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Heterosis for Yield and Quality Traits in Eggplant Hybrids Grown in Rainy Season

Rashmi Kumari, Randhir Kumar, Shirin Akhtar, R. B. Verma, Gireesh Chand, Chandan Kishore

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Abstract Eggplant is among the few vegetables capable of high yields in hot-wet environments and hence suitable for Indian rainy season. Exploitation of heterosis breeding in this crop can result in enhanced yield with high quality fruits. Hence, 21 F_1 hybrids along with their seven parental lines developed by half diallel mating design excluding reciprocals was evaluated in rainy season against the check Pusa Hybrid-6 and direction and magnitude of heterosis was studied. Based on heterosis from yield point of view, the most superior three crosses were BRBL-01 × BRBL-04 (63.55%), Swarna Mani × BRBL-04 (57.01%) and Muktakeshi × BRBL-01 (47.66%). The estimates of heterobeltiosis and standard heterosis effects were low in negative direction while moderate in positive direction for yield and attributing components.

Keywords Eggplant, Hybrid, Yield attributes, Bioactive compounds.

Introduction

Eggplant, brinjal or aubergine (*Solanum melongena* L.) is a popular and nutritionally chief solanaceous vegetable crop grown widely throughout the year in all parts of the world. It is widely cultivated in both subtropical and tropical areas of the globe primarily for its young fruits and leaves used as vegetables. It is popular among individuals of all communal sections and hence, it is referred as vegetable of masses (Roychowdhury and Tah 2011). India is the 2nd largest brinjal producing country having area, production and productivity 0.66 million ha, 12.51 million tonnes and 18.54 MT, respectively (Anonymous 2017). Bihar ranks 5th among brinjal producing states. Compared to other solanaceous crops such as tomato and hot and sweet peppers, eggplant are well adapted to high rainfall and high temperatures that prevail during the May to September months in South Asia. Eggplant is among the few vegetables capable of high yields in hot-wet environments. While, prices of many vegetable crops rise dramatically in the hot-wet season, eggplant fruit is available at affordable prices. Because eggplant is an important source of plant-derived nutrients during lean periods of the year, development of eggplant genotypes with high yield and nutrient content could be particularly beneficial to poor consumers. However, the productivity of the crop remains low. Besides, eggplant genotypes having high yield and nutritional quality is the need of the hour. India being the center of diversity of the crop, high variability exists for genotypes which may be improved through heterosis breeding. Heterosis is the superiority of F_1 over the mean of the parents or over the better parent or over the standard check (Hayes et al. 1955). The crucial objective of heterosis breeding is to attain a significant jump in yield and quality aspects of any crop plants. The increase in

Rashmi Kumari, Randhir Kumar, Shirin Akhtar*, R. B. Verma
Department of Horticulture (Vegetable and Floriculture), Bihar Agricultural College, Bihar Agricultural University, Sabour, Bhagalpur, Bihar 813210, India

Gireesh Chand, Chandan Kishore
Department Plant Breeding and Genetics, Bihar Agricultural College, Bihar Agricultural University, Sabour, Bhagalpur, Bihar 813210, India
e-mail: shirin.0410@gmail.com
*Corresponding author

productivity in the minimum possible time can be achieved only through heterosis breeding, which is feasible in eggplant (Kakikazi 1931). Identification followed by utilization of highly productive hybrids may effectively raise production and improve food security (Patil 2007).

Potential of the hybrids may be estimated from the percentage increase or decrease of their performance over the mid parent (average heterosis) and better parent (heterobeltiosis) (Hochholdinger and Hoecker 2007). Heterobeltiosis is more realistic and practical because it shows the performance of the hybrid with respect to the best parent unlike relative heterosis that compares the hybrid with the mean of the two parents (Lamkey and Edwards 1999).

The present investigation was aimed at determination of the degree and direction of heterosis and heterobeltiosis for yield and its attributing traits as well as the nutritional quality traits in 21 hybrids grown in the rainy season.

