The Original

ESTIMATION OF HETEROSIS FOR YIELD TRAITS IN BOTTLE GOURD [*LAGENARIA SICERARIA* (MOL.) STANDL.] UNDER DIFFERENT ENVIRONMENTAL CONDITIONS

Subhash Verma[1], R. B. Verma*[1], Amrita Kumari[1], Pushpam Patel[2], Sangita Kumari[2], Manju Kumari[2], Ashutosh Kumar[3], Shani Kumar[4]

[1]Department of Horticulture (Vegetable Science), Bihar Agricultural University, Bhagalpur, Bihar 813210
[2]Subject Matter Specialist, Bihar Agricultural University, Sabour, Bhagalpur 813210
[3]Subject Matter Specialist Horticulture, KVK Narkatiyaganj, RPCAU Pusa Samastipur Bihar
[4]Assistant Professor, School of Agriculture, Sanjeev Agrawal Global Educational University Bhopal 462022
*Corresponding author mail:- rbv1963@gmail.com

ABSTRACT
The current study was conducted to quantify heterosis for important yield characteristics in bottle gourd. Six genetically dissimilar inbred genotypes were crossed through full diallel mating scheme generating 30 F_1 hybrids that, together with parents and a commercial check 'Kashi Ganga', were tested in three environments, namely, Summer (E_1), Rainy (E_2) and Winter (E_3) of 2022 using Randomized Complete Block Design replicated thrice. Heterosis for fruit length, fruit diameter, number of fruits per vine, mean fruit weight and fruit yield attributes was calculated over mid-parent, better parent and standard check. Environmental effect on hybrid performance was very evident as considerable variation in heterotic performance was recorded among environments. In case of fruit length, F_1 hybrids NJ × BG-65, BG-21-2 × RBG and BG-65 × PN possessed high positive heterosis in all three environments. Highest heterosis for fruit diameter was recorded in hybrid RBG × BG-65 in all three environments. In the case of number of fruits per vine, crosses BG-21-2 × BG-23, BG-21-2 × PN and RBG × BG-23 had shown better heterotic responses, whereas crosses PN × BG-21-2, BG-65 × PN and BG-23 × BG-21-2 showed significant positive heterosis for average fruit weight. Some hybrids had also shown considerable standard heterosis over the commercial check and had the commercial potential. It has been observed in the present investigation that the level of heterosis depended upon environmental factors; but a few hybrids had shown superiority in terms of stability and adaptability. Crosses like BG-65 × PN, NJ × BG-65, BG-21-2 × RBG and RBG × BG-23 had been found to be most promising. These crosses can be used in commercial hybrid production and can serve as excellent source material for breeding bottle gourd cultivars in future breeding programs.

KEYWords: Bottle gourd, Heterosis, Yield traits, Full diallel and Environments

INTRODUCTION

Bottle gourd (*Lagenaria siceraria* (Mol.) Standl.) (2n = 2x = 22), which belongs to the family Cucurbitaceae, is considered to be one of the earliest domesticated vegetable crops that are grown in tropical and subtropical areas across the globe. It is suggested that bottle gourds originated in Africa, however, the archeological studies revealed that it was first domesticated in Asia including Indian sub-continent (Lal, et al., 2021). In India, the bottle gourds are widely grown under various climatic conditions in rainy and summer season due to their adaptability, short duration and higher yield potential, (Yadav, et al., 2023).

The bottle gourd is not only popular for its yield value but is also rich in nutritional and medicinal values. The young fruit is taken as vegetable preparations and is extensively utilized in cooking curries, soups, desserts, raita, kofta, and pickles. These are rich in moisture content, carbohydrates, dietary fiber, vitamins and minerals but low in calorie content and, thus, play a vital role in the balanced diet regimen (Singh, et al., 2012). Apart from being nutritive, the bottle gourd is an antioxidant, cardiotonic, diuretic, anti-inflammatory, and digestive agent. The seeds have protein and oil content while the mature fruits are traditionally utilized in preparing vessels, utensils, handicrafts, and musical instruments (Mkhize, et al., 2023).

Yield of fruits in the bottle gourd crop is a complicated quantitative character, and its expression is determined by many component factors that work together and have both additive and non-additive effects (Vasudeo C.G. 2016). Also, the expression of yield and other characters is significantly influenced by environmental factors such as temperature, rainfall, humidity and seasonality, which results in high levels of genotype-environment interaction. Hence, it becomes very important to test the heterosis of different genotypes under different environments. Multi-environment trials will help to find out superior hybrids and parents for their use in future breeding programs, (Shaikh, et al., 2011).

Due to the increasing demand for bottle gourd in the domestic and export markets, there is an increasing necessity for the development of hybrids that can produce higher yields along with having good qualities of the fruit and good adaptability (Janaranjani, et al., 2016). However, due to lack of improved hybrids, narrow genetic diversity among the varieties grown, vulnerability to biotic and abiotic stress factors and variations in environment, the productivity has not achieved its full genetic potential. Hence, utilization of genetic diversity via hybridization has emerged as one of the most promising strategies to improve productivity and stability in yield, (Mauriya, et al., 2021). There is increasing need to develop improved hybrids that are high yielding and have good fruit quality because of the increasing need for bottle gourd in domestic and export markets. But productivity has remained low compared to the genetic potential of the crop because of a lack of improved hybrids, low genetic variability of varieties grown, disease and pest attacks, and varying environment conditions, (Yadav, et al., 2025).

The bottle gourd crop is basically cross-pollinating and monoecious, showing extensive natural out-crossing. This makes the utilization of heterosis, or hybrid vigor, very easy and practical. The bottle gourd crop shows wide genetic diversity in economically important characters including length of the fruit (cm), diameter of the fruit (cm), number of fruits per vine, mean weight of the fruit (g) and yield of fruits per vine (kg). There have been successful cases of heterosis utilization in many vegetables, especially cucurbits. Commercial hybrids of these crops usually perform better than open pollinated varieties in terms of yield, uniformity, earliness, and acceptability in the market (Ghuge et al., 2016).

