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Heterosis analysis for yield and quality in eggplant (*Solanum melongena* L.)

Abstract. The experiment was conducted with 55 eggplant hybrids derived from 11 x 11 half diallel crosses along with standard variety at the field 10 and field 15 of University of Putra Malaysia (Serdang, Selangor, Malaysia) at one season during November 2020 to January 2021. The aim of this research was to develop high yield and quality eggplant hybrids. This research was followed by randomised complete block design with three replications at two locations. 15 morphological and

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biochemical traits were estimated for heterosis. Among these, BM9 × BB26 was chosen as the best hybrid for yield per plant considering standard heterosis, heterobeltosis and relative heterosis. Besides, BB1 × BT15 hybrid was also the best for total soluble solid over check variety and BT6 × BT15 was the best for total phenol content considering all three types of heterosis i.e. relative heterosis, heterobeltosis and standard heterosis. Conversely, the highest value for heterobeltosis and relative heterosis was found in the hybrid BM5 × BT15 and the hybrid BM9 × BB23 was the best over standard heterosis for DPPH of antioxidant activity. Hence, these two hybrids could be considered to get higher antioxidant activity in eggplants. The breeders, agronomists, and horticulturists can use these results to select the best hybrids for further practical research

Keywords: hybrids; half diallel; per se performance; best parent heterosis; antioxidant activity

INTRODUCTION

Eggplant is the most significant crop of solanaceae family, which is popular because of its high nutrition and palatability of fruits. It is widely spread as one of the most important vegetables cultivated in both tropical and subtropical regions throughout the world. The preferences of eggplant vary from area to area for colour, shape, and size. Thus, it is crucial to create hybrids, having high quality along with high yields. Heterosis has become widely used in the breeding method to increase production of solanaceaous vegetable like eggplant. The effect of heterosis in vegetable crops is clearly shown by the significant increases of yield observed over the last 50 years, following the introduction of hybrids into crop production. Both hybrids and enhanced agronomic techniques has resulted to a consistent, linear enhancement in the performance of vegetable crops. Hybrid vigour exploitation has become an effective tool to improve of eggplant. With the increasing popularity of F_1 hybrid, this trend has allowed for its commercial utilisation in the eggplant industry. Moreover, the researchers found that the level of heterosis is directly proportionate to the genetic diversity existed within parents, which provides together a variety of favourable alleles coming from multiple genes.

A lot of studies have been published by supporting the potentiality of heterosis in various traits. of E. Hassan (2021) indicated in the work that the hybrid (P3 x P6) had the highest value of relative heterosis and heterobeltosis i.e. 230.02% and 218.85% respectively for the character total yield. Furthermore, S. Anvesh *et al.* (2025) pointed out in the work that the highest level of heterosis over better parent (HB) was found in Punjab Sadabahar x Pant Rituraj (i.e. 72.26%) followed by the hybrid Pusa Purple Long x Pant Rituraj and NDB-2 x Pant Rituraj for the character yield. Besides, D. Rameshkumar & I. Vethamonai (2020) found that the hybrid Seetipulam Local x Sevathampatti Local was the superior cross combination for most of the studied characters like earliness and yield per plant considering better parent and standard heterosis. S. Mishra *et al.* (2023) revealed that the crosses BBSR-08-2 x selection from BBSR-145-1, BBSR-08-2 × BBSR-10-26 and the cross BBSR-08-2 × BBSR-10-25 showed significant positive heterosis for the trait fruit yield attributing traits, fruit yield and also for vegetative traits over relative heterosis, heterobeltosis and standard heterosis. The researchers, H. Thota & I. Delvadiya (2025) exhibited the highest significant and positive standard heterosis from the cross combination JBR-3 x JBR-5 for the character total yield per plant i.e. 154.49%. A. Kumari *et al.* (2025) recorded in the findings that the cross, PPL x Arka harshita, PPL x Pusa Anupam and PPL x PPC exhibited fruitful heterosis and appreciable heterobeltosis for the character yield and earliness. Z. Khasdhar *et al.* (2024) emphasised in the research that the highest value of standard heterosis for the character fruit yield per plant was recorded from the cross AB-08-14 x GBL-3 over standard check. The researchers Rajashree *et al.* (2023) found in the research that the highest positive heterosis from the cross combination KRCCH-11 x GL, KRCCH-12 x GL and KRCCH-10 x GL for the character earliness and yield parameters whereas KRCCH-11 × BL and KRCCH-11 x GL showed superior for quality trait. The main objectives of any hybridisation program are to create genetically modified and potential lucrative genotypes through accumulation of stable gene effects. Thus, it is critical to identify firstly more or less homozygous lines and flexible parental lines selection. Keeping this in mind, both heterosis and combining ability study are very much important for each plant breeding program due to providing necessary information for varietal improvement and commercial utilisation of heterosis (Quamruzzaman *et al.*, 2020).

This research was done to select the best hybrid from 55 hybrid combination that was developed by the researcher from 11 × 11 half diallel method of breeding with standard check varieties and to select the best hybrids (high yield and high quality) which can be used to mitigate nutritional security.

MATERIALS AND METHODS

Experiment site. The experiment was conducted with two locations (at field 10 and field 15) in one season at Universiti Putra Malaysia simultaneously from November 2020 to January 2021. Plant materials. Eleven eggplant genotypes were used as parents in 11 × 11 half diallel method (excluding reciprocal) to develop 55 F_1 hybrids in this research. These 11 genotypes were BB1, BB12, BB23, BB26, BB31, BT6, BT13, BT15, BT17, BM5 and BM9. Layout and design of experiment. This study was carried out in a RCB design (randomised complete block design) with three times replication. There were 5 plants in each replication. Spacing was maintained 60 cm between plants and 80 cm between rows. A well drainage system was kept in the field. Data collection. Data of 12 quantitative trait were taken from five plants in each genotype per replication. Quantitative trait likely days to first flower opening, days to 50% flower opening, plant height, stem diameter, no. of primary branches/plant, fruit diameter, fruit length, fruit girth, ratio of length to width of fruit, individual fruit weight, yield of fruit/plant, no. of fruits /plant, TSS (Total soluble solid), TPC (Total phenol content) and DPPH (Antioxidant activity) etc.

Statistical analysis. Heterosis estimation: expression of heterosis as % of increase of F_1 over mid parent, better parent and commercial check were determined for each trait by using the following formulae (Mohsin *et al.*, 2022):

$$\text{relative heterosis (MP)} = \frac{F1-MP}{MP} \times 100. \qquad (1)$$

$$\text{Heterobeltosis (HB)} = \frac{F1-BP}{BP} \times 100. \qquad (2)$$

$$\text{Standard heterosis} = \frac{F1-CV}{CV} \times 100, \qquad 3)$$

where F_1, MP, BP, and CV are the average of F_1, two parent (MP), better parent (BP) and check variety (CV) respectively.

Significant difference of F_1 were calculated with MP, BP, and CV by using "t" test. The following formula was used:

$$[\text{t}] = \frac{F1-MP}{SED} \times 100, \qquad (4)$$

where $\text{SED} = \sqrt{\frac{2EMS}{r}}$.

$$[\text{t}] = \frac{F1-BP}{SED} \times 100, \qquad (5)$$

where $\text{SED} = \sqrt{\frac{2EMS}{r}}$.

$$[\text{t}] = \frac{F1-CV}{SED} \times 100, \qquad (6)$$

where $\text{SED} = \sqrt{\frac{2EMS}{r}}$.

Here, SED means standard error of difference; EMS = error mean square; r = replication.

Besides, $\text{SED} = \sqrt{\frac{Variance}{Sample\ Size}}$.

The study was conducted in accordance with the ethical standards of the Convention on Biological Diversity (1992) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1976).

