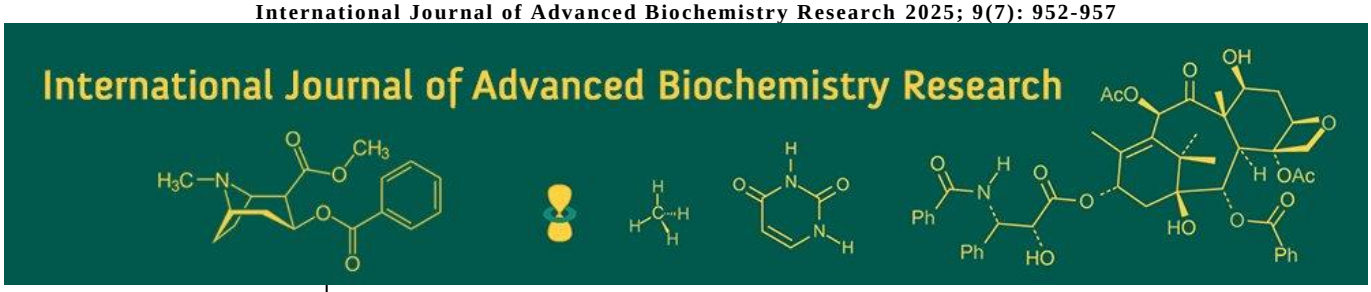

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Harsh M Badreshiya
M.Sc. Student Department Genetics and Plant Breeding, Junagadh Agricultural University JAU, Junagadh, Gujarat, India

Yogesh P Katariya
M.Sc. Student Department Genetics and Plant Breeding, Junagadh Agricultural University JAU, Junagadh, Gujarat, India

Vipul K Baraiya
Agricultural officer Vegetable Research Station Junagadh Agricultural University JAU, Junagadh, Gujarat, India

VH Kachhadia
Research Scientist Vegetable Research Station Junagadh Agricultural University JAU, Junagadh, Gujarat, India

RK Rathod
Assistant Research Scientist Vegetable Research Station Junagadh Agricultural University JAU, Junagadh, Gujarat, India

Corresponding Author:
Harsh M Badreshiya
M.Sc. Student Department Genetics and Plant Breeding, Junagadh Agricultural University JAU, Junagadh, Gujarat, India

Heterosis of brinjal [*Solanum melongena* L.] for fruit yield and its components characters

Harsh M Badreshiya, Yogesh P Katariya, Vipul K Baraiya, VH Kachhadia and RK Rathod

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Abstract
The experimental material comprised of six lines, four testers of brinjal, their 24 hybrids developed by line × tester design and one standard check hybrid (GJBH-4). They were evaluated in randomized block design with three replications at Vegetable Research Station, J.A.U., Junagadh during rabi 2025 for studies extent and magnitude of heterotic effects of hybrids over better parent and standard check. The analysis of experimental variance revealed highly significant differences among the the genotypes for all the traits. The heterobeltiosis for total fruit yield per plant was laid between-44.60% (JBR-21-12 × Swarnamani Black) to 40.58% (JBO-21-10 × GJLB-4), while, the standard heterosis ranged from-34.50% (JBR-21-12 × Swarnamani Black) and 37.56% (PLR-1 × Swarnamani Black). Further exploitation of these crosses could lead to the development of desirable hybrids of brinjal.

