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Combining ability study in brinjal (*Solanum melongena* L.)

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Abstract
A study was conducted to estimate combining ability effects for thirteen characters in brinjal. Result revealed that the line HE -100 was found good general combiner for characters like plant height, number of branches per plant, days to 50% flowering, days to first fruit harvest, number of flowers per cluster, number of fruits per cluster, fruit length (cm), fruit length to fruit diameter ratio, fruit yield per plant (kg) and fruit yield per hectare (q). The tester BR-112 was best general combiner for plant height, days to first fruit harvest, fruit diameter, average fruit weight (g), fruit yield per plant (kg) and fruit yield per hectare (q), HLB-12 found good combiner for number of braches per plant, number of flowers per cluster, number of fruits per cluster, fruit length (cm), fruit length to fruit diameter ratio and number of fruits per plant, and H-8 tester found good combiner for only days to 50% flowering. On the basis of SCA effects, the top performing crosses were HE-104 x H-8 (50.09) and HE-105 x BR-112 (45.04) for fruit yield per plant (kg) and fruit yield per hectare (q).

Keywords: Heterosis, GCA, SCA, line × tester, gene action

Introduction

Brinjal or eggplant (*Solanum melongena* L.) is an important Solanaceous crop of sub tropics and tropics. In India, it is one of the most common, popular and principal vegetable crops grown throughout the country except higher altitudes and can be grown throughout the year. In India, it is cultivated in an area of about 669 thousand hectare with a production of 12.4 lakh metric tonnes (Anonymous, 2017) [1]. Combining ability indicates capacity of individual parents to transmit superior performances to its off springs where general combining ability (GCA) refers to average performance of individual parents in a series of crosses, while specific combining ability (SCA) indicates performance of specific hybrid combinations. General combining ability is mainly due to additive gene effects and additive x additive interactions, while specific combining ability is a result of dominance and epistatic deviations and genotype x environment interactions. The study of general combining ability (GCA) effects help in selection of superior parents and specific combining ability (SCA) effects for superior hybrids/ lines. Information regarding combining ability estimates, different types of gene action and relative magnitude of variances are important parameters to improve the genetic make-up of brinjal crop. This helps in choosing the desirable parents for hybridization programme and to chalk out an efficient breeding strategy.

The present study was, therefore, undertaken to study extent of heterosis over the better parent in line X tester design for morphological and yield traits in brinjal.

Materials and Methods

The experiment was carried out at Research Farm of the Department of Vegetable Science, Chaudhary Charan Singh Haryana Agricultural University, Hisar located at 29° 10´ latitude North, 75° 46´ longitude East and 215.2 m above mean sea level with semi-arid subtropical climate during spring-summer and rainy season of 2017. The experimental material comprised of 18 parents: 15 as lines (HE-100, HE-101, HE-102, HE-103, HE-104, HE-105, HE-106, HE-107, HE-108, HE-109, HE-110, HE-111, HE-112, HE-113 & HE-114) and 3 as testers BR-112, Hisar Shyamal (H 8) & HLB-12 of brinjal along with 45 cross combinations and standard check.

Seeds of eighteen genotypes (15 lines and 3 testers) were sown on 18th November, 2016 in nursery bed and seedlings of these genotypes were transplanted on 23rd January, 2017 for making crosses in a line x tester mating fashion. Forty-five F_1 crosses were made by crossing 15 lines with 3 testers and seeds of 45 F_1 hybrids along with self-seeds of 18 parents were harvested separately.

Forty five F_1 crosses along with 15 parents and one standard check were sown on 15th June, 2017. Thirty five days old seedlings were planted at spacing of 75 x 60 cm on 20th July 2017 with 3 replications accommodating 15 plants in each treatment in Randomized Block Design. Five competitive plants were selected randomly in each genotypes replication for recording the observations (Plant height (cm), Number of branches per plant, Days to 50 percent flowering, Days to first fruit harvest, Number of flowers per cluster, Number of fruits per cluster, Fruit length (cm), Fruit diameter (cm), Fruit length to fruit diameter ratio, Number of fruits per plant, Average fruit weight (g), Fruit yield per plant (kg) & Fruit yield per hectare(q). All the recommended cultural practices of the crop were adopted for raising the crop successfully. The combining ability analysis was done using the line x tester method described by Kempthorne (1957) [7]. The data of all growth, biometrical and quality traits were subjected to analysis of variance.

