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Heterosis breeding for improving quality traits in brinjal for export in the tropics

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ABSTRACT

Brinjal has immense potential in heterosis breeding to develop hybrids with higher yield, good fruit quality and tolerance to fruit and shoot borer. Five diverse parents were crossed in diallel fashion without reciprocals to produce 10 F_1 hybrids to determine gene effects, extent of heterosis and to estimate combining ability. Suitable breeding strategies for the condition of different characters under study by additive (total sugar content, fruit borer infestation), non-additive (days to first flowering, days to 50% flowering, plant height, number of primary branches per plant, total fruit yield per plant, marketable fruit yield per plant), both additive and non-additive (fruit length, fruit diameter, fruit weight, number of fruits per plant, total fruit phenol content) effects were discussed. One promising donor BCB-40 was identified based on significant desired gca effects and *per se* performance for total fruit yield per plant, marketable fruit yield per plant, fruit weight and low infestation of fruit borer for future breeding program. The maximum extent of significant heterobeltiosis in desired directions was recorded for marketable fruit yield per plant (50.22 %) and total fruit yield per plant (44.98 %). We could able to isolate one promising hybrid BCB-40 × KS-224 having all the desirable attributes for export promotion and could commercially be exploited after critical evaluation. Partial to over-dominance reactions for different economic traits reflect the genetic basis of heterosis.

Key words: *Solanum melongena*, gene action, combining ability, fruit borer.

INTRODUCTION

Brinjal (*Solanum melongena* L.) is the most popular and widely cultivated vegetable crop in the central, southern and Southeast Asia and in some African Countries (Hazra *et al*., 10). Though India's share in the global market is still nearly 1% only, there is increasing acceptance of horticultural produce from the country. India ranks 24th in the export trade of vegetables due to non-harmonization of international quality standards, inadequacies of export infrastructure, and export friendly rules (Shende *et al*., 17). Now-a-days, vegetable consignments from India are being rejected due to standard gaps particularly lack of export specific varieties and problem of pesticide residues (Vanitha *et al*., 22). The specification of brinjal for export to international markets particularly in South-East and South-West countries are glossy purple round shaped fruit having green calyx and devoid of spines in any plant parts (Singh and Pandey, 19). The major export destinations of brinjal from India are Sri Lanka, Maldives, Singapore, Sudan, and Mali with a worth value of 84,000 USD during the year 2013 (Anonymous, 1). The varieties developed for export purpose exhibit low yield under different agro-climatic conditions of the country. Besides these, the farmers use various harmful chemicals repeatedly to control fruit and shoot borer (Shende *et al*., 17). Exclusive reliance on chemical pesticides as a control strategy against this menace has resulted in several undesirable effects including pesticide pollution, resurgence of secondary pests, pesticide resistance, elimination of beneficial fauna and different human health hazards. The most sustainable and ecofriendly approach is the development of tolerant variety/hybrid with higher yield and better fruit quality.

Brinjal could be improved through heterosis breeding and continues to be a choice of breeders for exploitation of heterosis due to hardy nature of crop, bigger size of flowers and large number of seeds in a single act of pollination (Shende *et al*., 17). Heterosis is manifested in the form of better growth, earliness in maturity, increased productivity, better quality attributes, and higher levels of resistance to biotic stress (Chattopadhyay *et al*., 5; Shende *et al*., 17). The varying consumer acceptance from country to country also demands for development of a large number of high yielding F_1 hybrids. Diallel cross (Griffing, 8) is a useful tool to identify good combiners *vis-a-vis* illustrate the nature of gene actions involved in the expression of desirable traits.

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In view of consumer acceptability for colour, shape, taste, etc., India is not in a position to promote any suitable cultivar for export in neibouring countries. It is, therefore, necessary to develop new hybrid combinations having high yield, good fruit quality, as well as to meet the specified export criteria to foreign countries. This necessitates the development of hybrids superior in yield and fruit quality traits like low total sugar and glycoalkaloid contents; high peel anthocyanin and phenol content for export trade.

