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Studies on combining ability for yield and quality traits in brinjal (*Solanum melongena* L.)

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ABSTRACT

The experimental material in brinjal (eggplant) comprised 19 parents (15 lines + 4 testers), 60 F_1 crosses and two standard checks (BH-1 and BH-2). This was grown in Randomized Block Design, with three replications. Lines vs. testers showed significance for all characters except plant height, plant spread, number of primary branches, dry matter, total sugars and total phenol. Analysis for parents vs. hybrids showed significance for all the characters except average fruit weight, number of fruits per plant, plant spread and number of primary branches. Analysis of Variance for combining ability revealed mean squares due to lines and testers were significant for all the characters except plant height, plant spread, number of primary branches, total sugars, total phenol and content of anthocyanins. The ratio of variance due to specific combining ability and general combining ability (σ²SCA: σ²GCA) was greater than unity, indicating non-additive genetic control for all traits except plant spread and total phenols. Among the females, Punjab Barsati, PBR-91-1, RCMBL-1-1, BSR-11; and among the males, BB-93-C and U-8-61-3 were best general combiners for yield and yield components. Punjab Barsati was the best combiner for days to 50% flowering, days to first fruit harvest, number of fruits per plant and number of primary branches. The cross JBR-3-16 × PB-64 manifested best SCA effects for days to 50% flowering; PBR-91-1JBSR-98-2 for average fruit weight; BSR-11 × PB-64 for fruit length; BSR-11× U-8-61-3 for fruit girth, and the cross HABL-1 × JBSR-98-2 for yield per plant and per hectare.

Key words: Brinjal, general combining ability, specific combining ability, additive gene action, crosses

INTRODUCTION

Brinjal (*Solanum melongena* L., 2n = 2x = 24) is one of the most commonly grown vegetables in India as also other parts of the world. It can be grown round the year in almost all parts of the country (except in the plains) due to its wide adaptability. It is cultivated for its tender and immature fruits under tropical and subtropical conditions in our country. Brinjal has medicinal properties. Its fruits are excellent for remedy liver problems. Brinjal, being native to India and often a cross-pollinated crop, possesses considerable diversity for plant type, fruit colour, fruit shape, fruit size, yield and other quality traits. This offers an opportunity to exploit genetic divergence for improvement of the crop. The improvement may be with respect to developing new germplasm, varieties or hybrids. Combining ability analysis helps identify of good combining parents and superior F_1 crosses. The most efficient method providing information on general combining ability (GCA) and specific combining ability (SCA) effects involving large numbers of parents is Line × Tester design. It can also help determine gene action with reference to the traits under study. Estimation of combining ability has been previously done by Baig and Patil (2002), Kumar and Pathania (2003), Singh *et al* (2003), Singh and Singh (2004) and Singh (2006).

MATERIAL AND METHODS

The present investigation was carried out at the Department of Vegetable Crops, Punjab Agricultural University, Ludhiana, during rainy season of the year 2006-07 using 15 diverse lines, four testers and two standard checks (BH-1 and BH-2). Parents were crossed to obtain 60 F_1 hybrids. These F_1 hybrids, along with their parents and standard checks, were transplanted to the field with spacing of 60cm x 45cm. Other cultural practices were followed as per the package of practices recommended by Punjab Agricultural University, Ludhiana. The experiment was laid out in Randomized Block Design with three replications. Observation recorded were: days to 50% flowering, days to first fruit harvest, average fruit weight (g), fruit length (cm), fruit girth (cm), number of fruits per plant, plant height (cm), plant spread (cm), number of primary branches, yield per plot (kg), yield per hectare (q), dry matter content (%), total sugars (%), total phenols (mg/100g) (Swain and Hill, 1959), and anthocyanin content (mg/100g) (Mahadevan and Sridhar, 1986).

Data were recorded on per plot basis with three replications. Analysis of Variance for the design was performed to obtain error mean squares, for use in further analysis. Combining ability analysis for various traits was done as per Kempthorne (1957) with computer software CPCS (Singh and Cheema, 1985).