Results and Discussion

The analysis of variance for GCA and SCA for different characters observed in brinjal revealed that the mean sum of squares due to GCA of males and females were highly significant for all the characters. The mean sum of squares due to SCA was also highly significant for all the characters. The variances due to GCA and SCA were highly significant for all the characters indicating the importance of both additive and non-additive gene action in the inheritance of these traits. Similar finding have also been reported by Bhushan *et al*. (2012) [4], Patel *et al*. (2013) [10] Ansari *et al*. (2014) [2] and Yadav *et al*. (2017) [13].

If ratio of variance due to specific combining ability and general combining ability effects was greater than unity non-additive gene action was predominant for all such traits. This indicated that non-additive gene effects had a greater role in controlling inheritance of characters like number of branches per plant, days to 50 percent flowering, days to first fruit harvest, fruit yield per plant (kg) and fruit yield per hectare (q). This indicates that heterosis breeding can be exploited for improvement in these traits. For plant height, number of flowers per cluster, number of fruits per cluster, fruit length (cm), fruit diameter (cm), number of fruits per plant and average fruit weight (g) additive gene action was predominant and improvement can be made by selection. Padmanabham and Jagadish (1996) [9] reported that the characters like yield per plant, fruit weight, number of fruits per plant and plant height to be predominantly governed by non-additive gene action. Similarly, Aswani and Khandewal (2005) [3] reported predominance of non-additive variance for characters, including fruit yield and plant height.

General combining ability (GCA) effects

The term general combining ability is used to designate the mean or average performance of a genotype in cross combinations involving a set of other genotypes. The GCA effects emulate the breeding value of parental genotypes and it facilitate in finding the genotypes to be used for developing better or superior populations. The estimates of general combining ability (GCA) effects for fifteen female, three male parents and 45 crossed are given in the table 1.

(A) Growth characters

The highest positive and significant GCA effects for plant height was recorded in lines HE-100 (18.91) which was closely followed by HE-101 (15.70), HE-112 (7.73) and HE-105 (6.76) and these were good general combiners. Among testers, the maximum positively significant GCA effects was recorded in BR-112 (3.78) while other two were negatively significant combiners. Similar results have been reported by Bhushan *et al*. (2012) [4], Kumar *et al*. (2012) [8], Patel *et al*. (2013) [10], Ansari *et al*. (2014) [2], Dishri and Mishra (2017) [5] and Hussain *et al*. (2017) [6]. The line HE-100 (3.10) showed the maximum positive and significant GCA effect for number of branches per plant which was closely followed by HE-101 (1.48), HE-114 (1.19) and HE-111 (1.12) and these were good general combiners. Among tester HLB-12 (0.23) and BR-112 (0.12) were significantly positive general combiner while H-8 (-0.35) was significantly negative general combiner. These results are in agreement with the reports of Patel *et al*. (2013) [10], Ansari *et al*. (2014) [2], Dishri and Mishra, (2017) [5] and Hussain *et al*. (2017) [6] who found significant GCA effects for number of branches per plant.

(B) Earliness characters

Among lines, most negative significant GCA for days to 50% flowering was shown by HE-100 (-11.84) and among testers by H-8 (-0.26). Earliness is a desirable character which is indicated by negative GCA effect. These results confirms the findings of Bhushan *et al*. (2012) [4], Kumar *et al*. (2012) [8], Patel *et al*. (2013) [10], Hussain *et al*. (2017) [6] and Yadav *et al*. (2017) [13]. The highest negative significant GCA for days to first fruit harvest was shown by line HE-100 (-12.99) followed by HE-109 (-6.54) and HE-114 (-5.53), and among testers by BR-112 (-1.63). These results are matching the results of Bhushan *et al*. (2012) [4], Kumar *et al*. (2012) [8], Patel *et al*. (2013) [10], Hussain *et al*. (2017) [6] and Yadav *et al*. (2017) [13].