MATERIALS AND METHODS

Five diverse genotypes *viz*. BCB-40, Swarna Mani, KS-224, White Jhuri Begun, and 10/BRBW Res-3 were selected on the basis of fruit characters (Shape and colour) and yield potentiality (Table 1) to raise 10 cross combinations during *autumn-winter* season of 2016 under the research plot of AICRP on Vegetable Crops, Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal, India, situated at 23.5^0 N latitude and 89^0 E longitude at a mean sea level of 9.75m. The seeds of the five parental lines were sown in well-prepared nursery bed to raise the seedlings during first week of July, 2016. The seeds were treated with Thiram @ 3 g/kg of seed. Twenty five days old seedlings were transplanted in the crossing block during end of July, 2016 to obtain F_1s. Parents were crossed in diallel fashion excluding reciprocals and hybrid seeds were collected for the next year evaluation. Seeds of 10 F_1s and 5 parental lines were again sown in nursery bed to raise the seedlings during 1^{st} week of July, 2017. Twenty five days old seedlings of 5 parental lines and 10 F_1's were transplanted in 3.6 m × 3.0 m plot spaced at 60 cm in both ways accommodating 30 plants in each plot in the main field following Randomized Block Design with 3 replications at the end of August, 2017. Recommended dose of inorganic fertilizers @ 150:75:75 [N (urea): P (single super phosphate): K (muriate of potash)] kg/ha was applied. All recommended package of practices were followed as per Chattopadhyay *et al*. (4).

Data on days to first flowering, days to 50 % flowering, plant height (cm), and number of primary branches per plant were recorded from fifteen randomly selected plants of each plot. Samples of fifteen randomly selected fruits per plot were taken to measure the fruit characteristics i.e., fruit length (cm), fruit diameter (cm) and fruit weight (g). By adding the fruit number of each periodical harvest, total number of fruits were calculated and then averaged. Average fruit weight from all the periodical harvests in the fifteen selected plants of each genotype was recorded as total fruit yield per plant and expressed in kilogram. Similarly marketable fruit yield per plant without borer infestation was recorded and expressed in kilogram. Ten fruits per genotype were taken to make replication-wise composite sample for recording different fruit quality traits. Total sugar content of fruit (%) was estimated by acid hydrolysis method as per Ranganna (14). Total phenol content of fruit (mg/100 g) was carried out with the Folin-Ciocalteau reagent as per Sadasivam and Manickam (15). In case of fruit borer infestation (%), number of healthy and damaged fruits of each harvest was recorded and per cent damage was calculated as suggested by Mishra *et al*. (12).

Data were statistically analyzed using the standard methods of the randomized complete block design as per Gomez and Gomez (7). The magnitude of heterosis was estimated in relation to mid-parent as well as better-parent values as per Hayes *et al*. (9). The dominance estimates (Potence ratio), was computed using the following formula as suggested by Smith (20). Combining ability variances and effects were worked out according to Griffing's (8) Model 1 and Method 2. Statistical analyses were done using statistics analytical software WindoStat version 8.1.

Table 1. Characteristics of parental lines with their source of collection.

Genotype	Source	Characteristics
BCB-40	B.C.K.V. West Bengal	Deep purple fruit colour, oblong fruit shape, green with purple ting calyx and spine present at fruit calyx
Swarna Mani	I.C.A.R. Res. Complex for Eastern Regions, Ranchi, Jharkhand	Dark purple fruit colour, round fruit shape, green with purple ting fruit calyx, spineless fruit calyx
KS-224	Kalyanpur, Uttar Pradesh	Light purple fruit colour, round fruit shape, green fruit calyx, spineless fruit calyx
White Jhuri Begun	B.C.K.V. West Bengal	Whitish-green fruit colour, round-oblong fruit shape, green fruit calyx, spineless fruit calyx
10/BRBW Res-3	IIVR, Varanasi, Uttar Pradesh	Light-green fruit colour with white basal stripes, round-oblong fruit shape, green fruit calyx, spineless fruit calyx