RESULTS AND DISCUSSION

Heterosis were calculated for each crosses of 55 hybrids for yield, yield related characters and some biochemical characters over mid parent, better parent and standard variety. Here, heterosis results have been shown in Tables 1-4. All types of heterosis (mid, better, and standard) were discussed individual trait-wise in the following way. Fruit length. The fruit length is an important character to develop high yielding variety. Out of 55 hybrids, 33 hybrids, 15 hybrids and 6 hybrids showed significant positive relative heterosis, heterobeltosis and standard heterosis respectively. The rest of the hybrids showed significant negative heterosis. The hybrid BM5 × BT13 had the highest value of relative heterosis that is 57.60% and the least value of relative heterosis was -38.33% recorded from the hybrid BM5 × BT15 (Table 1). On the other hand, the highest and the lowest value of heterobeltosis was 31.94% (BM9 × BB1) and -64.01% (BM5 × BT15) respectively. Besides, the hybrid's standard heterobeltosis value was ranged from -71.09% (BB12 × BT15) to 21.73% (BB31 × BT13). Considering all three types of heterosis, hybrids BM9 × BT13, BB26 × BM5, BB31 × BT13 and BM5 × BT13 were found as the best hybrids due to the positive heterosis over the mid parent, better parent and check variety across the environment.

Fruit diameter. For this character, relative heterosis varied from -43.39 to 28.98% for the hybrids BB12 × BT17 and BB1 × BB31, respectively. Out of 55 hybrids – 18 hybrids, 7 hybrids and 31 hybrids showed significant positive relative heterosis, heterobeltosis and standard heterosis respectively. The heterobeltosis value for this trait varied from -58.77 to 20.795% for the hybrids BB12 × BT17 and BM9 × BB1, respectively. Besides, standard heterosis for this trait varied from -35.05 (BT13 × BT15) to 60.28% (BT17 × BB1). Considering all types of heterosis, the crosses BM9 × BB26, BM9 × BB1, BB1 × BB26 and BB1 × BB31 performed positive over all types of heterosis among all the studied hybrids. Fruit girth. In this trait, all the hybrids showed highly significantly values for relative heterosis and standard heterosis but in case of heterobeltosis all hybrids performed significantly except two hybrids (BB12 × BM5 and BB12 × BT13) showed non-significant values. The highest value for relative heterosis was found by BB31 × BT6 with the value of 37.29% and the least value was recorded by BM9 × BB23 with the value of -44.21%. The value of HB was ranged from -60.65 to 15.18% from the hybrids BM9 × BB23 and BM9 × BB26 respectively. The SH value ranged from -33.14 (BM9 × BB23) to 79.91% (BM9 × BB1) for fruit girth.

Fruit length to width ratio. Most of the hybrids showed highly significant values, except three crosses in case of relative heterosis (RH). These three crosses showed non-significant values. The value of RH for this trait varied from -40.29 (BB1 × BB31) to 143.01% (BM9 × BT13). The HB value for ranged from -61.07 (BM5 × BT15) to 54.87% (BM9 × BB31), and the standard heterosis value varied from -71.05 (BT17 × BT6) to 56.75% (BM9 × BB31). The hybrids namely; BM9 × BB23, BM9 × BB31, BM9 × BT13, BB26 × BM5, BB31 × BM5, BB31 × BT13 and BM5 × BT13 had a positive significant value for all three types of heterosis. Individual fruit weight. Most of the hybrids showed positively significant values for relative heterosis (RH) except four. These four hybrids were non-significant for RH. The RH value ranged from -60.15 (BM5 × BT15) to 153.30% (BT13 × BT 6). The HB varied from -79.08 (BM5 × BT15) to 99.73% (BT13 × BT6). The SH was -84.93 (BB12 × BT15) to 105.04% (BM9 × BB1) (Table 2). The crosses BM9 × BB1, BM9 × BB26, BT17 × BB26, and BB26 × BM5 had the significant positive value for all types of heterosis namely; RH, HB and SH.

Yield per plant. The highest RH value was performed with the hybrid BM9 × BB26 (466.53%), and the minimum value was recorded from the hybrid BT6 × BT15 (-74.83%). The value of HB ranged from 315.07 (BM9 × BB26) to -81.15% (BT6 × BT15). The heterosis over check variety was performed from 130.79 (BM9 × BB26) to 82.63% (BT6 × BT15) (Tables 1-4). The hybrids BB12 × BB1, BB12 × BT6, BT17 × BB1, BM9 × BB26, BM9 × BM5, BB23 × BB31, BB23 × BM5, BB26 × BM5, BB31 × BM5, BB31 × BT13, BB31 × BT6 and BB31 × BT15 performed positively significant for all types of heterosis (Table 5). Number of primary branches per plant (PB). The extent of RH for the trait PB ranged from 57.66 (BB12 × BT15) to -52.75% (BB1 × BT6). Besides, the value of HB and SH 41.51 to -61.35% and 91.34 to -51.41% respectively. Fourteen hybrids were found to be good over MP, BP, and CV for this character (Tables 1-4). Days to first flower opening (DF). The values of SH, HB and RH ranged from -27.91 to 53.49%, -37.87 to 71.45% and -54.32 to 71.45% respectively. The cross BB1 × BT6 showed the highest value for all heterosis. The least value of HB and RH was found from the crosses BM5 × BT15 and BB23 × BB31, respectively. On the other side, the lowest value for SH was performed from the cross BM5 × BT15. Days to 50% flower opening (DFF). The maximum value of SH, HB and RH for this character found from the cross BB1 × BT6 with the value of 53.59%, 42.18% and 63.96% respectively.

Similarly, the minimum value of SH, HB and RH was found from the cross BM5 × BT 15 with the value of -29.53%, -38.83% and -38.60% respectively (Table 3). Besides, no hybrid performed non-significant relation with all three types of heterosis.

Number of fruits per plant (NF). All the hybrids showed positively significant value for all SH, HB and RH except BB23 × BT6, which showed non-significant value for SH. The RH value varied from 315.14 (BM9 × BB26) to -90.80% (BT6 × BT15). The HB value varied from 206.71 (BB31 × BM5) to -94.79% (BT17 × BT15). On the other hand, the extent of SH from 354.46 (BT13 × BT15) to -79.55% (BB1 × BB26) (Tables 1-4). Plant height (PH). The magnitude of RH, HB and SH valued from 61.56 to –24.92% (BB23 × BT15 to BB1 × BB26), 54.24 to -33.15% (BB23 × BT15 to BB1 × BB26) and 41.45 to 18.34% (BM9 × BB26 to BB1 × BT13) respectively (Table 3). Besides, all the hybrids showed positively significant value except two hybrids for standard heterosis, which showed non-significant value. Stem diameter (SD). The maximum value (27.05%) of RH was recorded from the several hybrids like BT17 × BB1, BB12 × BB1, BM9 × BB23, BB31 × BT13, BB23 × BT6 and BB1 × BB31 (Table 3). Other side, the lowest value(-25.40%)ofRHwasrecordedfromthecrosses BB12 × BM9, BT17 × BM9, BM9 × BB1, BB1 × BB26, BB23 × BT13, BB31 × BM5 and BT13 × BT15. Besides, the HB for this trait ranged from -8.56 to -19.55%, in which none of the crosses showed positive heterobeltosis. Here, the standard heterosis (SH) lied in between 32.48 to 19.59%, whereas, none crosses showed negative value of SH.

Total soluble solid (TSS) (Table 4). The value of RH, HB and SH range varied from 16.09 (BM9 × BB26) to -15.01% (BT17 × BT15), 8.24 (BB12 × BM9) to -29.91% (BM9 × BT15) and 17.69 (BB1 × BT15) to -7.86% (BB26 × BT13) respectively. Total phenol content (TPC). The RH for this character ranged from 71.98 to -76.52% whereas, the HB ranged from 71.29 to -81.30%. But a wide range of variation was recorded for SH from 192.43 to -71.32%. The highest and the lowest value was found from the hybrid BT6 × BT15 and BB31 × BT13 respectively for RH, HB and SH. DPPH (antioxidant activity). This character was shown relative heterosis (RH) ranged from 53.45 to -37.02% from the cross BM5 × BT15 and BB26 × BT13 respectively. The value of HB for DPPH ranged from 33.34 (BM5 × BT15) to -39.01% (BB26 × BT13) (Table 3). Besides, depend on standard heterosis, the top hybrid for all the studied traits is shown in Table 5.