Consequently, the current study entitled "Estimation of Heterosis for Yield traits in Bottle Gourd [*Lagenaria siceraria* (Mol.) Standl.] under Different Environmental Conditions " has been carried out in order to estimate the degree of heterosis for important yield and yield components characters under varied environments and to select superior hybrid combinations for their better utilization in bottle gourd breeding programs.

MATERIALS AND METHODS

The current study entitled "Estimation of Heterosis for Yield Traits in Bottle Gourd [*Lagenaria siceraria* (Mol.) Standl.] under Different Environmental Conditions" was carried out in 2022 in the Vegetable Research Farm, Department of Horticulture (Vegetable and Floriculture), Bihar Agricultural College, Bihar Agricultural University, Sabour, Bhagalpur, Bihar, India located at 25°15′ N latitude and 87°02′ E longitude, with an elevation of around 75 m above the mean sea level, having a humid subtropical type of climate.

The experimental material used consisted of six genetically distinct inbred lines of bottle gourd including BRBG-23, BRBG-65, BRBG-21-2, Narendra Jyoti, Pusa Naveen, and RBG, along with one commercial hybrid of Kashi Ganga as standard check. In 2021, the six parental lines were crossed using a complete diallel crossing scheme to produce 30 F_1 hybrids. The hybrid namely Narendra Jyoti x BG-23, Narendra Jyoti x BG-65, Narendra Jyoti x Pusa Naveen, Narendra Jyoti x BRBG-21-2, Narendra Jyoti x RBG, BG-23 x Narendra Jyoti, BG-23 x BG-65, BG-23 x Pusa Naveen, BG-23 x BRBG-21-2, BG-23 x RBG, BG-65 x Narendra Jyoti, BG-65 x 23, BG-65 x Pusa Naveen, BG-65 x BRBG-21-2, BG-65 x RBG, Pusa Naveen x BG-65, Pusa Naveen x BG-23, Pusa Naveen x BRBG-21-2, Pusa Naveen x Narendra Joyti, Pusa Naveen x RBG, BRBG-21-2 x Narendra Joyti, BRBG-21-2 x BG-23, BRBG-21-2 x BG-65, BRBG-21-2 x Pusa Naveen, BRBG-21-2 x RBG, RBG x Narendra Joyti, RBG x BG-23, RBG x BG-65, RBG x Pusa Naveen and RBG x BRBG-21-2. All the thirty F_1 along with their six parents and one commercial check (Kashi Ganga) were studied for their heterosis and yield potential under various environments. Controlled crossing was done by covering the flower buds prior to anthesis and manually pollinating them between 1:30 PM to 4:00 PM.

A total of 37 genotypes consisting of 30 F_1 hybrids, six parental lines, and one standard check line were tested under three contrasting environments, which included summer (E_1, February 2022), rainy (E_2, May 2022), and winter (E_3, September 2022). The trial was conducted using a Randomized Complete Block Design (RCBD) with three replications. Plots with a size of 4.0 × 3.0 m and a spacing of 3.0 m × 0.5 m were used to accommodate eight plants per plot. Agronomic practices were uniformly followed in all environments. The observations were taken on five randomly selected plants in each plot regarding the length of the fruit (cm), diameter of the fruit (cm), number of fruits per vine, mean weight of the fruit (g), and yield of fruits per vine (kg). The fruit yield per vine was obtained by multiplying the mean weight of the fruit with the number of fruits per vine. Relative heterosis, heterobeltiosis, and standard heterosis for all yield characteristics were estimated over mid-parent, better parent, and standard check respectively.

Estimation of heterosis

The magnitude of heterosis was studied using information on various quantitative and fruit quality traits. Heterosis expressed as per cent increase or decrease in the mean values of F1's (hybrid) over better-parent (heterobeltiosis) and standard variety (standard heterosis) was calculated according to method suggested by Hayes et al. (1955). The formula used for estimation of heterosis are as follows:

(1) **Heterobeltiosis** (%) $= \frac{\overline{F_1}-\overline{BP}}{\overline{BP}} \times 100$

(2) **Economic heterosis** (%) $= \frac{\overline{F_1}-\overline{SV}}{\overline{SV}} \times 100$

(3) **Average/relative heterosis** (%) $= \frac{\overline{F_1}-\overline{MP}}{\overline{MP}} \times 100$

Where,

$\overline{F_1}$= mean value of F_1

$\overline{BP}$= mean value of better-parent

$\overline{SV}$= mean value of standard variety

$\overline{MP}$ = mean value of mid-parent

The significance of heterosis was tested by't' tests as given below.

't' (Mid-parent) = $\frac{\overline{F_1}-\overline{MP}}{SE}$

t' (Heterobeltiosis) = $\frac{\overline{F_1}-\overline{BP}}{SE}$

't' (Standard heterosis) = $\frac{\overline{F_1}-\overline{SV}}{SE}$

SE of heterosis over better-parent and standard variety = Me/r

Where,

Me = Error mean of square

r = Number of replications

SE = The standard error of the treatments means and (t) is the table value of (t) at 5% or 1% level of significance at error of degree of freedom.

The calculated' value was compared with table value't' at error d.f. at 5% and 1% level of probability for testing the significance of heterosis.

The observations were statistically analyzed through analysis of variance (ANOVA) for each environment separately as well as for all environments pooled together according to the method described by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

The estimates of heterotic responses (superiority over better mid and standard parent) of bottle gourd hybrids in each F1 hybrid were worked out for all the characters under study over the three environmental seasons (February 2022 Environment-I, May 2022 Environment-II and September 2022, Environment-III). The negative estimates of heterosis were considered desirable for the maturity trait, viz., days to first male flower opening, days to first female flower opening, days to first fruit harvest, number of nodes to the first male flower and number of nodes to the first female flower appearance while for the rest of the characters, positive estimates were considered desirable. The character-wise results on the above aspect have been presented as fallows.

