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Research Note

Harnessing heterosis in eggplant (*Solanum melongena* L.)

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Abstract
A study was undertaken to examine the extent of heterosis and to identify promising parents and superior crosses in eggplant for yield and its component traits. The experiment consisted of 36 hybrids generated by half diallel mating, nine parents and a standard check. The trial was laid out in a randomized block design with three replications at the research farm, School of Agriculture, LPU, Punjab, during the *kharif* season of 2022-2023. Analysis of mean squares for 10 traits revealed significant variations among the entries. Heterotic effects, including heterobeltiosis and standard heterosis, exhibited a broad range indicating extensive heterosis for various traits. The hybrid JBR-3 x JBR-5 proved to be the top performer, displaying the highest heterobeltiosis and standard heterosis for total fruit yield per plant, followed by JBL-1 x JBR-5, JBR-4 x JBR-5, JBR-1 x JBR-5, and JBR-5 x JBR-6. The combination JBR-3 x JBR-5 showcased the highest positive and significant standard heterosis for total yield per plant (154.49%) and also exhibited notable negative heterosis for days to 50% flowering (-20.37%), days to first picking (-8.61%), and fruit borer infestation (-40.08%). These factors are vital for leveraging heterosis to improve earliness and resistance in brinjal cultivation. The F_1 hybrid JBR-3 x JBR-5, demonstrating a notable capacity for high yield, holds promise for potential commercial cultivation after further assessment

Keywords: Brinjal, Half-diallel, heterosis, fruit borer

Eggplant (*Solanum melongena* L., 2n = 24) is often referred to as the king of vegetables, owing to its diverse applications in various dishes (Kumar *et al*., 2020). This vegetable is commonly known as brinjal or aubergine. It is well-suited for diverse agroclimatic conditions, allowing for year-round cultivation. Although naturally a perennial, it is grown commercially as an annual crop (Gangadhara *et al*., 2021). The increasing interest in brinjal among both the general public and the scientific community can be attributed to its numerous medicinal and antioxidant qualities (Susmitha *et al*., 2023). India ranks as the world's second-largest producer of brinjal, with an area of 0.753 million hectares, production of 13.023 million metric tons and productivity of 17.3 tons per hectare . The major brinjal-producing states in the country are West Bengal, Odisha, Gujarat, Bihar, and Madhya Pradesh (Mishra *et al.,*2023). The area under eggplant cultivation has seen a significant rise of 50% in recent times, largely attributed to the widespread embrace of high-yielding varieties and hybrid options (Farooq and Delvadiya 2023). Eggplant is highly susceptible to insect infestations, with a notable vulnerability to damage inflicted by *Leucinodes orbonalis*, commonly referred to as the fruit and shoot borer (FSB). As FSB belongs to the Lepidoptera family, the larval stage is the key phase responsible for damage. After hatching, the larvae tunnel into the fruits and shoots, leading to severe harm and rendering the fruits unfit for consumption. Hence, one of the major goals of any breeding program is to identify resistant hybrid varieties that can withstand the impact of the fruit and shoot borer (Thota *et al*., 2023). Choosing the right parental lines is essential for developing hybrids suitable for commercialization (Mishra *et al.,*2023).

Exploiting hybrid vigor or heterosis stands out as a dependable approach in enhancing crops, making use of heterozygous lines to create hybrids with increased yield. The initial observation of hybrid vigor in brinjal was made by Nagai and Kida (1926). To make optimal use of hybrid vigor, it is essential to assess the degree of genetic diversity among the parental entities involved in the crossbreeding process (Kerure and Pitchaimuthu, 2019). This is essential because a substantial genetic diversity between parents results in the highest heterotic response (Kumar *et al*., 2013). Yield holds a crucial significance in both brinjal varieties and hybrids, leading to substantial efforts being made to improve characteristics related to yield, production, and quality (Kumar *et al*., 2023). Heterosis denotes the superior performance of F_1 hybrids compared to their parents or the standard check (Shull, 1948). The economical exploitation of this phenomenon has been made possible in eggplant, due to the cost-effectiveness of producing F_1 seeds and the minimal seed requirement per unit area (Chaudhari *et al*., 2020). Also, brinjal exhibits a higher flower-to-fruit ratio, facilitating efficient pollination as a single flower can successfully pollinate multiple others (Ginoya *et al*., 2021). Hence, the present study was carried out to investigate the most effective crosses for the development of hybrids with improved yield through the utilization of heterosis.

MATERIALS AND METHODS

Nine genotypes, namely JBL-1, JBR-1, JBR-2, JBR-3, JBL-2, JBL-3, JBR-4, JBR-5, and JBR-6, which exhibited variations in shape, size, and colour (**Table 1**), were selected as parents for the hybridisation. The parents were crossed in a half-diallel fashion excluding reciprocals, following the method outlined by Griffing (1956) during Autumn season of 2022-23 at Research Farm, School of Agriculture, LPU, Punjab. The 36 hybrids thus generated were raised during spring season of 2022-23 at the Research Farm, School of Agriculture, LPU, Punjab, for evaluation, along with the parents and a check Nishant-Advanta, in a randomised block design with three replications adopting a spacing of 50cm between plants and 50 cm between plants. To ensure optimal growth of brinjal, all essential agronomic practices were diligently implemented throughout the experimental period.