(C) Yield and yield characters

The line HE-100 (1.62) showed the maximum positive and significant GCA effect for number of flowers per cluster which was closely followed by HE-107 (0.86), HE-108 (0.74) and HE-111 (0.50) and these were good general combiners. Among testers, HLB-12 (0.78) was significantly positive general combiner. Similar results were observed by Kumar *et al*. (2012) [8], Ansari *et al*. (2014) [2] and Dishri and Mishra (2017) [5]. The line HE-100 (1.02) showed the maximum significantly positive GCA effect for number of fruits per cluster which was closely followed by HE-107 (0.70), HE-111 (0.32) and HE-108 (0.17) and these were good general combiners. Among testers, HLB-12 (0.45) was significantly positive general combiner while BR-112 (-0.37) and H-8 (-0.08) were significantly negative general combiner. These results were in agreement with the findings of Kumar *et al*. (2012) [8], Ansari *et al*. (2014) [2] and and Dishri and Mishra (2017) [5]. The highest positive and significant GCA effects for fruit length was recorded in lines HE-100 (5.11) which was closely followed by HE-112 (4.46), HE-107 (3.28) and HE-108 (1.64). Tester HLB-12 (1.53) was found to be good general combiner for fruit length. These results confirms the findings of Bhushan *et al*. (2012) [4], Kumar *et al*. (2012) [8], Patel *et al*. (2013) [10], Dishri and Mishra (2017) [5] and

Hussain *et al.* (2017) [6]. The highest positive and significant GCA effects for fruit diameter was recorded in lines HE-114 (0.75) which was closely followed by HE-103 (0.74), HE-106 (0.70) and HE-108 (0.30). Tester BR-112 (0.70) and H-8 (0.09) were found to be good general combiners for fruit diameter. Among testers, the highest significantly positive GCA effect for number of fruits per plant was observed in HLB-12 (5.21) which was good general combiner. Among lines, HE-107 (9.33), HE-108 (6.48), HE-111 (3.73) and HE-100 (3.44) were good general combiner and showed significantly positive GCA effect for number of fruits per plant. These results are in agreement with the reports of Bhushan *et al*. (2012) [4], Patel *et al*. (2013) [10], Dishri and Mishra (2017) [5] and Hussain *et al*. (2017) [6]. The significantly highest positive GCA effect for average fruit weight was recorded in line HE-106 (23.97) and was the best general combiner followed by HE-101 (15.43) and HE-112 (13.58). Among testers, BR-112 (17.50) was found best general combiner for average fruit weight. Similar findings were reported by Bhushan *et al*. (2012) [4], Kumar *et al*. (2012) [8], Patel *et al*. (2013) [10], Dishri and Mishra (2017) [5] and Hussain *et al*. (2017) [6]. The maximum positive GCA effect for fruit yield per plant was exhibited by the line HE-100 (0.31) which was closely followed by HE-101 (0.23), HE-106 and HE-109 (0.14) which were found as good general combiners. Among the testers, BR-112 (0.07) was rated as the best general combiner. This result is similar to the reports of Bhushan *et al*. (2012) [4], Kumar *et al*. (2012) [8], Patel *et al*. (2013) [10], Ansari *et al*. (2014) [2], Dishri and Mishra (2017) [5] and Hussain *et al*. (2017) [6]. The line HE-100 (67.93) followed by HE-101 (49.75), HE-109 (31.81) HE-106 (30.77) exhibited the maximum positive GCA effect for fruit yield per hectare and these were good general combiner. Among testers, BR-112 (14.48) was rated as best general combiner. This result was in agreement with the findings of Suneetha *et al*. (2005) [12], Bhushan *et al*. (2012) [4], Ansari *et al*. (2014) [2] and Hussain *et al*. (2017) [6].

Specific combining ability effects

Specific combining ability (SCA) indicates deviation in performance of a cross-combination from that predicted, on the basis of general combining abilities of parents. It can be either negative or positive. Estimates for specific combining ability effects for different traits are presented in Table 2.

(A) Growth characters

The significantly highest positive SCA effect for plant height was reported by the cross HE-110 x HLB-12 (8.26) followed by crosses HE-112 x HLB-12 (7.59), HE-105 x H-8 (4.26) and HE-102 x H-8 (4.07). Positive SCA effects for this trait was also reported by Bhushan *et al*. (2012) [4], Kumar *et al*. (2012) [8], Patel *et al*. (2013) [10], Ansari *et al*. (2014) [2], Dishri and Mishra (2017) [5] and Hussain *et al*. (2017) [6]. The cross HE-100 x HLB-12 (1.31) showed the best specific combining ability effect for number of branches per plant which was followed by crosses HE-108 x BR-112 (1.17) and HE-106 x H-8 (0.99). Similar results were reported by Sao and Mehta (2010), Bhushan *et al*. (2012) [4], Kumar *et al*. (2012) [8], Patel *et al*. (2013) [10] and Ansari *et al*. (2014) [2]