RESULTS AND DISCUSSION

Highly significant component of gca and sca mean squares for all the quantitative traits in F_1 generation except days to 1st flowering was recorded (Table 2). The importance of additive and non-additive genetic effects for the control of characters is also ascertained by the predictability ratio as suggested by Baker (2). The study reflected the preponderance of non-additive gene effects (predictability ratio < 0.50) for days to 1st flowering, days to 50% flowering, plant height, number of primary branches per plant, total fruit yield per plant and marketable fruit yield per plant (Table 2). In such case, heterosis breeding would be the best possible option for improving these traits in brinjal. On the other hand, fruit length, fruit diameter, fruit weight, number of fruits per plant, and phenol content of fruit were controlled by both additive and non-additive gene action (≥ 0.50 and < 0.80). Diallel selective mating or mass selection with concurrent random mating or restricted recurrent selection by intermating the most desirable segregates followed by selection (Shende *et al*., 18) could be followed for the improvement of traits controlled by both additive and non-additive gene action. In contrast, ≥ 0.80 predictability ratio for total sugar content of fruit and fruit borer infestation indicated additive genetic control for the conditioning of these traits. Selection of trait governed by additive gene action should be done in later generation when the effects of non-additive gene action will be minimized and those of additive gene action effects will be fixed. The overwhelming response of non-additive gene action for the concerned character in the present study was reported by previous workers (Pramila *et al*., 13). The response of additive gene action for the conditioning of total sugar content of fruit and fruit borer infestation was not so far been reported in brinjal. The importance of both additive and non-additive gene action for the control of characters in the present study was also recorded (Kumar *et al*., 11). However, it is assumed that genetic effects controlling characters generally depend on donor parent, environmental variation, crossing fashion and the precision of the experiment.

The estimates of relative heterosis (Tables 3–5) reflected many significant effects in desirable directions for different character under study. On the other hand, the estimates of heterobeltiosis values expressed desired significant effects on most of the traits except plant height, number of primary branches per plant, fruit diameter and fruit borer infestation. The maximum extent of heterobeltiosis in desired direction was observed for marketable fruit yield per plant (50.22 %), total fruit yield per plant (44.98 %), number of fruits per plant (30.06 %), phenol content (24.35 %), fruit borer infestation (-13.45 %) and total sugar content (- 9.24 %) (Tables 3–5). The maximum positive and significant heterobeltiosis was observed in KS-224 × 10/BRBW/RES-3 followed by BCB-40 × KS-224 for marketable fruit yield per plant coupled with other important horticultural traits. The hybrid BCB-40 × KS-224 also showed significantly negative relative heterosis and non-significant negative heterobeltiosis for fruit borer infestation. On the basis of *per se* performance, the best hybrid for total fruit yield per plant and marketable fruit yield per plant was BCB-40 × KS-224 and the promising parent was KS-224 (Table 7). This hybrid possessed all the major export quality attributes (Round glossy purple fruit having green calyx and devoid of spines), comparatively low sugars and high phenol contents, and also exhibited minimum severity of fruit borer infestation because of sugars in fruit act as feeding stimuli and phenolics substances act as repelling agent, inhibit the growth of this insect and sometimes higher concentration killed this insects. Absence of significant heterobeltiosis in most of the cross combinations in the present study might be due to the internal cancellation of heterosis components as observed in our previous study (Shende *et al*., 17). The extent of heterobeltiosis to such extent for different characters was also observed by previous workers (Chattopadhyay *et al*., 5; Shende *et al*., 17). The most promising hybrid BCB 40 × KS-224 identified in this study could make a dent by fulfilling the major horticultural attributes in export trade after critical evaluation, or a desirable line could be isolated from the segregating population. Correlation study between quantitative traits also depicted that fruit borer infestation exerted significantly negative correlation with phenol content of fruit and significant positive correlation with total sugar content of fruit, besides significant and positive associationships between fruit yield per plant and other economic traits (Table 6). Many biochemical factors such as total sugar, free amino acids, silica contents, polyphenol oxidase, phenylalanine ammonia lyase, peroxidase and glycoalkaloids are known to be associated with insect resistance and it is obvious that the biochemical factors are more important than morphological and physiological factors in conferring non-preference and antibiosis (Dar *et al*., 6). Relatively tolerant hybrid BCB 40 × KS-224 against fruit borer contained higher amount of phenols and low amount of sugars which often associated with the feeding deterrence, growth inhibition, and could ward off this pest because of the direct toxicity caused by quinones formed by oxidation of phenols bind covalently to leaf proteins, and inhibit the protein digestion in herbivores. In brinjal, the low sugar content and higher phenolic

Table 2. Analysis of variance (mean square) for combining ability (Griffing's Model 1 and Method 2) of thirteen characters in brinjal.