Length of fruit (cm)

In environment I, Table 1 showed that the F_1 hybrids namely NJ x BG-65 (32.68%, 25.99%) followed by BG-65 x RBG and BG-21-2 x RBG(30.11%, 27.02%) over mid parent and BG-23 x NJ and BG-23 x PN (22.04%, 20.13%) over better parent had maximum positive significant heterosis for fruit length. Among the F_1 hybrid, NJ x BG-65 (26.82%) followed by BG-23 x NJ (26.23%) and BG-23 x PN (24.26%) showed maximum positive heterosis in fruit length over the standard check (Kashi Ganga), closed as result reported by (Shaikh, et al., 2011). In environment II, Table 1 showed that the F_1 hybrids namely BG-21-2 x RBG (33.32%) followed by PN x RBG (27.38%) and BG-65 x PN (23.58%) recorded maximum positive significant heterosis over mid parent. F_1 hybrids BG-65 x PN (23.42) followed by BG-23 x BG-21-2 (17.05%) and BG-23 x BG-65 (15.88%) indicated maximum positive significant heterosis over the better parent. Among the F_1 hybrids namely BG-65 x PN (23.94%) followed by NJ x BG-65 (20.59%) and BG-23 x BG-21-2 (20.18%) showed the highest positive significant standard heterosis over check (Kashi Ganga).In environment III, Table 1 showed that the twelve hybrids over mid parent, six hybrids over better parent and nine hybrids over standard check expressed significant positive heterosis. F_1 hybrids namely BG-21-2 x RBG (28.97%) followed by BG-65 x RBG (28.45%) and BG-65 x PN (24.67%) had maximum positive significant heterosis over mid parent, BG-65 x PN (24.24%) followed by PN x BG-65 (19.79%) and BG-23 x BG-21-2 (17.58%) over the better parent and BG-65 x PN (24.62%) followed by NJ x PN (22.34%) and NJ x BG-23 (20.95%) showed the highest positive significant standard heterosis over ckeck (Kashi Ganga).The better performance of such hybrids could be explained due to complementary relationship among genetically distinct parents and preponderance of non-additive gene actions regulating fruit length. Heterosis for fruit length in favour of F1 hybrids has been observed by (Parmar et al. 2016), (Parmar, 2018), (Janaranjani, et al. 2016) and (Kumar, and Ram 2021), suggesting that hybridization is a successful strategy for improvement in fruit size of bottle gourd.

Diameter of fruit (cm)

In environment I, Table 2 indicates that the F_1 hybrids namely RBG x BG-65 (15.43%), RBG x NJ (14.83%), RBG x PN (11.10%) and BG-23 x BG-65 (10.65%) exhibited maximum positive significant heterosis over mid-parent and none of the F_1 hybrids showed positive significant in heterobeltiosis. The F_1 hybrids namely, RBG x PN (33.90%) followed by RBG x BG-65 (32.87%) exhibited maximum significant positive heterosis over the standard check (Kashi Ganga). In environment II, Table 2 indicated that the nine F_1 hybrids exhibited positive significant heterosis over mid-parent with maximum in RBG x BG-65 (27.36%), followed by RBG x BG-21-2 (21.07%) and RBG x NJ (20.39%), two F_1 hybrids exhibited positive significant heterosis over the better parent, *i.e.,* RBG x BG-21-2 (11.55%) and RBG x BG-65 (10.97%). While, F_1 hybrids RBG x BG-21-2 (47.24%) followed by RBG x BG-65 (46.47%) and RBG x PN (39.95%) exhibited maximum significant positive heterosis over the standard check (Kashi Ganga). In environment III, Table 3 showed that the eight F_1 hybrids exhibited positive significant heterosis over mid-parent with the maximum in RBG x BG-65 (25.07%) while, none of the F_1 hybrids showed positive significant heterosis over better parent. F_1 hybrid namely RBG x BG-65 (45.00%), followed by RBG x NJ (41.69%) and RBG x BG-65 (45.00%) showed maximum positive significant standard heterosis over check (Kashi Ganga).The higher heterosis effect seen for fruit diameter was mainly due to dominance and over-dominance effects on account of the genetic diversity of the parents. Similar results have also been found by (Singh et al. 2016), (Tulluru, et al., 2023) and (Mkhize, et al. 2025) for heterosis of bottle gourd fruit diameter.

Number of fruits per vine

In environment I, Table 3 showed that the nine F_1 hybrids over mid-parent, five over better parent and twenty-five over standard check (Kashi Ganga) had positive significant heterosis with the maximum in BG-21-2 x BG-23 (36.74%, 26.80%) over mid and better parent respectively, while in standard heterosis F_1 hybrids RBG x BG-23 (66.60%) followed by BG-21-2 x BG-23 (66.17%) and BG-23 x RBG (59.49%) showed maximum positive heterosis over check (Kashi Ganga). In environment II, Table 3 indicated that the F_1 hybrid BG-21-2 x PN (30.82% and 24.54%) recorded maximum significant positive heterosis over both the mid and better parents. F_1 hybrid namely RBG x BG-23 (56.43%), followed by RBG x PN (39.99%) and BG-23 x RBG (35.35%) showed positive significant standard heterosis over check (Kashi Ganga).In environment III, Table 3 showed that the F_1hybrids BG-21-2 x PN (21.46%)followed by PN x BG-23 (20.30%)over mid-parent, none of the hybrids over better parent and RBG x BG-23 (48.60%) followed by BG-65 x RBG (30.80%) and BG-23 x RBG (28.60%) exhibited maximum significant positive heterosis over the standard check (Kashi Ganga). These may be the fact that the heterosis could be attributed to better flowering performance, higher fruit setting, and effective partitioning of assimilates for reproductive development. These findings have also been corroborated by studies conducted by (Maurya, et al., 2009), (Vanrajbhai et al. 2016), (Gautam, et al. 2017), and (Singh, et al. 2025), where they found that the number of fruits per vine was one of the significant components of heterosis.