Materials and Methods

Seven diverse inbred lines of brinjal, Rajendra Baingan-2 (P_1), Muktakeshi (P_2), BRBL-02 (P_3), Swarna Mani (P_4), BRBR-01, BRBL-01 (P_6) and BRBL-04 (P_7) derived from indigenous collections and maintained at vegetable farm section of Bihar Agricultural University, Sabour, Bhagalpur, selected on basis of previous diversity studies were used as parental lines. Twenty one F_1 hybrids were developed in half diallel mating scheme excluding reciprocals in the autumn-winter season of 2016-17. These 21 F_1 hybrids along with the seven parental lines and check Pusa Hybrid-6 were evaluated in Randomized Block Design in the rainy season of 2017 with June 2017 transplanting time at the vegetable research farm of Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India. Recommended agricultural practices to raise a good crop were carried out. Five random plants per replication were selected to record observation on each genotype for 10 different growth and reproductive characters and five biochemical characters of fresh fruits of horticultural maturity estimated from composite fruit samples taken from each selected plant of the replication. The magnitude of heterosis was studied using information on these quantitative characters. Heterosis was expressed as percent increase or decrease in the mean values of F_1's (hybrid) over better - parent (heterobeltiosis) and standard variety was calculated according to method suggested by Hayes et al. (1955). The formulas used for estimation of heterosis are as follows :

$$\text{Heterobeltiosis (\%)} = \frac{\bar{F}_1 - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Standard heterosis (\%)} = \frac{\bar{F}_1 - \overline{SV}}{\overline{SV}} \times 100$$

Where, $\bar{F}_1$ = Mean value of F_1, $\overline{BP}$ = Mean value of better-parent and $\overline{SV}$ = Mean value of standard variety.

Results and Discussion

Heterosis for morphological and yield attributing traits

The heterosis and heterobeltiosis for the plant growth, reproductive, fruit morphological and yield and attributing traits have been presented in Tables 1 and 2.

The range for better parent heterosis and standard heterosis for days to 50% flowering were –26.99% (BRBR-01 × BRBL-01) to 12.74% (Rajendra Baingan-2 × Muktakeshi) and –6.30% (BRBR-01 × BRBL-01) to 47.24% (Rajendra Baingan-2 × BRBL-04), respectively. Among 21 hybrids 17 hybrids showed significant negative heterosis over better parent and only BRBR-01 × BRBL-01 (–6.30%) shows significant negative heterosis over standard check.

For days to first harvesting, range of heterobeltiosis was –27.27% (Muktakeshi × Swarna Mani) to 26.16% (Rajendra Baingan-2 × BRBR-01). Among 21 hybrids 11 exhibited significant negative heterobeltiosis. Variation in the range of standard heterosis was -11.43% (BRBR-01 × BRBL-01) to 24.00% (Rajendra Baingan-2 × BRBR-01). Among 21 hybrids three exhibited significant negative heterosis over check.

Table 1. Heterosis for growth and reproductive traits. *Significant at 5% level of probability, **Significant at 1% of probability. Characters : BPH (Better parent heterosis), SH (Standard heterosis).

Characters	Days to 50% flowering		Days to 1st harvest		Plant height (cm)	
Hybrid	BPH	SH	BPH	SH	BPH	SH
Rajendra Baingan-2×Muktakeshi	12.74**	39.37**	18.07**	12.00**	− 1.44	38.68**
Rajendra Baingan-2×BRBL-02	−5.49**	22.05**	− 6.74	− 5.14	− 14.73**	19.98**
Rajendra Baingan-2×Swarna Mani	− 9.55**	11.81**	− 8.18**	15.43**	− 12.56**	44.55**
Rajendra Baingan-2×BRBR-01	3.07	32.28**	26.16**	24.00**	− 14.52**	20.27**
Rajendra Baingan-2×BRBL-01	−1.85	25.20**	15.12**	13.14**	− 17.94**	15.45**
Rajendra Baingan-2×BRBL-04	6.25**	47.24**	2.88	22.29**	− 24.51**	6.22
Muktakeshi×BRBL-02	−20.73**	2.36	− 10.11**	− 8.57*	− 16.39**	12.78**
Muktakeshi × Swarna Mani	– 10.81**	3.94	27.27	− 8.57*	– 23.04**	27.22**
Muktakeshi×BRBR-01	−19.02**	3.94	− 3.49	− 5.14	− 16.20**	13.03*
Muktakeshi×BRBL-01	−11.11**	13.39**	− 5.23	− 6.86	− 10.33*	20.94**
Muktakeshi×BRBL-04	−18.18**	13.39**	− 12.02**	4.57	− 11.95**	18.76**
BRBL-02×Swarna Mani	− 4.88*	22.83**	− 13.64**	8.57*	− 30.60**	14.73*
BRBL-02×BRBR-01	−21.95**	0.79	− 5.06	− 3.43	− 18.94**	5.32
BRBL-02×BRBL-01	−12.20**	13.39**	2.25	4	− 18.52**	5.87
BRBL-02×BRBL-04	−6.25**	29.92**	− 4.33	13.71**	−9.43*	17.68**
Swarna Mani × BRBR-01	− 9.82**	15.75**	− 16.36**	5.14	− 36.19**	5.48
Swarna Mani × BRBL-01	− 9.88**	14.96**	− 13.64**	8.57*	− 31.47**	13.28*
Swarna Mani × BRBL-04	− 21.02**	9.45**	− 21.82**	− 1.71	− 25.76**	22.73**
BRBR-01 × BRBL-01	− 26.99**	− 6.30*	− 9.88*	− 11.43**	− 22.74**	− 0.8
BRBR-01 × BRBL-04	− 12.50**	21.26**	− 15.87**	0	− 21.25**	1.11
BRBL-01 × BRBL-04	− 16.48**	15.75**	− 18.75**	− 3.43	− 9.51	4.37

