.49) in E_2 GAOB-2 (0.49), GOB-1 (0.09), Punjab Sadabahar (0.14), JBGR-1 (0.47) in E_3 and GAOB-2 (0.50), GOB-1 (0.06), Punjab Sadabahar (0.15), JBGR-1 (0.48) in pooled basis. Hence, they were registered as good general combiners for total phenol content. Among the remaining parents, GCA effects were significant and negative for Swarna Mani (-0.57), Pusa Upkar (-0.08), GRB-5 (-0.33), GJLB-4 (0.20) in E_1; Swarna Mani (-0.54), Pusa Upkar (-0.08), GRB-5 (-0.34), GJLB-4 (-0.22) in E_2; Swarna Mani (-0.53), GRB-5 (-0.35), GJLB-4 (-0.22) in E_3 and Swarna Mani (-0.55), Pusa Upkar (-0.07), GRB-5 (-0.34) on pooled basis. Hence, they were registered as poor general combiners for total phenol content.

Negative and significant SCA effects were observed for 11 hybrids in E_1; 14 hybrids in E_2; and 23 hybrids in E_3. Among these, GAOB-2 x Swarna Mani, GAOB-2 x Pusa Upkar, GAOB-2 x GRB-5, GAOB-2 x NBL-117, GAOB-2 x GJLB-4, GOB-1 x JBGR-1, GOB-1 x Pusa Upkar, GOB-1 x GRB-5, GOB-1 x GJLB-4, Punjab Sadabahar x JBGR-1, Punjab Sadabahar x Swarna Mani, Punjab Sadabahar x Pusa Upkar, Punjab Sadabahar x NBL-117, Punjab Sadabahar x GJLB-4, JBGR-1 x Swarna Mani, JBGR-1 x Pusa Upkar, JBGR-1 x GRB-5, JBGR-1 x GJLB-4, Swarna Mani x NBL-117, Pusa Upkar x GJLB-4 and GRB-5 x NBL-117 exhibited negative and significant SCA effects in the desired direction for this trait in all the environments. Similar finding in accordance to the above result has also been reported by Suneetha *et al.* (2008) [22], Kumar and Arumugam (2013) [10], Hussain *et al.* (2017) [6], Patel *et al.* (2017) [13], Patil *et al.* (2019) [14], Kumar *et al.* (2019) [9] and Datta *et al.* (2021) [2].

Total soluble sugars

The GCA effects of parents ranged from -0.22 (GAOB-2) to 0.36 (Punjab Sadabahar); -0.27 (GAOB-2) to 0.35 (Punjab Sadabahar); -0.27 (GAOB-2) to 0.490 (Punjab Sadabahar) and -0.25 (GAOB-2) to 0.37 (Punjab Sadabahar) in E_1, E_2, E_3 and on pooled, respectively. The estimates of GCA and SCA effects for total soluble sugars is given in Table 4.39. GCA effects was found significant and positive for Punjab Sadabahar (0.36), Swarna Mani (0.07), Pusa Upkar (0.17) in E_1; Punjab Sadabahar (0.35), Pusa Upkar (0.25) in E_2; Punjab Sadabahar (0.40), Swarna Mani (0.13), Pusa Upkar (0.24) in E_3 and Punjab Sadabahar (0.37), Swarna Mani (0.08), Pusa Upkar (0.22) on pooled basis. Hence, they were registered as good general combiners for total soluble sugars.

The magnitude of SCA effects in hybrids ranged from -1.18 (Pusa Upkar x NBL-117) to 0.87 (Pusa Upkar x GJLB-4) in E_1; -1.22 (Swarna Mani x Pusa Upkar) to 1.06 (GOB-1 x NBL-117) in E_2; -1.18 (Swarna Mani x Pusa Upkar) to 1.22 (Pusa Upkar x GJLB-4) in E_3 and -1.15 (Swarna Mani x Pusa Upkar) to 1.22 (Pusa Upkar x GJLB-4) on pooled basis for this trait. For the trait TSS, hybrids *viz.*, GAOB-2 x JBGR-1, GAOB-2 x Pusa Upkar, GAOB-2 x GJLB-4, GOB-1 x Punjab Sadabahar, GOB-1 x JBGR-1, GOB-1 x Pusa Upkar, GOB-1 x NBL-117, Punjab Sadabahar x Pusa Upkar, Punjab Sadabahar x GJLB-4, JBGR-1 x Swarna Mani, JBGR-1 x Pusa Upkar, JBGR-1 x GRB-5, Swarna Mani x GJLB-4 and Pusa Upkar x GJLB-4 exhibited significant and positive SCA effects in the desired direction for over all three environments.

Similar result has also been reported by Suneetha *et al*. (2008) [22], Patel *et al.* (2017) [13], Dhirendra Kumar *et al*. (2017) [4], Singh and Chaudhry (2018) [19] and Kumar *et al.* (2019) [9].

Shoot and fruit borer infestation

As the non-significance of GCA mean square of combing ability ANOVA for shoot and fruit borer infestation at Navsari (E_1) and Vanarasi (E_2) location. Further evaluation for pooled over combining analysis has not been deemed fit to be true and their further GCA effect analysis has been avoided.

The negative and significant SCA effect was exhibited by hybrids *viz.*, GAOB-2 x GOB-1 (-3.60), Swarna Mani x Pusa Upkar (-3.68), and Swarna Mani x GRB-5 (-4.90) at Navsari, in addition to these crosses GAOB-2 x GOB-1 (-4.13), Punjab Sadabahar x GRB-5 (-3.22) and Punjab Sadabahar x NBL-117 (-2.11) had negative and significant SCA effect at Vanarasi location, furthermore hybrid *viz.*, GAOB-2 x Punjab Sadabahar (-2.84), GAOB-2 x Swarna Mani (-1.97), GOB-1 x Swarna Mani (-1.41), Punjab Sadabahar x GRB-5 (-2.50), JBGR-1 x Pusa Upkar (-1.85), JBGR-1 x GJLB-4 (-2.91), Swarna Mani x GJLB-4 (-2.05), Pusa Upkar x GRB-5 (-3.95) and GRB-5 x GJLB-4 (-2.39) exhibited negative and significant SCA effect for shoot and fruit borer infestation (Table 4). Similar results were also reported by Kumar and Arumugam (2013) [10] and Siva *et al.* (2020) [20].

Little leaf incidence

As the non-significance of GCA mean square of combing ability ANOVA for shoot and fruit borer infestation at Navsari (E_1) and Waghai (E_3) location. Further evaluation for pooled over combining analysis has not been deemed fit to be true and their further GCA effect analysis has been avoided. In general, the estimates of SCA effects in hybrids ranged from -4.85 (GRB-5 x NBL-117) to 6.86 (GOB-1 x GRB-5); -6.04 (Punjab Sadabahar x GRB-5) to 6.68 (GAOB-2 x JBGR-1); -5.16 (GRB-5 x NBL-117) to 8.75 (GAOB-2 x GRB-5) and -3.45 (GRB-5 x NBL-117) to 5.39 (GAOB-2 x GRB-5) and in E_1, E_2, E_3 and on pooled, respectively. The negative and significant SCA effect for little leaf incidence was exhibited by hybrids *viz.*, GRB-5 x NBL-117 (-4.79) and GRB-5 x NBL-117 (-4.85) at Navsari, in addition to which hybrids particularly GOB-1 x GRB-5 (-4.92), Punjab Sadabahar x GRB-5 (-6.04), JBGR-1 x Pusa Upkar (-5.06) and GRB-5 x NBL-117 (-4.10) had negative and significant SCA effect at Vanarasi location, furthermore hybrid *viz.*, GAOB-2 x Punjab Sadabahar (-5.25), GOB-1 x NBL-117 (-3.82), Punjab Sadabahar x Pusa Upkar (-4.27), Swarna Mani x NBL-117 (-4.53) and GRB-5 x NBL-117 (-5.16) exhibited negative and significant SCA effect for little leaf incidence. (Table 4.41). Similar results were also reported by Kumar and Arumugam (2013) [10].