Source of variation (df)	Days to first flowering	Days to 50% flowering	Plant height (cm)	Number of primary branches/ plant	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Number of fruits/ plant	Total fruit yield/ plant (kg)	Marketable fruit yield/ plant (kg)	Total Sugar (%)	Phenol content (mg/100g)	Fruit borer infestation (%)
GCA (4)	0.71	2.57*	235.43**	0.79**	8.72**	10.57**	3166.95**	13.15**	0.18**	0.25**	0.58**	0.34**	115.93**
SCA (10)	2.15**	16.22**	94.41**	0.44**	1.35**	1.13**	528.53**	3.61**	0.23**	0.18**	0.03**	0.03**	3.16**
Error (28)	0.48	0.68	9.22	0.05	0.05	0.02	38.48	0.34	0.03	0.02	0.00	0.00	0.33
α^2a	0.07	0.54	64.63	0.21	2.48	3.01	893.85	3.66	0.04	0.07	0.17	0.10	33.03
α^2na	1.67	15.53	85.20	0.39	1.30	1.10	490.05	3.26	0.20	0.16	0.03	0.03	2.83
$\frac{\alpha^2a}{\alpha^2a + \alpha^2na}$	0.04	0.03	0.43	0.35	0.66	0.73	0.65	0.53	0.18	0.29	0.84	0.74	0.92

*, ** Significant at 0.05 and 0.01 level of probability, respectively.

Table 3. Heterosis percentages (MP- Mid parent and BP-better parent) and dominance estimate (DE) of F_1 hybrids for D1st F-Days to first flowering, D50F-Days to 50% flowering, PH- Plant height (cm), NPBPP- Number of primary branches /plant.

Cross combinations	D1st F			D50F			PH			NPBPP		
	MP (%)	BP (%)	DE	MP (%)	BP (%)	DE	MP (%)	BP (%)	DE	MP (%)	BP (%)	DE
BCB-40× Swarna Mani	2.33	2.80	5.06	-7.96**	-1.49	-1.21	10.82**	-7.04	0.56	10.04	0.00	1.00
BCB-40 × KS-224	-5.52*	-4.64	-5.99	-10.07**	-7.40**	-3.49	5.07	2.50	2.02	-28.06**	-35.76**	-2.34
BCB-40 × White Jhuri Begun	-5.59*	-4.70	-5.96	-5.47*	-3.71	-3.00	-3.54	-7.19	-0.90	0.00	-18.26	0.00
BCB-40 × 10/BRBW/RES-3	0.95	2.88	0.50	-1.05	3.71	-0.23	3.58	-3.38	0.50	4.86	0.00	1.00
Swarna Mani × KS-224	-5.09	-3.76	-3.68	-13.80**	-10.49**	-3.73	27.67**	9.33**	1.65	-13.17	-28.69**	-0.60
Swarna Mani × White Jhuri Begun	-4.23	-3.76	-8.82	-9.53**	-5.01	-2.00	18.12**	2.37	1.18	-12.57	-22.33	-1.00
Swarna Mani × 10/BRBW/RES-3	-1.42	0.00	-1.00	-19.87**	-18.24**	-10.00	13.86**	1.50	1.14	-15.96	-20.12	-3.06
KS-224 × White Jhuri Begun	0.92	2.83	0.49	-3.18	-2.14	-3.00	3.28	1.82	2.29	23.71**	-7.28	0.71
KS-224 × 10/BRBW/RES-3	-11.21**	-8.65**	-4.00	-21.65**	-20.29**	-12.65	5.60	0.86	1.19	-41.75**	-50.11**	-2.49
White Jhuri Begun × 10/BRBW/RES-3	0.00	0.95	0.00	-13.54**	-11.08**	-4.89	10.39**	6.89	3.17	-17.67	-30.03	-1.00
S.E.	0.84	0.97	-	1.01	1.16	-	3.71	4.29	-	0.28	0.38	-

*, ** Significant at 0.05 and 0.01 level of probability, respectively.

Table 4. Heterosis percentages (MP- Mid parent and BP-better parent) and dominance estimate (DE) of F_1 hybrids for FL-Fruit length (cm), FD- Fruit diameter (cm), FW- Fruit weight (g), NFPP-Number of fruits/plant.