Table 1. Percentage of heterosis (mid-parent, better-parent and standard heterosis) for fruit morphology traits in eggplant hybrids

Crosses	FL			FD			FG			FLWR		
	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)
BB12 × BT17	-49.37**	-14.00**	-7.59**	28.97**	-58.77**	-43.39**	-14.37**	-53.83**	-35.75**	-32.02**	5.61**	39.93**
BB12 × BM9	-43.98**	-9.79**	-0.67**	4.44**	-36.34**	-21.96**	-17.71**	-36.51**	-21.89**	-29.96**	8.81**	14.57**
BB12 × BB1	-47.20**	-13.80**	-5.67**	12.38**	-27.75**	-2.22 NS	14.93**	-32.37**	-8.44**	-52.87**	-26.78**	-14.08**
BB12 × BB23	-42.86**	-12.91**	-1.74**	-15.65**	-3.82**	-0.09**	5.10**	-4.55**	9.93**	-33.06**	-12.29**	-4.71**
BB12 × BB26	-34.10**	14.34**	21.67**	10.05**	-25.38**	-5.73**	13.43**	-18.78**	2.76**	-36.98**	-2.10**	18.83**
BB12 ×BB31	-20.95**	-25.80**	0.52**	-7.01**	-15.55**	-4.73**	-10.50**	-18.80**	-6.44**	-11.40**	-12.47**	7.01**
BB12 × BM5	-22.04**	-28.38**	-2.27**	-16.12**	-6.85**	-3.48**	-8.55**	-0.35 NS	5.80**	-3.48**	-23.83**	1.02**
BB12 × BT13	-18.26**	-2.86**	21.24**	-25.23**	-9.46**	-1.82*	-19.19**	-0.38NS	7.69**	12.58**	-6.68**	21.70**
BB12 × BT6	-63.32**	-27.72**	-14.51**	-24.53**	-26.18**	-20.69**	-23.09**	-5.18**	0.45**	-40.28**	-7.23**	4.24**
BB12 × BT15	-71.09**	-43.02**	-16.18**	-28.74**	-16.76**	-5.30**	-21.71**	-3.48**	8.61**	-57.66**	-34.22**	-9.45**
BT17 × BM9	-38.55**	-1.05**	1.60**	52.57**	-33.80**	-23.15**	27.01**	-31.51**	-19.38**	-48.72**	-11.42**	13.10**
BT17 × BB1	-27.28**	18.74**	21.08**	60.28**	-12.60**	-3.43**	62.26**	-12.50**	-8.66**	-53.54**	2.46**	18.91**
BT17 × BB23	-27.91**	9.87**	15.83**	32.24**	-36.32**	-14.72**	31.13**	-29.29**	-11.25**	-34.58**	-14.28**	19.69**
BT17 × BB26	-37.37**	6.39**	7.52**	57.94**	-12.53**	-1.92**	58.32**	-14.63**	-2.58**	-60.29**	-4.77**	6.61**
BT17 × BB31	-14.47**	-19.71**	3.46**	40.89**	-34.67**	-17.88**	23.72**	-33.28**	-16.30**	-25.07**	-25.97**	11.83**
BT17 × BM5	-14.09**	-21.08**	2.45**	32.01**	-51.80**	-35.34**	-9.50**	-51.20**	-34.71**	2.83**	-18.85**	28.93**
BT17 × BT13	-22.02**	-7.33**	9.05**	22.90**	-42.81**	-17.59**	0.74**	-45.68**	-20.81**	-23.14**	-36.30**	0.18NS
BT17 × BT6	-58.66**	-29.78**	-12.03**	23.36**	-19.74**	15.21**	47.14**	-20.65**	14.28**	-71.05**	-42.57**	-30.58**
BT17 × BT15	-61.19**	-34.07**	0.72**	19.16**	-31.68**	1.54**	28.27**	-30.83**	3.25**	-68.39**	-4.19**	2.07**
BM9 × BB1	-18.06**	31.94**	32.86**	35.75**	20.79**	27.85**	79.91**	5.87**	20.16**	-52.50**	-17.95**	-7.61**
BM9 × BB23	-37.91**	-5.37**	-2.77**	7.71**	-50.79**	-41.50**	-33.14**	-60.65**	-44.21**	0.98**	32.32**	50.70**
BM9 × BB26	-24.51**	21.56**	26.10**	33.41**	8.77**	13.34**	60.87**	15.18**	19.52**	-48.99**	-11.89**	2.44**

Table 1, Continued

Crosses	FL			FD			FG			FLWR		
	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)
BM9 × BB31	3.59**	-2.76**	22.90**	16.36**	-45.07**	-39.56**	-14.18**	-33.78**	-28.43**	56.75**	54.87**	97.03**
BM9 × BM5	-5.39**	-13.09**	10.68**	7.48**	-32.48**	-19.57**	-7.21**	-28.41**	-16.18**	9.89**	-13.29**	19.04**
BM9 × BT13	4.01**	23.61**	42.25**	-1.64**	-37.90**	-19.16**	-15.58**	-34.86**	-14.99**	31.34**	8.86**	143.01**
BM9 × BT6	-36.12**	2.87**	31.43**	-1.17**	-44.89**	-28.61**	-24.74**	-41.93**	-25.36**	-10.90**	53.90**	64.86**
BM9 × BT15	-66.32**	-45.77**	-16.11**	-5.37**	-45.68**	-26.50**	-19.69**	-38.04**	-16.62**	-47.30**	-8.97**	21.09**
BB1 × BB23	-46.49**	-18.45**	-15.64**	15.65**	-10.03**	11.78**	31.38**	-22.68**	-6.16**	-59.51**	-46.95**	-33.33**
BB1 × BB26	-37.61**	1.87**	4.97**	41.36**	2.82**	4.52**	55.58**	-8.44**	0.53**	-57.49**	-6.25**	-2.33**
BB1 × BB31	-28.79**	-33.15**	-15.08**	24.30**	11.57**	28.98**	59.87**	-5.92**	14.19**	-56.24**	-56.77**	-40.29**
BB1 × BM5	-29.36**	-35.10**	-16.94**	15.19**	-8.02**	14.74**	36.38**	-19.74**	4.26**	-45.18**	-56.74**	-36.27**
BB1 × BT13	-42.75**	-31.96**	-21.24**	6.07**	-39.38**	-17.88**	0.18**	-41.04**	-16.10**	-31.17**	-42.95**	-17.07**
BB1 × BT6	-43.17**	-7.20**	17.97**	6.78**	-12.63**	17.58**	21.58**	-28.45**	0.53**	-55.36**	-11.45**	-6.57**
BB1 × BT15	-65.51**	-43.69**	-13.18**	2.57**	-31.76**	-4.40**	6.24**	-37.48**	-8.79**	-64.81**	-22.40**	-5.53**
BB23 × BB26	-26.26**	12.38**	19.66**	13.32**	-17.65**	1.03**	5.41**	-24.53**	-15.59**	-35.05**	-14.90**	10.25**
BB23 × BB31	-18.32**	-23.33**	-5.08**	-3.74**	-3.34**	5.34**	-0.54**	-9.76**	-9.68**	-17.95**	-18.93**	-7.46**
BB23 × BM5	-6.56**	-14.16**	7.11**	-12.85**	-7.07**	-6.57**	-8.16**	-16.59**	-8.99**	18.93**	-6.15**	17.27**
BB23 × BT13	-13.41**	2.91**	15.64**	-21.96**	9.16**	22.55**	-1.73**	-10.75**	9.78**	-9.11**	-24.66**	-7.61**
BB23 × BT6	-42.84**	-12.89**	13.49**	-21.26**	-13.33**	-3.56**	-10.51**	-18.73**	-1.71**	-17.27**	8.40**	30.56**
BB23 × BT15	-70.41**	-54.90**	-29.38**	-25.47**	-26.27**	-13.32**	-17.37**	-24.95**	-4.57**	-54.22**	-40.01**	-13.01**
BB26 × BB31	-10.84**	-16.30**	8.66**	21.96**	-10.87**	1.53**	22.02**	-12.64**	-2.29**	-28.10**	-28.97**	0.61NS
BB26 × BM5	9.38**	0.49**	31.40**	12.85**	-36.74**	-22.12**	6.72**	-23.59**	-7.74**	32.59**	4.63**	57.45**
BB26 × BT13	-37.01**	-25.15**	-11.15**	3.74**	-50.20**	-33.30**	4.90**	-24.90**	0.60**	-9.75**	-25.20**	11.18**
BB26 × BT6	-50.94**	-14.88**	5.79**	4.44**	-39.10**	-18.98**	-2.52**	-30.21**	-7.87**	-41.84**	15.39**	26.58**
BB26 × BT15	-65.31**	-39.80**	-8.50**	0.23**	-30.55**	-3.73**	2.27**	-26.78**	0.90**	-64.64**	-14.80**	-0.19NS
BB31 × BM5	7.90**	-0.87**	0.22*	-4.21**	-20.18**	-12.52**	-16.17**	-23.94**	-16.99**	27.77**	0.83**	12.11**
BB31 × BT13	21.73**	14.27**	27.72**	-13.32**	-19.62**	-2.65**	-13.54**	-21.56**	-3.49**	42.38**	18.01**	28.35**
BB31 × BT6	-26.81**	-31.29**	3.39**	-12.62**	3.26**	24.06**	25.10**	13.50**	37.29**	-30.57**	-31.40**	-8.29**
BB31 × BT15	-58.69**	-61.22**	-33.78**	-16.82**	-9.94**	13.67**	-6.67**	-15.33**	7.78**	-56.07**	-56.60**	-32.61**
BM5 × BT13	14.64**	5.32**	57.60**	-22.20**	-8.25**	2.35**	-18.57**	-11.27**	1.30**	44.67**	14.16**	16.97**
BM5 × BT6	-15.76**	-22.61**	17.03**	-21.73**	-16.78**	-7.71**	-28.30**	-21.87**	-12.47**	17.95**	-6.92**	33.33**
BM5 × BT15	-60.83**	-64.01**	-38.33**	-25.93**	-9.47**	6.10**	-22.14**	-15.16**	0.61**	-50.67**	-61.08**	-36.71**
BT13 × BT6	-36.97**	-25.09**	5.70**	-30.84**	-1.95**	-0.96**	-19.92**	11.18**	13.56**	-5.94**	-22.04**	10.11**
BT13 × BT15	-62.18**	-55.05**	-26.09**	-35.05**	-4.71**	0.78*	-22.34**	7.83**	17.70**	-41.09**	-51.17**	-21.35**
BT6 × BT15	-63.67**	3.52**	36.30**	-34.35**	19.84**	12.16**	-21.45**	9.06**	16.34**	-50.57**	-1.94**	24.57**