Table 9: Estimates of GCA and SCA effects for days to 50 per cent flowering & Branches per plant

Sr. No.	Parents	Days to 50 per cent flowering				Branches per plant			
		GCA Effects				GCA Effects			
		Navsari (E_1)	Vanarasi (E_2)	Waghai (E_3)	Pooled	Navsari (E_1)	Vanarasi (E_2)	Waghai (E_3)	Pooled
1.	GAOB-2	0.30	1.53 *	1.16 *	1.00*	0.58 *	0.21	0.11	0.30*
2.	GOB-1	0.42	1.38 *	1.59 *	1.13*	-0.16	-0.08	-0.40 *	-0.21*
3.	Punjab Sadabahar	-1.39 *	-0.67 *	-0.77 *	-0.94*	-0.51 *	-0.12	-0.49 *	-0.37*
4.	JBGR-1	0.69 *	0.39	0.38	0.48	-0.22	0.06	0.52 *	0.11*
5.	Swarna Mani	-1.09 *	-1.46 *	-1.22 *	-1.26*	-0.09	0.08	-0.07	-0.02
6.	Pusa Upkar	-1.42 *	-1.70 *	-2.13 *	-1.75*	0.45 *	0.17	0.70 *	0.44*
7.	GRB-5	0.21	0.21	-0.04	0.12	0.43 *	0.29 *	0.24 *	0.32*
8.	NBL-117	-2.39 *	-2.52 *	-2.04 *	-2.32*	-0.24	-0.35 *	-0.29 *	-0.29*
9.	GJLB-4	4.69 *	2.84 *	3.07 *	3.53*	-0.24 *	-0.25 *	-0.31 *	-0.27*
	S.E.gi	0.27	0.24	0.33	0.16	0.12	0.11	0.11	0.06
	Hybrids	SCA Effects				SCA Effects			
1.	GAOB-2 x GOB-1	-1.16	-0.33	0.16	-0.44	1.04 *	0.80 *	1.08 *	0.97*
2.	GAOB-2 x PS	2.66 *	2.73 *	2.85 *	2.75*	1.05 *	0.84 *	0.58	0.82*
3.	GAOB-2 x JBGR-1	-6.76 *	-4.33 *	-4.30 *	-5.13*	0.80 *	0.96 *	-0.04	0.57*
4.	GAOB-2 x SM	-0.31	2.85 *	1.98 *	1.51*	0.76 *	0.84 *	-0.64 *	0.32*
5.	GAOB-2 x PU	5.02 *	4.76 *	3.88 *	4.55*	-1.78 *	-1.18 *	-1.82 *	-1.59*
6.	GAOB-2 x GRB-5	-2.61 *	-4.15 *	-2.87 *	-3.21*	-1.66 *	-1.14 *	-0.46	-1.09*
7.	GAOB-2 x NBL-117	1.99 *	1.58 *	0.79	1.45*	-0.45	0.17	0.75 *	0.16
8.	GAOB-2 x GJLB-4	-2.10 *	-0.12	0.34	-0.63	-1.74 *	-1.39 *	-0.97 *	-1.37*
9.	GOB-1 x PS	0.87	2.21 *	1.76	1.61*	-0.60	-0.27	-0.23	-0.37
10.	GOB-1 x JBGR-1	2.45 *	6.82 *	7.61 *	5.63*	-0.36	-0.94 *	-1.02 *	-0.77*
11.	GOB-1 x SM	-0.43	-0.67	-1.45	-0.85	0.90 *	1.23 *	1.21 *	1.11*
12.	GOB-1 x PU	2.57 *	4.24 *	4.79 *	3.87*	0.96 *	1.94 *	2.23 *	1.71*
13.	GOB-1 x GRB-5	3.27 *	4.00 *	3.37 *	3.55*	-0.78 *	-0.32	-0.44	-0.51
14.	GOB-1 x NBL-117	-5.46 *	-10.27 *	-8.96 *	-8.23*	-1.01 *	-1.60 *	-1.26 *	-1.29*
15.	GOB-1 x GJLB-4	0.45	-2.30 *	-0.75	-0.87	-0.23	-1.04 *	-0.85 *	-0.71*
16.	PS x JBGR-1	2.60 *	3.21 *	2.64 *	2.82*	-1.34 *	-0.81 *	-0.72 *	-0.96*
17.	PS x SM	4.39 *	4.39 *	4.58 *	4.45*	0.09	0.77 *	1.41 *	0.76*
18.	PS x PU	-2.61 *	-2.36 *	-2.51 *	-2.49*	-1.09 *	-1.15 *	-0.6	-0.95*
19.	PS x GRB-5	0.75	-1.94 *	-0.6	-0.60	-1.00 *	-1.45 *	-1.88 *	-1.44*
20.	PS x NBL-117	-4.31 *	-1.88 *	-2.27 *	-2.82*	-1.09 *	-0.50	-0.20	-0.60
21.	PS x GJLB-4	1.60 *	0.42	0.61	0.88	-1.18 *	-1.00 *	-1.09 *	-1.09*
22.	JBGR-1 x SM	1.96 *	-3.67 *	-3.24 *	-1.65*	0.90 *	0.49	1.95 *	1.11*
23.	JBGR-1 x PU	1.63 *	-2.76 *	-2.33 *	-1.15*	-0.98 *	-1.50 *	1.57 *	-0.30
24.	JBGR-1 x GRB-5	-1.67 *	-3.67 *	-3.42 *	-2.92*	0.62	1.11 *	1.10 *	0.94*
25.	JBGR-1 x NBL-117	3.27 *	3.39 *	3.25 *	3.30*	-0.34	-0.08	0.08	-0.11

26.	JBGR-1 x GJLB-4	2.18 *	1.36	2.13 *	1.89*	0.63	0.52	-0.21	0.31
27.	SM x PU	-1.92 *	-0.24	-1.05	-1.07	1.08 *	0.85 *	0.21	0.71*
28.	SM x GRB-5	0.45	1.85 *	1.85	1.38	-1.29 *	-1.35 *	-1.00 *	-1.21*
29.	SM x NBL-117	0.39	1.58 *	2.52 *	1.50*	0.65	0.37	-0.72 *	0.10
30.	SM x GJLB-4	3.96 *	0.88	0.07	1.64*	-0.21	-0.36	-0.81 *	-0.46
31.	PU x GRB-5	2.45 *	3.42 *	2.76 *	2.88	0.47	0.89 *	1.82 *	1.06*
32.	PU x NBL-117	5.39 *	0.15	1.43	2.32*	2.04 *	0.78 *	-0.84 *	0.66*
33.	PU x GJLB-4	-0.04	2.79 *	3.31 *	2.02*	1.95 *	1.98 *	1.58 *	1.84*
34.	GRB-5 x NBL-117	1.42	1.24	1.01	1.22	0.27	-0.02	0.59	0.28
35.	GRB-5 x GJLB-4	0.33	0.21	-0.78	-0.08	-0.89 *	-0.92 *	-0.96 *	-0.92*
36.	NBL-117 x GJLB-4	1.93 *	3.61 *	3.55 *	3.03*	1.78 *	2.73 *	3.34 *	2.62*
	S.E.sij	0.88	0.80	1.07	0.53	0.39	0.38	0.35	0.21