T**able 1.** Continued.

Characters	Plant spread (cm)		Number of primary branches	
Hybrid	BPH	SH	BPH	SH
Rajendra Baingan-2 × Muktakeshi	9.30*	18.30**	25.00*	15.34
Rajendra Baingan-2 × BRBL-02	− 2.28	– 13.87**	13.04	0.00
Rajendra Baingan-2 × Swarna Mani	−6.2	9.09	15.34	15.34
Rajendra Baingan-2 × BRBR-01	7.45	– 0.89	− 3.54	3.81
Rajendra Baingan-2 × BRBL-01	1.94	– 10.15*	8.6	– 3.92
Rajendra Baingan-2 × BRBL-04	0.14	– 11.74*	– 4.13	– 11.53
Muktakeshi × BRBL-02	−8.67*	– 1.15	12.5	3.81
Muktakeshi × Swarna Mani	− 1.15	14.97**	3.81	3.81
Muktakeshi × BRBR-01	− 13.32**	– 6.19	– 7.07	0.00
Muktakeshi × BRBL-01	−17.22**	– 10.40*	0	– 7.73
Muktakeshi × BRBL-04	−8.38	− 0.84	– 12.5	−19.26
BRBL-02 × Swarna Mani	− 13.96**	0.06	− 3.92	– 3.92
BRBL-02 × BRBR-01	10.68*	2.09	− 24.97**	−19.26
BRBL-02 × BRBL-01	3.26	– 12.74**	8.6	−3.92
BRBL-02 × BRBL-04	20.98**	2.23	16.62	7.61
Swarna Mani × BRBR-01	– 13.85**	0.19	– 21.44**	−15.46
Swarna Mani × BRBL-01	– 27.96**	– 16.22**	– 3.92	−3.92
Swarna Mani × BRBL-04	– 23.00**	– 10.45*	3.81	3.81
BRBR-01 × BRBL-01	– 13.82**	– 20.51**	– 17.79	−11.53
BRBR-01 × BRBL-04	– 19.12**	– 25.40**	– 32.15**	−26.99**
BRBL-01 × BRBL-04	17.89**	– 12.27**	16.62	7.61

The results for days to 50% flowering and fist harvest are in conformation with those of earlier workers viz., Chowdhury et al. (2010), Nalini et al. (2011), Reddy et al. (2011), Reddy and Patel (2014). Early flowering and first harvest is generally an indication of early yield (Yordanov 1983).

Table 2. Heterosis for fruit morphological and yield traits. *Significant at 5% level of probability, **Significant at 1% of probability. Characters : BPH (Better parent heterosis), SH (Standard heterosis).