Note: DFF – days to 50% flower opening, NF – number of fruits per plant, PH – plant height, SD – stem diameter, RH – relative heterosis, HB – heterobeltosis, SH – standard heterosis

Source: research by the authors

Table 2. Percentage of heterosis for yield components in eggplant hybrids

Crosses	FW			PB			YPP			DF		
	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)
BB12 × BT17	-64.99**	-72.46**	-54.85**	38.52**	-21.15**	-11.81**	-27.70**	-34.49**	1.14*	-2.33**	-10.64**	-6.04**
BB12 × BM9	-63.80**	-62.69**	-42.05**	8.48**	-21.68**	-17.90**	-11.65**	171.02**	202.21**	-2.79**	-16.40**	-9.52**
BB12 × BB1	-49.19**	-60.19**	-34.67**	-17.22**	-40.24**	-24.24**	43.16**	268.33**	300.62**	-19.07**	-23.01**	-20.55**
BB12 × BB23	-43.26**	-19.05**	15.78**	25.71**	-9.25**	18.12**	-31.19**	82.00**	95.46**	-3.26**	-11.11**	-6.71**
BB12 × BB26	-46.73**	-31.85**	0.42NS	-34.28**	-52.55**	-40.54**	-59.88**	-27.84**	-9.02**	0.00NS	-14.68**	-7.31**
BB12 × BB31	-37.28**	-54.61**	-24.49**	8.57**	-21.62**	-1.78**	-25.16**	-14.42**	24.68**	-0.93**	0.47**	1.92**
BB12 × BM5	-46.45**	-54.19**	-26.05**	5.66**	-23.72**	-11.42**	-26.29**	11.05**	48.94**	2.33**	-15.06**	-6.58**
BB12 × BT13	-53.04**	20.63**	40.48**	8.48**	-21.68**	-20.38**	-70.75**	-70.79**	-55.92**	-9.30**	-8.02**	-6.02**
BB12 × BT6	-78.72**	-23.81**	-15.55**	91.43**	38.20**	44.88**	10.12**	140.13**	180.70**	-7.91**	24.53**	6.76**
BB12 × BT15	-84.93**	-46.05**	-10.84**	79.95**	29.91**	57.66**	-20.62**	-13.86**	27.25**	-12.09**	-21.25**	-16.36**
BT17 × BM9	-27.73**	-43.16**	-35.51**	65.64**	-5.71**	9.95**	-46.59**	-51.61**	-21.60**	14.42**	4.68**	1.43**
BT17 × BB1	20.90**	-5.26**	-5.09**	25.71**	-28.44**	-1.61**	66.27**	50.66**	122.84**	0.93**	-13.20**	-5.87**
BT17 × BB23	6.60**	-16.16**	8.10**	17.14**	-33.32**	-6.24**	-13.85**	-21.94**	16.29**	21.40**	11.31**	11.31**
BT17 × BB26	30.65**	2.76**	27.27**	-20.05**	-54.49**	-38.05**	-43.13**	-48.47**	-31.47**	-0.93**	-12.52**	-12.52**
BT17 × BB31	24.90**	-9.61**	-5.85**	14.22**	-34.98**	-11.49**	6.72**	-3.31**	7.90**	6.51**	-7.29**	3.85**
BT17 × BM5	-29.91**	-44.87**	-42.56**	0.00NS	-43.07**	-27.43**	-22.60**	-29.87**	-12.41**	21.86**	6.06**	6.06**
BT17 × BT13	-35.19**	-49.03**	-21.95**	-8.57**	-47.95**	-40.92**	-15.40**	-23.34**	-19.62**	-5.58**	-7.31**	-7.31**
BT17 × BT6	-6.38**	-26.37**	25.15**	5.66**	-39.85**	-29.86**	-16.17**	-24.04**	7.32**	1.40**	10.67**	10.67**
BT17 × BT15	-54.43**	-64.16**	-31.48**	7.11**	-39.02**	-19.25**	-59.97**	-63.73**	-60.46**	0.00NS	-9.47**	-9.47**
BM9 × BB1	105.04**	60.67**	82.57**	0.00NS	-20.45**	-2.75**	-31.16**	77.12**	112.67**	11.16**	0.41**	0.41**
BM9 × BB23	-56.95**	-55.62**	-48.47**	31.36**	4.50**	31.36**	-81.25**	-50.41**	-41.11**	2.79**	-8.67**	-8.67**