RESULTS AND DISCUSSION

Highly significant combining ability was observed for all the characters, except number of primary branches, total sugars and anthocyanin content. Similarly, mean squares due to males were highly significant for all characters except plant height, plant spread, total sugars, total phenols and anthocyanin content. Mean sum of squares due to females and males were also highly significant except for plant height, plant spread, number of primary branches, total sugars, total phenols and anthocyanin content.

Ratio of variance due to specific combining ability and general combining ability effects (σ^2sca: σ^2gca) was greater than unity, indicating non-additive genetic control for all the traits under study except plant spread and total phenols. This indicated that non-additive gene effects had a greater role in controlling inheritance of characters like days to 50% flowering, days to first fruit harvest, average fruit weight, fruit length, fruit girth, number of fruits per plant, plant height, number of primary branches, yield per plot, dry matter content, total sugars, anthocyanin content and yield per hectare. This indicates that heterosis breeding can be exploited for improvement in these traits. For plant spread and total phenols, additive gene action was predominant, whereby, improvement can be made by selection. Padmanabham and Jagadish (1996) reported most of the characters (including 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) reported predominance of non-additive variance for most characters, including fruit yield, plant height and plant spread.

General combining ability (GCA) reflects the average performance of a parent in a series of cross-combinations, estimated from performance of F_1s. Estimates for general combining ability effects are presented in Table 1. For days to 50% flowering, HABL-1, Jamuni Gola and Punjab Barsati were good combiners among the female lines for earliness, due to the highly significant, negative general combining ability effects. However, among males, PB-64 was found to be a good combiner for earliness. Days to first fruit harvest showed that the female parents Punjab Barsati, BSR-11, Jamuni Gola and JBR-3-16 were good combiners for early fruit harvest. Among the males, PB-64 was found to be a good combiner for days to first fruit harvest. Average fruit weight indicated that the female parents RCMBL-1-1 and JBR-3-16 and the male parents U-8-61-3 and BB-93-C were good combiners for improvement in average fruit weight in brinjal. For fruit length, GCA effect among females was significant in PB-1, Punjab Barsati, PB-2 and KS-331. Among males, U-8-61-3 and PB-64 were found to be good combiners for improving fruit length. For fruit girth, the female lines RCMBL-1-1, PPL, Jamuni Gola, IVBR-3 and NDB-21 and the tester BB-93-C exhibited significant, positive general combining ability effects. For number of fruits per plant, female lines JBR-3-16, Jamuni Gola, Punjab Barsati and KS-331 were found to be good combiners; while, among male lines, JBSR-98-2 and U-8-61-3 were good general combiners, with significant, positive GCA effects. For plant height, among the female lines, HABL-1 and PB-2 recorded highly significant, positive general combining ability effects and were, hence, good combiners. Male line BB-93-C was the best combiner for plant height. Lines PB-1, HABL-1 and RCMBL-1-1 exhibited high and significant, positive general combining ability effects for plant spread. Among the testers, BB-93-C was found to be a good combiner, exhibiting significant, positive GCA effects. As for number of primary branches, among the females KS-331, IVBR-3 and, Punjab Barsati, and among males, U-8-61-3 exhibited high and significant, positive general combining ability effects. High yield is the prime objective of most varietal improvement programme and the new variety is expected to have a yield potential higher than or equal to existing cultivars. Punjab Barsati, followed by PBR-91-1, RCMBL-1-1 and BSR-11 among the female parents; and BB-93-C and U-8-61-3 among male parents, were found to be good combiners for yield.

Analysis of combining abilities for dry matter content revealed that among females, HABL-1, Jamuni Gola, Punjab Barsati, RCMBL-1-1 and PBR-91-1 were good general combiners. Among males, JBSR-98-2 was found to be a good general combiner. For total sugars, among the females, best combiners were PB-2, PPL, JPM/PKB-105-2 and PB-1. Among males, the best combiners were BB-93-C and U-

8-61-3. For total phenols, PB-2, PBR-91-1 and PB-1 among females, and among males, U-8-61-3, BB-93-C and PB-64 were found to be good combiners. For anthocyanin content, female lines RCMBL-1-1, Punjab Barsati and PPL, and a male line BB-93-C, were found to be good general combiners.