Characters	Fruit length (cm)		Fruit girth (cm)		Average fruit weight (g)	
Hybrid	BPH	SH	BPH	SH	BPH	SH
Rajendra Baingan-2×Muktakeshi	− 4.92	58.71**	− 33.65**	− 38.49**	− 29.42**	− 13.29
Rajendra Baingan-2×BRBL-02	−19.61**	34.19**	− 19.86**	− 45.32**	− 14.77	− 37.49**
Rajendra Baingan-2×Swarna Mani	−34.14**	9.93	− 27.93**	− 24.51**	− 8.5	− 8.8
Rajendra Baingan-2×BRBR-01	− 26.66**	22.42**	− 27.61**	− 29.64**	− 8.68	− 23.36**
Rajendra Baingan-2×BRBL-01	− 22.47**	29.41**	− 30.42**	− 40.31**	1.75	− 25.38**
Rajendra Baingan-2×BRBL-04	− 26.45**	22.77**	− 35.62**	− 49.28**	− 18.80*	− 40.44**
Muktakeshi×BRBL-02	− 13.98**	34.42**	− 18.26**	− 24.22**	− 32.01**	− 16.46*
Muktakeshi×Swarna Mani	−29.87**	0.88	− 22.07**	− 18.37**	− 7.17	− 14.06*
Muktakeshi×BRBR-01	− 12.64**	25.67**	− 10.54**	− 13.05**	− 14.64**	4.88
Muktakeshi×BRBL-01	− 16.06**	20.74**	− 13.40**	− 19.71**	− 22.20**	− 4.41
Muktakeshi × BRBL-04	−19.17**	16.27**	− 10.76*	− 17.27**	− 20.20**	− 1.96
BRBL-02×Swarna Mani	− 31.39**	7.22	− 26.74**	− 23.26**	− 34.83**	− 35.04**
BRBL-02×BRBR-01	− 25.18**	16.92**	− 33.33**	− 35.20**	− 27.71**	− 39.33**
BRBL-02×BRBL-01	−21.73**	22.31**	− 31.20**	− 40.98**	− 28.90**	− 50.33**
BRBL-02×BRBL-04	−14.32**	33.88**	− 27.49**	− 42.88**	− 7.39	− 46.48**
Swarna Mani×BRBR-01	− 2.23	8.75	− 1.74	2.93	8.34	7.99
Swarna Mani×BRBL-01	− 27.19**	− 2.64	− 6.66	− 2.23	− 2.55	− 2.87
Swarna Mani×BRBL-04	− 0.03	15.58*	− 13.30**	− 9.18*	− 16.90*	− 17.17*
BRBR-01×BRBL-01	− 18.34**	9.21	− 25.24**	− 27.34**	− 6.81	− 21.80**
BRBR-01×BRBL-04	−17.87**	− 5.04	− 15.49**	− 17.87**	− 22.00**	− 34.54**
BRBL-01×BRBL-04	−31.88**	− 8.9	− 26.33**	− 36.81**	− 11.63	− 38.27**

Table 2. Continued.

Characters	Number of fruits / plant		Yield / plant (kg)	
Hybrid	BPH	SH	BPH	SH
Rajendra Baingan-2 × Muktakeshi	31.77*	69.83**	27.27	4.67
Rajendra Baingan-2 × BRBL-02	19.04	88.77**	31.96*	19.63
Rajendra Baingan-2 × Swarna Mani	18.55	52.80**	25	2.8
Rajendra Baingan-2 × BRBR-01	28.50*	65.62**	− 2.27	− 19.63
Rajendra Baingan-2 × BRBL-01	5.78	86.21**	9.93	44.86**
Rajendra Baingan-2 × BRBL-04	− 4.01	99.49**	− 2.88	26.17*
Muktakeshi × BRBL-02	− 30.73**	9.84	11.34	0.93
Muktakeshi × Swarna Mani	27.89	− 10.69	21.43	−4.67
Muktakeshi × BRBR-01	31.12	5.54	42.86**	12.15
Muktakeshi × BRBL-01	−13.28	52.66**	12.06	47.66**
Muktakeshi × BRBL-04	−43.28**	17.88	2.16	32.71**
BRBL-02 × Swarna Mani	− 2.85	54.05**	28.87*	16.82
BRBL-02 × BRBR-01	9.75	74.04**	21.65	10.28
BRBL-02 × BRBL-01	− 1.74	72.96**	7.8	42.06**
BRBL-02 × BRBL-04	22.40**	154.36**	6.47	38.32**
Swarna Mani × BRBR-01	21.65	− 2.08	39.02*	6.54
Swarna Mani × BRBL-01	− 24.55**	32.81*	6.38	40.19**
Swarna Mani × BRBL-04	− 35.24**	34.57*	20.86*	57.01**
BRBR-01 × BRBL-01	−38.30**	8.62	2.84	35.51**
BRBR-01 × BRBL-04	−15.41	75.80**	− 2.16	27.10*
BRBL-01 × BRBL-04	− 7.68	91.87**	24.11**	63.55**