Table 2, Continued

Crosses	FW			PB			YPP			DF		
	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)
BM9 × BB26	42.83**	47.24**	63.07**	25.71**	0.00NS	20.74**	130.79**	315.07**	466.53**	3.26**	-11.55**	-11.55**
BM9 × BB31	-1.33**	-28.60**	-16.09**	2.83**	-18.20**	-1.23**	-66.00**	-61.12**	-40.00**	6.98**	0.88**	0.88**
BM9 × BM5	-12.16**	-24.86**	-17.87**	28.53**	2.25**	11.36**	0.02NS	50.68**	116.85**	-8.84**	-22.99**	-22.99**
BM9 × BT13	-15.71**	-13.11**	24.02**	0.00NS	-25.53**	-22.97**	-23.69**	-23.78**	21.13**	-20.93	-24.94**	-24.94**
BM9 × BT6	-56.98**	-55.66**	-27.99**	54.24**	22.70**	22.70**	-77.13**	-50.12**	-36.23**	10.23**	15.90**	15.90**
BM9 × BT15	-78.76**	-78.11**	-58.72**	26.39**	0.55**	17.34**	-59.30**	-55.84**	-31.04**	-6.98**	-18.36**	-18.36**
BB1 × BB23	-26.46**	-42.38**	-25.61**	-34.28**	-17.79**	-6.00**	-73.27**	-31.22**	-30.26**	20.47**	12.62**	12.62**
BB1 × BB26	16.17**	-8.97**	12.90**	-37.19**	-24.12**	-22.68**	-72.30**	-50.18**	-41.36**	-4.65**	-14.22**	-14.22**
BB1 × BB31	33.99**	-3.04**	0.82NS	-51.41**	-41.30**	-40.19**	-40.73**	-32.23**	-6.16**	18.14**	17.59**	17.59**
BB1 × BT13	-39.82**	-52.84**	-27.73**	-10.03**	-32.99**	-15.87**	-57.90**	-57.96**	-39.43**	4.19**	4.43**	4.43**
BB1 × BT6	-25.37**	-41.52**	-0.54NS	-51.41**	-61.35**	-52.75**	-57.31**	-6.90**	0.78NS	53.49**	71.45**	71.45**
BB1 × BT15	-69.52**	-76.12**	-54.33**	-8.57**	1.67**	7.78**	-11.19**	-3.62**	35.57**	-27.44**	-33.04**	-33.04**
BB23 × BB26	-31.44**	-12.29**	-7.51**	-20.05**	-3.42**	1.97**	-75.66**	-56.22**	-47.88**	22.33**	8.23**	8.23**
BB23 × BB31	-19.95**	-42.07**	-23.13**	-11.48**	6.94**	12.90**	18.10**	35.05**	88.57**	-6.51**	-8.64**	-54.32**
BB23 × BM5	-11.88**	-24.62**	-5.74**	25.71**	25.71**	44.25**	46.05**	120.03**	180.37**	-15.35**	-26.16**	-26.16**
BB23 × BT13	-17.91**	17.12**	50.61**	40.02**	4.28**	34.49**	-30.82**	-30.91**	0.31NS	19.07**	17.18**	17.18**
BB23 × BT6	-58.64**	-40.98**	-10.61**	28.53**	2.25**	28.53**	-53.49**	1.43**	11.19**	-8.37**	0.25NS	0.25NS
BB23 × BT15	-83.78**	-76.86**	-57.30**	17.14**	30.25**	42.84**	-55.65**	-51.87**	-31.75**	-9.30**	-17.72**	-17.72**
BB26 × BB31	12.76**	-18.40**	4.23**	17.14**	41.51**	41.51**	-41.57**	-33.19**	-18.31**	3.26**	-3.04**	-3.04**
BB26 × BM5	20.88**	3.40**	23.93**	-34.28**	-34.28**	-27.98**	73.75**	161.77**	184.89**	5.12**	-11.54**	-11.54**
BB26 × BT13	-35.34**	-17.29**	10.44**	-37.19**	-53.22**	-42.10**	-78.76**	-78.79**	-72.72**	23.26**	16.50**	16.50**
BB26 × BT6	-58.64**	-47.09**	-17.80**	17.14**	-6.82**	12.79**	-18.93**	45.80**	59.81**	-5.12**	-0.73**	-0.73**
BB26 × BT15	-73.22**	-65.74**	-36.27NS	17.14**	30.25**	35.62**	-61.54**	-58.27**	-47.94**	-2.33**	-14.63**	-14.63**
BB31 × BM5	-22.84**	-44.16**	-39.51**	17.14**	17.14**	28.36**	48.74**	70.09**	93.39**	-8.84**	-15.70**	-15.70**
BB31 × BT13	-15.17**	-38.61**	-4.20**	-11.48**	-34.08**	-18.40**	2.99**	2.86**	9.81**	3.26**	8.57**	8.57**
BB31 × BT6	-7.53**	-33.08**	15.12**	5.66**	-15.95**	1.48**	3.54**	18.40**	55.34**	-8.84**	7.42**	7.42**
BB31 × BT15	-66.59**	-75.82**	-53.62**	-17.22**	-7.96**	-4.17**	6.12**	15.16**	18.17**	-16.74**	-19.72**	-19.72**
BM5 × BT13	-21.68**	-33.00**	0.52NS	51.41**	12.76**	29.45**	-3.55**	-3.67**	15.85**	-10.70**	-16.88**	-16.88**
BM5 × BT6	-50.88**	-57.98**	-29.50**	17.14**	-6.82**	3.80**	-55.57**	-33.06**	-20.82**	31.16**	34.94**	34.94**
BM5 × BT15	-75.54**	-79.08**	-60.16**	0.00NS	0.00NS	5.42**	-19.02**	-12.13**	2.16**	-27.91**	-37.87**	-37.87**
BT13 × BT6	-22.25**	99.73**	153.30**	-11.48**	-34.08**	-31.82**	-19.84**	-19.94**	9.82**	-2.33**	16.05**	16.05**
BT13 × BT15	-79.55**	-47.46**	-8.68**	59.90**	19.08**	27.98**	-4.77**	-4.89**	-0.94**	-14.42**	-16.92**	-16.92**
BT6 × BT15	-80.16**	-11.67**	40.08**	-20.05**	-36.40**	-25.78**	-82.63**	-81.15**	-74.83**	-17.67**	-11.28**	-11.28**

Note: FW – individual fruit weight, PB – number of primary branches per plant, YPP – yield per plant, DF – days to first flower opening, RH – relative heterosis, HB – heterobeltosis, SH – standard heterosis
Source: collected from authors' research

Table 3. Percentage of heterosis for flowering and fruiting traits in eggplant hybrids

Crosses	DFF			NF			PH			SD		
	SH (%)	HB (%)	RH (%)	RH (%)	HB (%)	SH (%)	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)
BB12 × BT17	-5.91**	-10.80**	-8.70**	35.17**	38.28**	38.28**	-12.46**	-17.13**	-12.21**	-25.67**	-33.65**	-20.44**
BB12 × BM9	-8.02**	-19.56**	-12.45**	122.67**	127.79**	273.53**	-1.66**	-7.15**	-1.51**	-32.48**	-36.28**	-25.40**
BB12 × BB1	-15.19**	-21.48**	-16.77**	139.71**	145.22**	294.67**	17.04**	19.18**	21.92**	5.72**	16.17**	27.05**
BB12 × BB23	-6.33**	-13.62**	-8.26**	10.74**	13.28**	52.11**	-1.44**	5.09**	18.43**	-8.27**	-9.81**	3.86**
BB12 × BB26	-2.95**	-16.97**	-8.73**	-37.53**	-36.09**	-17.88**	7.95**	-14.17**	-1.67**	-18.49**	-13.77**	-4.56**
BB12 × BB31	-2.95**	1.32**	1.32**	9.65**	12.17**	48.11**	9.73**	-9.52**	2.04**	-9.61**	-25.47**	-8.27**
BB12 × BM5	-3.80**	-16.48**	-8.80**	31.22**	34.24**	69.75**	24.46**	23.99**	28.20**	-7.42**	10.61**	-20.44**
BB12 × BT13	-10.55**	-7.42**	-7.02**	-51.12**	-79.56**	-70.96**	0.87NS	-3.08**	1.96**	17.40**	23.72**	-20.44**
BB12 × BT6	-8.02**	-3.96**	-3.96**	280.57**	68.42**	134.97**	1.14**	-3.35**	1.94**	-4.62**	9.49**	-20.44**
BB12 × BT15	-8.44**	-19.93**	-12.85**	351.02**	-68.42**	-40.87**	12.09**	19.51**	40.23**	19.59**	57.78**	-20.44**
BT17 × BM9	10.97**	-2.95**	0.96**	-25.56**	-11.44**	41.09**	10.31**	4.15**	4.29**	-4.74**	-14.98**	-25.40**
BT17 × BB1	-0.84**	-8.20**	-7.11**	15.34**	37.23**	114.45**	22.79**	16.24**	20.48**	19.46**	6.62**	27.05**
BT17 × BB23	12.66**	3.89**	5.33**	-11.38**	5.43**	34.58**	11.60**	5.66**	25.19**	13.14**	0.97NS	3.86**
BT17 × BB26	-6.75**	-20.22**	-16.13**	-63.63**	-56.73**	-47.54**	14.25**	-9.15**	-1.25**	8.88**	-2.82**	-4.56**
BT17 × BB31	2.53**	-2.81**	2.10**	-29.58**	-16.22**	4.66**	7.62**	-11.25**	-5.14**	1.95	-15.86**	-8.27**
BT17 × BM5	14.35**	-0.73**	3.63**	17.01**	39.21**	66.33**	6.92**	1.22**	3.79**	7.18**	-4.65**	-20.44**
BT17 × BT13	-5.91**	-10.80**	-6.89**	36.91**	-42.73**	-15.25**	9.28**	3.46**	4.22**	4.01**	-7.47**	-20.44**
BT17 × BT6	-0.84**	-6.00**	7.31**	-24.44**	-66.56**	-51.25**	14.44**	8.35**	8.85**	7.91**	-4.00**	-20.44**
BT17 × BT15	0.84**	-11.81**	-8.25**	-25.56**	-94.79**	-90.15**	9.04**	3.23**	27.00**	-9.49**	-19.48**	-20.44**
BM9 × BB1	8.86**	-4.80**	-2.09**	-68.20**	34.05**	41.36**	27.05**	19.95**	24.48**	-3.77**	-9.18**	-25.40**
BM9 × BB23	3.38**	-9.60**	-7.20**	-67.08**	-30.90**	-4.73**	-6.49**	-11.72**	4.72**	-16.55**	-21.24**	27.05**
BM9 × BB26	2.53**	-12.28**	-11.31**	57.91**	189.20**	315.14**	41.45**	12.47**	22.10**	8.39**	2.29NS	3.86**
BM9 × BB31	1.27**	-11.45**	-3.42**	-67.08**	-34.82**	-8.52**	-8.38**	-24.45**	-19.35**	-3.89**	-20.76**	-4.56**