(B) Earliness characters

Among all the cross combinations, the crosses HE-107 x HLB-12 (-5.15), HE-113 x H-8 (-4.82) and HE-106 x H-8 (-4.38) showed higher negative SCA effect for days to 50% flowering. The cross HE-113 x BR-112 (4.70) and HE-107 x BR-112 (4.05) showed positive SCA effects were the poor specific cross combinations favouring late flowering. This result was in agreement with the findings of Bhushan *et al*. (2012) [4], Kumar *et al*. (2012) [8], Patel *et al*. (2013) [10], Dishri and Mishra (2017) [5] and Hussain *et al*. (2017) [6]. Among all the cross combinations, the crosses HE-114 x BR-112 (-7.02), HE-113 x H-8 (-6.52) and HE-106 x H-8 (-5.59) showed higher significant negative SCA effect for days to first fruit harvest. Bhushan *et al*. (2012) [4], Kumar *et al*. (2012) [8], Patel *et al*. (2013) [10] and Hussain *et al*. (2017) [6] also reported significant negative SCA effects for days to first fruit harvest.

(C) Yield and yield characters

The cross HE-108 x HLB-12 (0.46) showed the best specific combining ability effect for number of flowers per cluster which was followed by crosses HE-110 x H-8 (0.44) and HE-105 x HLB-12 (0.35). These results are in agreement with the findings of Kumar *et al.* (2012) [8], Ansari *et al.* (2014) [2], and Dishri and Mishra, (2017) [5]. The cross HE-100 x HLB-12 (0.38) showed the best specific combining ability effect for number of fruits per cluster which was followed by crosses HE-102 x BR-112 (0.31) and HE-108 x BR-112 (0.29). Similar result was also observed by Kumar *et al.* (2012) [8], Ansari *et al.* (2014) [2] and Dishri and Mishra, (2017) [5]. The best cross was HE-100 x BR-112 (1.92) for fruit length closely followed by HE-108 x HLB-12 (1.59), HE-102 x HLB-12 (1.56) and HE-104 x H-8 (1.56). Significant estimates of SCA effects of crosses for fruit length were also reported earlier by Bhushan *et al*. (2012) [4], Kumar *et al*. (2012) [8], Patel *et al*. (2013) [10], Dishri and Mishra (2017) [5] and Hussain *et al*. (2017) [6]. The significantly maximum positive SCA effect for fruit diameter was observed in cross HE-103 x BR-112 (1.18) followed by HE-107 x HLB-12 (0.72) and HE-108 x HLB-12 (0.60). Bhushan *et al.* (2012) [4], Patel *et al*. (2013) [10], Dishri and Mishra (2017) [5] and Hussain *et al*. (2017) [6] also observed significant estimates for specific combining ability effects of crosses for fruit diameter. Among 45 cross combinations studied, a total of 17 crosses manifested significantly positive SCA effect for number of fruits per plant.

Table 1: General combining ability effects of parents for different characters in brinjal