For plant height, better parent heterosis and standard heterosis ranged from –36.19% (Swarna Mani×BRBR-01) to –1.44% (Rajendra Baingan-2×Muktakeshi) and –0.8% (Rajendra Baingan-2 ×Muktakeshi) to 44.55% (Swarna Mani × BRBR-01), respectively. Out of 21 crosses, 14 crosses showed

Table 3. Heterosis for fruit biochemical and quality traits. *Significant at 5% level of probability, **Significant at 1% of probability. Characters : BPH (Better parent heterosis), SH (Standard heterosis).

Characters	Ascorbic acid content (mg/100 g)		Total sugar content (%)		Total anthocyanin content (mg/100 g)	
Hybrid	BPH	SH	BPH	SH	BPH	SH
Rajendra Baingan-2×Muktakeshi	29.18**	23.14**	4.49	− 9.59*	− 17.28**	− 22.24**
Rajendra Baingan-2×BRBL-02	4.77	− 0.13	11.24*	− 2.85	− 2.21	− 24.72**
Rajendra Baingan-2×Swarna Mani	67.37**	59.54**	0.11	2.28	− 30.04**	− 33.73**
Rajendra Baingan-2×BRBR-01	− 27.98**	− 9.86**	9.88*	− 2.28	− 35.85**	− 38.83**
Rajendra Baingan-2×BRBL-01	7.67**	29.58**	11.31*	− 9.02*	− 19.02	− 90.77**
Rajendra Baingan-2×BRBL-04	12.52**	14.79**	30.09**	15.98**	16.67	− 90.89**
Muktakeshi×BRBL-02	−2.7	− 8.85**	8.5	− 5.25	6.02	− 0.34
Muktakeshi×Swarna Mani	41.59**	28.70**	3.69	5.94	− 4.6	− 9.63**
Muktakeshi×BRBR-01	−18.99**	1.39	22.98**	9.36*	− 6.86	− 11.18**
Muktakeshi×BRBL-01	−8.09**	10.62**	20.18**	4	− 13.15**	− 18.36**
Muktakeshi×BRBL-04	− 8.05**	− 6.19**	12.42**	0.23	− 23.16**	− 27.77**
BRBL-02×Swarna Mani	16.60**	9.23**	9.83*	12.21**	2.61	− 2.8
BRBL-02×BRBR-01	−18.18**	2.4	9.63*	− 2.51	− 0.15	− 4.79
BRBL-02×BRBL-01	−17.44**	− 0.63	22.35**	6.85	0.7	− 22.48**
BRBL-02×BRBL-04	−10.90**	− 9.10**	21.51**	8.33*	− 13.94**	− 33.75**
Swarna Mani×BRBR-01	− 1.31	23.51**	− 12.29**	− 10.39*	0.09	− 4.55
Swarna Mani×BRBL-01	− 17.75**	− 1.01	− 7.37	− 5.37	− 17.57**	− 21.92**
Swarna Mani×BRBL-04	− 9.91**	− 8.09**	− 9.27*	− 7.31	− 23.38**	− 27.43**
BRBR-01×BRBL-01	−1.72	23.01**	38.25**	22.95**	− 65.37**	− 66.97**
BRBR-01×BRBL-04	−13.54**	8.22**	16.90**	4.22	− 56.52**	− 58.54**
BRBL-01×BRBL-04	−21.95**	− 6.07*	16.39**	3.77	− 31.7	− 92.21**

Table 3. Continued.