Observations on 10 morphological traits namely, days to 50% flowering, days to first picking, fruit length (cm), average fruit weight (g), fruit girth (cm), number of fruits per plant, number of primary branches per plant, plant height (cm), total fruit yield per plant (kg), and fruit borer infestation (%) were recorded in each treatment. During the research period, observation and surveillance were carried out on the stages of development, fruit attributes, yield metrics, and the degree of pest infestation. This methodical approach aimed to gain a comprehensive understanding of the growth patterns and productivity of the experimental plants.

The percentage change in F_1 hybrids compared to both superior parent and standard checks was computed to assess heterosis, utilizing the approach introduced by Fonseca and Patterson in 1968. The significance of heterosis was examined utilizing the standard error through a 't' test for statistical validation.

RESULTS AND DISCUSSION

Analysis of variance: The examination of variance (ANOVA) revealed that the mean squares attributed to genotypes were statistically significant across almost all the observed characteristics (**Table 2**). This observation can be clarified by the existence of significant genotypic distinctions among the parental individuals and their hybrids, leading to the observed variations in phenotypes. The significance of mean squares attributed to parents versus hybrids was pronounced across all traits, except for days to first picking, average fruit weight, and fruit girth. This highlights that the observed variations in the performance of both parents and hybrids were authentic, with the presence of heterosis is evident.

Table 1. Features of parents used for developing crosses

S. No.	Parent Name	Features
1.	JBL-1	Fruits are medium in size with medium-long shapes and violet in colour. Plants are semi-spreading type.
2.	JBR-1	Fruits are small in size with a round shape. Fruits are purple in colour. Plants are semi-spreading type.
3.	JBR-2	Fruits are medium in size with a round shape. Fruits are light purple-greenish in colour. Plants are semi-spreading type.
4.	JBR-3	Fruits are medium in size with a round shape and purple colour. Plants are semi-spreading type.
5.	JBL-2	Fruits are large in size with long shape and white colour. Plants are semi-spreading type.
6.	JBL-3	Fruits are medium in size with long shapes and pink colour. Plants are semi-spreading type.
7.	JBR-4	Fruits are medium in size with a round shape and white with purple strips in color. Plants are semi-spreading type.
8.	JBR-5	Fruits are large in size with a round shape and green with white strips in color. Plants are semi-spreading type.
9.	JBR-6	Fruits are medium in size with round shape and violet colour and good shining.
10.	Check=Nishant (Advanta)	Fruits are medium in size with oblong shape with purple colour and good shining. Plants are medium in size and semi-spreading type.

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Table 2. Analysis of variance showing mean squares for fruit yield and its attributes in brinjal.

Source of Variation	Degree of freedom	Days to 50%flowering	Days to first picking	Fruit length	Average fruit weight	Fruit girth
Replication	2	5.81*	0.01	0.29	53.44	0.01
Genotypes	44	113.24**	75.86**	18.12**	2673.07**	19.41**
Parents	8	41.56**	119.07**	21.98**	3087.21**	41.03**
Hybrids	35	127.80**	68.09**	17.73**	2652.44**	15.02**
Parent Vs Hybrids	1	177.04**	2.10	0.98**	81.90	0.01
Error	88	1.83	0.84	0.10	79.74	0.23

Source of Variation	Degree of freedom	Number of fruits per plant	Number of primary branches per plant	Plant height	Total fruit yield per plant	Fruit borer infestation
Replication	2	0.19	0.17*	4.84	0.02	0.15
Genotypes	44	34.91**	1.94**	82.65**	0.32**	56.63**
Parents	8	62.38**	0.38**	76.95**	0.19**	74.70**
Hybrids	35	28.26**	1.69**	83.98**	0.36**	53.75**
Parent Vs Hybrids	1	48.03**	23.10**	81.72**	0.05*	13.01**
Error	88	0.18	0.04	2.30	0.01	0.16

*, ** significant at 5 per cent and 1 per cent levels of significance, respectively

Mean performance of parents and their hybrids: In any plant breeding programme, the mean performance is an important criterion in the choice of parents and hybrids. In this study, among nine parents, JBR-5, JBR-3, and JBR-6 emerged as most superior based on their mean performance for fruit yield per plant (**Table 3**). Hybrids containing one of these parents in their crosses also exhibited superiority in yield parameters. JBR-5 claimed the top position for fruit girth, average fruit weight, and fruit length. For maturity characters like days to 50 % flowering and days to first picking parent JBR-5 was found most earliest followed by JBR-6 and JBL-2. Considering mean performance, the most superior cross combinations for fruit yield per plant included JBR-3 x JBR-5, JBL-1 x JBR-5, and JBR-4 x JBR-5. These combinations demonstrated high *per se* performance for one or more yield-contributing traits.

Estimation of Heterobeltiosis and Standard Heterosis: The extent of heterosis displayed wide variation among different crosses for all the observed traits. The significant heterosis observed in specific hybrids, coupled with lower levels in others, indicates a diverse gene action influenced by the genetic makeup of the parent plants. The character-wise results on heterosis over better parent (heterobeltiosis) and standard check, Nishant (standard heterosis) are presented below and described as under **table 4**. In the case of brinjal, early flowering is a favorable characteristic. Significant and desirable (negative) estimates of heterobeltiosis and standard heterosis were noted in three and 16 crosses, respectively. (**Table 4**). The heterobeltiosis ranged from -22.28 (JBR3 x JBR4) to 95.1 per cent (JBR4 x JBR6), while standard heterosis ranged from -25.44 (JBR5 x JBR6) to 55.87 per cent (JBR4 x JBR6). For days to first picking, heterosis over better parent ranged from -5.61 (JBL2 x JBR4) to 20.15 percent (JBR1 x JBR4), whereas heterosis over standard check varied from -19.38 (JBR1 x JBR5) to 11.02 percent (JBR2 x JBL2). Similar findings were also revealed by Makasare *et al.* (2020), Shalini Singh*.,* (2021), Kolekar *et al.* (2022), and Farooq and Delvadiya (2023).