Weight of fruit (g)

Out of thirty crosses, nineteen F_1 hybrids over mid-parent, twelve over better parent and six over standard check showed positive significant heterosis in environment I (Table 4) with the maximum in PN x BG-21-2 (36.25%) followed by BG-23 x PN (32.02%) and NJ x BG-65 (30.28%) over mid-parent, PN x BG-21-2 (35.78%) followed by NJ x BG-65 (29.76%) and PN x BG-65 (28.26%) over heterobeltiosis and PN x BG-21-2 (28.97%) followed by NJ x BG-65 and PN x BG-65 (20.99%) over check (Kashi Ganga) showed the highly positive significant economic heterosis, respectively. In environment II, Table 4 showed that the F_1 hybrids BG-65 x PN (35.80%, 29.09%) followed by PN x BG-65 (30.53%) and BG-23 x BG-21-2 (30.47%) over mid-parent, BG-23 x BG-65 (26.74%) and PN x BG-65 (24.07%) over better parent and BG-65 x PN (24.57%) followed by the hybrids PN x BG-65 (19.74%) over check (Kashi Ganag) had maximum significant positive heterosis. In environment III, Table 4 indicated that the eight hybrids over mid-parent, six hybrids over better parent and seven hybrids over standard check showed maximum positive significant heterosis with the maximum in BG-65 x PN (36.92% and 30.53%) followed by hybrid BG-23 x BG-21-2 (32.57% and 28.72%) showed the highly positives significant over mid and standard heterosis, respectively. F_1 hybrids BG-23 x BG-65 (29.71%) followed by BG-65 x PN (26.18%) had maximum positive significant heterosis over heterobeltiosis. This can be inferred from the better performance of the above-hybrid combinations due to the presence of non-additive effects in regulating fruit weight. Similar observations have also been made by (Ghuge, et al., 2016), (Masud, et al. 2016), and (Khot, et al. 2021), where significant heterosis was observed for fruit weight in bottle gourd.

Table-1: Estimation of Heterosis Length of Fruit (cm)

		Heterosis (%) Length of fruit(cm)									
Treatment			E1			E2			E3		
T	F_1	Cross	MP	BP	SH	MP	BP	SH	MP	BP	SH
1	1*2	NJ x BG-23	1.04	-0.32	3.10	4.35	2.39	9.24	-0.49	-4.88	6.99
2	1*3	NJ x BG-65	32.68**	25.99**	26.82**	16.59**	13.03**	20.59**	13.68**	7.53	20.95**
3	1*4	NJ x PN	21.91**	17.77**	18.54**	12.45**	9.15	16.45**	15.36**	8.77	22.34**
4	1*5	NJ x BG-21-2	19.26**	15.17**	15.93**	17.00**	11.71*	19.18**	12.40*	6.86	20.20**
5	1*6	NJ x RBG	19.92**	-15.94**	-15.38**	14.50*	-17.25**	-11.72*	10.64	-21.38**	-11.57
6	2*1	BG-23 x NJ	23.70**	22.04**	26.23**	2.26	0.33	7.04	-1.54	-5.88	5.86
7	2*3	BG -23 x BG-65	11.95*	4.96	8.56	17.31**	15.88**	18.98**	16.92**	15.64**	18.60**
8	2*4	BG-23 x PN	25.99**	20.13**	24.26**	6.32	5.16	7.97	1.47	0.02	2.58
9	2*5	BG-23 x BG-21-2	2.37	-2.42	0.93	20.35**	17.05**	20.18**	18.24**	17.58**	20.58**
10	2*6	BG-23 x RBG	22.42**	-14.85**	-11.92*	21.23**	-11.33*	-8.96	11.35	-18.60**	-16.52**
11	3*1	BG-65 x NJ	12.37*	6.71	7.41	10.17*	6.80	13.94**	1.59	-3.91	8.08
12	3*2	BG-65 x BG-23	11.66*	4.69	8.28	6.74	5.43	8.25	1.50	0.38	2.95
13	3*4	BG-65 x PN	18.02**	15.94**	8.77	23.58**	23.42**	23.94**	24.67**	24.24**	24.62**
14	3*5	BG-65 x BG-21-2	10.40	8.49	1.71	6.90	5.23	5.41	7.10	6.52	8.01
15	3*6	BG-65 x RBG	30.11**	-5.86	-14.79**	22.98**	-9.34	-9.18	28.45**	-5.44	-5.15

16	4*1	PN x NJ	6.08	2.48	3.15	10.46*	7.21	14.38**	-0.86	-6.52	5.14
17	4*2	PN x BG-23	9.79	4.69	8.28	2.64	1.51	4.23	5.51	4.00	6.66
18	4*3	PN x BG-65	6.30	4.43	-2.03	8.60	8.46	8.92	20.20**	19.79**	20.15**
19	4*5	PN x BG-21-2	12.68*	12.63*	5.67	9.70*	7.85	8.31	13.32**	12.33*	13.90*
20	4*6	PN x RBG	23.09**	-11.91	-17.36**	27.38**	-6.17	-5.77	23.06**	-9.21	-9.55
21	5*1	BG-21-2 x NJ	8.15	4.44	5.13	4.17	-0.54	6.11	3.14	-1.94	10.30
22	5*2	BG-21-2 x BG-23	-5.77	-10.18	-7.10	11.90**	8.83	11.75*	13.55**	12.91*	15.80**
23	5*3	BG-21-2 x BG-65	7.82	5.96	-0.67	3.80	2.18	2.35	3.16	2.60	4.04
24	5*4	BG - 21-2 x PN	2.09	2.06	-4.26	5.56	3.79	4.23	9.31	8.35	9.87
25	5*6	BG-21-2 x RBG	27.02**	-9.08	-14.77**	33.32**	-0.70	-3.63	28.97**	-5.39	-4.06
26	6*1	RBG x NJ	-26.45**	-48.44**	-48.10**	-33.02**	-51.59**	-48.36**	-25.00**	-46.70**	-40.06**
27	6*2	RBG x BG-23	-24.27**	-47.32**	-45.51**	-22.48**	-43.30**	-41.78**	-14.17	-37.26**	-35.66**
28	6*3	RBG x BG-65	-22.55**	-43.97**	-49.28**	-19.09**	-40.35**	-40.25**	-16.35*	-38.42**	-38.24**
29	6*4	RBG x PN	-26.16**	-47.16**	-50.43**	-26.38**	-45.77**	-45.54**	-18.98**	-40.23**	-40.45**
30	6*5	RBG x BG-21-2	-22.66**	-44.64**	-48.10**	-24.67**	-43.89**	-45.55**	-18.04**	-39.87**	-39.03**
		SEd (±)	1.82	2.10	2.10	1.57	1.81	1.81	1.51	1.75	1.75
		CD 5%	3.89	4.50	4.50	3.37	3.89	3.89	3.25	3.75	3.75