Keywords: Brinjal, line × tester analysis, heterosis

Introduction
Brinjal is an herbaceous annual with erect or semi-spreading growth habit belonging to solanaceae family. It is self-compatible and often cross-pollinated crop. In hot, humid climate cross pollination from surrounding plants may occur up to 20% by insects or wind (Grubben, 1977) [11]. It has 2n=24 somatic chromosome number. Several species of Solanum are used in native medicine throughout the tropics. The most important among them are *Solanum melongena* L., *S. indicum* L., *S. trilonatum* L., *S. viarum Dunal*, *S. nigram* L. and *S. xanthocarpum Schrad* and *Wendl* (Peter, 1998) [22]. There are three main botanical varieties under the species *Solanum melongena* L. The round or egg-shaped cultivars are grouped under var. esculentum, the long, slender types are included under var. serpentinum and dwarf brinjal plants are put under var. depressum. Eggplant is a nutritious vegetable rich in dietary fiber, water, protein, and carbohydrates. It contains total water-soluble sugars, free reducing sugars, and amide proteins. Brinjal, a type of eggplant, has bitterness due to its presence of glycoalkaloids. The content of these glycoalkaloids varies from 0.4 to 0.5 mg per 100 g of fresh weight. Purple varieties have higher copper, amino acid, and polyphenol oxidase activity, while green cultivars have the highest iron and catalase activity. Brinjal also has ayurvedic properties and is beneficial for liver problems and diabetic patients. The peel of brinjal has significant amounts of anthocyanin with antioxidant activity and protects against cancer, ageing, inflammation and neurological diseases (Hanur *et al.*, 2006) [12].

Materials and Methods
The experimental material comprised of six (Female) lines *viz.*, JBL-19-02, JBL-19-05, JBL-21-11, JBR-21-12, JBO-21-10, PLR-1; four (male) testers of brinjal viz., Swarnmani Black, GJB-3, GJLB-4, GRB-7 (Table 1) and their 24 F1s hybrids developed by line × tester design and one standard check hybrid (GJBH-4). They were evaluated in randomized block design (RBD) with three replications at Vegetable Research Station, J.A.U., Junagadh during rabi 2025. Row to row and plant to plant spacing was of 90 cm × 60 cm. To produce a better crop, the region's recommended agronomic practices were followed. The observations were recorded on five randomly selected plants expect the plot basis from parents and crosses for 12 characters viz., days to 50% flowering, days to first picking, fruit length (cm), fruit girth (cm), average, fruit weight (g), number of fruits per plant, number of primary branches per

plant, plant height (cm), days to last picking, number of pickings, total fruit yield per plant (kg) and total soluble solids and Mean data were used for statistical analysis. The variance analysis for each character was performed using the method described by Panse and Sukhatme (1995) [20]. Heterosis was estimated in term of two parameters, i.e. heterobeltiosis (heterosis over better parental value) as suggested by Fonseca and Patterson (1968) [8] and standard heterosis (heterosis over standard check) as suggested by Meredith and Bridge (1972) [16].

Results and Discussion

The analysis of variance showed highly significant differences among the genotypes for all the traits. The genotypic variance was further partitioned into parents (lines, testers and L. *vs* T.), hybrids and parents vs. hybrids. The differences among parents and hybrids were found highly significant for all the traits. Differences due to parents vs hybrids were also found highly significant for all the characters under investigation except for days to first picking, fruit length (cm) number of primary branches per plant and total soluble solids. The mean squares due to lines were significant for all the traits except days to first picking and number of pickings. The mean squares due to testers were significant for all the traits except Number of primary branches per plant. This indicated the presence of wide genetic variability in the material used. The mean squares due to lines vs testers were significant for all traits except days to first picking, indicating the significant difference between female and male parents for these traits. Magnitude of variability was higher with testers for days to 50% flowering, days to first picking and number of pickings in comparison to lines. This indicated that the more contribution of testers in total variance for these characters, while, the magnitude of variability was higher with female for the rest of the traits under studied to the total variance **(**Table 2). Similar result observed by Balwani *et al.* (2017) [2], Kalaiyarasi *et al.* (2018) [13], Bhatt *et al.* (2019) [3], Rameshkumar and Vethamonai (2020) [25], Koulagi *et al.* (2023) [15], Yadav *et al.* (2023) [37], Dhatt *et al.* (2024) [6] and Thota *et al.* (2025) [35] for days to 50% flowering, days to first picking, fruit length (cm), fruit girth (cm), average, fruit weight (g), number of fruits per plant, number of primary branches per plant, plant height (cm), days to last picking, number of pickings, total fruit yield per plant (kg) and total soluble solids.