For fruit length, heterobeltiosis ranged from -40.01 (JBL3 x JBR4) to 20.69 percent (JBL1 x JBR6), whereas standard heterosis ranged from -31.72 (JBL3 x JBR4) to 68.07 percent (JBR3 x JBR5). For Average fruit weight (gm), out of 36 hybrids, three hybrids were reported with significant and desirable (positive) heterobeltiosis, whereas 30 hybrids exhibited significant and desirable (positive) standard heterosis (**Table 3**.). The heterobeltiosis varied from -38.47 (JBL3 x JBR5) to 8.51 percent (JBR2 x JBR6), whereas standard heterosis ranged from -21.28 (JBL1 x JBR1) to 121.44 percent (JBL2 x JBR5).

In case of fruit girth (cm), heterobeltiosis ranged from -34.97 (JBL2 x JBL3) to 9.73 percent (JBR3 x JBR6), whereas standard heterosis ranged from -5.02 (JBR3 x JBL3) to 51.47 percent (JBL2 x JBR5). Similar results have been reported by Shalini Singh *et al.* (2021), Timmareddygari *et al.* (2021), Kolekar *et al.* (2022) and Susmitha *et al.* (2023). For number of fruits per plant, heterobeltiosis ranged from -28.35 (JBR2 x JBL2)