Characters	Total phenolics content (mg/100 g)		Total antioxidant capacity (µmol trolox equivalent/g)	
Hybrid	BPH	SH	BPH	SH
Rajendra Baingan-2 × Muktakeshi	− 11.09**	− 1.94	− 40.40**	21.48**
Rajendra Baingan-2 × BRBL-02	8.51*	22.94**	19.07**	106.71**
Rajendra Baingan-2 × Swarna Mani	− 2.93	7.06	− 45.26**	18.79**
Rajendra Baingan-2 × BRBR-01	− 16.50**	− 7.91	− 18.09**	24.61**
Rajendra Baingan-2 × BRBL-01	− 0.41	9.84*	55.84**	76.06**
Rajendra Baingan-2 × BRBL-04	− 16.78**	− 8.22	5.9	76.73**
Muktakeshi × BRBL-02	− 11.53**	0.23	− 22.06**	58.84**
Muktakeshi × Swarna Mani	− 4.57	4.67	4.85	127.52**
Muktakeshi × BRBR-01	29.30**	41.82**	22.94**	150.56**
Muktakeshi × BRBL-01	− 15.83**	− 7.68	5.27	114.54**
Muktakeshi × BRBL-04	− 14.64**	− 6.38	− 13.50**	76.29**
BRBL-02 × Swarna Mani	4.22	18.08**	− 36.91**	36.91**
BRBL-02 × BRBR-01	33.39**	51.13**	18.43**	105.59**
BRBL-02 × BRBL-01	− 14.79**	− 3.46	9.92*	90.83**
BRBL-02 × BRBL-04	10.62**	25.33**	75.39**	204.47**
Swarna Mani × BRBR-01	12.45**	19.42**	75.05**	279.87**
Swarna Mani × BRBL-01	3.46	9.88*	45.26**	215.21**
Swarna Mani × BRBL-04	− 6.33	− 0.52	− 2.37	111.86**
BRBR-01 × BRBL-01	− 4.84	− 2.9	− 20.15**	21.48**
BRBR-01 × BRBL-04	35.49**	37.97**	4.42	74.27**
BRBL-01 × BRBL-04	− 4	− 2.04	− 5.5	57.72**

significant positive heterosis over check and none of them showed significant positive heterosis over better parents. The top three crosses for this trait were Rajendra Baingan-2 × Swarna Mani (44.55%), Rajendra

Baingan-2 × Muktakeshi (38.68%) and Muktakeshi × Swarna Mani (27.22%). Better parent heterosis for plant height has been observed up to 24.82% by Balwani et al. (2017).

For plant spread, the range of heterosis over better parent was –27.96% (Swarna Mani × BRBL-01) to 20.98% (BRBL-02 × BRBL-04). Among 21 hybrids, four recorded significant positive heterosis over better parent. Range of standard heterosis for plant spread was –25.40% (BRBR-01×BRBL-04) to 18.30% (Rajendra Baingan-2×Muktakeshi). Among 21 hybrids, Rajendra Baingan-2×Muktakeshi (18.30%) and Muktakeshi×Swarna Mani (14.97%) exhibited significant positive heterosis over check.

For number of primary branches, range of heterobeltiosis and standard heterosis was from –32.15% (BRBR-01 × BRBL-04) to 25.00% (Rajendra Baingan-2 × Muktakeshi) and –26.99% (BRBR-01 × BRBL-04) to 15.34% (Rajendra Baingan-2 × Muktakeshi and Rajendra Baingan-2 × Swarna Mani), respectively. Among 21 hybrids, only Rajendra Baingan-2 × Muktakeshi (25%) exhibited significant positive heterosis over better parent but none of them showed significant positive heterosis over check. Results were consistent with the earlier report of Shahjahan et al. (2016).

Variation in the range for heterobeltiosis and standard heterosis for fruit length was recorded from –34.14% (Rajendra Baingan-2×Swarna Mani) to –0.03% (Swarna Mani × BRBL--4) and –8.9% (BRBL-01 × BRBL-04) to 58.71% (Rajendra Baingan-2 × Muktakeshi), respectively in rainy season crop. Among 21 hybrids, none of them recorded significant positive better parent heterosis. On the other hand, 13 crosses showed significant positive heterosis over check and top three were Rajendra Baingan-2-2 × Muktakeshi (58.71%), Muktakeshi × BRBL-02 (34.42%) and Rajendra Baingan-2-2 × BRBL-02 (34.19%).