	Plant height	Number of branches per plant	Days to 50 percent flowering	Days to first fruit harvest	Number of flowers per cluster	Number of fruits per cluster	Fruit length	Fruit diameter	Fruit length to fruit diameter ratio	Number of fruits per plant	Average fruit weight	Fruit yield per plant	Fruit yield per hectare
Lines													
HE-100	18.91**	3.10**	-11.84**	-12.99**	1.62**	1.02**	5.11**	-0.62**	1.58**	3.44**	1.48*	0.31**	67.93**
HE-101	15.70**	1.48**	12.51**	10.15**	0.10	-0.72**	0.44**	0.10*	-0.04	-1.51**	15.43**	0.23**	49.75**
HE-102	1.49*	0.11	-2.14**	-2.49**	0.20**	0.00	-2.33**	-0.23**	-0.46**	-2.35**	-0.05	-0.11**	-24.05**
HE-103	-4.47**	-0.86**	5.20**	8.04**	-0.40**	-0.04	-1.89**	0.74**	-0.69**	-5.05**	10.67**	-0.14**	-29.94**
HE-104	-2.40**	-0.89**	-3.47**	-3.19**	-0.31**	-0.05	-1.79**	0.06	-0.46**	-1.55**	-6.13**	-0.21**	-45.56**
HE-105	6.76**	0.47**	1.32**	-1.20*	-0.22**	0.10*	0.71**	-0.18**	0.18**	-2.28**	0.18	-0.13**	-28.32**
HE-106	-5.29**	-0.79**	6.88**	7.82**	-1.45**	-0.64**	-1.72**	0.70**	-0.67**	-5.16**	23.97**	0.14**	30.77**
HE-107	-11.24**	-1.21**	9.77**	9.73**	0.86**	0.70**	3.28**	-0.85**	1.32**	9.33**	-23.55**	-0.07*	-15.31*
HE-108	-10.00**	-0.68**	2.59**	3.20**	0.74**	0.17**	1.64**	0.30**	0.11**	6.48**	-14.58**	0.07*	14.20**
HE-109	-3.19**	-0.87**	-5.03**	-6.54**	-0.03	-0.08	-3.02**	0.19**	-0.80**	-0.42	5.77**	0.14**	31.81**
HE-110	2.06**	-1.96**	3.36**	6.36**	-0.46**	-0.12*	-2.84**	-0.17**	-0.60**	1.56**	-6.40**	0.03	7.48
HE-111	-2.24**	1.12**	-3.61**	-5.06**	0.50**	0.32**	1.17**	-0.34**	0.37**	3.73**	-19.76**	-0.22**	-48.89
HE-112	7.73**	-0.12*	-5.77**	-5.51**	0.00	-0.21**	4.46**	0.23**	0.84**	-3.92**	13.58**	0.05	10.21
HE-113	-6.76**	-0.08	-2.31**	-2.80**	-0.50**	-0.15**	-1.38**	-0.68**	-0.03	-0.39	-4.13**	-0.09**	-19.65**
HE-114	-7.07**	1.19**	-7.44**	-5.53**	-0.66**	-0.31**	-1.84**	0.75**	-0.66**	-1.92**	3.53**	0.00	-0.42
SE gi	0.751	0.074	0.503	0.667	0.069	0.059	0.09	0.06	0.047	0.329	0.823	0.034	7.561
CD at 1%	1.78	0.18	1.19	1.58	0.16	0.14	0.21	0.14	0.11	0.78	1.95	0.08	17.91
CD at 5%	1.25	0.12	0.84	1.11	0.11	0.10	0.15	0.10	0.08	0.55	1.37	0.06	12.57
Tester													
BR-112	3.78**	0.12**	-0.22	-1.63**	-0.64**	-0.37**	-0.23**	0.70**	-0.38**	-4.51**	17.50**	0.07**	14.48**
H-8	-3.09**	-0.35**	-0.26	0.29	-0.14**	-0.08**	-1.30**	0.09**	-0.39**	-0.70**	-1.32**	-0.02*	-4.87*
HLB-12	-0.69**	0.23**	0.48**	1.34**	0.78**	0.45**	1.53**	-0.79**	0.77**	5.21**	-16.19**	-0.04**	-9.62**
SE gj	0.284	0.028	0.19	0.252	0.026	0.022	0.034	0.023	0.018	0.124	0.311	0.013	2.858
CD at 1%	0.67	0.07	0.45	0.60	0.06	0.05	0.08	0.05	0.04	0.29	0.74	0.03	6.77
CD at 5%	0.47	0.05	0.32	0.42	0.04	0.04	0.06	0.04	0.03	0.21	0.52	0.02	4.75

**Significant at 1% & *Significant at 5% level respectively

Table 2: Specific combining ability effects of crosses for different characters in brinjal