Table 3, Continued

Crosses	DFF			NF			PH			SD		
	SH (%)	HB (%)	RH (%)	RH (%)	HB (%)	SH (%)	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)
BM9 × BM5	-5.06**	-17.58**	-17.28**	4.53**	83.87**	167.63**	12.03**	5.77**	8.61**	9.25**	3.10**	-8.27**
BM9 × BT13	-19.83**	-29.89**	-24.00**	-22.73**	-67.68**	-40.69**	1.56**	-4.11**	-3.27**	4.26**	-1.61NS	-20.44**
BM9 × BT6	5.49**	-7.76**	8.93**	-62.51**	-83.41**	-69.70**	2.32**	-3.40**	-2.81**	-13.38**	-18.25**	-20.44**
BM9 × BT15	-1.69**	-14.03**	-14.02**	22.70**	-91.41**	-83.07**	4.59**	-1.25**	21.62**	-8.27**	-13.43**	-20.44**
BB1 × BB23	16.46**	7.40**	7.60**	-67.08**	-30.90**	-7.47**	-17.20**	-15.67**	-3.08**	-13.87**	-15.31**	-20.44**
BB1 × BB26	-0.84**	-15.15**	-11.82**	-79.55**	-62.55**	-47.64**	-15.92**	-33.15**	-24.92**	-22.75**	-18.27**	-25.40**
BB1 × BB31	18.57**	9.76**	16.60**	-69.33**	-39.27**	-17.13**	1.56**	-16.25**	-7.45**	-2.19	-19.36**	27.05**
BB1 × BM5	-18.57**	-29.30**	-27.03**	-21.06**	38.85**	95.94**	11.37**	10.95**	12.17**	-12.77**	-4.14**	3.86**
BB1 × BT13	13.08**	4.68**	10.52**	-28.43**	-70.06**	-45.48**	-18.34**	-21.52**	-19.25**	-16.55**	-12.05**	-4.56**
BB1 × BT6	53.59**	42.18**	63.96**	-60.22**	-82.40**	-68.11**	-16.91**	-20.59**	-18.07**	-15.09**	-6.68**	-8.27**
BB1 × BT15	-20.25**	-30.26**	-28.27**	117.01**	-84.80**	-70.10**	13.40**	15.49**	38.06**	-14.48**	-6.02**	-20.44**
BB23 × BB26	20.68**	3.24**	7.12**	-71.57**	-47.94**	-44.40**	0.62NS	-20.00**	1.41**	5.60**	3.83**	-20.44**
BB23 × BB31	-4.64**	-12.06**	-6.42**	31.22**	159.78**	167.36**	10.37**	-8.98**	13.83**	-0.97	-18.35**	-20.44**
BB23 × BM5	-7.17**	-19.41**	-16.98**	49.97**	163.79**	187.58**	7.86**	7.46**	24.67**	-1.95**	-3.59**	-20.44**
BB23 × BT13	13.92**	5.07**	11.11**	-10.26**	-62.46**	-37.40**	2.51**	-1.50**	16.00**	-0.36NS	-2.03**	-25.40**
BB23 × BT6	10.55**	1.95**	17.75**	0.00NS	-55.75**	-26.91**	-5.12**	-9.33**	7.03**	-14.11**	-15.55**	27.05**
BB23 × BT15	-9.28**	-20.67**	-18.56**	140.83**	-83.14**	-67.36**	12.08**	54.24**	61.56**	-14.48**	-15.90**	3.86**
BB26 × BB31	16.88**	22.57**	10.14**	-55.69**	-12.28**	-15.69**	33.58**	6.21**	8.15**	3.04**	-15.04**	-8.27**
BB26 × BM5	9.70**	-4.76**	-5.45**	42.02**	149.82**	155.33**	22.45**	-2.64**	8.29**	-5.35**	0.13NS	-20.44**
BB26 × BT13	32.49**	37.12**	24.11**	-72.73**	-88.59**	-81.43**	-7.06**	-26.10**	-19.13**	-25.06**	-20.72**	-20.44**
BB26 × BT6	-5.91**	18.62**	-4.09**	81.77**	-19.56**	29.57**	40.41**	11.64**	21.88**	-6.57**	-1.15**	-20.44**
BB26 × BT15	-3.38**	-15.50**	-16.42**	32.92**	-90.69**	-82.07**	29.70**	3.13**	35.21**	-6.45**	-1.03**	-20.44**
BB31 × BM5	5.06**	-8.79**	-0.20NS	74.37**	206.71**	225.45**	16.82**	-3.67**	5.41**	1.82	-16.04**	-25.40**
BB31 × BT13	6.75**	10.48**	11.21**	-2.90**	-59.38**	-32.93**	1.51**	-16.29**	-9.90**	4.01**	-14.24**	27.05**
BB31 × BT6	-0.42**	4.42**	4.42**	13.05**	-49.97**	-18.22**	7.89**	-11.03**	-4.48**	-0.73**	-18.15**	3.86**
BB31 × BT15	-15.19**	-25.83**	-19.11**	189.16**	-79.75**	-60.89**	26.67**	4.45**	35.22**	-6.33**	-22.77**	-4.56**
BM5 × BT13	-2.95**	-15.75**	-8.37**	25.53**	-47.49**	-15.10**	2.70**	-1.32**	0.46NS	5.11**	10.77**	-20.44**
BM5 × BT6	25.74**	9.16**	29.28**	5.08**	-53.50**	-25.64**	-7.72**	-11.82**	-9.98**	12.41**	29.05**	-20.44**
BM5 × BT15	-29.54**	-38.83**	-38.60**	197.10**	-79.19**	-59.98**	17.00**	16.57**	40.58**	5.60**	26.16**	-20.44**
BT13 × BT6	-3.80**	-0.45**	9.35**	64.76**	-31.08**	-29.14**	16.34**	11.18**	11.48**	5.72**	11.41**	-20.44**
BT13 × BT15	-9.28**	-20.66**	-14.00**	354.46**	-68.18**	-45.48**	14.63**	10.15**	34.74**	-4.50**	0.64NS	-25.40**
BT6 × BT15	-8.44**	-19.93**		-23.89**	-94.67**	-90.80**	-3.84**	-8.10**	12.67**	-20.07**	-8.24**	14.06**

Note: DFF – days to 50% flower opening, NF – number of fruits per plant, PH – plant height, SD – stem diameter, RH – relative heterosis, HB – heterobeltosis, SH – standard heterosis
Source: collected from authors' research

Table 4. Percentage of heterosis for vegetative growth traits in eggplant hybrids