** Significant at 1% and * significant at 5%, Where NJ= (Narendra Joyti), BG-23= (BRBG-23), BG-65= (BRBG-65), PN= (Pusa Naveen), BG-21-2= (BRBG-21-2) and RBG= (Round bottle gourd).

Table-2:- Estimation of Heterosis Diameter of fruit (cm)

			Heterosis (%) Diameter of fruit (cm)								
Treatment			E1			E2			E3		
T	F_1	Cross	MP	BP	SH	MP	BP	SH	MP	BP	SH
1	1*2	NJ x BG-23	-4.75	-8.06	-10.64	-3.02	-4.01	-6.84	1.05	-1.16	-4.42
2	1*3	NJ x BG-65	-4.89	-6.12	-6.34	6.12	5.59	3.50	4.43	2.13	-1.20
3	1*4	NJ x PN	-10.88*	-16.28**	-7.41	-2.11	-6.13	-0.75	2.15	1.47	-6.16
4	1*5	NJ x BG-21-2	2.66	1.14	1.31	-6.17	-12.15*	-2.28	11.72	10.67	2.35
5	1*6	NJ x RBG	1.23	-11.67**	15.22**	7.94	-6.34	23.62**	14.63**	-3.46	30.45**
6	2*1	BG-23 x NJ	-1.31	-4.74	-7.41	4.20	3.14	0.09	-7.25	-9.28	-12.27
7	2*3	BG -23 x BG-65	10.65*	5.47	5.23	11.51*	9.83	7.65	12.61*	12.59	8.92
8	2*4	BG-23 x PN	-9.05	-17.34**	-8.59	-6.58	-11.29*	-6.21	3.75	0.83	-2.50
9	2*5	BG-23 x BG-21-2	4.97	-0.13	0.03	-2.24	-9.34	0.84	16.23**	12.65	8.93
10	2*6	BG-23 x RBG	3.87	-12.06**	14.71**	13.01**	-2.80	28.30**	0.17	-14.07**	16.12**
11	3*1	BG-65 x NJ	-8.17	-9.36	-9.57	-0.35	-0.85	-2.81	-10.95	-12.91	-15.75*
12	3*2	BG-65 x BG-23	5.19	0.26	0.03	6.78	5.18	3.09	1.12	1.10	-2.19
13	3*4	BG-65 x PN	-10.95*	-15.30**	-6.34	0.38	-3.28	2.26	4.13	1.17	-2.12
14	3*5	BG-65 x BG-21-2	-8.46	-8.64	-8.49	-5.67	-11.27*	-1.30	-2.67	-5.69	-8.76
15	3*6	BG-65 x RBG	-5.86	-16.93**	8.36	12.59**	-1.90	29.49**	2.83	-11.77**	19.21**
16	4*1	PN x NJ	-2.39	-8.31	1.40	-10.71*	-14.38**	-9.47	3.90	3.22	-4.55
17	4*2	PN x BG-23	1.86	-7.42	2.38	8.49	3.02	8.92	-0.69	-3.49	-6.67
18	4*3	PN x BG-65	5.29	0.14	10.74	13.01**	8.90	15.13**	5.50	2.51	-0.83
19	4*5	PN x BG-21-2	9.34	4.19	15.22**	-4.71	-7.06	3.37	-0.01	-0.29	-9.01
20	4*6	PN x RBG	1.97	-5.79	22.89**	5.58	-4.93	25.49**	0.39	-15.90**	13.64*
21	5*1	BG-21-2 x NJ	4.85	3.29	3.46	2.91	-3.65	7.18	-2.35	-3.26	-10.54
22	5*2	BG-21-2 x BG-23	-4.18	-8.84	-8.69	-2.01	-9.13	1.08	-2.62	-5.62	-8.73
23	5*3	BG-21-2 x BG-65	-9.95	-10.13	-9.98	3.90	-2.27	8.70	-4.25	-7.21	-10.24
24	5*4	BG -21-2 x PN	-0.79	-5.47	4.54	2.78	0.23	11.49	-0.07	-0.35	-9.06
25	5*6	BG-21-2 x RBG	-0.42	-11.97**	14.83**	-2.43	-10.10*	18.66**	-21.23**	-34.17**	-11.04
26	6*1	RBG x NJ	14.83**	0.19	30.70**	20.39**	4.46	37.88**	24.51**	4.86	41.69**
27	6*2	RBG x BG-23	1.52	-14.05**	12.12*	16.44**	0.16	32.20**	11.97**	-3.94	29.79**
28	6*3	RBG x BG-65	15.43**	1.86	32.87**	27.36**	10.97**	46.47**	25.07**	7.31	45.00**
29	6*4	RBG x PN	11.10**	2.65	33.90**	17.74**	6.03	39.95**	11.93*	-6.24	26.70**
30	6*5	RBG x BG-21-2	5.31	-6.92	21.42**	21.07**	11.55**	47.24**	15.52**	-3.45	30.46**
		SEd (±)	0.48	0.55	0.55	0.41	0.47	0.47	0.42	0.48	0.48
		CD 5%	1.03	1.19	1.19	0.88	1.02	1.02	0.89	1.03	1.03

** Significant at 1% and * significant at 5%, Where NJ= (Narendra Joyti), BG-23= (BRBG-23), BG-65= (BRBG-65), PN= (Pusa Naveen), BG-21-2= (BRBG-21-2) and RBG= (Round bottle gourd).