Many crosses depicted significant heterosis over better parent and standard check in favorable direction for days to 50% flowering (10,3), days to first picking (10, 2), fruit length (cm) (2, 4), fruit girth (cm) (0, 2), average, fruit weight (g) (1, 3), number of fruits per plant (10, 3), number of primary branches per plant (1, 0), plant height (cm) (0, 3), days to last picking (10, 2), number of pickings (0, 0), total fruit yield per plant (kg) (6, 3) and total soluble solids (5, 8), respectively (Table 3).

Performance of crosses in respect of heterosis over better parent and standard check (GJBH-4) revealed that the high magnitudes of heterobeltiosis and standard heterosis in desirable direction were found for days to 50% flowering, days to first picking, number of fruits per plant, total fruit yield per plant and total soluble solids. While, the low amount of heterobeltiosis was noticed for fruit length (cm), fruit girth (cm), average fruit weight, number of primary branches per plant and plant height (cm) and the low magnitude of heterosis over standard check was noticed for days to first picking, fruit girth (cm), number of primary branches per plant and days to last picking. Similar observations were also made by Balwani *et al.* (2017) [2], Kalaiyarasi *et al.* (2018) [13], Bhatt *et al.* (2019) [3], Rameshkumar and Vethamonai (2020) [25], Koulagi *et al.* (2023) [15], Yadav *et al.* (2023) [37] and Dhatt *et al.* (2024) [6].

Earliness is desirable character in brinjal and days to 50% flowering is component which effects on earliness. The heterobeltiosis for this trait was ranged from-15.72% (JBO-21-10 × GJLB-4) to 1.45% (JBL-21-11 × GRB-7). The standard heterosis varied from-5.42% (JBL-19-02 × GJB-3) to 3.94% (JBR-21-12 × GJLB-4). (Table 3). Similar observations were also reported by Venkata Naresh *et al.* (2016) [36], Balwani *et al.* (2017) [2] and Yadav *et al.* (2023) [37].

In brinjal, earliness in days to first picking is a desirable trait and the heterobeltiosis for this trait was ranged from-15.14% (JBO-21-10 × GJLB-4) to 8.22% (JBL-19-05×Swarnamani Black). The standard heterosis varied from-8.58% (JBO-21-10×GJLB-4) to 4.29% (JBL-19-02×GRB-7). Similar findings were reported by Saikia *et al.* (2019) [29], Rameshkumar and Vethamonai (2020) [25], Yadav *et al.* (2023) [37] and Dhatt *et al.* (2024) [6].

More fruit length generally directly responsible for high yield and hence, their positive values found beneficial in brinjal. The heterobeltiosis was ranged from-28.12% (PLR-1 × GJB-3) to 51.00% (JBL-19-05 × Swarnamani Black). The standard heterosis varied from-33.30 (PLR-1 × GRB-7) to 38.27% (JBL-19-05 × GJLB-4). These results are agreed with the result obtained by Bhatt *et al.* (2019) [3], Rameshkumar and Vethamonai (2020) [25], Koulagi *et al.* (2023) [15] and Dhatt *et al.* (2024) [6].

None of the crosses showed positive and significant heterosis over better parent, for fruit girth. The range of standard heterosis was noted from-35.26% (PLR-1 × GRB-7) to 13.34% (JBR-21-12 × GRB-7). These results are agreed with the results obtained by Patel *et al.* (2017) [21], Sivakumar *et al.* (2017) [33], Kalaiyarasi *et al.* (2018) [13].

The estimated heterosis over better parent varied from 38.40% (JBL-19-05 × Swarnamani Black) to 15.20% (JBO-21-10 × GJLB-4) for average fruit weight. The standard heterosis varied from-27.56% (PLR-1 × GRB-7) to 42.08% (JBR-21-12 × Swarnamani Black). Positive estimation of heterosis in this trait was also reported by Phor *et al.* (2022) [23], Gill *et al.* (2023) [10], Yadav *et al.* (2023) [37] and Dhatt *et al.* (2024) [6].