For fruit girth, range of heterobeltiosis varied from −35.62% (Rajendra Baingan-2 × BRBL -04) to –1.74% (Swarna Mani × BRBR-01). Range of standard heterosis was from –49.28% (Rajendra Baingan-2 × BRBL-04) to 2.93% (Swarna Mani × BRBR-01). Among 21 hybrids, none recorded significant positive heterobeltiosis and standard heterosis over check. Significant positive heterosis for fruit length and fruit girth was also earlier reported by Makani et al. (2013), Galani et al. (2016), Bhushan et al. (2016), Balwani et al. (2017), Sivakumar et al. (2017).

For average fruit weight range of heterobeltiosis was –34.83% (BRBL-02 × Swarna Mani) to 8.34% (Swarna Mani × BRBR-01). Out of 21 hybrids, none showed significant positive heterosis over better parent. Variation in the range of standard heterosis was from –50.33% (BRBL-02 ×BRBL-01)to 14.06% (Muktakeshi × Swarna Mani). Among 21 crosses, only Muktakeshi × Swarna Mani (14.06%) showed significant positive heterosis over check. Similar findings were reported for average fruit weight by Rani et al. (2018).

The estimate of range for better parent heterosis and standard heterosis for number of fruits per plant varied from –43.28% (Muktakeshi × BRBL-04) to 31.77% (Rajendra Baingan-2 × Muktakeshi) and −10.69% (Muktakeshi × Swarna Mani) to 154.36% (BRBL-02 × BRBL-04) respectively. Out of 21 hybrids, three crosses namely, Rajendra Baingan-2 × Muktakeshi (31.77%), Rajendra Baingan-2 × BRBR-01 (28.50%) and BRBL-02×BRBL-04 (22.40%) showed significant positive heterosis over better parent while 15 crosses recorded significant and positive standard heterosis over check. Among these 15 crosses, top three were BRBL-02 ×BRBL-04 (154.36%), Rajendra Baingan-2 × BRBL-04 (99.49%) and BRBL-01×BRBL-04 (91.87%). In eggplant, heterosis over standard check for number of fruits per plant has been detected up to 69.36% by Balwani (2017) and up to 92.12% by Sivakumar (2017).

Range of heterobeltiosis for yield per plant ranged from –2.88% (Rajendra Baingan-2 × BRBL-04) to 42.86% (Muktakeshi × BRBR-01). Among 21 hybrids, 6 in rainy season recorded significant positive heterosis over better parent. Top three crosses in terms of heterosis over better parent were (Muktakeshi× BRBL-01) (42.86%), Swarna Mani ×BRBR-01 (39.02%) and Rajendra Baingan-2×BRBL-02 (31.96%). Standard heterosis ranged-19.63% (Rajendra Baingan-2× BRBR-01) to 63.55% (BRBL-01 × BRBL-04). Out of 21 hybrids, 11 showed significant positive heterosis over standard check. Based on heterosis from yield point of view, the most superior three crosses were BRBL-01× BRBL-04 (63.55%), Swarna Mani × BRBL-04 (57.01%) and Muktakeshi × BRBL-01 (47.66%). The estimates of heterobeltiosis and standard heterosis effects were low in negative direction while moderate in positive direction. The results are congruent with the findings of Patel et al. (2017) for heterobeltiosis and standard heterosis.

Heterosis for biochemical and quality traits

The heterosis and heterobeltiosis for the biochemical and quality traits have been depicted in Table 3. For ascorbic acid, the range of heterobeltiosis and standard heterosis in rainy season was from −27.98% (Rajendra Baingan-2 × BRBR-01) to 67.37% (Rajendra Baingan-2 × Swarna Mani) and –9.86% (Rajendra Baingan-2 × BRBR-01) to 59.54% (Rajendra Baingan-2 × Swarna Mani), respectively. Among 21 hybrids, 7 showed significant positive heterosis over better parent for ascorbic acid content and superior three were Rajendra Baingan-2 × Swarna Mani (67.37%), Muktakeshi × Swarna Mani (41.59%) and Rajendra Baingan-2 × Muktakeshi (29.18%). Besides, 10 crosses showed significant positive heterosis over check and best three were Rajendra Baingan-2 × Swarna Mani (59.54%), Rajendra Baingan-2 × BRBL-01 (29.58%) and Muktakeshi × Swarna Mani (28.70%). The heterobeltiosis and standard heterosis ranging from –42.37 to 22.39% and –41.27 to 24.74% has been observed by Patel et al. (2017) and up to 40.37% and 44.96% by Balwani et al. (2017).