Cross	Plant height	Number of branches per plant	Days to 50 percent flowering	Days to first fruit harvest	Number of flowers per cluster	Number of fruits per cluster	Fruit length	Fruit diameter	Fruit length to fruit diameter ratio	Number of fruits per plant	Average fruit weight	Fruit yield per plant	Fruit yield per hectare
HE-100 x BR-112	0.24	0.73**	-1.70**	-3.30**	0.06	-0.20**	1.92**	-0.07	0.18**	-2.31**	-0.39	-0.12**	27.25**
HE-100 x H-8	3.91**	-2.04**	0.81	0.31	-0.17*	-0.18*	-2.34**	-0.36**	-0.35**	-1.73**	6.03**	0.06	13.38
HE-100 x HLB-12	-4.15**	1.31**	0.90	2.99**	0.11	0.38**	0.43**	0.42**	0.16**	4.04**	-5.64**	0.06	13.87
HE-101 x BR-112	-1.35	-0.05	0.51	1.60*	0.24**	0.24**	0.25*	-0.12	0.07	-2.57**	15.70**	-0.04	-7.90
HE-101 x H-8	3.32**	-0.18*	3.29**	3.07**	-0.16*	-0.25**	0.56**	0.12	0.08	1.72**	-8.05**	0.01	2.98
HE-101 x HLB-12	-1.97*	0.23*	-3.79**	-4.67**	-0.08	0.02	-0.81**	0.00	-0.15*	0.85*	-7.65**	0.02	4.92
HE-102 x BR-112	-1.24	-0.69**	-1.74**	0.13	0.04	0.31**	-0.38**	-0.46**	0.05	1.48**	-4.06**	-0.01	-2.46
HE-102 x H-8	4.07**	0.92**	1.91**	1.31	0.11	-0.07	-1.18**	0.36**	-0.41**	0.96*	-6.04**	-0.11**	-24.76*
HE-102 x HLB-12	-2.83**	-0.23*	-0.17	-1.44	-0.14	-0.24**	1.56**	0.10	0.36**	-2.44**	10.10**	0.12**	27.22**
HE-103 x BR-112	-0.65	0.25**	0.22	-1.49	0.04	-0.04	0.88**	1.18**	-0.05	0.75	7.99**	0.09*	19.30*
HE-103 x H-8	3.19**	-0.71**	0.86	1.99*	0.04	-0.10	-0.38**	-0.68**	0.14*	1.26**	-2.06*	0.06	12.64
HE-103 x HLB12	-2.54**	0.47**	-1.08	-0.50	-0.08	0.14*	-0.51**	-0.50**	-0.09	-2.01**	-5.93**	-0.14**	-31.94**
HE-104 x BR-112	-0.75	0.02	-1.52*	-0.24	0.15	0.07	-0.75**	-0.05	-0.12*	0.450	0.05	0.03	5.64
HE-104 x H-8	3.96**	0.95**	1.43*	2.41**	-0.18*	-0.02	1.56**	0.30**	0.23**	3.16**	0.94	0.23**	50.09**
HE-104 x HLB-12	-3.21**	-0.97**	0.08	-2.17*	0.03	-0.05	-0.81**	-0.25**	-0.11*	-3.61**	-0.99	-0.25**	-55.73**
HE-105 x BR-112	1.38	0.43**	-3.20**	-2.66**	-0.51**	-0.19*	0.32**	-0.27**	0.14*	0.91*	7.88**	0.21**	45.04**
HE-105 x H-8	4.26**	-0.57**	2.04**	2.72**	0.16*	0.13	-0.24*	0.11	-0.11*	1.20**	-5.74**	-0.06	-13.04
HE-105 x HLB-12	-5.64**	0.14	1.16	-0.06	0.35**	0.06	-0.07	0.16*	-0.02	-2.11**	-2.14*	-0.15**	-32.00**
HE-106 x BR-112	-0.16	-0.12	3.64**	3.13**	0.33**	0.29**	0.07	0.31**	0.01	2.09**	1.02	0.07	14.74
HE-106 x H-8	-2.25*	0.99**	-4.38**	-5.59**	-0.41**	-0.13	0.28*	0.19*	0.03	-0.93*	3.97**	-0.06	-11.48
HE-106 x HLB-12	2.42*	-0.87**	0.74	2.46**	0.08	-0.16*	-0.35**	-0.50**	-0.03	-1.16**	-4.99**	-0.01	-3.26
HE-107 x BR-112	-0.85	-0.63**	4.05**	4.69**	-0.05	-0.15*	0.61**	-0.50**	0.31**	-3.10**	-5.06**	-0.07	-14.74
HE-107 x H-8	-1.41	0.31**	1.10	0.26	0.08	0.06	-0.76**	-0.22**	-0.06	-2.28**	2.26*	-0.03	-7.52
HE-107 x HLB-12	2.26*	0.32**	-5.15**	-4.95**	-0.03	0.09	0.15	0.72**	-0.25**	5.38**	2.80**	0.10*	22.26*
HE-108 x BR-112	-0.32	1.17**	-2.20**	-0.26	-0.26**	-0.29**	-1.75**	-0.02	-0.33**	-2.26**	-5.04**	-0.11**	-23.66*
HE-108 x H-8	2.42*	-1.16**	-0.72	-0.12	-0.20*	0.06	0.16	-0.58**	0.36**	-2.07**	3.98**	0.00	0.42
HE-108 x HLB-12	-2.11*	-0.01	2.93**	0.37	0.46**	0.23**	1.59**	0.60**	-0.03	4.33**	1.05	0.11**	23.24*
HE-109 x BR-112	-0.20	-1.04**	-0.95	-3.41**	-0.13	-0.2	0.41**	0.19*	0.11*	0.01	2.05*	0.03	7.16