Table 3. Mean Performance of genotypes for ten morphological characters

Treatments	Days to 50% flowering	Days to first picking	Fruit length (cm)	Average fruit weight(gm)	Fruit girth (cm)	Number of fruits per plant	No. of primary branches per plant	Plant height (cm)	Total fruit yield/plant (Kg)	Fruit borer infestation (%)
JBL-1	33.73	59.46	8.99	84.21	18.06	19.03	2.60	71.99	1.63	10.40
JBR-1	33.40	**54.60**	**6.63**	**72.74**	13.70	20.78	2.50	67.56	**1.54**	12.70
JBR-2	**39.13**	63.80	7.48	92.46	17.97	16.84	2.20	63.75	**1.54**	**4.87**
JBR-3	36.80	66.00	7.73	113.77	19.15	17.67	2.93	71.04	1.94	15.67
JBL-2	30.60	**75.23**	12.45	131.53	23.68	**9.23**	2.77	**77.53**	1.67	8.20
JBL-3	31.33	70.73	10.81	73.57	**13.59**	**23.03**	**2.07**	72.92	1.70	**19.99**
JBR-4	38.00	63.60	8.76	121.02	20.28	14.67	2.20	69.31	1.76	9.36
JBR-5	**28.80**	62.67	**15.19**	**172.80**	**24.17**	10.33	2.40	70.53	**2.37**	18.67
JBR-6	29.93	58.40	9.44	100.96	19.11	18.37	**3.13**	**60.43**	1.84	14.60
JBL1 X JBR1	40.73	53.67	8.09	**64.13**	15.42	21.21	3.53	70.82	1.47	12.67
JBL1 X JBR2	43.20	62.07	8.67	89.44	18.85	18.26	3.13	67.81	1.54	8.40
JBL1 X JBR3	28.27	63.40	8.49	93.54	18.25	17.60	4.43	74.45	1.73	12.33
JBL1 X JBL2	36.40	63.07	10.67	102.35	18.95	18.77	3.40	76.20	1.34	11.57
JBL1 X JBL3	32.33	64.47	7.83	86.78	16.67	24.39	3.50	73.93	1.74	**24.40**
JBL1 X JBR4	29.60	57.71	9.71	96.58	21.20	18.30	3.27	73.18	1.75	8.30
JBL1 X JBR5	35.63	61.77	13.67	173.36	19.83	17.57	3.33	68.50	2.60	14.30
JBL1 X JBR6	36.73	58.00	11.39	94.41	20.15	20.17	3.50	57.42	1.85	15.90
JBR1 X JBR2	31.93	63.67	8.06	84.55	15.79	19.67	3.17	65.27	1.66	10.17
JBR1 X JBR3	40.27	58.67	8.22	98.57	17.35	18.27	4.20	70.93	1.77	6.20
JBR1 X JBL2	36.07	64.03	9.84	103.87	18.51	17.85	3.83	75.30	1.37	10.10
JBR1 X JBL3	37.73	64.43	6.83	73.60	14.48	**25.76**	3.20	71.87	**1.28**	12.33
JBR1 X JBR4	39.93	65.60	6.97	99.12	18.25	19.07	3.17	72.60	1.92	11.27
JBR1 X JBR5	31.80	**53.40**	10.13	153.53	20.33	17.70	**6.17**	69.17	2.27	10.50
JBR1 X JBR6	46.00	61.87	10.04	83.35	18.03	21.93	4.03	63.49	1.83	10.77
JBR2 X JBR3	49.27	68.33	8.08	94.46	18.51	18.03	3.90	73.43	1.72	12.23
JBR2 X JBL2	34.67	**73.53**	10.79	135.25	19.14	12.07	3.20	76.45	1.49	**3.23**
JBR2 X JBL3	35.33	70.23	7.29	75.30	14.87	19.77	3.40	72.63	1.49	18.07
JBR2 X JBR4	39.97	61.77	7.87	96.23	18.31	17.30	**2.33**	73.49	1.65	5.77
JBR2 X JBR5	33.80	60.77	10.93	154.41	19.93	13.37	3.20	62.55	1.99	15.10
JBR2 X JBR6	37.27	58.67	9.45	109.55	18.17	19.00	3.00	**56.57**	1.78	9.97
JBR3 X JBL2	36.33	72.13	10.76	121.75	21.46	13.43	3.20	78.52	1.72	9.40
JBR3 X JBL3	44.00	67.87	7.11	83.43	**14.25**	21.07	3.60	70.63	1.62	11.93
JBR3 X JBR4	28.60	65.57	7.88	115.39	21.74	16.17	4.77	70.81	1.76	9.93
JBR3 X JBR5	29.83	60.53	**15.97**	162.57	22.31	18.83	3.60	74.58	**2.93**	10.07
JBR3 X JBR6	45.47	59.20	9.07	108.03	21.01	19.07	3.57	71.43	2.04	12.80
JBL2 X JBL3	32.07	72.47	10.61	93.47	15.40	19.40	2.73	**81.85**	1.82	9.97
JBL2 X JBR4	29.73	60.03	10.92	123.21	21.35	17.53	4.53	77.26	1.83	9.13
JBL2 X JBR5	33.93	68.13	14.76	**180.40**	**22.72**	**9.70**	2.80	73.40	1.73	6.20
JBL2 X JBR6	32.00	65.67	14.67	112.51	19.43	14.27	5.20	72.07	1.76	12.13
JBL3 X JBR4	29.57	64.47	**6.49**	106.46	19.30	18.67	3.47	71.54	1.97	15.87
JBL3 X JBR5	33.53	68.00	10.65	106.33	21.53	17.17	4.00	71.03	1.77	22.20
JBL3 X JBR6	36.00	65.60	10.65	81.34	18.44	20.80	3.20	67.25	1.74	17.20
JBR4 X JBR5	35.67	64.27	10.33	154.81	20.35	16.43	3.20	76.28	2.57	14.17
JBR4 X JBR6	**58.40**	64.67	9.61	112.53	19.39	17.67	**2.33**	73.05	2.06	13.43
JBR5 X JBR6	**27.93**	59.07	15.13	131.67	20.18	17.27	3.33	74.73	2.20	11.90
Check	**37.46**	**66.23**	**9.5**	**81.46**	**15**	**13.2**	**2.33**	**61.86**	**1.15**	**16.8**
Mean	**35.85**	**63.64**	**9.88**	**108.71**	**18.79**	**17.75**	**3.33**	**70.81**	**1.80**	**12.19**
C.V	**3.8**	**1.51**	**3.40**	**1.60**	**2.61**	**2.37**	**6.64**	**2.15**	**6.15**	**3.38**
C.D	**2.19**	**1.56**	**0.54**	**2.83**	**0.79**	**0.68**	**0.36**	**2.47**	**0.18**	**0.67**
Minimum	**27.93**	**53.40**	**6.49**	**64.13**	**13.59**	**9.23**	**2.33**	**56.57**	**1.28**	**3.23**
Maximum	**58.40**	**75.23**	**15.97**	**180.40**	**24.17**	**25.76**	**6.17**	**81.85**	**2.93**	**24.40**
S.E	**0.040**	**0.020**	**0.002**	**0.065**	**0.005**	**0.003**	**0.001**	**0.050**	**0.001**	**0.003**

Table 4. Estimates of heterobeltiosis (H1) and standard heterosis (H2) for different characters in brinjal