Having observed the overall performance of all female parents for general combining ability effects, it can be inferred that the female parent Punjab Barsati was the best combiner for days to 50% flowering, days to first fruit harvest, number of fruits per plant and number of primary branches. The female parent RCMBL-1-1 was also a good combiner for average fruit weight, fruit girth and plant spread. BSR-11 was the best combiner for days to first fruit harvest and for total yield.

Among the testers, BB-93-C was a good combiner for average fruit weight, fruit girth, plant height, plant spread, yield per plot and total yield. PB-64 was the best male parent for days to 50% flowering and days to first fruit harvest. U-8-61-3 was the best male combiner for average fruit weight, fruit length and number of primary branches. Variation in combining ability among genotypes has been reported earlier by Varshney *et al* (1999), Das and Barva (2001), Kumar and Pathania (2003) and Ashwani and Khandelwal (2005).

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. Days to 50% flowering in eleven crosses showed desirable significant, negative specific combining ability effects. The cross JBR-3-16×PB-64 recorded highest value for significant, negative SCA effects. Kumar and Pathania (2003) and Ashwani and Khandewal (2005) also reported significant negative SCA effects for days to first fruit harvest. For this trait, thirteen crosses showed desirable significant negative, specific combining ability effects. The cross combination Punjab Barsati × U-8-61-3 recorded highest negative SCA effects, followed by the other crosses. For average fruit weight, ten crosses showed positive specific combining ability effects. The cross PBR-91-1 × JBSR-98-2 was observed to be the best specific combiner for this character, followed by the other crosses. Padmanabham and Jagadish (1990) and Varshney *et al* (1999) also found significant, positive specific combining ability effects for average fruit weight. Among the thirteen crosses exhibiting significant, positive specific combining ability effects for fruit length, highest SCA effect was recorded in the cross BSR-11 × PB-64, followed by the other crosses. Significant estimates of SCA effects of crosses for fruit length in brinjal were also reported earlier by Varshney *et al* (1999) and Ashwani and Khandewal (2005). For fruit girth, 17 cross-combinations showed significant, positive SCA effects. The cross-combination BSR-11 × U-8-61-3 recorded highest SCA estimates, followed by the other crosses. Ingale and Patil (1997) and Varshney *et al* (1999) also found significant estimates for specific combining ability effects of crosses made for fruit diameter. Number of fruits per plant revealed that thirteen crosses had significant desirable specific combining ability effects. The cross IVBR-3 × PB-64 exhibited highest positive SCA effects, followed by the other crosses. These results are in conformity with findings of Padmanabham and Jagadish (1996) and Ashwani and Khandewal (2005).

SCA effects on plant height revealed fifteen crosses as having significant, positive SCA estimates. The cross HABL-1 × U-8-61-3 showed highest significant, positive SCA effects, followed by the other crosses. Significant estimates for specific combining ability effects of crosses for plant height in brinjal have also been reported by Ponnuswami and Irulappan (1992) and Varshney *et al* (1999). For plant spread, 11 cross-combinations exhibited significant, positive specific combining ability effects. Cross-combinations with high values for significant, positive SCA effects for this trait were IVBR-3 × BB-93-C, followed by other crosses.

SCA effects on number of primary branches revealed that 17 crosses had significant positive effects. The cross PBR-91-1 × BB-93-C showed highest significant positive SCA. For yield per plot and yield per hectare, specific combining ability revealed that 13 cross combinations had significant positive estimates. The combination HABL-1 × JBSR-98-2 was observed to have highest significant positive SCA, followed by the other crosses. Ingale and Patil (1997), Varshney *et al* (1999) and Ashwani and Khandewal (2005) also reported similar observations in F_1 hybrids of brinjal for fruit yield per plant. Significant estimates for specific combining ability of crosses for yield per hectare in brinjal was also reported earlier by Varshney *et al* (1999) and Kumar and Pathania (2003).