* and ** indicate significance at 5% and 1% levels of probability, respectively

Table 10: Estimates of GCA and SCA effects for plant height and fruit length

Sr. No.	Parents	Plant height				Fruit length			
		GCA Effects				GCA Effects			
		Navsari (E_1)	Vanarasi (E_2)	Waghai (E_3)	Pooled	Navsari (E_1)	Vanarasi (E_2)	Waghai (E_3)	Pooled
1.	GAOB-2	-1.62 *	-0.44	-0.83	-0.96*	0.45 *	-0.15	0.18	0.16
2.	GOB-1	2.29 *	1.98 *	0.09	1.45*	-0.34 *	-0.56 *	-0.56 *	-0.49*
3.	Punjab Sadabahar	3.13 *	0.22	-0.91	0.81	2.12 *	1.88 *	2.38 *	2.12*
4.	JBGR-1	0.06	-2.13 *	-1.50 *	-1.18*	0.30 *	0.45 *	0.69 *	0.48*
5.	Swarna Mani	-7.33 *	-4.86 *	-1.70 *	-4.63*	-0.33 *	-0.08	-0.19	-0.20*
6.	Pusa Upkar	-0.78	0.14	3.74 *	1.03*	-0.46 *	-0.49 *	-0.70 *	-0.55*
7.	GRB-5	-0.31	1.92 *	-1.39 *	0.07	-1.08 *	-0.63 *	-0.66 *	-0.79*
8.	NBL-117	0.69	0.62	1.51 *	0.94*	-1.21 *	-0.82 *	-1.07 *	-1.04*
9.	GJLB-4	3.87 *	2.54 *	0.98	2.46*	0.57 *	0.40 *	-0.06	0.30*
	S.E.gi	0.68	0.64	0.58	0.36	0.10	0.11	0.11	0.06
	Hybrids	SCA Effects							
1.	GAOB-2 x GOB-1	-2.08	-3.92 *	-1.18	-2.39	2.07 *	2.14 *	2.81 *	2.34*
2.	GAOB-2 x PS	-1.57	3.21	-3.08	-0.48	-3.50 *	-3.97 *	-4.93 *	-4.13*
3.	GAOB-2 x JBGR-1	-2.31	9.47 *	1.52	2.89*	1.69 *	1.15 *	0.16	1.00*
4.	GAOB-2 x SM	6.96 *	-0.82	1.06	2.40	1.74 *	1.08 *	1.65 *	1.49*
5.	GAOB-2 x PU	1.73	2.74	-3.67 *	0.27	0.91 *	0.91 *	2.05 *	1.29*
6.	GAOB-2 x GRB-5	7.68 *	2.31	3.50 *	4.50*	3.08 *	3.83 *	4.05 *	3.65*
7.	GAOB-2 x NBL-117	-2.21	-8.21 *	-6.73 *	-5.72*	2.31 *	2.62 *	1.32 *	2.08*
8.	GAOB-2 x GJLB-4	-2.06	2.22	4.16 *	1.44	-2.68 *	-2.62 *	-3.04 *	-2.78*
9.	GOB-1 x PS	5.59 *	-4.43 *	3.28	1.48	-1.38 *	-1.23 *	-2.12 *	-1.58*
10.	GOB-1 x JBGR-1	6.94 *	1.57	4.01 *	4.17*	-0.55	-1.18 *	-0.06	-0.60*
11.	GOB-1 x SM	10.49 *	11.78 *	2.72	8.33*	0.31	1.24 *	1.30 *	0.95
12.	GOB-1 x PU	-1.47	3.64	-0.56	0.54	1.63 *	1.30 *	1.16 *	1.36-
13.	GOB-1 x GRB-5	6.89 *	4.67 *	2.48	4.68*	-0.18	0.18	0.19	0.06
14.	GOB-1 x NBL-117	-11.52 *	-4.59 *	3.99 *	-4.04*	-1.36 *	-0.84 *	-1.80 *	-1.33*
15.	GOB-1 x GJLB-4	-0.24	2.27	0.02	0.68	-1.86 *	-1.44 *	-1.04 *	-1.45*
16.	PS x JBGR-1	6.65 *	2.10	0.29	3.01*	0.40	-0.57	-0.62 *	-0.26
17.	PS x SM	6.88 *	6.02 *	11.00 *	7.97*	0.31	-0.21	0.93 *	0.34
18.	PS x PU	1.48	-8.06 *	-0.93	-2.50*	-1.39 *	-2.17 *	-2.65 *	-2.07*
19.	PS x GRB-5	7.16 *	2.94	-3.74 *	2.12*	0.93 *	0.23	0.15	0.44
20.	PS x NBL-117	5.13 *	0.51	9.17 *	4.94*	0.48	-0.50	-0.76 *	-0.26
21.	PS x GJLB-4	-11.16 *	-4.10 *	-5.04 *	-6.77*	3.08 *	2.74 *	3.87 *	3.23*
22.	JBGR-1 x SM	2.73	1.63	6.71 *	3.69	1.91 *	0.52	1.18 *	1.20
23.	JBGR-1 x PU	6.26 *	5.40 *	4.45 *	5.37*	-1.36 *	-1.53 *	-1.51 *	-1.47*
24.	JBGR-1 x GRB-5	10.61 *	2.23	5.11 *	5.98*	-0.83 *	-0.71 *	-0.28	-0.61*
25.	JBGR-1 x NBL-117	1.07	-5.93 *	-6.51 *	-3.79*	-0.77 *	-0.65	-0.74 *	-0.72*
26.	JBGR-1 x GJLB-4	-2.60	-6.68 *	-11.6 *	-6.97*	-1.07 *	0.65	-1.06 *	-0.49
27.	SM x PU	0.42	0.55	-5.64 *	-1.56*	-1.41 *	-1.02 *	-0.80 *	-1.08*
28.	SM x GRB-5	-6.56 *	-2.40	-2.74	-3.90	1.22 *	0.83 *	-0.21	0.61*
29.	SM x NBL-117	0.23	-1.99	-2.12	-1.29	-1.12 *	-0.82 *	-0.62 *	-0.85*
30.	SM x GJLB-4	-1.65	-7.44 *	-8.04 *	-5.71*	-1.38 *	-1.76 *	-1.79 *	-1.64*
31.	PU x GRB-5	-4.31 *	0.85	4.17 *	0.24*	1.84 *	1.24 *	0.29	1.12*
32.	PU x NBL-117	2.40	1.51	-0.93	0.99	0.78 *	0.46	0.73 *	0.66
33.	PU x GJLB-4	-1.44	7.94 *	0.40	2.30	0.75 *	0.71 *	0.49	0.65
34.	GRB-5 x NBL-117	-4.43 *	8.84 *	-7.18 *	-0.92*	-0.84 *	-0.47	-1.01 *	-0.77
35.	GRB-5 x GJLB-4	3.90 *	-2.86	6.46 *	2.50*	-1.67 *	-2.03 *	-2.02 *	-1.91*
36.	NBL-117 x GJLB-4	5.00 *	0.22	10.48 *	5.23*	1.64 *	0.87 *	1.11 *	1.21*
	S.Esij	2.19	2.08	1.88	1.18	0.34	0.38	0.33	0.20