Considering heterosis over better parent, the variation for number of fruits per plant was from-33.33% (JBO-21-10 × Swarnamani Black) to 48.55% (JBL-21-11 × Swarnamani Black). Estimations of standard heterosis for number of fruits per plant was ranged from-59.56% (JBO-21-10 × Swarnamani Black) to 37.83% (PLR-1 × GRB-7). Similar findings were also reported by Sharma *et al.* (2016) [31], Rani *et al.* (2018) [26], Badr *et al.* (2021) [1] and Koulagi *et al.* (2023) [15].

For number of primary branches per plant, the estimates of heterobeltiosis ranged from-43.16% (JBO-21-10 × Swarnamani Black) to 25.00% (JBR-21-12 × GJB-3). None of the crosses showed positive and significant heterosis over standard check for number of primary branches per plant. Similar results for number of primary branches of plant in brinjal were also observed by Bhushan and Singh (2013) [4], Dudhat *et al.* (2013) [7], Reddy and Patel (2014) [28], Ramani

et al. (2015) [24], Sharma *et al*. (2016) [31].

None of the crosses showed positive and significant heterosis over better parent for plant height. The minimum and the maximum values of heterosis over standard check were 33.79% (JBO-21-10 × GJB-3) and 18.71% (JBL-19-02 × GJB-3). These results are agreed with the results obtained Sao and Mehta (2010) [30], Nalini *et al.* (2011) [18], Singh *et al.* (2012) [32].

The values of heterobeltiosis for days to last picking ranged from--9.24% (JBL-19-05 × GRB-7) to 14.88% (JBO-21-10 × GJLB-4). The standard heterosis, the range was noted from-10.39% (JBL-21-11 × Swarnamani Black) to 6.52% (JBR-21-12 × GRB-7). These findings are akin to those of results reported by Naresh *et al.* (2013) [19], Gadhiya *et al.* (2015) [9] and Sharma *et al.* (2016) [31].

None of the crosses showed positive and significant heterosis over better parent and standard check for number of pickings.

The heterobeltiosis for this trait was ranged from-44.60% (JBR-21-12 × Swarnamani Black) to 40.58% (JBO-21-10 × GJLB-4) for total fruit yield per plant. The highest desirable heterobeltiosis was recorded in cross JBO-21-10 × GJLB-4 (40.58%) followed by JBL-19-02 × GJLB-4 (34.94%) and JBL-19-02 × GJB-3 (29.68%). The standard heterosis varied from-34.50% (JBR-21-12 × Swarnamani Black) to 37.56% (PLR-1 × Swarnamani Black). The hybrid PLR-1 × Swarnamani Black exhibited the highest magnitude of standard heterosis (37.56%) in desirable direction followed by JBL-19-02 × GJB-7 (22.25%) and JBL-19-02 × Swarnamani Black (13.87%). These results are in conformation to the findings of Khapte *et al.* (2017) [14], Rashmi *et al.* (2019) [27], Chaudhari *et al.* (2020) [5], Rameshkumar and Vethamonai (2020) [25], Badr *et al.* (2021) [1], Subha Laxmi ***et al.*** (2023) [34], Mistry *et al.* (2023) [17] and Dhatt *et al.* (2024) [6].

The heterobeltiosis ranged from-21.44% (PLR-1 × GJLB-4) to 11.96% (JBL-19-02 × GRB-7) for total soluble solids. The Heterosis over standard check ranged from-9.28% (PLR-1 × GJB-3) to 27.93% (JBR-21-12 × GJLB-4) for total soluble solids. These results are in conformation to the findings of Bhushan *et al.* (2016) [4], Sharma *et al.* (2016) [31], Rani *et al.* (2018) [26], Subha Laxmi ***et al.*** (2023) [34].

The superior cross PLR-1 × Swarnamani Black was also exhibited significant standard heterosis in desired direction for the characters, viz., fruit length, fruit girth, average fruit weight and number of fruits per plant suggesting the greater role of these traits towards the total fruit yield per plant. This cross had also registered significant heterobeltiosis in desirable direction for total fruit yield per plant and number of fruits per plant. (Table 4).