Cross combinations	FL			FD			FW			NFPP		
	MP (%)	BP (%)	DE	MP (%)	BP (%)	DE	MP (%)	BP (%)	DE	MP (%)	BP (%)	DE
BCB-40 × Swarna Mani	9.17**	-9.31**	0.45	11.79**	-3.70	0.73	5.68	4.39	4.57	8.48	-25.39**	-0.37
BCB-40 × KS-224	-21.68**	-32.85**	-1.30	-21.80**	-33.02**	-1.30	28.89**	22.75**	5.78	21.00**	5.22	1.40
BCB-40 × White Jhuri Begun	-1.01	-11.62**	-0.08	-15.87**	-36.75**	-0.48	-12.13**	-24.26**	-0.76	31.72**	30.06**	24.84
BCB-40 × 10/BRBWRES-3	7.58**	-3.10	0.69	15.06**	-6.59	0.65	2.60	-14.04**	0.13	4.73	-0.70	0.86
Swarna Mani × KS-224	-23.75**	-26.60**	-6.12	-32.74**	-33.19**	-47.92	23.18**	18.72**	6.17	21.40*	12.47	2.70
Swarna Mani × White Jhuri Begun	-3.39	-11.03**	-0.40	-19.06**	-44.80**	-0.41	-2.96	-15.47**	-0.20	43.73**	18.35*	2.04
Swarna Mani × 10/BRBWRES-3	0.07	-8.68**	0.01	-9.02**	-34.00**	-0.24	-1.52	-16.66**	-0.08	25.10**	-2.10	0.90
KS-224 × White Jhuri Begun	3.56	-1.10	0.76	-18.28**	-44.47**	-0.39	-1.68	-11.50*	-0.15	1.98	-10.35	0.14
KS-224 × 10/BRBW/RES-3	-19.05**	-23.42**	-3.33	-8.82**	-34.13**	-0.23	29.56**	13.15**	2.04	14.58	-4.75	0.72
White Jhuri Begun × 10/BRBWRES-3	10.46**	9.37**	10.45	-2.34	-11.74*	-0.22	2.61	4.39	0.76	38.85**	-25.39**	5.77
S.E.	0.26	0.31	-	0.18	0.21	-	7.59	8.77	-	0.71	0.82	-

Table 5. Heterosis percentages (MP- Mid parent and BP-better parent) and dominance estimate (DE) of F_1 hybrids for TFYPP-Total fruit yield/plant (kg), MFYPP–Marketable fruit yield/plant (kg), TS-Total sugar content (%), PC-Phenol content (mg/100 g), FBI- Fruit borer infestation (%).

Cross combinations	TFYPP			MFYPP			TS			PC			FBI		
	MP (%)	BP (%)	DE	MP (%)	BP (%)	DE	MP (%)	BP (%)	DE	MP (%)	BP (%)	DE	MP (%)	BP (%)	DE
BCB-40 × Swarna Mani	-3.98	-22.49*	-0.17	-7.02	-29.47**	-0.22	4.27**	46.40**	0.15	5.20**	-14.24**	0.23	4.87	54.27**	0.15
BCB-40 × KS-224	54.54**	28.78**	2.73	61.40**	36.99**	3.45	-11.40**	-1.94	-1.18	-0.33	-1.65	-0.25	-26.84**	-13.45	-1.74
BCB-40 × White Jhuri Begun	15.14	-1.74	0.88	16.62	1.72	1.13	-11.48**	-9.24**	-4.67	-2.27	-5.08**	-0.76	-4.61	18.37	-0.24
BCB-40 × 10/BRBWRES-3	8.33	-5.09	0.59	7.62	-7.05	0.48	-9.47**	3.20	-0.77	9.84**	-9.15**	0.47	2.13	12.26	0.24
Swarna Mani × KS-224	50.89**	44.98**	12.49	42.71**	24.27	2.88	21.58**	94.17**	0.58	-0.20	-19.47**	-0.01	21.56**	122.01**	0.48
Swarna Mani × White Jhuri Begun	43.87**	34.47**	6.28	45.59**	23.37	2.53	-18.84**	17.65**	-0.61	12.50**	-6.12**	0.63	-8.42*	77.55**	-0.17
Swarna Mani × 10/BRB-WRES-3	29.87*	17.97	2.96	25.69	7.54	1.52	15.03**	38.75**	0.88	26.65**	24.35**	14.43	7.89*	41.38**	0.33
KS-224 × White Jhuri Be-gun	1.95	-0.95	0.67	1.52	-1.68	0.47	-5.41**	1.94	-0.75	-3.27**	-7.26**	-0.76	3.77	8.16	0.93
KS-224 × 10/BRBWRES-3	52.45**	43.77**	8.69	53.36**	50.22**	25.53	-11.03**	13.59**	-0.51	12.10**	-8.25**	0.55	-2.25	28.88**	-0.09
White Jhuri Begun × 10/BRBW/RES-3	42.57**	-22.49*	13.65	41.21**	-29.47**	35.18	-11.83**	46.40**	-0.80	17.20**	-14.24**	0.95	8.09	50.00**	0.29
S.E.	0.19	0.22	-	0.16	0.19	-	0.25	0.29	-	0.30	0.35	-	0.70	0.80	-

*, ** Significant at 0.05 and 0.01 level of probability, respectively.