S. No.	Crosses	Days to 50% flowering		Days to first picking		Fruit length (cm)	
		H_1	H_2	H_1	H_2	H_1	H_2
1	JBL1 X JBR1	21.96**	8.72**	-1.71	-18.97**	-10.01**	-14.88**
2	JBL1 X JBR2	28.06**	15.30**	4.37**	-6.29**	-3.49	-8.70**
3	JBL1 X JBR3	-16.21**	-24.56**	6.61**	-4.28**	-5.56	-10.67**
4	JBL1 X JBL2	18.95**	-2.85	6.05**	-4.78**	-14.25**	12.35**
5	JBL1 X JBL3	3.19	-13.70**	8.41**	-2.67*	-27.56**	-17.54**
6	JBL1 X JBR4	-12.25**	-21.00**	-2.96*	-12.87**	8.01*	2.18
7	JBL1 X JBR5	23.73**	-4.89	3.87**	-6.74**	-10.05**	43.86**
8	JBL1 X JBR6	22.72**	-1.96	-0.68	-12.43**	**20.69****	19.93**
9	JBR1 X JBR2	-4.39	-14.77**	16.61**	-3.88**	7.75*	-15.16**
10	JBR1 X JBR3	20.56**	7.47*	7.45**	-11.42**	6.29	-13.47**
11	JBR1 X JBL2	17.86**	-3.74	17.28**	-3.32**	-20.94**	3.58
12	JBR1 X JBL3	20.43**	0.71	18.01**	-2.72*	-36.81**	-28.07**
13	JBR1 X JBR4	19.56**	6.58*	**20.15****	-0.96	-20.4**	-26.6**
14	JBR1 X JBR5	10.42**	-15.12**	-2.20	**-19.38****	-33.3**	6.67*
15	JBR1 X JBR6	53.67**	22.78**	13.31**	-6.59**	6.36*	5.68
16	JBR2 X JBR3	33.88**	31.49**	7.11**	3.17**	4.48	-14.95**
17	JBR2 X JBL2	13.29**	-7.47*	15.26**	**11.02****	-13.28**	13.61**
18	JBR2 X JBL3	12.77**	-5.69	10.08**	6.04**	-32.61**	-23.30**
19	JBR2 X JBR4	5.18	6.67*	-2.88*	-6.74**	-10.12**	-17.12**
20	JBR2 X JBR5	17.36**	-9.79**	-3.03*	-8.25**	-28.08**	15.02**
21	JBR2 X JBR6	24.5**	-0.53	0.46	-11.42**	0.14	-0.49
22	JBR3 X JBL2	18.74**	-3.02	9.29**	8.91**	-13.55**	13.26**
23	JBR3 X JBL3	40.43**	17.44**	2.83*	2.47*	-34.22**	-25.12**
24	JBR3 X JBR4	**-22.28****	-23.67**	3.09*	-1.01	-10.05**	-17.05**
25	JBR3 X JBR5	3.59	-20.37**	-3.40**	-8.61**	5.09**	**68.07****
26	JBR3 X JBR6	51.89**	21.35**	1.37	-10.62**	-3.88	-4.49
27	JBL2 X JBL3	4.79	-14.41**	2.45*	9.41**	-14.73**	11.72**
28	JBL2 X JBR4	-2.83	-20.64**	**-5.61****	-9.36**	-12.27**	14.95**
29	JBL2 X JBR5	17.82**	-9.43**	8.72**	2.87*	-2.85	55.37**
30	JBL2 X JBR6	6.90	-14.59**	12.44**	-0.86	17.84**	54.39**
31	JBL3 X JBR4	-5.64	-21.09**	1.36	-2.67*	**-40.01****	**-31.72****
32	JBL3 X JBR5	16.44**	-10.50**	8.51**	2.67*	-29.93**	12.07**
33	JBL3 X JBR6	20.27**	-3.91	12.33**	-0.96	-1.54	12.07**
34	JBR4 X JBR5	23.84**	-4.80	2.55*	-2.97*	-32.03**	8.70**
35	JBR4 X JBR6	**95.1****	**55.87****	10.73**	-2.37*	1.84	1.19
36	JBR5 X JBR6	-3.01	**-25.44****	1.14	-10.82**	-0.44	59.23**
	SE±	1.10	1.10	0.75	0.75	0.26	0.26
Number of crosses with desirable and significant heterosis		**3**	**16**	**5**	**24**	**6**	**17**
Range of heterosis (%)		-22.28 to 95.1	-25.44 to 55.87	-5.61 to 20.15	-19.38 to 11.02	-40.01 to 20.69	-31.72 to 68.07

*, ** significant at 5 per cent and 1 per cent levels of significance, respectively Cont..

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Table 4. Contd.