Table-3: Estimation of Heterosis Number of fruits per vine

		Heterosis (%) Number of fruits per vine									
Treatment			E1			E2			E3		
T	F_1	Cross	MP	BP	SH	MP	BP	SH	MP	BP	SH
1	1*2	NJ x BG-23	-11.04	-12.85	14.20	-11.97*	-16.98**	3.09	-5.10	-11.54	5.80
2	1*3	NJ x BG-65	1.16	-3.41	21.41**	2.42	1.34	11.52	0.40	0.00	4.20
3	1*4	NJ x PN	0.43	-0.85	24.63**	12.86	4.21	14.69	12.06	5.46	9.02
4	1*5	NJ x BG-21-2	23.78**	17.04**	47.11**	-12.20	-14.97*	-6.43	-9.24	-10.53	-4.80
5	1*6	NJ x RBG	-8.70	-17.29**	28.05**	-6.16	-21.52**	28.39**	-4.72	-20.22**	22.23**
6	2*1	BG-23 x NJ	-2.14	-4.14	25.62**	-10.35	-15.45*	4.99	-10.84	-16.89*	-0.60
7	2*3	BG -23 x BG-65	-6.77	-12.71	14.39	-11.45	-17.32**	2.67	-14.03*	-19.57**	-3.80
8	2*4	BG-23 x PN	-21.34**	-23.91**	-0.28	5.53	-7.64	14.69	0.95	-11.04	6.40
9	2*5	BG-23 x BG-21-2	-0.09	-7.35	21.41**	-18.18**	-25.13**	-7.03	-20.18**	-24.58**	-9.80
10	2*6	BG-23 x RBG	11.58*	3.01	59.49**	-5.93	-17.27**	35.35**	-5.72	-16.06**	28.60**
11	3*1	BG-65 x NJ	7.05	2.21	28.48**	9.20	8.05	18.90*	-8.85	-9.21	-5.40
12	3*2	BG-65 x BG-23	2.79	-3.76	26.12**	14.73**	7.13	33.03**	-20.45**	-25.57**	-10.98
13	3*4	BG-65 x PN	18.26**	14.34*	40.04**	-7.24	-13.50	-6.82	-22.62**	-27.45**	-24.40**
14	3*5	BG-65 x BG-21-2	27.53**	26.22**	44.33**	10.60	8.22	16.58*	7.69	6.58	13.40
15	3*6	BG-65 x RBG	9.63	-4.70	47.54**	1.48	-15.85**	37.67**	1.63	-14.62**	30.80**
16	4*1	PN x NJ	-0.26	-1.53	23.77**	12.45	3.83	14.27	14.29	7.56	11.19
17	4*2	PN x BG-23	12.16*	8.50	42.18**	21.82**	6.62	32.40**	20.30**	6.02	26.80**
18	4*3	PN x BG-65	-6.81	-9.91	10.35	-9.13	-15.26*	-8.71	-9.31	-14.97	-11.40
19	4*5	PN x BG-21-2	-16.71**	-20.28**	-2.36	9.34	4.09	7.31	3.04	-4.32	1.80
20	4*6	PN x RBG	-2.08	-12.31*	35.76**	-1.81	-22.94**	26.07**	0.29	-20.00**	22.56**
21	5*1	BG-21-2 x NJ	7.75	1.87	28.05**	2.87	-0.38	9.63	-0.65	-2.07	4.20
22	5*2	BG-21-2 x BG-23	36.74**	26.80**	66.17**	-7.61	-15.45*	4.99	-11.86	-16.72*	-0.40
23	5*3	BG-21-2 x BG-65	22.04**	20.79**	38.12**	-9.40	-11.35	-4.50	-9.21	-10.15	-4.40
24	5*4	BG -21-2 x PN	17.81**	12.76	38.12**	30.82**	24.54**	28.39**	21.46**	12.78	20.00*
25	5*6	BG-21-2 x RBG	-9.04	-21.62**	21.34**	-0.24	-18.69**	33.03**	-4.31	-18.93**	24.20**
26	6*1	RBG x NJ	-3.21	-12.31*	35.76**	-7.86	-22.94**	26.07**	-8.33	-23.24**	17.60*
27	6*2	RBG x BG-23	16.55**	7.61	66.60**	8.72	-4.38	56.43**	8.94	-3.00	48.60**
28	6*3	RBG x BG-65	0.77	-12.40*	35.62**	-7.17	-23.02**	25.93**	-9.71	-24.15**	16.20
29	6*4	RBG x PN	8.11	-3.18	49.89**	9.03	-14.43**	39.99**	-18.17**	-34.73**	0.00
30	6*5	RBG x BG-21-2	3.21	-11.07*	37.69**	-4.03	-21.78**	27.97**	-12.63*	-25.98**	13.40
		SEd (±)	0.32	0.37	0.37	0.30	0.35	0.35	0.33	0.38	0.38

		CD 5%	0.68	0.79	0.79	0.65	0.75	0.75	0.71	0.82	0.82

** Significant at 1% and * significant at 5%, Where NJ= (Narendra Joyti), BG-23= (BRBG-23), BG-65= (BRBG-65), PN= (Pusa Naveen), BG-21-2= (BRBG-21-2) and RBG= (Round bottle gourd).