In the case of dry matter content, seven cross-combinations showed positive, significant SCA. The cross HABL-1 × BB-93-C gave highest significant positive SCA effects for this trait. In the case of total sugars, analysis of

Table 1. General combining ability effects of some lines and testers for various traits in brinjal

Parent	Days to 50% flowering	Days to first fruit harvest	Average fruit weight	Fruit length	Fruit girth	No. of fruits per plant	Plant height	Plant spread	No. of primary branches	Yield per plot	Yield per hectare	Dry matter content	Total sugars	Total phenols	Anthocyanin content
Female parent															
BSR-11	0.28	-1.62**	-13.31	0.14	-0.37	-0.51	-8.25**	-7.36**	-0.92**	1.76**	65.54**	-0.81**	-0.25**	-32.56**	-0.18
IVBR-3	-0.97	-0.46	-20.81**	-1.37**	0.71**	0.91	1.32	-1.87	0.89**	-0.32	-11.64	-0.34	0.05	10.43	-0.35**
HABL-1	-2.87*	0.38	-5.81	0.51	-0.64**	0.51	6.24*	6.80**	0.49	-0.21	57.31**	1.07**	-0.06	-17.49	0.11
Punjab Barsati	-2.63**	-2.37**	9.19	2.36**	-1.11*	1.58*	1.72	3.55	0.84**	3.05**	113.29**	0.85**	-0.06	14.52	0.42**
JPM/PKB-105-2	0.53	1.21**	10.03	-0.70	0.09	-0.01	2.88	0.89	-0.21	-0.26	-11.99	0.35	0.22**	19.97	0.23
PBR-91-1	-0.88	-0.04	-18.72**	-2.78**	-0.42*	-1.26*	-3.01	-5.53*	-0.89**	2.20**	81.89**	0.65*	-0.18*	31.23**	0.18
RCMBL-1-1	2.63**	1.38**	68.36**	-0.27	1.35**	-3.92**	3.34	5.35*	0.04	2.01**	74.79**	0.75**	-0.02	-8.07	0.45**
PB-1	-0.30	1.71**	-12.06	4.52**	-0.82**	-0.26	-0.09	6.95**	-0.98**	-3.49**	-128.94**	-1.09**	0.15*	28.94*	0.16
H-8	-0.88	-0.12	9.19	-0.59	-0.44*	0.41	3.39	1.08	-0.07	-0.18	-6.22	-0.30	0.14	-13.68	0.22
NDB-21	0.78	1.21**	10.44	-1.80**	0.53*	-.309**	-1.71	-5.90*	-0.74*	0.32	12.29	0.46	0.08	-1.50	-0.10
JBR-3-16	2.95**	-0.79*	42.53**	0.46	0.30	3.41**	1.23	5.11	-0.10	0.35	13.21	-0.32	-0.04	-33.51**	-0.39**
KS-331	-0.47	0.63	-16.22*	1.16**	-0.64**	1.49*	0.85	2.60	0.95**	-1.85**	-70.49**	-0.78**	-0.16*	-11.98	-0.11
Jamuni Gola	-2.65**	-1.21**	-35.39**	-2.25**	0.74**	2.08**	-8.06	-1.63	-0.65*	-1.57**	-57.69**	0.93**	-0.19**	-18.97	0.13
PPL	1.53	0.71	-23.72**	-0.94*	0.76**	-0.26	-5.57*	-5.25*	-0.27	-2.46**	-90.66**	-0.09	0.23**	-23.57*	0.36**
PB-2	-1.30	-0.62	-3.72	1.56**	-0.03	-0.09	5.73*	1.60	0.43	0.64	23.93	0.33	0.26**	32.28**	-0.13
CD (*P=0.05*)	1.98	0.75	13.45	0.75	0.42	1.18	5.51	5.16	0.64	0.83	31.15	0.55	0.15	23.47	0.26
CD (*P=0.01*)	2.60	0.98	17.70	0.96	0.55	1.6	7.25	6.8	0.84	1.09	41.00	0.72	0.19	30.90	.0.34
Male parent															
BB-93-C	1.98**	0.78**	12.86**	-2.07**	0.91**	-0.45	3.62**	3.16**	0.27	3.56**	132.24**	0.03	0.096**	15.27**	0.17**
U-8-61-3	-0.60	-0.24	18.19**	2.16**	0.04	0.71**	2.29	2.26	0.42**	1.48**	53.64**	-0.15	0.078*	16.86**	-0.11
PB-64	-0.91*	-0.52**	-27.03**	0.54**	-0.97**	-1.43**	-2.21	-2.04	-0.39**	-4.05**	-149.49**	-0.32**	-0.098**	15.26**	-0.19**
JBSR-98-2	-0.47	-0.31	-4.03	-0.64**	0.02	1.17**	-3.64**	-3.41**	0.25	-0.99**	-36.40**	0.44**	-0.068	7.34	-0.10
CD (*P=0.05*)	0.91	0.34	6.22	0.33	0.19	0.54	2.55	2.35	0.29	0.38	14.42	0.25	0.072	10.86	0.12
CD (*P=0.01*)	1.19	0.44	8.18	0.43	0.25	0.71	3.35	3.13	0.38	0.50	18.98	0.32	0.094	14.29	0.15