Table 6. Correlation comparison matrix between total fruit yield per plant and component traits.

Characters	Days to 50% flowering	Plant height (cm)	Number of primary branches / plant	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Number of fruits/ plant	Total fruit yield/plant (kg)	Marketable fruit yield/ plant (kg)	Total sugar content (%)	Phenol content (mg/100 g)	Fruit borer infestation (%)
Days to first flowering	0.510	-0.152	0.441	0.355	0.323	-0.113	-0.416	-0.506	-0.472*	0.074	0.010	0.066
Days to 50% flowering		-0.527*	0.337	0.189	0.239	-0.259	-0.443	-0.656**	-0.611*	0.150	-0.430	0.128
Plant height (cm)			0.120	0.077	-0.275	0.258	0.313	0.537*	0.587*	-0.531*	0.685**	-0.515*
Number of primary branches/plant				0.192	0.473	0.143	-0.427	-0.288	-0.241	-0.139	0.168	-0.107
Fruit length (cm)					-0.153	-0.387	0.312	-0.029	0.022	-0.280	0.219	-0.215
Fruit diameter (cm)						0.576*	-0.739**	-0.248	-0.308	0.355	-0.107	0.409
Fruit weight (g)							-0.413	0.445	0.381	0.145	0.159	0.162
Number of fruits/plant								0.623*	0.633*	-0.358	0.224	-0.331
Total fruit yield/plant (kg)									0.969**	-0.278	0.399	-0.251
Marketable fruit yield/plant (kg)										-0.488	0.542*	-0.472
Total sugar content (%)											-0.791**	0.956**
Phenol content (mg/10 g)												-0.770**

*Values ranged from ≥ 0.514 to ≤ 0.641, significant at 0.05% level of probability; **Values ≥ 0.641, significant at 0.01% level of probability.

Table 7. Selected crosses with high heterobeltiosis, their corresponding gca and sca effects, and type of combinations.

Characters	Crosses with high heterobeltiosis (%) in desired direction	Parents with GCA effects in parentheses	Crosses having SCA effects with *per se* performance[a]	Type of combinations
Days to first flowering	KS-224 × 10/BRBW/RES-3 (-8.65%)	KS-224 (0.02), 10/BRBW/RES-3(-0.50*)	-2.82** (31.67)	L × H
Days to 50% flowering	KS-224 × 10/BRBW/RES-3 (-20.29%)	KS-224(-0.58*), 10/BRBW/RES-3 (-0.32)	-5.67** (38.00)	H × L
	Swarna Mani × 10/BRBW/RES-3 (-18.24%)	Swarna Mani (0.99**), 10/BRBW/RES-3(-0.32)	-4.91** (40.33)	H × L
Fruit length (cm)	White Jhuri Begun × 10/BRBW/RES-3(9.37%)	White Jhuri Begun (0.32**) 10/BRBW/RES-3 (0.29**)	0.80** (12.14)	H × H
Fruit weight (g)	BCB-40 × KS-224 (22.75%)	BCB-40 (14.99**), KS-224 (19.03**)	36.60** (265.00)	H × H
	Swarna Mani × KS-224 (18.72%)	Swarna Mani (11.96**), KS-224 (19.03**)	24.63** (250.00)	H × H
Number of fruits per plant	BCB-40 × White Jhuri Begun (30.06%)	BCB-40(0.25), White Jhuri Begun (1.11**)	1.99** (14.96)	L × H
	Swarna Mani × White Jhuri Begun (18.35%)	Swarna Mani (-1.59**), White Jhuri Begun (1.11**)	2.15** (13.27)	L × H
Total fruit yield/ plant (kg)	Swarna Mani × KS-224 (44.98%)	Swarna Mani (-0.19**), KS-224 (0.01)	0.37* (2.40)	L × L
	KS-224 × 10/BRBW/RES-3 (43.77%)	KS-224 (0.01), 10/BRBW/RES-3 (0.04)	0.42* (2.69)	L × L
Marketable fruit yield/ plant (kg)	KS-224 × 10/BRBW/RES-3 (50.22%)	KS-224 (0.06), 10/BRBW/RES-3 (0.01)	0.39** (2.33)	L × L
	BCB-40 × KS-224 (36.99%)	BCB-40 (0.23**), KS-224 (0.06)	0.76** (2.91)	H × L
Total sugar content (%)	BCB-40 × White Jhuri Begun (-9.24%)	BCB-40 (-0.13**), White Jhuri Begun (-0.21**)	-0.01 (1.08)	L × L
Phenol content (mg/100g)	Swarna Mani × 10/BRBW/RES-3 (24.35%)	Swarna Mani (-0.29**), 10/BRBW/RES-3 (-0.18**)	0.25** (2.40)	L × L