HE-109 x H-8	-3.39**	0.36**	0.10	2.40**	0.17*	0.22**	-0.56**	-0.07	-0.06	-0.27	3.64**	0.07	14.63
HE-109 x HLB-12	3.58**	0.68**	0.85	1.02	-0.04	-0.02	0.15	-0.12	-0.05	0.26	-5.69**	-0.10*	-21.79*
HE-110 x BR-112	-1.42	-0.25**	-3.17**	-1.45	-0.33**	-0.06	-0.27*	0.05	-0.05	1.37**	-8.61**	-0.07	-14.18
HE-110 x H-8	-6.84**	0.92**	1.11	1.93*	0.44**	0.05	0.60**	0.17*	0.05	1.85**	0.61	0.10*	22.38*
HE-110 x HLB-12	8.26**	-0.67**	2.06**	-0.48	-0.11	0.02	-0.33**	-0.22**	0.01	-3.22**	8.01**	-0.04	-8.19
HE-111 x BR-112	-0.82	0.10	0.96	1.61*	0.14	0.20**	-0.08	-0.71**	0.28**	0.50	-7.15**	-0.01	-1.25
HE-111 x H-8	-3.04**	0.98**	-1.66*	-2.92**	-0.06	0.02	-0.11	0.27**	-0.18**	-1.08**	1.01	-0.06	-12.96
HE-111 x HLB-12	3.86**	-1.08**	0.70	1.31	-0.08	-0.22**	0.19	0.45**	-0.11*	0.58	6.14**	0.07	14.21
HE-112 x BR-112	1.22	-0.15	0.68	2.72**	-0.06	0.02	-0.17	0.25**	-0.34**	1.11**	3.51**	0.05	11.00
HE-112 x H-8	-8.81**	-0.28**	-2.77**	-4.87**	0.24**	0.07	0.10	-0.03	-0.05	0.76	-4.77**	-0.07	-15.09
HE-112 x HLB-12	7.59**	0.43**	2.08**	2.15*	-0.18*	-0.1	0.07	-0.22**	0.39**	-1.88**	1.26	0.02	4.09
HE-113 x BR-112	1.30	0.20*	4.70**	5.94**	0.24**	-0.03	-0.53**	-0.20**	-0.12*	-0.94*	-6.55**	-0.21**	-45.86**
HE-113 x H-8	-3.39**	-0.23*	-4.82**	-6.52**	-0.06	0.08	1.21**	0.01	0.27**	-0.09	4.84**	0.10*	22.70*
HE-113 x HLB-12	2.08*	0.02	0.13	0.57	-0.18*	-0.05	-0.68**	0.19*	-0.14*	1.04*	1.71	0.10*	23.17*
HE-114 x BR-112	3.62**	0.04	-0.27	-7.02**	0.11	0.02	-0.51**	0.43**	-0.15*	2.51**	-1.34	0.16**	34.43**
HE-114 x H-8	3.99**	-0.26**	1.71**	3.62**	0.01	0.07	1.10**	0.41**	0.09	-2.47**	-0.62	-0.24**	-54.37**
HE-114 x HLB-12	-7.61**	0.22*	-1.44*	3.41**	-0.11	-0.10	-0.60**	-0.84**	0.06	-0.04	1.95*	0.09*	19.94*
SE gij	1.06	0.11	0.71	0.94	0.10	0.08	0.13	0.08	0.07	0.47	1.16	0.05	10.69
CD at 1%	2.52	0.25	1.68	2.23	0.23	0.20	0.30	0.20	0.16	1.10	2.76	0.11	25.33
CD at 5%	1.77	0.17	1.18	1.57	0.16	0.14	0.21	0.14	0.11	0.77	1.93	0.08	17.77