* and ** significant at 5 and 1 per cent, respectively

Table 2. Specific combining ability effects of crosses for various traits in brinjal

Hybrid	Days to 50% flowering	Days to first fruit harvest	Average fruit weight	Fruit length	Fruit girth	No. of fruits per plant	Plant height	Plant spread	No. of primary branches	Yield per plot	Yield per hectare	Dry matter content	Total sugars	Total phenols	Anthocyanin content
BSR-11´BB-93-C	-4.62**	-2.44**	-102.02**	-3.29**	-1.73**	5.95**	-8.96	-9.45*	-1.74**	-1.89**	-70.51*	1.60**	-0.38**	33.35	-0.19
BSR-11´U-8-61-3	1.18	1.91**	102.63**	-6.64**	3.82**	-6.87**	10.19**	-11.79**	1.77**	3.02**	113.02**	-0.34	0.15	-38.81	0.15
BSR-11´PB-64	5.82**	0.22	7.86	8.53**	-1.52**	-2.40*	14.59**	12.30**	-0.99	-4.15**	-154.20**	-1.38**	0.45**	-28.49	0.29
BSR-11´JBSR-98-2	-0.95	0.31	-8.4	1.40*	-0.55	3.32**	-12.82**	-5.46	0.17	3.02**	111.69**	-0.24	-0.37**	65.95**	-0.17
IVBR-3´BB-93-C	-1.14	-1.61**	8.80	0.53	-0.29	-5.80**	13.96**	13.93**	1.57**	-1.37	-51.40	1.50**	-0.16	17.39	0.31
IVBR-3´U-8-61-3	7.10**	-1.25	-4.8	-4.20**	0.05	-0.62	-13.41**	12.19**	-1.49**	0.34	13.63	-1.00*	0.37**	19.59	-0.73**
IVBR-3´PB-64	-5.14**	0.72	-11.30	3.95**	-1.73**	6.84**	14.17**	6.41	1.58**	0.99	36.53	-0.15	-0.27*	-24.65	0.28
IVBR-3´JBSR-98-2	-0.03	2.14**	7.36	-0.27	1.97**	-0.42	-15.73**	-13.54**	-0.53	0.04	1.23	-1.34**	-0.12	-63.22**	-0.82**
HABL-1´BB-93-C	7.02**	9.88**	-52.86**	-1.12	1.14**	-6.71**	-8.94	-12.53**	1.76**	-11.76**	-435.96**	1.70**	0.11	-26.72	-0.22
HABL-1´U-8-61-3	-1.73	-4.42**	5.13	0.30	-0.23	4.79**	15.11**	7.55	1.48**	1.79*	67.33*	0.57	-0.44**	31.30	0.63**
HABL-1´PB-64	-0.75	1.55*	13.69	-5.16**	0.84*	-2.73**	-14.82**	12.16**	-0.68	1.24	45.80	1.49**	0.17	62.19**	-0.03
HABL-1´JBSR-98-2	-4.53**	-7.02**	34.02**	5.99*	-0.74*	4.66**	-7.17	-5.17	1.06	8.72**	322.81**	0.63	0.36**	-13.78	-0.20
Punjab Barsati ´BB-93-C	5.52**	2.63*	-37.86**	-6.07**	0.60	2.20*	13.34**	5.72	-0.55	-1.32	-49.49	-1.52**	-0.38**	-12.51	0.32
Punjab Barsati ´U-8-61-3	-5.56**	-7.33**	13.47	3.05**	-1.56**	1.04	-5.97	-12.49**	-1.79**	6.86**	255.40**	1.54**	-0.18	-27.34	-0.22