S. No.	Crosses	Average fruit weight (gm)		Fruit girth (cm)		Number of fruits per plant	
		H_1	H_2	H_1	H_2	H_1	H_2
1	JBL1 X JBR1	-23.84**	**-21.28****	-14.62**	2.80	2.07	60.71**
2	JBL1 X JBR2	-3.28*	9.78**	4.37	25.67**	-4.06*	38.33**
3	JBL1 X JBR3	-17.79**	14.82**	-4.67*	21.69**	-7.53**	33.33**
4	JBL1 X JBL2	-22.19**	25.63**	-19.96**	26.36**	-1.40	42.17**
5	JBL1 X JBL3	3.05	6.53**	-7.68**	11.16**	5.90**	84.80**
6	JBL1 X JBR4	-20.20**	18.55**	4.55*	41.36**	-3.85*	38.64**
7	JBL1 X JBR5	0.32	112.79**	-17.98**	32.18**	-7.71**	33.08**
8	JBL1 X JBR6	-6.48**	15.89**	5.44*	34.31**	5.95**	52.78**
9	JBR1 X JBR2	-8.57**	3.78*	-12.13**	5.24	-5.37**	48.99**
10	JBR1 X JBR3	-13.37**	20.99**	-9.37**	15.69**	-12.11**	38.38**
11	JBR1 X JBL2	-21.03**	27.50**	-21.82**	23.42**	-14.10**	35.25**
12	JBR1 X JBL3	0.04	-9.66**	5.67	-3.47	11.84**	**95.15****
13	JBR1 X JBR4	-18.09**	21.67**	-10.01**	21.67**	-8.26**	44.44**
14	JBR1 X JBR5	-11.16**	88.45**	-15.89**	35.56**	-14.84**	34.09**
15	JBR1 X JBR6	-17.45**	2.31	-5.65**	20.18**	5.53**	66.16**
16	JBR2 X JBR3	-16.98**	15.95**	-3.34	23.38**	2.08	36.62**
17	JBR2 X JBL2	2.83*	66.02**	-19.17**	27.60**	**-28.35****	-8.59**
18	JBR2 X JBL3	-18.57**	-7.57**	-17.22**	-0.84	-14.18**	49.75**
19	JBR2 X JBR4	-20.48**	18.13**	-9.73**	22.04**	2.73	31.06**
20	JBR2 X JBR5	-10.65**	89.53**	-17.54**	32.89**	-20.63**	1.26
21	JBR2 X JBR6	**8.51****	34.47**	-4.88*	21.16**	3.45	43.94**
22	JBR3 X JBL2	-7.44**	49.44**	-9.38**	43.07**	-23.96**	1.77
23	JBR3 X JBL3	-26.67**	2.41	-25.59**	**-5.02**	-8.54**	59.60**
24	JBR3 X JBR4	-4.65**	41.64**	7.20**	44.93**	-8.49**	22.47**
25	JBR3 X JBR5	-5.93**	99.55**	-7.72**	48.71**	6.6**	42.68**
26	JBR3 X JBR6	-5.05**	32.60**	**9.73****	40.07**	3.81*	44.44**
27	JBL2 X JBL3	-28.93**	14.74**	**-34.97****	2.67	-15.77**	46.97**
28	JBL2 X JBR4	-6.33**	51.24**	-9.84**	42.33**	**19.55****	32.83**
29	JBL2 X JBR5	4.39**	**121.44****	-6.01**	**51.47****	-6.13	**-26.52****
30	JBL2 X JBR6	-14.46**	38.11**	-17.95**	29.53**	-22.32**	8.08**
31	JBL3 X JBR4	-12.03**	30.68**	-4.83*	28.67**	-18.96**	41.41**
32	JBL3 X JBR5	**-38.47****	30.52**	-10.92**	43.56**	-25.47**	30.05**
33	JBL3 X JBR6	-19.43**	-0.16	-3.51	22.91**	-9.70**	57.58**
34	JBR4 X JBR5	-10.42**	90.02**	-15.80**	35.69**	12.05**	24.49**
35	JBR4 X JBR6	-7.01**	38.13**	-4.40*	29.24**	-3.81*	33.84**
36	JBR5 X JBR6	-23.81**	61.62**	-16.51**	34.56**	-5.99**	30.81**
	SE±	7.29	7.29	0.39	0.39	0.34	0.34
	Number of crosses with desirable and significant heterosis	**3**	**30**	**4**	**30**	**8**	**33**
	Range of heterosis (%)	-38.47 to 8.51	-21.28 to 121.44	-34.97 to 9.73	-5.02 to 51.47	-28.35 to 19.55	-26.52 to 95.15

*, ** Significant at 5 per cent and 1 per cent levels of significance, respectively

Table 4. Cont..

S. No.	Crosses	No of primary branches per plant		Plant height (cm)		Total fruit yield per plant (kg)	
		H_1	H_2	H_1	H_2	H_1	H_2
1	JBL1 X JBR1	35.90**	51.43**	-1.63	14.47**	-10.02	27.54**
2	JBL1 X JBR2	20.51**	34.29**	-5.81**	9.60**	-5.32	34.20**
3	JBL1 X JBR3	51.14**	90.00**	3.42	20.34**	-10.82*	50.43**
4	JBL1 X JBL2	22.89**	45.71**	-1.72	23.17**	-19.80**	16.23*
5	JBL1 X JBL3	34.62**	50.00**	1.31	19.50**	2.16	51.01**
6	JBL1 X JBR4	25.64**	40.00**	1.66	18.29**	-0.76	51.88**
7	JBL1 X JBR5	28.21**	42.86**	-4.84**	10.72**	9.86*	126.09**
8	JBL1 X JBR6	11.70*	50.00**	**-20.24****	-7.19**	0.54	61.16**
9	JBR1 X JBR2	26.67**	35.71**	-3.38	5.51**	7.58	44.06**
10	JBR1 X JBR3	43.18**	80.00**	-0.15	14.66**	-8.59	54.2**
11	JBR1 X JBL2	38.55**	64.29**	-2.88	21.71**	-17.60**	19.42*
12	JBR1 X JBL3	28.00**	37.14**	-1.52	16.16**	-24.90**	**11.01**
13	JBR1 X JBR4	26.67**	35.71**	4.74**	17.35**	8.90	66.67**
14	JBR1 X JBR5	**146.67****	**164.29****	-1.93	11.80**	-4.23	97.10**
15	JBR1 X JBR6	28.72**	72.86**	-6.02**	2.62	-0.90	58.84**
16	JBR2 X JBR3	32.95**	67.14**	3.37	18.70**	-11.17*	49.86**
17	JBR2 X JBL2	15.66*	37.14**	-1.39	23.58**	-10.60	29.57**
18	JBR2 X JBL3	54.55**	45.71**	-0.47	17.40**	-12.16*	29.86**
19	JBR2 X JBR4	6.06	**0**	6.02**	18.78**	-6.25	43.48**
20	JBR2 X JBR5	33.33**	37.14**	-11.31**	1.11	-15.77**	73.33**
21	JBR2 X JBR6	-4.26	28.57**	-11.27**	**-8.56****	-3.25	55.07**
22	JBR3 X JBL2	9.09	37.14**	1.27	26.92**	-11.34*	49.57**
23	JBR3 X JBL3	22.73**	54.29**	-3.22	14.16**	-16.49**	40.87**
24	JBR3 X JBR4	62.5**	104.29**	-0.31	14.46**	-9.45*	52.75**
25	JBR3 X JBR5	22.73**	54.29**	4.99**	20.55**	**23.66****	**154.49****
26	JBR3 X JBR6	13.83*	52.86**	0.55	15.45**	5.33	77.68**
27	JBL2 X JBL3	-1.20	17.14*	5.57**	**32.31****	7.25	58.55**
28	JBL2 X JBR4	63.86**	94.29**	-0.35	24.88**	4.17	59.42**
29	JBL2 X JBR5	1.20	20.00*	-5.34**	18.64**	**-26.76****	50.72**
30	JBL2 X JBR6	65.96**	122.86**	-7.05**	16.49**	-4.34	53.33**
31	JBL3 X JBR4	57.58**	48.57**	-1.97	15.63**	11.93*	71.30**
32	JBL3 X JBR5	66.67**	71.43**	-2.66	14.81**	-25.35**	53.62**
33	JBL3 X JBR6	2.13	37.14**	-7.84**	8.71**	-5.61	51.30**
34	JBR4 X JBR5	33.33**	37.14**	**8.15****	23.29**	8.45*	123.19**
35	JBR4 X JBR6	**-25.53****	**0**	5.39**	18.07**	11.57*	78.84**
36	JBR5 X JBR6	6.38	42.86**	5.96**	20.8**	-7.04	91.3**
	SE±	0.18	0.18	1.23	1.23	0.09	0.09
Number of crosses with desirable and significant heterosis		**29**	**34**	**7**	**32**	**5**	**35**
Range of heterosis (%)		-25.53 to 146.67	0 to 164.29	-20.24 to 8.15	-8.56 to 32.31	-26.76 to 23.66	11.01 to 154.49