* and ** indicate significance at 5% and 1% levels of probability, respectively

Table 13: Estimates of GCA and SCA effects for fruits girth & fruit weight

Sr. No.	Parents	Fruit girth				Fruit weight			
		GCA Effects				GCA Effects			
		Navsari (E_1)	Vanarasi (E_2)	Waghai (E_3)	Pooled	Navsari (E_1)	Vanarasi (E_2)	Waghai (E_3)	Pooled
1.	GAOB-2	8.42 *	8.87 *	6.77 *	8.02*	1.76 *	0.79	0.51	1.28*
2.	GOB-1	2.85 *	4.07 *	6.01 *	4.31*	1.60 *	0.55	0.24	0.80
3.	Punjab Sadabahar	-3.15 *	-3.71 *	-4.49 *	-3.78*	-2.90 *	-2.96 *	-3.06 **	-2.98*
4.	JBGR-1	-6.78 *	-9.67 *	-6.85 *	-7.77*	1.35 *	2.12 *	1.73 **	1.73*
5.	Swarna Mani	8.10 *	7.79 *	5.38 *	7.09*	0.50	0.05	0.81	0.45
6.	Pusa Upkar	9.11 *	10.79 *	8.71 *	9.54*	-0.99 *	-0.60	-0.55	-0.71
7.	GRB-5	-7.58 *	-5.93 *	-6.79 *	-6.77*	3.53 *	3.84 *	3.19 **	3.52*
8.	NBL-117	-4.97 *	-6.28 *	-5.47 *	-5.57*	0.71	0.79	0.43	0.64
9.	GJLB-4	-5.98 *	-5.91 *	-3.27 *	-5.05*	-5.56 *	-4.59 *	-3.31 **	-4.49*
	S.E.gi	1.42	1.41	1.28	0.74	0.46	0.46	0.45	0.26
	Hybrids	SCA Effects							
1.	GAOB-2 x GOB-1	8.50 *	8.29 *	6.75 *	7.85*	5.55 *	5.41 *	4.66 *	5.21*
2.	GAOB-2 x PS	-3.41	-13.28 *	4.12	-4.19	-6.04 *	-7.74 *	-8.04 *	-7.27*
3.	GAOB-2 x JBGR-1	7.30	18.04 *	9.26 *	11.53*	2.69 *	0.06	3.80 *	2.18
4.	GAOB-2 x SM	10.65 *	10.78 *	8.39 *	9.94*	0.66	-0.78	1.31	0.40
5.	GAOB-2 x PU	6.00	0.09	-5.39	0.23	-0.43	-0.13	-0.87	-0.48
6.	GAOB-2 x GRB-5	-11.96 *	-6.54	-11.06 *	-9.85*	1.77	-1.86	-2.06	-0.72
7.	GAOB-2 x NBL-117	-5.86	1.15	-0.77	-1.83	1.19	4.94 *	2.28	2.80*
8.	GAOB-2 x GJLB-4	7.13	-0.62	1.02	2.51	2.76 *	0.79	1.92	1.82
9.	GOB-1 x PS	11.50 *	17.76 *	0.99	10.08*	-1.02	-2.02	-2.32	-1.79
10.	GOB-1 x JBGR-1	-3.46	-7.87 *	18.89 *	2.52	1.3	0.31	0.78	0.80
11.	GOB-1 x SM	-2.38	-0.67	10.23 *	2.39	-0.5	-1.25	1.63	-0.04
12.	GOB-1 x PU	17.91 *	22.21 *	18.31 *	19.48*	2.06	-0.04	6.06 *	2.69*
13.	GOB-1 x GRB-5	-12.00 *	-23.79 *	-22.95 *	-19.58*	1.22	-1.32	-1.94	-0.68
14.	GOB-1 x NBL-117	-5.24	-17.15 *	-8.45 *	-10.28*	-1.25	-0.98	-1.71	-1.31
15.	GOB-1 x GJLB-4	-8.90 *	-10.43 *	-16.96 *	-12.10*	-2.80 *	0.73	-3.34 *	-1.80*
16.	PS x JBGR-1	10.30 *	8.36 *	5.57	8.08*	-0.37	-0.90	-2.95 *	-1.41
17.	PS x SM	-3.37	3.54	-0.52	-0.12	-0.61	1.56	3.32 *	1.42*
18.	PS x PU	-11.05 *	-21.42 *	-10.08 *	-14.18*	2.35	-1.23	2.83 *	1.32*
19.	PS x GRB-5	-9.36 *	-23.95 *	-13.47 *	-15.59*	-1.11	1.54	0.44	0.29
20.	PS x NBL-117	-3.09	-1.11	-4.36	-2.85	-0.47	-0.29	-1.45	-0.74
21.	PS x GJLB-4	13.72 *	13.51 *	3.38	10.20*	-1.05	1.96	3.18 *	1.36*
22.	JBGR-1 x SM	0.53	0.77	-11.20 *	-3.30	2.53	2.72 *	1.12	2.12*
23.	JBGR-1 x PU	-6.45	-13.56 *	-15.50 *	-11.84*	2.52	5.97 *	2.08	3.52*
24.	JBGR-1 x GRB-5	0.98	-8.60 *	-11.53 *	-6.38*	-0.72	6.35 *	5.80 *	3.81*
25.	JBGR-1 x NBL-117	7.78	-4.03	7.62 *	3.79	-1.89	-5.90 *	-1.99	-3.26*
26.	JBGR-1 x GJLB-4	-13.80 *	-15.65 *	-10.53 *	-13.33*	-5.98 *	-3.12 *	-1.74	-3.61*
27.	SM x PU	-4.26	-5.04	-1.83	-3.71	3.62 *	7.18 *	1.82	4.21*
28.	SM x GRB-5	15.80 *	15.53 *	6.75 *	12.69*	5.88 *	4.91 *	2.54	4.44*
29.	SM x NBL-117	-9.41 *	-7.28 *	-10.66 *	-9.12*	-2.07	-2.14	-4.37 *	-2.86*
30.	SM x GJLB-4	-4.17	-10.07 *	4.62	-3.21	-4.89 *	-4.05 *	-1.48	-3.47*
31.	PU x GRB-5	11.77 *	14.89 *	12.27 *	12.98*	-2.91 *	-2.79 *	2.08	-1.21*
32.	PU x NBL-117	11.73 *	12.27 *	1.51	8.50*	1.98	3.33 *	0.68	2.00*
33.	PU x GJLB-4	1.78	-7.76 *	4.61	-0.46	-4.31 *	-5.85 *	-7.25 *	-5.80*
34.	GRB-5 x NBL-117	12.05 *	7.13	3.62	7.60	1.11	0.65	3.07 *	1.61*
35.	GRB-5 x GJLB-4	-13.34 *	-6.56	-10.18 *	-10.03*	-1.85	1.75	-0.50	-0.20*
36.	NBL-117 x GJLB-4	8.92 *	8.22 *	11.44 *	9.53*	2.85 *	-0.56	2.55	1.61*
	S.E.sij	4.58	3.68	4.12	2.39	1.53	1.49	1.45	0.85

* and ** indicate significance at 5% and 1% levels of probability, respectively

Table 15: Estimation of GCA and SCA for fruits per plant and seeds per fruit

Sr. No.	Parents	Fruit per plant				Seeds per fruit			
		GCA Effects				GCA Effects			
		Navsari (E_1)	Vanarasi (E_2)	Waghai (E_3)	Pooled	Navsari (E_1)	Vanarasi (E_2)	Waghai (E_3)	Pooled
1.	GAOB-2	1.76 *	0.79	0.51	1.28*	92.44 *	65.65 *	105.71 *	87.94*
2.	GOB-1	1.60 *	0.55	0.24	0.80	-0.46	20.87	39.56 *	19.99
3.	Punjab Sadabahar	-2.90 *	-2.96 *	-3.06 **	-2.98*	-173.48 *	-185.99 *	-205.43 *	-188.30*
4.	JBGR-1	1.35 *	2.12 *	1.73 **	1.73*	110.41 *	142.81 *	145.32 *	132.84*
5.	Swarna Mani	0.50	0.05	0.81	0.45	3.04	17.44	1.50	7.32
6.	Pusa Upkar	-0.99 *	-0.60	-0.55	-0.71	137.26 *	121.06 *	102.92 *	120.41*
7.	GRB-5	3.53 *	3.84 *	3.19 **	3.52*	84.65 *	44.75 *	78.39 *	69.26*
8.	NBL-117	0.71	0.79	0.43	0.64	-102.01 *	-86.62 *	-91.45 *	-93.36*