Punjab Barsati ´PB-64	-1.58	-1.02	8.69	8.08**	-0.28	-2.82**	-13.10**	-13.47**	1.46**	-0.41	-15.55	-1.04*	0.56**	55.65**	-0.78**
Punjab Barsati ´JBSR-98-2	5.63**	5.72**	15.69	-5.06**	1.25**	-0.42	14.73**	5.24	0.30	-5.13**	-190.35**	1.03*	0.18	-16.04	0.26
JPM/PKB-105-2 ´BB-93-C	2.02	0.72	111.30**	0.02	1.30**	-3.54**	13.23**	6.81	-2.12**	5.65**	211.95**	0.96*	-0.21	-18.77	0.72**
JPM/PKB-105-2 ´U-8-61-3	-1.06	-0.25	-17.36	3.93**	2.18**	2.29*	-12.89**	-12.32**	1.92**	-2.29**	-92.41**	-0.59	-0.55**	-52.61**	0.06
JPM/PKB-105-2 ´PB-64	5.24**	2.05**	-42.13**	-1.70**	-0.51	-3.90**	-7.13	-4.98	1.04	-2.93**	-106.30**	-1.33**	0.11	61.72**	-0.42
JPM/PKB-105-2 ´JBSR-98-2	-1.20	-2.52**	-51.80**	-2.25**	-0.98**	5.16**	-8.99	-5.64	-0.83	-0.42	-13.23	-0.23	0.22	-57.72**	-0.29
PBR-91-1´BB-93-C	-4.56**	-2.69**	-49.94**	0.64	-0.70	2.70**	6.63	-4.86	2.01**	2.12**	78.57**	1.04*	0.38**	-68.88**	0.77**
PBR-91-1U-8-61-3	5.35**	-0.005	-46.94**	0.24	-0.75*	0.21	13.43**	12.48**	0.66	-2.75**	-100.86**	-1.32**	0.29*	-26.19	-0.17
PBR-91-1 ´PB-64	1.66	0.30	-26.72*	-1.15	2.04**	0.34	-12.27*	-11.85	-1.94**	-1.52*	-56.99*	0.57	-0.13	-18.43	-0.69**
PBR-91-1JBSR-98-2	2.55	2.39*	123.61**	0.26	1.42**	-3.25**	7.20	8.55	1.56**	2.15**	79.27**	-0.29	-0.14	56.61**	0.73**
RCMBL-1-1 ´BB-93-C	-0.81	-0.44	19.63	-0.93	1.09**	-0.96	-12.60**	-7.48	1.74**	1.08	39.97	1.01*	0.13	17.06	0.19
RCMBL-1-1 ´U-8-61-3	2.43	3.57**	57.63**	-3.16**	-0.73*	-1.12	-8.36	-6.04	-1.69**	0.60	23.50	0.45	0.44**	-35.84	-0.15
RCMBL-1-1 ´PB-64	-0.25	1.55*	-27.13*	-2.43**	0.16	-1.98	-9.18	12.66**	1.36*	4.06**	150.14**	-0.19	-0.13	-59.21**	0.60**
RCMBL-1-1 ´JBSR-98-2	-1.36	-4.68**	-50.13**	6.53**	0.47	4.07**	12.72**	7.97	0.41	-5.75**	-213.62**	-0.26	-0.04	-22.00	-0.22
PB-1BB-93-C	-2.14	-0.11	-3.27	0.33	2.44**	1.03	5.71	-6.06	1.77**	-3.01**	-111.96**	-1.50**	-0.16	34.02	0.34
PB-1U-8-61-3	7.43	3.24**	-11.94	4.98**	-0.56	1.21	-13.56**	-7.89	-0.74	-3.19**	-117.19**	0.88	0.14	34.95	-0.71**
PB-1PB-64	-5.45**	-1.44**	38.27**	-1.94**	1.41**	-2.32*	13.03**	-4.99	1.48**	-0.43	16.52	0.72	0.62**	-22.62	0.13

Table 2. Contd.