*, ** Significant at 0.05 and 0.01 level of probability, respectively; GCA = General combining ability, SCA = Specific combining ability; [a] *per se* performance in parentheses, H= Significant GCA effect in desired direction, L= Non-significant GCA effect.

compounds offered a significant level of resistance to fruit borer as observed previously (Dar *et al.*, 6), suggesting their implication as selection indices for identification of genotype tolerant to fruit borer. Since sugar is considered one of the vital nutrients in plants, higher amount of sugars might act as phago-stimulants to FSB feeding on brinjal. Phenols are the extremely abundant plant allelochemicals, often associated with feeding deterrent or growth inhibition of herbivores. Phenolic compounds work by producing reactive oxygen species, specifically tannins get oxidized in the guts of insects and the oxidation products have the potential to damage vital nutrients causing either insect deterrence or antibiosis (Summers and Felton, 21). The values of dominance estimates (potence ratio) illustrated in 10 F_1s are presented in Tables 3-5. Preponderance of partial to over-dominance effects was reflected for fruit yield and other important horticultural traits under study. Our results agreed well with the observations of Shende *et al*. (17) in round brinjal.

Based on gca effects, the most heterotic crosses involved four types of cross combinations (Table 7). Additive as well as additive × additive type of interactions were involved in H × H type cross combinations which would be very useful as desirable segregates that could be fixed in early advance generation. Crosses of H × L type or L × H type involved at least one parent with significant gca effect which indicated that predominantly additive effect was present in good combiner and possibly complementary epistatic effect in poor combiner and these two gene actions acted in complementary fashion to maximize the expression. In crosses involving L × L category, sca effects seemed to have played a very important role and high performance was due to non-additive gene action (Bhutia *et al*., 3). Parents with low × low gca effects resulted in most promising heterotic combinations like Swarna Mani × KS-224 and KS-224 × 10/BRBW RES-3. Perhaps, it implies that the gca only identifies better parental lots but it will be unwise to discard the low gca types. Therefore, it can be concluded that the prediction of heterosis on the basis of gca effect of parents may not always be accurate.

No single parent was found to be a good combiner for all the traits under study. Among the parental lines, the only significant gca effects in desired direction was recorded by BCB-40 for ten characters including fruit yield per plant and fruit borer infestation (Table 6). The highest *per se* values for total fruit yield per plant, marketable fruit yield per plant, fruit weight and low infestation of fruit borer was also recorded in BCB-40. So, the parent BCB-40 was found most promising because it produced the maximum frequency of high yielding hybrids with appreciable fruit borer tolerance when crossed with other parents. This parent could be identified as good donor for future use in breeding programme. Based on sca effects and *per se* performance, two cross combinations namely, BCB 40 × KS-224 and KS-224 × 10/BRBW RES-3 could be identified as good specific combiners for fruit yield and other important traits (Table 7). It appeared that different cross combinations exhibited different sca effects and only a few crosses showed consistently either positive or negative sca effects for few traits. However, the cross BCB 40 × KS-224 showing desirable specific combining ability having involved one good combiner would be expected to produce segregates with high yield, and better tolerance to fruit borer infestation of fixable nature in segregating generations through simple pedigree method. Significant gca and sca effects in desired direction for traits under study have also been reported by earlier workers (Sharma *et al*., 16; Kumar *et al*., 11).

The present study highlighted the breeding strategies for improvement of traits governed by different gene effects. BCB-40 was identified as good combiner which could be utilized in future hybrid breeding programme. We could able to identify one promising hybrid BCB 40 × KS-224 which could make a dent in export trade by fulfilling the major horticultural attributes after critical evaluation in the tropics. Commercially useful fruit borer tolerant hybrid could be developed with the involvement of a tolerant genotype having low sugar and high phenol contents.

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