9.	GJLB-4	-5.56 *	-4.59 *	-3.31 **	-4.49*	-151.87 *	-139.97 *	-176.53 *	-156.12*
	S.E.gi	0.46	0.46	0.45	0.26	15.84	14.38	12.94	8.33
	Hybrids	SCA Effects							
1.	GAOB-2 x GOB-1	5.55 *	5.41 *	4.66 *	5.21*	53.29	83.66 *	7.01	47.99
2.	GAOB-2 x PS	-6.04 *	-7.74 *	-8.04 *	-7.27*	-128.29 *	-45.44	-113.63 *	-95.79*
3.	GAOB-2 x JBGR-1	2.69 *	0.06	3.80 *	2.18	-129.78 *	-189.05 *	-146.78 *	-155.20*
4.	GAOB-2 x SM	0.66	-0.78	1.31	0.40	-157.41 *	-196.78 *	-150.20 *	-168.13*
5.	GAOB-2 x PU	-0.43	-0.13	-0.87	-0.48	52.50	-10.37	-139.68 *	-32.52
6.	GAOB-2 x GRB-5	1.77	-1.86	-2.06	-0.72	-6.32	62.94	84.68 *	47.10
7.	GAOB-2 x NBL-117	1.19	4.94 *	2.28	2.80*	150.11 *	64.45	191.86 *	135.47*
8.	GAOB-2 x GJLB-4	2.76 *	0.79	1.92	1.82	-177.06 *	-44.83	-70.70	-97.53
9.	GOB-1 x PS	-1.02	-2.02	-2.32	-1.79	-8.38	71.85	99.39 *	54.29
10.	GOB-1 x JBGR-1	1.3	0.31	0.78	0.80	-104.24 *	-89.66 *	-7.06	-66.99
11.	GOB-1 x SM	-0.5	-1.25	1.63	-0.04	99.92 *	91.14 *	9.95	67.00
12.	GOB-1 x PU	2.06	-0.04	6.06 *	2.69*	-76.27	17.25	-33.43	-30.82
13.	GOB-1 x GRB-5	1.22	-1.32	-1.94	-0.68	131.78 *	35.13	24.70	63.87
14.	GOB-1 x NBL-117	-1.25	-0.98	-1.71	-1.31	-16.59	91.34 *	85.52 *	53.42*
15.	GOB-1 x GJLB-4	-2.80 *	0.73	-3.34 *	-1.80*	-7.96	-22.61	-32.51	-21.03
16.	PS x JBGR-1	-0.37	-0.90	-2.95 *	-1.41	-169.12 *	-226.67 *	-162.63 *	-186.14*
17.	PS x SM	-0.61	1.56	3.32 *	1.42*	58.82	-88.56 *	-40.78	-23.51
18.	PS x PU	2.35	-1.23	2.83 *	1.32*	-188.51 *	-297.48 *	-160.93 *	-215.64*
19.	PS x GRB-5	-1.11	1.54	0.44	0.29	-5.73	3.06	32.63	9.99
20.	PS x NBL-117	-0.47	-0.29	-1.45	-0.74	86.34	110.67 *	122.48 *	106.50*
21.	PS x GJLB-4	-1.05	1.96	3.18 *	1.36*	314.04 *	364.42 *	230.15 *	302.87*
22.	JBGR-1 x SM	2.53	2.72 *	1.12	2.12*	181.69 *	164.27 *	28.40	124.79*
23.	JBGR-1 x PU	2.52	5.97 *	2.08	3.52*	-98.77 *	208.34 *	-37.18	24.13*
24.	JBGR-1 x GRB-5	-0.72	6.35 *	5.80 *	3.81*	11.68	27.18	33.91	24.26
25.	JBGR-1 x NBL-117	-1.89	-5.90 *	-1.99	-3.26*	40.91	89.36 *	11.06	47.11
26.	JBGR-1 x GJLB-4	-5.98 *	-3.12 *	-1.74	-3.61*	-86.42	-111.62 *	-134.53 *	-110.86*
27.	SM x PU	3.62 *	7.18 *	1.82	4.21*	52.34	-94.44 *	195.63 *	51.18*
28.	SM x GRB-5	5.88 *	4.91 *	2.54	4.44*	-77.64	-26.54	73.32 *	-10.29
29.	SM x NBL-117	-2.07	-2.14	-4.37 *	-2.86*	124.31 *	218.36 *	252.17 *	198.28*
30.	SM x GJLB-4	-4.89 *	-4.05 *	-1.48	-3.47*	-405.89 *	-266.73 *	-464.51 *	-379.04*
31.	PU x GRB-5	-2.91 *	-2.79 *	2.08	-1.21*	152.76 *	222.68 *	188.21 *	187.88*
32.	PU x NBL-117	1.98	3.33 *	0.68	2.00*	65.24	146.78 *	178.01 *	130.01
33.	PU x GJLB-4	-4.31 *	-5.85 *	-7.25 *	-5.80*	-138.06 *	-233.36 *	-145.65 *	-172.36*
34.	GRB-5 x NBL-117	1.11	0.65	3.07 *	1.61*	295.46 *	60.33	-37.77	106.01
35.	GRB-5 x GJLB-4	-1.85	1.75	-0.50	-0.20*	-118.06 *	-147.72 *	-110.87 *	-125.55*
36.	NBL-117 x GJLB-4	2.85 *	-0.56	2.55	1.61*	-98.52 *	-37.08	-29.94	-55.18
	S.E.sij	1.53	1.49	1.45	0.85	50.98	46.27	41.63	36.82

* and ** indicate significance at 5% and 1% levels of probability, respectively

Table 16: Estimates of GCA and SCA effects for fruit yield per plant

Sr. No.	Genotypes	Fruit yield per plant			
		Navsari (E_1)	Vanarasi (E_2)	Waghai (E_3)	Pooled
	Parents	**GCA Effects**			
1.	GAOB-2	314.80 *	221.71 *	160.53 *	232.35*
2.	GOB-1	163.19 *	126.78 *	144.83 *	144.94*
3.	Punjab Sadabahar	-435.96 *	-417.71 *	-324.55 *	-392.74*
4.	JBGR-1	13.19	-128.67 *	-103.29 *	-72.92*
5.	Swarna Mani	272.83 *	117.03 *	228.47 *	206.11*
6.	Pusa Upkar	191.01 *	343.63 *	190.80 *	241.81*
7.	GRB-5	181.24 *	97.50	65.60	114.78*
8.	NBL-117	-120.83	40.83	-29.39	-36.46
9.	GJLB-4	-579.50 *	-401.11 *	-333.00 *	-437.87*
	S.E.gi	62.32	52.54	40.83	30.09
	Hybrids	SCA Effects			
1.	GAOB-2 x GOB-1	342.92	855.28 *	548.31 *	582.17*
2.	GAOB-2 x PS	-606.58 *	-779.80 *	-537.68 *	-641.35*
3.	GAOB-2 x JBGR-1	673.42 *	541.29 *	458.18 *	557.63*
4.	GAOB-2 x SM	373.97 *	-35.17	248.88 *	195.89*
5.	GAOB-2 x PU	64.85	-430.54 *	-190.98	-185.56
6.	GAOB-2 x GRB-5	-67.58	-341.16 *	-374.10 *	-260.95*
7.	GAOB-2 x NBL-117	-75.83	375.44 *	69.34	122.98
8.	GAOB-2 x GJLB-4	640.59 *	116.89	220.65	326.04
9.	GOB-1 x PS	369.18 *	37.44	-148.68	85.98