Hybrid	Days to 50% flowering	Days to first fruit harvest	Average fruit weight	Fruit length	Fruit girth	No. of fruits per plant	Plant height	Plant spread	No. of primary branches	Yield per plot	Yield per hectare	Dry matter content	Total sugars	Total phenols	Anthocyanin content
PB-1JBSR-98-2	-0.36	-1.68**	-23.05	-3.37**	-0.28	0.07	-6.18	12.53**	-1.43*	6.64**	245.37**	0.50	-0.15	-67.34**	-0.30
H-8´BB-93-C	-1.56	-1.94**	35.47**	1.69**	0.51	3.03**	-8.33	6.71	-1.48**	1.97**	72.84**	-0.62	0.14	-48.38*	0.67**
H-8´U-8-61-3	5.35**	1.74**	-53.19**	-0.61	-0.82*	1.21	-5.55	-5.39	-0.85	1.32	50.21	0.56	-0.27*	29.00	-0.21
H-8´PB-64	-1.68	-2.27**	-17.97	0.30	-0.21	2.67*	-8.67	13.55**	-0.96	-1.95**	-72.58**	-1.73**	-0.31**	-33.53	0.45
H-8´JBSR-98-2	2.21	2.47**	35.69	-1.38*	0.52	-6.92**	7.56	-11.87**	1.78**	-1.35*	-50.47	0.80	0.12	20.91	-0.55*
NDB-21BB-93-C	-5.22**	-0.27	37.55**	1.98**	-0.14	-2.13*	13.52**	7.09	1.06	1.27	46.90	1.32**	-0.17	33.22	-0.17
NDB-21U-8-61-3	5.01**	-0.25	-14.44	0.52	2.21**	-1.28	6.48	-6.31	0.77	-1.35	-49.16	-0.68	-0.15	63.47**	-0.47*
NDB-21PB-64	2.99	-1.27**	19.11	-1.08	1.11**	-0.15	6.02	-5.73	0.80	0.38	13.84	-1.33**	0.16	-62.22**	-0.18
NDB-21JBSR-98-2	3.21	1.81*	-42.22**	-1.42*	-0.18	3.57**	-14.03**	-4.04	-1.64**	-0.30	-11.58	0.69	0.11	-26.67	0.21
JBR-3-16´BB-93-C	10.93**	-1.61**	-4.52	-0.24	0.14	1.70	-8.09	-13.84**	-1.47**	2.95**	108.94**	1.19*	-0.47**	38.16	-0.32
JBR-3-16U-8-61-3	-0.81	3.07**	23.47*	-0.68	0.55	0.54	-12.59**	-8.98	1.66**	0.15	6.71	-0.30	0.19	-53.65**	-0.12
JBR-3-16PB-64	-8.17**	-4.27**	38.69**	-2.14**	1.22**	-1.98	14.45**	5.69	-1.60**	1.12	41.31	0.62	0.11	28.41	0.62**
JBR-3-16JBSR-98-2	-1.95	2.81**	-57.63**	3.07**	-1.91**	-0.25	9.93	7.14	0.57	-4.22**	-156.97**	-1.50**	0.37**	-14.26	0.18
KS-331BB-93-C	-2.64	0.97	30.88**	3.50**	-0.36	0.28	7.06	12.76**	0.38	1.01	39.54	-0.63	0.17	32.49	-0.21
KS-331U-8-61-3	-5.06**	-1.33*	5.55	0.20	-0.77*	-0.87	-13.06**	-8.61	-1.56**	-0.94	-40.81	-0.91	-0.57**	27.20	0.38
KS-331PB-64	1.91	0.97	-15.88	-1.16	0.47	3.59**	-8.96	-5.16	1.48**	0.25	11.41	1.08*	-0.17	-37.54	-0.11
KS-331JBSR-98-2	1.79	-0.60	-20.55	-2.54**	0.65	-3.00**	5.87	-12.38**	-0.58	-0.32	-10.14	0.46	0.18	-42.15*	-0.15