Table 4. Estimation of Heterosis Weight of fruit(g)

		Heterosis (%) Weight of fruit(g)									
			E1			E2					
T	F_1	Cross	MP	BP	SH	MP	BP	SH	MP	BP	SH
1	1*2	NJ x BG-23	15.09*	9.96	2.53	5.65	0.85	-5.53	1.86	-6.14	-2.13
2	1*3	NJ x BG-65	30.28**	29.76**	20.99**	24.21**	19.76**	12.17	22.32**	12.32	17.12*
3	1*4	NJ x PN	21.83**	21.13**	14.26*	19.72**	17.97**	13.84*	17.26**	16.79**	21.78**
4	1*5	NJ x BG-21-2	-2.02	-2.92	-7.79	22.32**	19.61**	17.23**	17.33**	16.20*	23.53**
5	1*6	NJ x RBG	20.93**	8.80	1.44	5.47	-8.18	-14.00*	1.70	-14.24*	-10.57
6	2*1	BG-23 x NJ	30.00**	24.21**	15.81*	6.24	1.41	-5.01	0.41	-7.48	-3.53
7	2*3	BG -23 x BG-65	15.57*	10.84	2.53	28.07**	26.74**	10.21	30.20**	29.71**	13.99*
8	2*4	BG-23 x PN	32.02**	25.44**	18.33**	2.38	-3.64	-7.01	-1.57	-8.97	-5.84
9	2*5	BG-23 x BG-21-2	12.95*	6.98	1.61	30.47**	21.91**	19.49**	32.57**	21.08**	28.72**
10	2*6	BG-23 x RBG	7.73	1.14	-14.10*	2.59	-6.89	-20.71**	-1.69	-10.81	-21.62**
11	3*1	BG-65 x NJ	17.38**	16.92*	9.01	14.02*	9.93	2.97	10.35	1.33	5.65
12	3*2	BG-65 x BG-23	25.97**	20.82**	11.76	13.12*	11.95	-2.65	13.28	12.85	-0.82
13	3*4	BG-65 x PN	9.75	8.69	2.53	35.80**	29.09**	24.57**	36.92**	26.18**	30.53**
14	3*5	BG-65 x BG-21-2	18.24**	16.69*	10.84	5.32	-0.62	-2.60	2.56	-6.65	-0.76
15	3*6	BG-65 x RBG	13.70*	2.66	-5.04	11.67	0.40	-12.69*	10.35	0.46	-12.38
16	4*1	PN x NJ	8.34	7.72	1.61	8.29	6.70	2.97	1.73	1.32	5.65
17	4*2	PN x BG-23	23.76**	17.59**	10.93	1.68	-4.30	-7.65	-2.34	-9.69	-6.57
18	4*3	PN x BG-65	29.52**	28.26**	20.99**	30.53**	24.07**	19.74**	31.08**	20.79**	24.96**
19	4*5	PN x BG-21-2	36.25**	35.78**	28.97**	6.64	5.81	3.71	1.55	0.19	6.51
20	4*6	PN x RBG	17.98**	5.60	-0.39	7.30	-7.76	-10.98	2.37	-13.40	-10.41
21	5*1	BG-21-2 x NJ	19.81**	18.71**	12.76	10.29	7.85	5.71	3.34	2.34	8.80
22	5*2	BG-21-2 x BG-23	-4.70	-9.75	-14.27*	17.47**	9.76	7.58	14.28*	4.38	10.96
23	5*3	BG-21-2 x BG-65	-3.41	-4.68	-9.46	5.32	-0.62	-2.60	2.56	-6.65	-0.76
24	5*4	BG -21-2 x PN	17.10**	16.69*	10.84	5.69	4.88	2.80	0.55	-0.81	5.45
25	5*6	BG-21-2 x RBG	10.08	-1.78	-6.70	4.90	-10.40	-12.18	-0.83	-17.03**	-11.79
26	6*1	RBG x NJ	13.40	2.02	-4.87	8.21	-5.80	-11.76	0.86	-14.94*	-11.31
27	6*2	RBG x BG-23	4.29	-2.10	-16.85**	6.82	-3.05	-17.44**	3.03	-6.52	-17.85**
28	6*3	RBG x BG-65	21.67**	9.85	1.61	15.66*	4.00	-9.57	14.88	4.59	-8.78
29	6*4	RBG x PN	10.50	-1.10	-6.71	4.16	-10.46	-13.59*	-1.06	-16.30*	-13.41
30	6*5	RBG x BG-21-2	8.80	-2.92	-7.78	11.74	-4.56	-6.45	6.58	-10.82	-5.20
		SEd (±)	64.13	74.05	74.05	61.04	70.48	70.48	58.74	67.83	67.83
		CD 5%	137.55	158.83	158.83	130.92	151.17	151.17	125.99	145.48	145.48

** Significant at 1% and * significant at 5%, Where NJ= (Narendra Joyti), BG-23= (BRBG-23), BG-65= (BRBG-65), PN= (Pusa Naveen), BG-21-2= (BRBG-21-2) and RBG= (Round bottle gourd).

CONCLUSION

It is inferred from the above study that there is considerable heterosis for yield and yield attributing characters in bottle gourd under three different environments, thus showing significant potential for the utilization of heterosis in the improvement of bottle gourd varieties. There was considerable variation in the amount and direction of heterosis among the three environments, which showed the effect of environment on the manifestation of quantitative characters. In the case of fruit length, the hybrids NJ x BG-65, BG-21-2 x RBG and BG-65 x PN were found to have high positive heterosis over the mid-parent, better parent and standard check in the three environments, which indicated their superiority in fruit length production. In the same way, the hybrids RBG x BG-65, RBG x BG-21-2 and RBG x NJ were the best ones in fruit diameter.

As far as the fruits per vine is concerned, the crosses BG-21-2 × BG-23, BG-21-2 × PN, and RBG × BG-23 have shown maximum heterosis in a positive direction. Among these crosses, RBG × BG-23 has shown maximum heterosis in standard conditions throughout all the three environments, which implies that it can be utilized for enhancing marketable fruits. Concerning average fruit weight, the crosses such as PN × BG-21-2, BG-65 × PN, PN × BG-65, nd BG-23 × BG-21-2 have demonstrated positive heterosis relative to mid-parent, better parent, and standard check. The study further revealed that

none of the hybrids was better than others for all the characters except BG-65 × PN, NJ × BG-65, BG-21-2 × RBG, RBG × BG-23, PN × BG-21-2, and RBG × BG-65, whiich have been found to be the best hybrids on the basis of their superior heterosis expression for at least one or two yield related characters. Finally it may be concluded that the The superior hybrids having good performance under various environments could be subjected to multi-environment tests prior to their commercial application and can be used as parent materials in future breeding programmes of bottle gourd.