10.	GOB-1 x JBGR-1	-3.04	76.76	547.25 *	206.99
11.	GOB-1 x SM	-193.92	-387.90 *	149.72	-144.03
12.	GOB-1 x PU	763.89 *	604.00 *	699.51 *	689.13*
13.	GOB-1 x GRB-5	-304.25	-727.06 *	-703.51 *	-578.27*
14.	GOB-1 x NBL-117	-73.59	-562.76 *	-350.71 *	-329.02*
15.	GOB-1 x GJLB-4	-370.18 *	-142.35	-580.59 *	-364.37*
16.	PS x JBGR-1	290.95	124.75	142.69	186.13
17.	PS x SM	90.76	304.92 *	335.50 *	243.73*
18.	PS x PU	77.04	-522.78 *	-21.74	-155.83
19.	PS x GRB-5	-461.62 *	-502.11 *	-300.39 *	-421.37*
20.	PS x NBL-117	-409.64 *	-159.70	-332.06 *	-300.47*
21.	PS x GJLB-4	-30.17	588.21 *	220.08	259.37
22.	JBGR-1 x SM	341.86	-21.56	-241.16 *	26.38
23.	JBGR-1 x PU	131.04	-22.58	-287.38 *	-59.64
24.	JBGR-1 x GRB-5	272.13	-76.63	-289.67 *	-31.39
25.	JBGR-1 x NBL-117	252.74	-537.12 *	76.67	-69.24
26.	JBGR-1 x GJLB-4	-917.59 *	-482.85 *	-329.44 *	-576.63*
27.	SM x PU	104.91	516.25 *	-23.6	199.19
28.	SM x GRB-5	580.55 *	660.02 *	293.72 *	511.43*
29.	SM x NBL-117	-301.41	-242.21	-733.09 *	-425.57
30.	SM x GJLB-4	-490.24 *	-519.65 *	20.16	-329.91*
31.	PU x GRB-5	162.97	356.67 *	944.32 *	487.99*
32.	PU x NBL-117	581.01 *	703.63 *	-0.09	428.18*
33.	PU x GJLB-4	-605.12 *	-910.68 *	-763.05 *	-759.62*
34.	GRB-5 x NBL-117	616.85 *	-100.29	287.95 *	268.17*
35.	GRB-5 x GJLB-4	-367.25 *	112.59	-88.63	-114.43
36.	NBL-117 x GJLB-4	641.85 *	498.22 *	695.56 *	611.88*
	S.E.sij	200.03	169.80	131.38	167.77

* and ** indicate significance at 5% and 1% levels of probability, respectively

Table 17: Estimates of GCA and SCA effects for total phenol content & total soluble sugar

Sr. No.	Parents	Total phenol content				Total soluble sugar			
		GCA Effects				GCA Effects			
		Navsari (E_1)	Vanarasi (E_2)	Waghai (E_3)	Pooled	Navsari (E_1)	Vanarasi (E_2)	Waghai (E_3)	Pooled
1.	GAOB-2	0.51 *	0.49 *	0.49 *	0.50*	-0.22 *	-0.27 *	-0.27 *	-0.25*
2.	GOB-1	0.05 *	0.05 *	0.09 *	0.06*	-0.03	0.01	0.09	-0.07
3.	Punjab Sadabahar	0.14 *	0.16 *	0.14 *	0.15*	0.36 *	0.35 *	0.40 *	0.37*
4.	JBGR-1	0.49 *	0.49 *	0.47 *	0.48*	-0.04 *	-0.03	-0.02	-0.03
5.	Swarna Mani	-0.57 *	-0.54 *	-0.53 *	-0.55*	0.07 *	0.04	0.13 *	0.08*
6.	Pusa Upkar	-0.08 *	-0.08 *	-0.05	-0.07*	0.17 *	0.25 *	0.24 *	0.22*
7.	GRB-5	-0.33 *	-0.34 *	-0.35 *	-0.34*	-0.03	0.01	-0.03	-0.02
8.	NBL-117	-0.02	0.01	-0.04	0.013	-0.19 *	-0.23 *	-0.27 *	-0.23*
9.	GJLB-4	-0.20 *	-0.22 *	-0.22 *	-0.21	-0.08 *	-0.11 *	-0.17 *	-0.12*
	S.E.gi	0.02	0.02	0.03	0.01	0.021	0.024	0.029	0.01
	Hybrids	SCA Effects				SCA Effects			
1.	GAOB-2 x GOB-1	2.19 *	2.19 *	2.15 *	2.18*	-0.88 *	-0.79 *	-1.00 *	-0.89*
2.	GAOB-2 x PS	3.30 *	3.05 *	3.19 *	3.18*	-0.34 *	-0.21 *	-0.25 *	-0.27*
3.	GAOB-2 x JBGR-1	2.53 *	2.53 *	2.51 *	2.52*	0.69 *	0.69 *	0.67 *	0.68*
4.	GAOB-2 x SM	-1.00 *	-1.01 *	-1.02 *	-1.01*	-0.68 *	-0.70 *	-0.63 *	-0.67*
5.	GAOB-2 x PU	-0.38 *	-0.40 *	-0.44 *	-0.41*	0.83 *	0.86 *	0.96 *	0.88*
6.	GAOB-2 x GRB-5	-1.40 *	-1.31 *	-1.34 *	-1.35*	-0.09	-0.26 *	-0.33 *	-0.23*
7.	GAOB-2 x NBL-117	-1.65 *	-1.61 *	-1.63 *	-1.63*	0.06	-0.04	-0.02	0.00
8.	GAOB-2 x GJLB-4	-0.62 *	-0.48 *	-0.52 *	-0.54*	0.44 *	0.45 *	0.57 *	0.49*
9.	GOB-1 x PS	1.18 *	1.07 *	0.99 *	1.08*	0.46 *	0.48 *	0.51 *	0.48*
10.	GOB-1 x JBGR-1	-1.64 *	-1.59 *	-1.61 *	-1.61	0.16 *	0.13 *	0.21 *	0.17*
11.	GOB-1 x SM	0.09	0.12 *	0.11	0.11	-0.18 *	-0.28 *	-0.27 *	-0.24*
12.	GOB-1 x PU	-1.22 *	-1.17 *	-0.94 *	-1.11*	0.57 *	0.56 *	0.61 *	0.58*
13.	GOB-1 x GRB-5	-0.98 *	-1.01 *	-1.19 *	-1.06*	-0.08	-0.09	-0.08	-0.08
14.	GOB-1 x NBL-117	-0.03	-0.1	0.09	-0.01	0.82 *	1.06 *	1.04 *	0.97*
15.	GOB-1 x GJLB-4	-1.63 *	-1.62 *	-1.63 *	-1.63*	-0.22 *	-0.31 *	-0.42 *	-0.32*
16.	PS x JBGR-1	-2.06 *	-2.03 *	-1.88 *	-1.99*	-0.01	-0.02	0.01	-0.01
17.	PS x SM	-0.98 *	-0.96 *	-0.93 *	-0.96*	0.01	0.1	0.11	0.07
18.	PS x PU	-0.57 *	-0.55 *	-0.48 *	-0.53*	0.29 *	0.38 *	0.34 *	0.34*
19.	PS x GRB-5	-0.19 *	-0.08	-0.19 *	-0.15*	-0.52 *	-0.46 *	-0.39 *	-0.46*
20.	PS x NBL-117	-0.89 *	-0.94 *	-0.90 *	-0.91*	0.18 *	0.13 *	0.11	0.14*
21.	PS x GJLB-4	-0.46 *	-0.50 *	-0.39 *	-0.45*	0.26 *	0.17 *	0.18 *	0.20*