Crosses	TSS			TPC			DPPH (antioxidant activity)		
	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)
BB12 × BT17	0.98**	-3.86**	2.30**	-1.79**	-20.70**	-13.06**	23.81**	8.13**	11.85**
BB12 × BM9	0.00NS	8.24**	8.68**	24.59**	-10.09**	-5.05**	17.98**	3.04**	7.90**
BB12 × BB1	-3.44**	-2.96**	0.64NS	-19.98**	-35.39**	-23.87**	-6.09**	-17.98**	-8.87**
BB12 × BB23	-4.18**	1.04**	2.36**	56.91**	26.69**	28.59**	5.20**	-8.12**	-5.43**
BB12 × BB26	-4.91**	2.93**	6.03**	48.48**	15.94**	17.88**	14.67**	-3.35**	-1.64**
BB12 × BB31	-5.16**	-1.53**	0.52**	6.35**	-14.14**	-0.95**	19.93**	3.86**	4.30**
BB12 × BM5	-3.44**	4.52**	6.07**	-3.13**	-21.79**	-13.82**	5.37**	-7.98**	1.60**
BB12 × BT13	-1.65**	-2.84**	1.60**	-12.08**	-42.67**	-36.56**	2.07**	-10.85**	-9.52**
BB12 × BT6	7.37**	5.30**	10.49**	59.60**	-5.75**	8.87**	0.12NS	-18.68**	-15.73**
BB12 × BT15	11.06**	-21.39**	-4.94**	49.70**	-12.32**	1.64**	16.00**	1.31**	26.74**
BT17 × BM9	-0.74**	-5.50**	0.94**	-20.42**	-42.57**	-5.05**	8.86**	1.86**	3.16**
BT17 × BB1	1.11**	-3.74**	-1.14**	-11.20**	-13.02**	-23.87**	-2.08**	-8.37**	-1.34**
BT17 × BB23	-4.18**	-8.77**	-4.12**	44.83**	20.53**	28.59**	-1.25**	-7.60**	-8.08**
BT17 × BB26	1.97**	-2.92**	6.21**	63.16**	27.41**	17.88**	2.83**	-13.33**	-8.80**
BT17 × BB31	-5.41**	-9.94**	-6.04**	-9.47**	-11.32**	-13.06**	-10.82**	-22.77**	-19.79**
BT17 × BM5	-4.91**	-9.47**	-2.33**	16.68**	14.30**	-5.05**	14.59**	7.23**	14.70**
BT17 × BT13	4.18**	-0.82**	1.01**	-21.37**	-48.72**	-23.87**	-5.78**	-15.23**	-13.57**
BT17 × BT6	-2.70**	-7.37**	-5.99**	9.36**	-35.42**	28.59**	0.55**	-18.33**	-12.56**
BT17 × BT15	4.67**	-25.91**	-15.01**	50.91**	-11.59**	17.88**	-2.71**	-8.96**	10.90**
BM9 × BB1	-4.91**	-4.44**	-0.51**	21.64**	-12.23**	-13.82**	3.35**	-0.80**	5.58**
BM9 × BB23	3.32**	3.83**	10.80**	41.27**	1.94**	-36.56**	28.28**	18.80**	20.94**
BM9 × BB26	3.69**	4.20**	16.09**	10.60**	-20.19**	8.87**	4.78**	-11.69**	-5.96**
BM9 × BB31	-5.16**	-4.69**	0.92**	-6.51**	-32.54**	1.64**	-9.00**	-21.19**	-17.13**
BM9 × BM5	-3.93**	-3.46**	5.96**	6.08**	-23.45**	-11.42**	1.02**	-3.03**	2.51**
BM9 × BT13	5.16**	3.88**	9.04**	65.08**	7.65**	-5.05**	20.26**	8.20**	11.69**

Table 4, Continued

Crosses	TSS			TPC			DPPH (antioxidant activity)		
	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)	SH (%)	HB (%)	RH (%)
BM9 × BT6	0.00NS	-1.93**	3.30**	-38.05**	-63.41**	-23.87**	5.43**	-14.37**	-7.23**
BM9 × BT15	-0.98**	-29.91**	-14.98**	95.19**	14.33**	28.59**	13.08**	8.55**	30.91**
BB1 × BB23	-4.42**	-3.95**	-1.64**	-37.70**	-48.15**	-13.06**	1.46**	-6.05**	1.66**
BB1 × BB26	-1.72**	-1.23**	5.40**	13.21**	-11.60**	-5.05**	-5.99**	-20.76**	-10.56**
BB1 × BB31	-1.72**	-1.23**	0.38**	9.73**	20.74**	-23.87**	-2.42**	-15.50**	-5.76**
BB1 × BM5	-1.23**	-0.74**	4.42**	-8.25**	-9.12**	28.59**	-1.40**	6.11**	6.86**
BB1 × BT13	-3.69**	-4.85**	-4.04**	-16.59**	-45.61**	17.88**	7.48**	-3.30**	6.02**
BB1 × BT6	-2.95**	-4.82**	-3.66**	-28.41**	-57.72**	-0.95**	-11.06**	-27.76**	-17.16**
BB1 × BT15	17.69**	-16.70**	-2.24**	58.55**	-7.13**	-13.82**	9.99**	20.06**	37.33**
BB23 × BB26	-3.19**	2.07**	6.49**	-2.43**	-23.81**	-0.01NS	-4.03**	-19.11**	-15.30**
BB23 × BB31	-6.39**	-1.30**	-2.06**	12.60**	-6.29**	0.01NS	-4.15**	-17.00**	-14.22**
BB23 × BM5	-2.21**	1.53**	5.99**	76.54**	46.92**	59.69**	-6.15**	-13.09**	-6.57**
BB23 × BT13	-1.23**	-2.47**	0.75**	6.69**	-30.42**	-21.99**	-12.01**	-20.83**	-19.69**
BB23 × BT6	3.69**	1.69**	5.37**	81.41**	7.13**	0.00NS	2.09**	-17.08**	-11.65**
BB23 × BT15	17.44**	-16.87**	-0.52**	87.66**	9.92**	0.00NS	25.27**	16.00**	41.90**
BB26 × BB31	-7.00**	-3.44**	1.47**	-26.84**	-42.87**	-13.06**	-1.94**	-17.35**	-16.24**
BB26 × BM5	1.97**	5.87**	15.44**	-40.74**	-53.73**	-5.05**	-15.16**	-28.49**	-19.79**
BB26 × BT13	-7.86**	-9.02**	-2.09**	-22.58**	-49.52**	-23.87**	-27.64**	-39.01**	-37.02**
BB26 × BT6	7.37**	5.30**	13.65**	25.37**	-25.96**	28.59**	5.98**	-13.93**	-12.34**
BB26 × BT15	5.65**	-25.22**	-7.43**	0.26NS	-41.27**	17.88**	-7.52**	-22.05**	-1.21**
BB31 × BM5	-5.90**	-2.30**	1.19**	-41.35**	-41.91**	-38.85**	8.41**	-6.12**	4.04**
BB31 × BT13	-4.42**	-5.58**	-3.23**	-71.32**	-81.30**	-76.52**	-26.37**	-36.23**	-35.01**
BB31 × BT6	3.19**	1.20**	4.09**	2.09**	-39.71**	-21.54**	-8.54**	-25.71**	-23.33**
BB31 × BT15	7.13**	-24.17**	-9.82**	124.67**	31.60**	71.77**	23.88**	7.27**	34.62**
BM5 × BT13	-1.23**	-2.43**	3.47**	-4.69**	-37.85**	-29.84**	5.98**	-4.65**	3.87**
BM5 × BT6	0.25**	-1.69**	4.62**	39.19**	-17.80**	37.86**	26.01**	2.35**	16.66**
BM5 × BT15	10.93**	-21.48**	-3.94**	45.27**	-14.91**	43.89**	23.90**	33.34**	53.45**
BT13 × BT6	4.67**	2.65**	3.05**	104.61**	20.83**	-13.06**	6.54**	-13.47**	-9.04**
BT13 × BT15	4.91**	-25.74**	-13.53**	88.37**	10.33**	-5.05**	-4.91**	-14.44**	5.83**
BT6 × BT15	11.06**	-21.36**	-8.69**	192.43**	71.29**	71.98**	7.31**	-12.84**	11.96**

Note: TSS – total soluble solid, TPC – total phenol content, RH – relative heterosis, HB – heterobeltosis, SH – standard heterosis