REFERENCE

1. Gautam, D. K., Yadav, G. C., Kumar, P., Kumar, V., & Singh, M. (2017). Estimation of heterosis for growth, yield and quality traits in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *Int. J. Curr. Microbiol. App. Sci*, *6*(8), 789-802.
2. Ghuge, M. B., Syamal, M. M., & Shraddha Karcho, S. K. (2016). Heterosis in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.].
3. Hayes HK, Immer F, Smith DC (1955) Methods of plant breeding. Mc. Graw-Hill Book Co., Inc. New York, pp. 52-66
4. Janaranjani, K. G., Kanthaswamy, V., & Kumar, S. R. (2016). Heterosis, combining ability, and character association in bottle gourd for yield attributes. *International Journal of Vegetable Science*, *22*(5), 490-515.
5. Khot, R. K., Evoor, S., Gasti, V. D., Koulagi, S., & Masuthi, D. A. (2018). Estimation of heterosis in the advanced lines of bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] for growth, earliness and yield parameters. *Int. J. Curr. Microbiol. App. Sci*, *7*(9), 3375-3384.
6. Kumar, P., & Ram, C. N. (2021). Estimation of heterosis in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). *The Pharma Innovation Journal*, *10*(7), 1044-1053.
7. Lal, M., Ram, C. N., Nath, S., & Gautam, S. K. (2021). Estimation of heterosis in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] for growth and earliness. *The Pharma Innovation Journal*, *10*(7), 1585-1592.
8. Masud, M. A. T., Azam, M. G., Hasan, M. Z., Rashid, A. H., Bagum, S. A., & Uddin, M. S. (2021). Heterosis and combining ability for yield and yield contributing characters in bottle gourd. *Journal of Global Agriculture and Ecology*, *11*(4), 13-20.
9. Mauriya, K. S., Pal, A. K., & Singh, A. K. (2021). Estimation of heterosis and inbreeding depression in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). *The Pharma Innovation Journal*, *10*(2), 550-554.
10. Maurya, S. K., Ram, H. H., & Singh, D. K. (2009). Standard heterosis for fruit yield and its components in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *Annals of Horticulture*, *2*(1), 79-84.
11. Mkhize, P., Shimelis, H., & Mashilo, J. (2023). Combining ability and heterosis among bottle gourd [*Lagenaria siceraria* (Molina) Standl.] selections for yield and related traits under drought-stressed and non-stressed conditions. *Diversity*, *15*(8), 925.
12. Mkhize, P., Shimelis, H., & Mashilo, J. (2025). Hybrid performance of bottle gourd [*Lagenaria siceraria*] under drought stress and non-stress conditions. *Ecological Genetics and Genomics*, *34*, 100316.
13. Panse VG, Sukhatme PV (1967) Statistical Methods for Agricultural Workers, ICAR, New Delhi, pp. 1-381.
14. Parmar, S. S. (2016). Heterosis and combining ability for yield and quality traits in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.). *MSc (Horticulture) thesis. Punjab Agricultural University, Ludhiana*.
15. Parmar, S. S., & Pathak, M. (2018). Combining ability and heterosis for yield and its contributing traits in bottle gourd (*Lagenaria siceraria*). *SKUAST Journal of Research*, *20*(1), 37-42.

16. Shaikh, J. A., Kathiria, K. B., & Acharya, R. R. (2011). Heterosis and combining ability for fruit yield and its component traits in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.]. *Vegetable Science*, *38*(02), 169-175.
17. Singh, R. P. (2016). Heterosis and Combining ability Studies in Bottle gourd (Lagenaria siceraria Mol. Standl).
18. Singh, R., Singh, B., Prakash, S., Kumar, M., Kumar, A., Kumar, M., ... & Sachan, S. (2025). Assessment of combining ability and heterosis in bottle gourd (Lagenaria siceraria L.) for yield and attributes character through line x tester design. *HORIZON*, *12*(1), 1-8.
19. Singh, S. K., Upadhyay, A. K., Pandey, J., & Pandey, A. K. (2012). Studies on heterosis and combining ability in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.) for yield traits. *Annals of Horticulture*, *5*(2), 246-251.
20. Tulluru, N. K., Jyothi, K. U., Babu, M. R., Paratpararao, M., Rao, P. G., & Sekhar, V. (2023). Studies on heterosis for growth, yield and quality attributing characters in bottle gourd (*Lagenaria siceraria* (Mol.) Standl.).
21. Vanrajbhai, M. A. (2016). "Study of heterosis and combining ability for yield and its contributing traits in bottle gourd *[Lagenaria siceraria* (Mol.) Standl.*]" A THESIS* (Doctoral dissertation, NAVSARI AGRICULTURAL UNIVERSITY NAVSARI).
22. Vasudeo, C. G. (2016). *Generation mean analysis for yield and its component traits in bottle gourd* (Doctoral dissertation, DR. PANJABRAO DESHMUKH KRISHI VIDYAPEETH).
23. Yadav, A., Yadav, G. C., Abha, R., Singh, V., & Yadav, P. (2023). Estimation of heterosis for yield and quality traits in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] over seasons under salt affected soil. *International Journal of Plant & Soil Science*, *35*(18), 1887-1903.
24. Yadav, A., Yadav, G., Abha, R., Kumar, S., Yadav, L., & Bhaiya, R. (2025). Estimation of combining ability and nature of gene action for yield and quality traits in bottle gourd [*Lagenaria siceraria* (Mol.) Standl.] under salt affected soil. *Vegetable Science*, *52*(01), 112-121.