**Significant at 1% & *Significant at 5% level respectively

Table 3: Best Specific and general combiner for different characters

Sr. No.	Character	Best cross combination		Best combiners	
		1st	2nd	Lines	Tester
1.	Plant height	HE-110 x HLB-12 (8.26)	HE-112 x HLB-12 (7.59)	HE-100 (18.91**)	BR-112 (3.78**)
2.	No. of braches per plant	HE-100 x HLB-12 (1.31)	HE-108 x BR-112 (1.17)	HE-100 (3.10**)	HLB-12 (0.23**)
3.	Days to 50% flowering	HE-107 x HLB-12 (-5.15)	HE-113 x H-8 (-4.82)	HE-100 (-11.84**)	H-8 (-0.26)
4.	Days to first fruit harvest	HE-114 x BR-112 (-7.02)	HE-113 x H-8 (-6.52)	HE-100 (-12.99**)	BR-112 (-1.63**)
5.	No. of flowers per cluster	HE-108 x HLB-12 (0.46)	HE-110 x H-8 (0.44)	HE-100 (1.62**)	HLB-12 (0.78**)
6.	No. of fruits per cluster	HE-100 x HLB-12 (0.38)	HE-102 x BR-112 (0.31)	HE-100 (1.02**)	HLB-12 (0.45**)
7.	Fruit length	HE-100 x BR-112 (1.92)	HE-108 x HLB-12 (1.59)	HE-100 (5.11**)	HLB-12 (1.53**)
8.	Fruit diameter	HE-103 x BR-112 (1.18)	HE-107 x HLB-12 (0.72)	HE-114 (0.75**)	BR-112 (0.70**)
9.	Fruit length to fruit diameter ratio	HE-112 x HLB-12 (0.39)	HE-102 x HLB-12 (0.36)	HE-100 (1.58**)	HLB-12 (0.77**)
10.	No. of fruits per plant	HE-107 x HLB-12 (5.38)	HE-108 x HLB-12 (4.33)	HE-107 (9.33**)	HLB-12 (5.21**)
11.	Average fruit weight	HE-101 x BR-112 (15.70)	HE-102 x HLB-12 (10.10)	HE-106 (23.97**)	BR-112 (17.50**)
12.	Fruit yield per plant	HE-104 x H-8 (0.23)	HE-105 x BR-112 (0.21)	HE-100 (0.31**)	BR-112 (0.07**)
13.	Fruit yield per hectare	HE-104 x H-8 (50.09)	HE-105 x BR-112 (45.04)	HE-100 (67.93**)	BR-112 (14.48**)

The cross HE-107 x HLB-12 (5.38) showed the best specific combining ability effect for number of fruits per plant which was followed by crosses HE-108 x HLB-12 (4.33) and HE-100 x HLB-12 (4.04). Similar results were observed by Patel *et al.* (2013) [10], Dishri and Mishra (2017) [5] and Hussain *et al*. (2017) [6]. The cross HE-101 x BR-112 (15.70) showed the best specific combining ability effect for average fruit weight which was followed by crosses HE-102 x HLB-12 (10.10) and HE-110 x HLB-12 (8.01). This result was in agreement with the findings of Bhushan *et al.* (2012) [4], Kumar *et al.* (2012) [8], Patel *et al.* (2013) [10], Dishri and Mishra (2017) [5] and Hussain *et al*. (2017) [6]. The cross combinations HE-104 x H-8 (0.23), HE-105 x BR-112 (0.21), HE-114 x BR-112 (0.16), HE-102 x HLB-12 (0.12) and HE-108 x HLB-12 (0.11) showed the best specific combining ability effect for fruit yield per plant. These results were similar to the findings of Bhushan *et al.* (2012) [4], Patel *et al.* (2013) [10] and Ansari *et al*. (2014) [2]. Eleven cross combinations registered positive and significant SCA effects for fruit yield per hectare in desirable direction. The cross combination HE-104 x H-8 (50.09) followed by HE-105 x BR-112 (45.04), HE-114 x BR-112 (34.43), HE-100 x BR-112 (27.25) and HE-102 x HLB-12 (27.22) was rated as the best specific combiner for fruit yield per hectare. These results are in agreement with the findings of Bhushan *et al*. (2012) [4], Ansari *et al*. (2014) [2] and Hussain *et al*. (2017) [6].

Conclusion

- Among all the fifteen lines, the line HE-100 was found good general combiner for characters like plant height, number of branches per plant, days to 50% flowering, days to first fruit harvest, number of flowers per cluster, number of fruits per cluster, fruit length (cm), fruit length to fruit diameter ratio, fruit yield per plant (kg) and fruit yield per hectare (q) as shown in Table 3.
- Similarly, among testers, BR-112 was best general combiner for plant height, days to first fruit harvest, fruit diameter, average fruit weight (g), fruit yield per plant (kg) and fruit yield per hectare (q), HLB-12 for number of braches per plant, number of flowers per cluster, number of fruits per cluster, fruit length (cm), fruit length to fruit diameter ratio and number of fruits per plant, and H-8 for days to 50% flowering as shown in Table 3.
- On the basis of SCA effects, the top performing crosses were HE-104 x H-8 (50.09) and HE-105 x BR-112 (45.04) for fruit yield per plant (kg) and fruit yield per hectare (q) as shown in Table 3.

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