22.	JBGR-1 x SM	-0.48 *	-0.39 *	-0.55 *	-0.47*	0.37 *	0.38 *	0.30 *	0.35*
23.	JBGR-1 x PU	-0.71 *	-0.78 *	-0.86 *	-0.78*	0.39 *	0.58 *	0.61 *	0.53*
24.	JBGR-1 x GRB-5	1.83 *	1.80 *	1.85 *	1.83*	0.26 *	0.33 *	0.36 *	0.32*
25.	JBGR-1 x NBL-117	0.06	0.05	0.04	0.05	-0.28 *	-0.33 *	-0.36 *	-0.32*
26.	JBGR-1 x GJLB-4	-0.30 *	-0.37 *	-0.35 *	-0.34*	-0.33 *	-0.46 *	-0.47 *	-0.42*
27.	SM x PU	-0.32 *	-0.31 *	-0.11	-0.25*	-1.04 *	-1.22 *	-1.18 *	-1.15*
28.	SM x GRB-5	0.14 *	0.11	0.14	0.13	-0.49 *	-0.60 *	-0.46 *	-0.52*
29.	SM x NBL-117	-0.68 *	-0.64 *	-0.54 *	-0.62*	-0.52 *	-0.68 *	-0.60 *	-0.60*
30.	SM x GJLB-4	0.99 *	0.90 *	0.85 *	0.91*	0.82 *	0.92 *	0.89 *	0.88*
31.	PU x GRB-5	0.62 *	0.64 *	0.61 *	0.62*	-0.49 *	-0.67 *	-0.64 *	-0.60*
32.	PU x NBL-117	1.78 *	1.85 *	1.84 *	1.82*	-1.18 *	-1.00 *	-1.03 *	-1.07*
33.	PU x GJLB-4	-1.43 *	-1.48 *	-1.69 *	-1.53*	0.87 *	1.05 *	1.22 *	1.05*
34.	GRB-5 x NBL-117	-0.24 *	-0.24 *	-0.29 *	-0.26*	0.06	0.15 *	0.05	0.09
35.	GRB-5 x GJLB-4	0.73 *	0.52 *	0.81 *	0.69*	-0.72 *	-0.51 *	-0.50 *	-0.58*
36.	NBL-117 x GJLB-4	1.80 *	1.93 *	1.71 *	1.81*	0.20 *	0.02	0.02	0.08
	S.E.sij	0.07	0.06	0.10	0.04	0.06	0.07	0.09	0.04

* and ** indicate significance at 5% and 1% levels of probability, respectively

Table 19: Estimates of GCA and SCA effects for Shoot and fruit borer infestation and little leaf incidence

Sr. No.	Parents	Shoot and fruit borer infestation				Little leaf incidence			
		SCA Effects				SCA Effects			
		Navsari (E_1)	Vanarasi (E_2)	Waghai (E_3)	Pooled	Navsari (E_1)	Vanarasi (E_2)	Waghai (E_3)	Pooled
1.	GAOB-2 x GOB-1	-3.60 *	-4.13 *	3.07 *	-1.55*	-0.06	2.49	4.47 *	2.30
2.	GAOB-2 x PS	-1.52	2.54 *	-2.84 *	-0.61*	4.57 *	0.35	-5.25 *	-0.11*
3.	GAOB-2 x JBGR-1	-2.10	2.68 *	1.97 *	0.85*	-1.92	6.68 *	-1.58	1.06
4.	GAOB-2 x SM	3.21	5.95 *	-1.97 *	2.40*	2.33	-0.29	-3.03	-0.33
5.	GAOB-2 x PU	-0.82	1.16	1.42 *	0.59	0.07	1.34	0.95	0.79
6.	GAOB-2 x GRB-5	6.23 *	-0.08	0.27	2.14	6.12 *	1.31	8.75 *	5.39*
7.	GAOB-2 x NBL-117	2.33	1.73	-0.03	1.34	2.53	-1.09	2.37	1.27
8.	GAOB-2 x GJLB-4	0.80	-0.91	0.39	0.09	-3.71	-2.91	-3.46	-3.36
9.	GOB-1 x PS	-0.20	2.52 *	-0.17	0.72	1.46	2.21	-1.82	0.62
10.	GOB-1 x JBGR-1	1.09	-0.35	-0.93	-0.06	-0.61	-1.91	-0.46	-0.99
11.	GOB-1 x SM	-0.70	0.58	-1.41 *	-0.51	0.71	-0.65	-3.21	-1.05
12.	GOB-1 x PU	4.63 *	0.74	1.56 *	2.31*	2.43	-3.09	5.55 *	1.63
13.	GOB-1 x GRB-5	7.02 *	2.23 *	0.88	3.38*	6.86 *	-4.92 *	5.64 *	2.53*
14.	GOB-1 x NBL-117	-2.58	2.74 *	-0.71	-0.18	-2.43	2.83	-3.82 *	-1.14
15.	GOB-1 x GJLB-4	0.65	-0.62	-0.84	-0.27	0.01	0.94	0.34	0.43
16.	PS x JBGR-1	3.87 *	5.05 *	-0.64	2.76*	2.26	0.20	-2.03	0.14
17.	PS x SM	3.91 *	-0.90	0.25	1.09	1.71	1.95	4.25 *	2.64
18.	PS x PU	-2.35	1.14	-0.86	-0.69	0.90	0.29	-4.27 *	-1.03
19.	PS x GRB-5	-1.50	-3.22 *	-2.50 *	-2.41*	-1.88	-6.04 *	-0.05	-2.66*
20.	PS x NBL-117	-1.50	-2.11 *	1.40 *	-0.74*	-0.72	0.04	0.59	-0.03
21.	PS x GJLB-4	2.46	-1.00	0.18	0.55	2.43	-1.05	2.16	1.18
22.	JBGR-1 x SM	2.47	0.8	0.85	1.37	2.43	-1.36	2.35	1.14
23.	JBGR-1 x PU	-0.56	-1.26	-1.85 *	-1.22	4.53 *	-5.06 *	3.01	0.83*
24.	JBGR-1 x GRB-5	0.89	-0.78	1.98 *	0.70	-2.78	-0.71	0.65	-0.95
25.	JBGR-1 x NBL-117	-0.54	-1.57	4.86 *	0.92	3.16	3.89 *	5.83 *	4.29*
26.	JBGR-1 x GJLB-4	-0.31	-1.53	-2.91 *	-1.58	0.81	-1.09	-1.44	-0.57
27.	SM x PU	-3.68 *	-0.80	0.52	-1.32	-3.31	0.87	-2.25	-1.56
28.	SM x GRB-5	-4.90 *	-1.78	1.36 *	-1.77*	-2.22	2.47	-1.00	-0.25
29.	SM x NBL-117	-2.40	1.02	-1.18	-0.85	-1.35	-0.85	-4.53 *	-2.24
30.	SM x GJLB-4	0.93	-0.88	-2.05 *	-0.67	2.75	2.46	-1.94	1.09
31.	PU x GRB-5	0.94	0.86	-3.95 *	-0.72	3.32	-0.70	-3.27	-0.22
32.	PU x NBL-117	3.33	0.65	-1.63 *	0.78	6.05 *	2.87	-0.18	2.91*
33.	PU x GJLB-4	-1.40	-1.66	1.02	-0.68	-4.79 *	-0.35	3.95 *	-0.40*
34.	GRB-5 x NBL-117	-1.65	-0.98	0.42	-0.74	-4.85 *	-0.33	-5.16 *	-3.45*
35.	GRB-5 x GJLB-4	3.52 *	0.25	-2.39 *	0.46	6.67 *	-4.10 *	2.07	1.55*
36.	NBL-117 x GJLB-4	2.45	-0.01	1.92 *	1.45	0.91	0.43	6.87 *	2.74
	S.E.sij	1.98	0.08	0.74	0.79	2.17	1.93	2.03	2.18