Range of heterobeltiosis for total sugar content was from −12.29% (Swarna Mani × BRBR-01) to 38.25% (BRBR-01 × BRBL-01). Standard heterosis ranged from –10.39 (Swarna Mani × BRBR-01) to 22.95% (BRBR-01 × BRBL-01). Out of 21 hybrids, 14 and 5 crosses reported significant positive heterosis over better parent and check, respectively. Among 21 crosses, in rainy season BRBR-01 × BRBL-01 (38.25%), Rajendra Baigan-2 × BRBL-04 (30.09%) and Muktakeshi × BRBR-01 (22.98%) were top three hybrids in terms of heterobeltiosis, while, BRBR-01 × BRBL-01 (22.95%), Rajendra Baigan-2 × BRBL-04 (15.98%) and BRBL-02 × Swarna Mani (12.21%) were superior three in terms of standard heterosis.

Estimated range for heterobeltiosis and standard heterosis for total anthocyanin content was from –65.37% (BRBR-01 × BRBL-01) to 16.67% (Rajendra Baingan-2 × BRBL-04) and –92.21% (BRBL-01 × BRBL-04) to −0.34% (Muktakeshi × BRBL-02), respectively. Out of 21 crosses, none of them showed significant positive heterosis over better parent and standard check. The results of present investigation revealed that the estimates of heterobeltiosis and standard heterosis were high in negative direction and low in positive direction. The findings are in conformity with report of Patel et al. (2017).

For total phenolics content (mg/100 g) range of heterobeltiosis was from –16.78% (Rajendra Baingan-2 × BRBL-04) to 35.49% (BRBR-01 × BRBL-04). Standard heterosis ranged from –8.22% (Rajendra Baingan-2 × BRBL-04) to 51.13% (BRBL-02 × BRBR-01). Among 21 crosses, six recorded significant positive heterosis over better parent, while 9 showed significant positive heterosis over check. The best three hybrids in terms of better parent were BRBR-01 × BRBL-04 (35.49%), BRBL-02 × BRBR-01 (33.39%) and Muktakeshi × BRBR-01 (29.30%). Superior three hybrids in terms of standard heterosis were BRBL-02 × BRBR-01 (51.13%), Muktakeshi × BRBR-01 (41.82%) and BRBR-01 × BRBL-04 (37.97%). Significant positive and negative heterosis for phenol content was also reported by Patel et al. (2017).

Range of better parent heterosis and standard heterosis for total antioxidant capacity in rainy season for heterobeltiosis and standard heterosis varied from –45.26% (Rajendra Baingan-2 × Swarna Mani) to 75.39% (BRBL-02 × BRBL-04) and 24.61% (Rajendra Baingan-2 × BRBR-01) to 279.87% (Swarna Mani × BRBR-01), respectively. Among 21 hybrids, 8 estimated significant positive heterosis over better parent. Superior three crosses for heterobeltiosis were BRBL-02 × BRBL-04 (75.39%), Swarna Mani × BRBR-01 (75.05%) and Rajendra Baingan-2 × BRBL-01 (55.84%). For standard heterosis the best three were Swarna Mani × BRBR-01 (279.87%), Swarna Mani × BRBL-01 (215.21%) and BRBL-02 × BRBL -04 (204.47%).

The commercial exploitation of heterosis is an outstanding application of the principles of genetics in the field of plant breeding. The heterotic response of F_1 is a symbolic of genetic diversity among the parents involved. Positive relative heterosis and heterobeltiosis in a desired trend is preferred in selection for yield and its components (Lamkey and Edwards 1999).

Conclusion

The most heterotic three crosses for yield attributes were found to be BRBL-01 × BRBL-04 (63.55%), Swarna Mani × BRBL-04 (57.01%) and Muktakeshi × BRBL-01 (47.66%), whereas for biochemical traits BRBL-02 × BRBR-01 and BRBL-02 × BRBL-04 were found promising. The estimates of heterobeltiosis and standard heterosis effects were low in negative direction while moderate in positive direction for yield and attributing components, hence may be effectively used for improvement of the traits.

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