The second highest heterotic cross JBL-19-02 × GRB-7 was recorded significant standard heterosis in desired direction for plant height, total soluble solids and fruit yield yield per plant. This cross had also exhibited significant heterobeltiosis in desired direction for total fruit yield per plant and total soluble solids. (Table 4).

The third highest heterotic cross JBL-19-02 × Swarnamani Black was recorded significant and positive heterosis over standard check for average fruit weight and total fruit yield per plant. (Table 4).

It is interesting to note that the high heterotic crosses for total fruit yield per plant did not show high heterosis for all the yield component traits (Table 4). However, the current study found that significant and positive heterosis for fruit yield was associated with significantly desirable heterosis for two or more yield-contribute traits. A similar cumulative heterotic effect of two or more yield components on total fruit yield per plant was previously reported by Badr *et al.* (2021) [1], Subha Laxmi *et al.* (2023) [34], Mistry *et al.* (2023) [17] and Dhatt *et al.* (2024) [6].

Table 1: Source and salient features of females and males of brinjal used in study

Sr. No.	Parents	Salient features
Lines		
1	JBL-19-02	Plant is erect in nature. Fruits are black, small and round.
2	JBL-19-05	Fruit size is long and color of fruits are pink. Plants have erect type habit and have a lower incidence of shoot and fruit borer.
3	JBR-21-12	Fruit size is medium long with round shape with long calyx. Fruits are dark purple in colour. Plant has erect type habit and resistant io Phomopsis blight.
4	JBL-21-11	Fruits are light purple in colour with good shining. Fruit size is medium long. It is resistant to shoot and fruit borer.
5	JBO-21-10	Plants are spreading in nature. Fruits are purple and small to round in shape and have cluster bearing. Calyx is of purple color.
6	PLR-1	Plants are non-spiny and semi spreading type. Fruits are oval in shape, dark purple with pink tinge and glossy.
Testers		
7	Swarna Mani Black	Black colored fruits with grooves and round in shape. Spreading type of habit and calyx of purple color.
8	GJB-3	Plants are medium in size and semi spreading. Fruits are medium to big in size with oval shape. Fruits are green in color with good shine. The fruit pulp is creamy white with less seeds.
9	GJLB-4	Fruits are medium in size with long shape. Fruit pulp is white with less seed. Fruits are light purple in color with good shine.
10	GRB-7	Fruits are medium in size with round shape. Fruit pulp is white with es seed. Fruits are green in colour with purple shadow strips and good shining. Plants are medium in size and erect type.
13	GJBH-4	Fruits are medium in size with long shape. Fruit pulp is white with less seed. Fruits are light purple in color with good shine.

Table 2: Analysis of variance for experimental design of different characters in brinjal

Source	d. f.	Days to 50% flowering	Days to first picking	Fruit length (cm)	Fruit girth (cm)	Average Fruit weight (g)	Number of fruits per plant
Replications	2	29.60**	60.03**	0.80	0.07	54.85	131.10**
Genotypes	33	14.75**	24.64**	10.31**	1.71**	794.68**	264.77**
Parents:	9	25.35**	36.28**	7.63**	2.80**	867.74**	218.93**
Lines	5	14.26**	19.57	24.74**	1.83**	1268.95**	460.95**
Testers	3	15.28**	62.63**	21.69**	0.79**	967.26**	223.28**
L. *vs* T.	1	7.03*	13.31	5.38**	0.82**	578.20**	173.10**
P. *vs* H.	1	36.09*	1.15	1.93	7.43**	495.10**	1195.87**
Hybrids	23	9.68*	21.10*	11.72**	1.04**	779.11**	242.22**
Error	66	5.59	10.47	0.92	0.12	46.56	8.94