*, ** significant at 5 per cent and 1 per cent levels of significance, respectively

Table 4. Contd.

S. No.	Crosses	Fruit borer infestation (%)	
		H_1	H_2
1	JBL1 X JBR1	21.79**	-24.60**
2	JBL1 X JBR2	72.60**	-50.00**
3	JBL1 X JBR3	18.59**	-26.59**
4	JBL1 X JBL2	41.06**	-31.15**
5	JBL1 X JBL3	134.62**	**45.24****
6	JBL1 X JBR4	-11.39**	-50.60**
7	JBL1 X JBR5	37.50**	-14.88**
8	JBL1 X JBR6	52.88**	-5.36**
9	JBR1 X JBR2	108.90**	-39.48**
10	JBR1 X JBR3	**-51.18****	-63.10**
11	JBR1 X JBL2	23.17**	-39.88**
12	JBR1 X JBL3	-2.89	-26.59**
13	JBR1 X JBR4	20.28**	-32.94**
14	JBR1 X JBR5	-17.32**	-37.50**
15	JBR1 X JBR6	-15.22**	-35.91**
16	JBR2 X JBR3	151.37**	-27.18**
17	JBR2 X JBL2	-33.56**	**-80.75****
18	JBR2 X JBL3	**271.23****	7.54**
19	JBR2 X JBR4	18.49**	-65.67**
20	JBR2 X JBR5	210.27**	-10.12**
21	JBR2 X JBR6	104.79**	-40.67**
22	JBR3 X JBL2	14.63**	-44.05**
23	JBR3 X JBL3	-23.83**	-28.97**
24	JBR3 X JBR4	6.05	-40.87**
25	JBR3 X JBR5	-35.74**	-40.08**
26	JBR3 X JBR6	-12.33**	-23.81**
27	JBL2 X JBL3	21.54**	-40.67**
28	JBL2 X JBR4	11.38**	-45.63**
29	JBL2 X JBR5	-24.39**	-63.10**
30	JBL2 X JBR6	47.97**	-27.78**
31	JBL3 X JBR4	69.4**	-5.56**
32	JBL3 X JBR5	18.93**	32.14**
33	JBL3 X JBR6	17.81**	2.38
34	JBR4 X JBR5	51.25**	-15.67**
35	JBR4 X JBR6	43.42**	-20.04**
36	JBR5 X JBR6	-18.49**	-29.17**
	SE±	0.32	0.32
	Number of crosses with desirable and significant heterosis	**10**	**32**
	Range of heterosis (%)	-51.18 to 271.23	-80.75 to 45.24

*, ** Significant at 5 per cent and 1 per cent levels of significance, respectively

Table 5. Five most heterotic crosses (Standard heterosis) for fruit yield per plant and their heterotic effects for different traits.

S. No.	Characters/Crosses	JBR-3 X JBR-5	JBL-1 X JBR-5	JBR-4 X JBR-5	JBR-1 X JBR-5	JBR-5 X JBR-6
1	Mean Fruit yield per plant (kg)	2.93	2.60	2.57	2.27	2.20
2	Total Fruit yield per plant (Kg)	154.49**	126.09**	123.19**	97.1**	91.30**
3	Days to 50% flowering	-20.37**	-4.89	-4.80	-15.12**	-25.44**
4	Days to First Picking	-8.61**	-6.74**	-2.97*	-19.38**	-10.82**
5	Fruit length(cm)	68.07**	43.86**	8.70**	6.67*	59.23**
6	Average fruit weight (gm)	99.55**	112.79**	90.02**	88.45**	61.62**
7	Fruit girth (cm)	48.71**	32.18**	35.69**	35.56**	34.56**
8	Number of Fruits per plant	42.68**	33.08**	24.49**	34.09**	30.81**
9	Number of Primary Branches per plant	54.29**	42.86**	37.14**	164.29**	42.86**
10	Plant height (cm)	20.55**	10.72**	23.29**	11.80**	20.80**
11	Fruit borer infestation (%)	-40.08**	-14.88**	-15.67**	-37.50**	-29.17**