* and ** indicate significance at 5% and 1% levels of probability, respectively

Conclusions

The parents GAOB-2, GOB-1, Swarna Mani and Pusa Upkar were good general combiners for fruit yield per plant and some of its direct components like fruit weight and fruits per plant. The parents Punjab Sadabahar, Swarna Mani, NBL-117 and Swarna Mani were good general combiners for dwarfness and early 50 per cent flowering. The hybrids GAOB-2 X Swarna Mani, GOB-1 x Punjab Sadabahar, GAOB-2 x JBGR-1, GOB-1 x Pusa Upkar and GAOB-2 x GOB-1 having high SCA effects for fruit yield per plant also registered high and

desirable SCA effects for fruit length, fruit girth, fruit weight, fruits per plant. Hybrid GOB-1 x NBL-117 and GAOB-2 x JBGR-1 also recorded a high and desirable SCA effect for days to 50 per cent flowering. Most of the crosses with high per se performance involved at least one good general combining parent such as Pusa Upkar, Swarna Mani, GOB-1 and GAOB-2 through out for all studied characters.

A good agreement between the best general combining parents and the best performing parents such as Swarna Mani, GAOB-2, Pusa Upkar and GOB-1 for most of the traits, revealed parallel behavior between *per se* performance and GCA effect of parents. Combining ability studies revealed that both additive and non-additive type of gene actions were involved in the expression of fruit yield and its related traits. However, non-additive gene action was found predominant in the expression of the traits. Many crosses having high SCA effects also involved at least one good general combiner parent which may be considered useful because such crosses provide transgressive type of segregants in the advanced generation more frequently than crosses with the poor combiner parents. None of the parents was a good general combiner for all the traits under study.

Conflict of Interest

Conflict of interest none declared.

References

1. Aswani AC, Khandelwal RC. Combining ability studies in brinjal. Ind. J Hort. 2005;62(1):37-40.
2. Datta DR, Rafii MY, Misran A, Jusoh M, Yusuff O, Haque MA, *et al*. Half diallel analysis for biochemical and morphological traits in cultivated eggplants (*Solanum melongena* L.). Agronomy. 2021;11(9):1769.
3. Dharwad NA, Patil SA, Salimath PM. Heterosis and Combining ability analysis for productivity traits in brinjal (*Solanum melongena* L.). Karnataka J Agric. Sci. 2011;24(5):622-625.
4. Dhirendra Kumar S, Patel RK, Dhoot R, Chandrabhan A. Diallel analysis for study of Combining ability for Qualitative and Quantitative traits in brinjal (*Solanum melongena* L.). Int. J Pl. App. Biosci. 2017;5(6):482-488.
5. Griffing B. Concept of general and specific combining ability in relation to diallel crossing system. Aust. J Biol. Sci. 1956;9:463-493.
6. Hussain K, Khan SH, Parveen K, Mukhdoomi MI, Nazir G, Afroza B, Dar ZA. Combining Ability Analysis in brinjal (*Solanum melongena* L.). Int. J Curr. Microbiol. App. Sci. 2017;6(7):1645-1655.
7. Kachouli B, Singh AK, Jatav SK, Kushwah SS. Combining ability analysis for yield and yield attributes characters in brinjal (*Solanum melongena* L.). J Pharm. and Phyto. 2019;8(3):4009-4012.
8. Kamalakkannan T, Karuppaiah P, Sekar K, Senthilkumar P. Line x tester analysis in brinjal for yield and shoot and fruit borer tolerance. Ind. J Hort. 2007;64(4):420-424.
9. Kumar DR, Swarna Priya R, Savitha BK, Ravikesavan R, Muthukrishnan N. Combining ability studies for quantitative and qualitative traits in brinjal (*Solanum melongena* L.). Pharm. Innov. J. 2019;8(11):16-20.
10. Kumar SR, Arumugam T. Gene action and combining ability analysis in brinjal (*Solanum melongena* L.). J Hort. Sci. 2013;8(2):249-254.
11. Makani AY, Patel AL, Bhatt MM, Patel PC. Heterosis for yield and its contributing attributes in brinjal (*Solanum melongena* L.). Biosciences. 2013;8(4):1369-1371.
12. Mishra RS, Vani AK, Singh MV, Kumar BK, Kumar BVR. Combining ability studies in elite breeding lines of brinjal (*Solanum melongena* L.) for plant characters. Asian J Bio. and Life Sci. 2013;2(3):275-278.
13. Patel AA, Gohil DP, Patel N, Patel DD. Combining ability and gene action studies in brinjal (*Solanum melongena* L.). J Pharm. and Phyto. 2017;6(5):2137-2147.
14. Patil SK, Lakshmana D, Kolakar SS, Devaraju GM, Chandana BC. Assessment of combining ability for fruit yield and its related traits in brinjal. Ind. J Chem. Stud. 2019;7(1):1210-1214.
15. Rajan N, Debnath S, Avijit K, Dutta A, Brijesh PB, Ajeet S, Singh RK. Elucidation of nature of gene action and estimation of combining ability effects for fruit yield improvement and yield attributing traits in brinjal landraces. J food quality. 2022;3(12):1745-4557
16. Sane SC, Bhalekar MN, Patil BT, Dhumal SS, Gaikwad AN, Kshirsagar DB. Combining ability for yield and yield contributing characters in brinjal (*Solanum melogena* L.). Asian J Hort. 2011;6(1):215-217.
17. Shinde KG, Bhalekar MN, Patil BT. Combining ability of quantitative characters in brinjal (*Solanum melongena* L.). Veg. Sci. 2011;38(2):231-234.
18. Singh AK, Pan RS, Bhavana P. Combining ability and gene action studies in brinjal (*Solanum melongena* L.). Veg. Sci. 2018;45(1):27-30.
19. Singh AP, Chaudhary V. Genetic analysis for yield and yield contributing characters in brinjal (*Solanum melongena* L.) over environments. Int. J Curr. Microbiol. App. Sci. 2018;7(08):1493-1504.
20. Siva M, Jyothi KU, Rao AD, Krishna BB, Uma K, Krishna MR, *et al*. Studies on combining ability for qualitative and quantitative traits in brinjal (*Solanum melongena* L.) over environments. J Entmol. and Zool. 2020;8(3):1688-1692.
21. Sprague GP, Tatum LA. General vs specific combining ability in single crosses of corn. J Am. Soc. Agron. 1942;34:923-932.
22. Suneetha Y, Kathiria KB, Patel JS, Srinivas T. Studies on heterosis and combining ability in late summer brinjal. Ind. J Agric. Res. 2008;42(3):171-176.
23. Thangavel P. Studies on gene action and combining ability for yield and other quantitative traits in brinjal (*Solanum melongena* L.). Int. J Curr. Agric. Sci. 2011;2(1):23-25.