Jamuni Gola ´BB-93-C	-1.89	-1.86**	20.05	0.47	-0.18	1.70	12.81**	6.23	0.88	1.19	44.05	-0.14	0.11	29.90	-0.27
Jamuni Gola ´U-8-61-3	1.35	1.82**	-26.94*	0.58	3.05**	0.21	4.97	12.11**	0.27	0.45	17.75	0.98*	-0.47**	-18.93	-0.12
Jamuni Gola´PB-64	5.66**	-1.52*	6.61	-1.86**	0.44	1.67	-6.25	-10.36*	-1.89**	1.40	51.85	-0.82	-0.17	-20.47	0.24
Jamuni Gola ´JBSR-98-2	-0.11	1.56*	0.27	0.81	-0.31	-3.58**	-5.53	-8.98	-1.05	-3.06**	-113.67**	-1.44**	-0.19	29.50	-0.83**
PPL´BB-93-C	-1.31	1.55*	-28.27*	1.19	0.46	-1.29	-13.97**	-5.84	-1.53**	-0.67	-25.41	-0.84	-0.18	55.73**	-0.68**
PPL´U-8-61-3	-4.60**	0.91	-8.61	-0.49	1.07**	-1.12	-6.68	-6.62	1.88**	-3.32**	-122.14**	0.64	0.16	-65.47**	0.41
PPL´PB-64	1.24	1.55	8.27	-1.92**	0.22	-0.32	13.50**	12.03**	0.53	0.60	22.12	0.15	-0.42**	17.05	-0.22
PPL JBSR-98-2	-5.33**	-4.2**	28.61	1.21	-0.75*	2.74**	-12.72**	7.43	1.78**	3.39**	125.42**	0.04	-0.16	-63.44**	0.64**
PB-2BB-93-C	-2.14	-2.77**	15.05	1.28*	-0.28	1.86	6.09	8.40	0.23	2.76**	101.93**	0.35	0.13	-9.96	-0.18
PB-2U-8-61-3	5.43**	-1.43*	-23.61*	1.97**	0.50	0.37	12.97**	6.52	-1.55**	-0.70	-25.00	0.30	-0.18	18.60	-0.11
PB-2PB-64	2.07	2.88*	-0.05	-0.28	2.32**	3.51**	-4.31	-5.02	0.98	1.33	49.13	1.41**	-0.07	12.65	0.15
PB-2JBSR-98-2	1.63	1.31*	8.61	-2.97**	-0.54	-5.75**	-6.71	6.09	1.08	-3.39**	-126.06**	-1.06*	-0.49**	-58.29**	-0.79**
CD (*P=0.05*)	3.43	1.30	23.31	1.27	0.73	2.05	9.55	8.94	1.11	1.44	53.96	0.96	0.27	40.66	0.46
CD (*P=0.01*)	4.51	1.71	30.68	1.67	0.96	2.69	12.57	11.76	1.46	1.89	71.02	1.26	0.35	53.52	0.60

* and ** significant at 5 and 1 per cent, respectively

SCA revealed that seven crosses had desirable specific combining ability. PB-1 × PB-64 (0.62) cross-combination exhibited highest positive SCA, followed by the other crosses. SCA in the case of total phenols revealed that seven crosses had significant, positive estimates. The crosses BSR-11 × JBSR-98-2, NDB-21 × U-8-61-3, HABL-1 × PB-64 and JPM/PKB-105-2 × PB-64 showed highest significant, positive SCA, followed by the other crosses. Anthocyanin (content) analysis for SCA revealed that eight crosses had desirable specific combining ability. PBR-91-1 × BB-93-C cross combination exhibited highest positive SCA.

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