*,** significant at 5 per cent and 1 per cent levels of significance, respectively

to 19.55 percent (JBL2 x JBR4), whereas standard heterosis ranged from -26.52 (JBL2 x JBR5) to 95.15 percent (JBR1 x JBL3). For number of primary branches per plant, 29 hybrids exhibited significant and positive heterosis over better parent and 34 hybrids over standard check. For plant height, the range of heterobeltiosis varied from -20.24 (JBL1 x JBR6) to 8.15 percent (JBR4 x JBR5), whereas standard heterosis ranged from -8.56 (JBR2 x JBR6) to 32.31 percent (JBL2 x JBL3). The hybrid JBL2 x JBL3 exhibited highest desirable standard heterosis (32.31 %). Similar results were reported by Bhatt *et al.* (2019), Shalini Singh *et al.* (2021), Timmareddygari *et al.* (2021), Kolekar *et al.* (2022) and Susmitha *et al.* (2023).

For total fruit yield per plant, out of the 36 crosses, five hybrids exhibited significant and positive heterosis over better parent and 35 hybrids over standard check (**Table 4**). The estimates of heterobeltiosis ranged from -26.76 (JBL2 x JBR5) to 23.66 percent (JBR3 x JBR5). The spectrum of variation for standard heterosis varied from -11.01 (JBR1 x JBL3) to 154.49 percent (JBR3 x JBR5). The hybrid JBR3 x JBR5 ranked first by expressing the highest standard heterosis (154.49 %) followed by JBL1 x JBR5 (126.09 %), JBR4 x JBR5 (123.19 %), and JBR1 x JBR5 (97.1 %). Similar results were reported by Bagade *et al.* (2020), Shalini Singh *et al.* (2021), Timmareddygari *et al.* (2021), Kolekar *et al.* (2022) and Susmitha *et al.* (2023). For fruit borer infestation (%), 10 hybrids exhibited significant and desirable (negative) heterosis over better parent and 32 hybrid depicted significant and desirable (negative) heterosis over standard check. The range of heterobeltiosis varied from -51.18 (JBR1 x JBR3) to 271.23 percent (JBR2 x JBL3), whereas standard heterosis ranged from -80.75 (JBR2 x JBL2) to 45.24 percent (JBL1 x JBL3).

Given that yield is the dependent trait, understanding the reasons for the manifestation of a diverse range of heterosis becomes crucial .William and Gilbert (1960) noted that even simple dominance in terms of yield could contribute to the expression of heterosis. This observation aligns with the findings of Hagberg (1952), who identified similar effects and referred to it as “Combinational Heterosis.” To assess whether similar situation exists in brinjal or not, a comparison was conducted among the five most valuable standard heterotic crosses for fruit yield, alongside an assessment of other traits related to yield (**Table 4**).

The hybrid JBR-3 x JBR-5 ranked first by expressing the highest standard heterosis followed by JBL-1 x JBR-5, JBR-4 x JBR-5, JBR-1 x JBR-5 and JBR-5 x JBR-6 for total fruit yield per plant (**Table 5**). Each of these crosses, exhibiting substantial and advantageous standard heterosis in terms of fruit yield per plant, also showcased noteworthy and desirable heterosis for one or more additional traits. For example, the cross JBR-3 x JBR-5 not only exhibited highly significant and desirable standard heterosis for fruit yield but also displayed significant standard heterosis for other traits like fruit length, average fruit weight coupled with fruit girth. Moreover, crosses JBL-1 x JBR-5, JBR-4 x JBR-5 and JBR-5 x JBR-6 exhibited highly significant and desirable standard heterosis for yield related traits like average fruit weight, fruit girth, days to 50% flowering coupled with number of fruits per plant.

The three primary crosses encompassed JRB-5 as a shared parent, and the resulting F_1 progeny exhibited distinct phenotypic variations. The observed differences manifested in terms of fruit size, color, and shape, affirming the existence of genetic diversity within the population. Additionally, the offspring derived from the JBR-4 X JBR-5 cross displayed a unique morphological trait characterized by the presence of spines on leaves and stems. This particular trait holds significance as it offers a beneficial attribute for pest avoidance, specifically against the fruit shoot borer.

The phenomenon of heterosis serves as a crucial tool for enhancing crop yields. In this study on brinjal, the extent of heterosis was observed to vary among hybrids for each trait. To optimize yield through selection, it is essential to consider various yield components. Notably, JBR-3, JBR-5, and JBR-6 have emerged as exceptionally high-performing parents based on the mean fruit yield per plant. The cross JBR-3 x JBR-5 (154.49%) were identified as the top standard heterotic cross, exhibiting superior fruit yield per plant. Following closely in performance were JBL-1 x JBR-5, JBR-4 x JBR-5, JBR-1 x JBR-5, and JBR-5 x JBR-6. These crosses have shown promising results compared to the standard check and could be further tested for potential commercial cultivation.

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