	d. f.	Number of primary branches per plant	Plant height (cm)	Days to last picking	Number of pickings	Total fruit yield per plant (kg)	Total soluble solids (TSS) (^{O}B)
Replications	2	3.32**	7.30	221.60**	5.66**	0.12**	0.03
Genotypes	33	2.28**	824.18**	263.99**	2.54**	0.30**	0.58**
Parents:	9	2.51**	1469.49**	276.50**	5.69**	0.36**	0.34**
Lines	5	4.84**	1888.32**	399.96**	0.96	0.74**	1.56**
Testers	3	0.41	84.15*	183.09**	2.31**	0.06*	0.33**
L. *vs* T.	1	1.81**	141.24**	94.92**	1.13*	0.15**	0.48**
P. *vs* H.	1	0.25	2159.76**	2250.25**	3.88*	0.54**	0.09
Hybrids	23	2.28**	513.6**	172.73**	1.24**	0.27**	0.70**
Error	66	0.21	23.63	26.18	0.58	0.02	0.03

*, ** Significant at 5% and 1% levels, respectively

Table 3: Range of heterobeltiosis (H1) and standard heterosis (H2) as well as number of crosses with specific heterotic effects for various traits in brinjal

Sr. No.	Characters	Range of heterosis (%)						Number of crosses with significant heterosis			
		Heterobeltiosis (H1) (%)			Standard heterosis(H2) (%)			H1		H2	
								+ Ve	-Ve	+ Ve	-Ve
1	Days to 50 percent flowering	-15.72	to	1.45	-5.42	to	3.94	0	10	0	3
2	Days to first picking	-15.14	to	8.22	-8.58	to	4.29	1	10	0	2
3	Fruit length	-28.12	to	51	-33.30	to	38.27	2	9	4	9
4	Fruit girth	-38.99	to	5.15	-35.26	to	13.34	0	16	2	15
5	Average Fruit weight	-38.40	to	15.20	-27.56	to	42.08	1	11	3	6
6	Number of fruits per plant	-33.33	to	48.55	-59.56	to	37.83	10	4	3	13
7	Number of primary branches per plant	-43.16	to	25	-40.66	to	12.09	1	9	0	14
8	Plant height	-41.92	to	8.12	-33.79	to	18.71	0	23	3	18
9	Days to last picking	-9.24	to	14.88	-10.39	to	6.52	10	2	2	7
10	Number of pickings	-13.64	to	7.50	-11.63	to	4.65	0	4	0	3
11	Total fruit yield per plant	-44.60	to	40.58	-34.50	to	37.56	6	8	3	12
12	Days to 50 percent flowering	-21.44	to	11.96	-9.28	to	27.93	5	13	8	2

Table 4: Comparative study of five most heterotic crosses for total fruit yield per plant and their heterotic effect for component characters in brinjal

Heterotic crosses	Total fruit yield per plant (kg)	Per cent heterosis for total fruit yield/plant over		sca effect for total fruit yield/plant	Significant and desirable heterosis for component traits over	
		Better parent	Standard check (GHJB-4)		Better parent	Standard check (GJBH-4)
PLR-1 × Swarnamani Black	4.34	16.36**	37.56**	0.47**	6,11	3,4,5,6,11
JBL-19-02 × GRB-7	4.08	3.33	22.25**	0.14	11,12	8,11,12
JBL-19-02 × Swarnamani Black	2.11	-3.68	13.87**	0.05	11	5,12

Where, *, ** Significant at 5% and 1% levels, respectively

1= Days to 50% flowering; 2= Days first picking; 3= fruit length (cm); 4= fruit girth (cm); 5= Average Fruit weight (g); 6= No. of fruits/plant; 7= No. of-primary branches/plant; 8= Plant height (cm); 9= Days to last picking; 10= No. of pickings; 11= Total fruit yield/plant (kg) and 12= Total soluble solids

Conclusion

From ongoing discussion, it could be concluded that the best three promising crosses namely PLR-1 × Swarnamani Black, JBL-19-02 × GRB-7 and JBL-19-02 × Swarnamani Black exhibited high per se performance, significant and positive heterobeltiosis as well as standard heterosis in desired direction for total fruit yield per plant and some other yield attributing traits. Therefore, these three best crosses could be further evaluated over years and locations to exploit for commercial cultivation through heterosis breeding or utilized in future breeding programme to obtain desirable transgressive segregants and to identify high yielding superior inbreds.

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