Source: collected from authors' research

Table 5. Best hybrids for different traits based on standard heterosis

Crosses	Traits
BM9 × BB26	Plant height, and yield per plant
BB12 × BT6	Number of primary branches per plant
BM5 × BT15	Days to first flower opening and days to 50% flower opening
BB12 × BT15	Stem diameter
BT13 × BT15	Number of fruits per plant
BB31 × BT13	Fruit length
BM9 × BB1	Individual fruit weight and fruit girth
BT17 × BB1	Fruit diameter
BB1 × BT15	Total soluble solid
BT6 × BT15	Total phenol content
BM9 × BB23	DPPH (antioxidant activity)

Source: compiled by the authors from their research

The information of heterosis is a prerequisite to develop hybrids is well known. A hybrid is good when it has abundant of heterosis for exploitation of commercially. Here, fruit length is a significant character which is directly correlated with yield. That's why positive heterosis is considerable for this trait, though fruit size varied on consumer's choice. The greatest value of RH, HB and SH was found from the hybrids BM5 × BT13, BM9 × BT13 and BB31 × BT13 with the value of 57.60%, 42.25% and 21.73% respectively which were considered the best hybrids over the environment. The researcher T. Sharma *et al.* (2016) reported more or less similar results that supported the above results. The top values of fruit diameter were found from the hybrids BT17 × BB1, BM9 × BB1 and BB1 × BB31 for SH, HB and RH respectively. Besides, regarding fruit girth, the hybrids BB31 × BT6, BM9 × BB26 and BM9 × BB1 performed the highest positive heterosis value for RH, HB and SH respectively. The findings of C. Mistry *et al.* (2018) support this researcher result for HB and RH. On the other hand, the character fruit length to width ratio BM9 × BT13 hybrid performed the best for RH and BM9 × BB31 hybrid recorded the best for HB and SH. The character individual fruit weight is directly connected to the trait yield per plant. Thus, the trait individual fruit weight is also crucial trait, as yield per plant is the target. The hybrid BT13 × BT6 registered the best for RH, and BM9 × BB1 hybrid found the best for SH and HB. Hence, it can be counted these hybrids for individual fruit weight. Besides, the final objective of the breeding program is to increase yield for each plant. As the character yield is a complex trait, so the trait yield for each plant is the final result of its components. Besides, heterosis plays a major part in it. Considering all types of heterosis, the hybrid BM9 × BB26 found the best. Breeding between various parents has been attempted, and non-additive gene action brightens a high heterosis value for fruit output per plant.

Findings of this result that is high heterosis are almost same findings with the researcher J. de Sousa & W. Maluf (1998). Hybrids namely BB12 × BT15, BB26 × BB31, and BB12 × BT6 were found as good for RH, HB and SH respectively considering the character number of primary branches per plant. This character performed low heterosis compared to others such as yield per plant, number of fruits per plant and individual fruit weight. This finding is similar to the previous researchers N. Dharwad *et al.* (2012) and J. Prohens *et al.* (2013). Earliness is one of the most crucial factors in the breeding program, in which days to first flower opening and days to 50% flower opening are two important characters that assess earliness. In this case, negative heterosis is desirable over mid parent, better parent and standard variety. Here, the majority of the hybrids displayed negative heterosis, meaning earliness. Among all the studied hybrid, the BM5 × BT15 cross was the earliest hybrid, as it had the lowest value of heterosis for both DF and DFF. Early flowering of eggplant occurs due to negative effect of heterosis has been reported by previous reporters S. Kumar & T. Arumugam (2013) and T. Sharma *et al.* (2016).

The trait number of fruits per plant is one of the important characters to enhance yield per plant in eggplant. 28 hybrids showed positive standard heterosis for this character. In case of number of fruits per plant, BT13 × BT15 performed the best, considering standard heterosis. Besides, the hybrid BB12 × BB1 and BB31 × BM5 showed the highest value of RH and HB. Similar findings were also reported by S. Dash (2017). The BM9 × BB26 hybrid performed the highest heterosis value for plant height over check variety meaning it would be preferable to generate taller plants over check variety and to develop shorter plant than the check variety, cross BB1 × BT13 perform the better. M. Shahjahan *et al.* (2016) found both positive and negative heterosis values for RH and HB. Regarding stem diameter, the hybrid BB12 × BT15 performed the best positive value of SH following the hybrid BT17 × BB1. Besides, no hybrid performed positive HB value. Considering the trait TSS, the hybrids BB1 × BT15, BB12 × BM9 and BM9 × BB26 showed the greatest value of SH, HB and RH respectively and these three hybrids can consider promising hybrids for the trait TSS. This result is supported by the earlier researcher A. Patel *et al.* (2017). Moreover, the negative heterosis signified low phenol content in hybrids (Lokesh *et al.*, 2025). Thus, BT6 × BT15 hybrid could be advised as the best for the trait TPC regarding all types of heterosis. Conversely, the highest value for HB and RH is found in the hybrid BM5 × BT15 and the hybrid BM9 × BB23 was best over SH for DPPH (antioxidant activity). Hence, these two hybrids could be considered to get higher antioxidant activity in eggplants.

CONCLUSIONS

The developed 55 hybrids for achieving high yield and high quality showed highly significant heterosis. Among these, the hybrid BM9 × BB26, considered the best hybrid, showed significant positive heterosis (130.79%) over check variety for yield per plant. Besides, the hybrid BT13 × BT15 (354.46%) and BM9 × BB1 (105.04%) performed the best significant positive standard heterosis for the character number of fruits per plant and individual fruit weight respectively. Additionally, the combination BT17 × BB1, BM9 × BB1, and BM9 × BB31 showed highly significant standard heterosis for the character fruit diameter, fruit girth, and fruit length to width ratio with the value of 60.28%, 79.915 and 56.75% respectively. On the other side, considering quality of the combination the hybrid BB1 × BT15 and BT6 × BT15 exhibited the best significant positive heterosis over check for the character of total soluble solid (17.69%) and total phenol content (192.43%) respectively. Besides, the cross combinations of BM9 × BB23 showed the best performance for the character DPPH over the check variety. These findings record a strong foundation for more research and the development of new hybrids with enhanced quality characters. Further research could be focused on analysing other quality traits in these hybrids to more comprehensively assess quality and further confirmation of yield and other yield related traits. After analysis of stability for yield and other yield related performances, it can be commercially exploited. Moreover, multi-location and multi-season trials are recommended to validate the consistency of heterotic performance under diverse agro-climatic conditions.

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CONFLICT OF INTEREST

There is no conflict of interest.

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Аналіз гетерозису врожайності та якості баклажанів (*Solanum melongena* L.)

Анотація. Дослід було проведено з 55 гібридами баклажана, отриманими в результаті 11 × 11 напівдіалельних схрещувань, разом зі стандартним сортом на дослідних полях 10 і 15 Університету Путра Малайзія (Серданг, штат Селангор, Малайзія) протягом одного сезону – з листопада 2020 року по січень 2021 року. Метою дослідження було створення високоврожайних і високоякісних гібридів баклажана. Дослідження проводили за схемою рандомізованого повного блокового дизайну з трьома повтореннями у двох локаціях. Для оцінки гетерозису визначали 15 морфологічних і біохімічних ознак. Серед досліджуваних гібридів BM9 × BB26 був визначений як найкращий за врожайністю з однієї рослини з урахуванням стандартного гетерозису, гетеробельтозису та відносного гетерозису. Крім того, гібрид BB1 × BT15 виявився найкращим за вмістом загальних розчинних сухих речовин порівняно зі стандартним сортом, а гібрид BT6 × BT15 – найкращим за вмістом загальних фенольних сполук з урахуванням усіх трьох типів гетерозису: відносного, гетеробельтозису та стандартного гетерозису. Натомість найвищі значення гетеробельтозису та відносного гетерозису за антиоксидантною активністю (DPPH) були виявлені у гібриду BM5 × BT15, тоді як гібрид BM9 × BB23 показав найкращі результати за стандартним гетерозисом. Отже, ці два гібриди можна рекомендувати для отримання баклажанів з підвищеною антиоксидантною активністю. Отримані результати можуть бути використані селекціонерами, агрономами та фахівцями з овочівництва для відбору найкращих гібридів у подальших практичних дослідженнях

Ключові слова: гібриди; напівдіалельні схрещування; власна продуктивність; гетерозис за кращим батьківським компонентом; антиоксидантна активність