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Studies on Effect of Heterosis on Fruit Characters and Yield in Bitter Gourd (*Momordica charantia* L.)

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A B S T R A C T

The present investigation was conducted at the Vegetables Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, during*Kharif* season of 2017 and 2018to determine heterosis in 28 crosses developed from 7 lines and 4 testers of bitter gourd. The testers used were BGCV-2, OBGCS-2, Shaktigopal Local, OBGCS-1 while Pusa Do Mausami was used as check. Most of the crosses manifested significant heterosis for many of the horticultural traits. From the study, it was observed in case of traits like fruit length and fruit girth, the cross Jaunpuri Green × OBGCS-1 exhibited highly significant and positive heterosis over mid parent, better parent as well as standard check. Also the top three performing hybrids which recorded higher value of mean as well as high percentage of heterosis were Meghna × BGCV-2, Meghna × OBGCS-2 and Katheri × OBGCS-2 in case of total soluble solid. The cross combinations Katheri × BGCV-2, Katheri × OBGCS-1 and Katheri × OBGCS-2 was found to be best which expressed significant positive heterosis over mid parent (50.52, 31.62 and 27.06 %), better parent (37.99, 18.03 and 15.86 %) and standard parent (47.98, 26.57 and 24.24 %) respectively for total fruit yield.

Introduction

Bitter gourd is an important tropical and subtropical commercial vegetable crop belonging to the family Cucurbitaceae. It exhibits high levels of heterozygosity being a cross pollinated crop. Bitter gourd has been utilised in various herbal medicine systems for a long time because of its disease preventing and health promoting phytochemical compounds like dietary fiber, minerals, vitamins, flavonoids and antioxidants(Singh *et al*., 2013). Because of high nutritive value especially ascorbic acid and iron, it is considered as a prized vegetable among cucurbits. Crop improvement involves strategies to enhance yield potentiality and quality components. Owing to awareness about its medicinal and nutritional value, its commercial significance increased and consumer demand is maintained round the year. There is a need of some better varieties with improved quality traits as well as higher yield which is preferable by both farmer and consumers. Thus it is important to exploit heterosis in bitter gourd which will help in development of varieties with improved quality parameters for commercial purposes. Heterosis is defined as the increase or decrease in vigour of the F_1 over the parents. Hybrids will be very easy to commercialize in bitter gourd due to its high seed content and easy seed extraction technique (Yadav *et al*., 2009). Bitter gourd can be profitably utilised for F_1 hybrid seed production at cheaper rate. Thus the present investigation was conducted involving Line x Tester analysis to study the heterosis for important fruit quality traits and yield component.

Materials and Methods

The experiment was conducted at the Vegetables Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, during *Kharif* season of 2017 and 2018. Seven promising lines of bitter gourd and four testers and their 28 hybrids were evaluated for quantification of desired quality traits. The lines used were PN-4, IC-085612, IC-085611, Jaunpuri Green , Katheri , Preethi, Meghnaalong with four testers were BGCV-2, OBGCS-2, Shaktigopal local and OBGCS-1.The Line × Tester experimental design was used for crossing to produce 28 F_1 hybrids. The individual plants of parents were selfed to maintain pure seed and the seeds from the mature ripe fruit of F_1 were extracted and collected for next generation sowing. All 28 F_1 hybrids along with 11 parents and a standard check (Pusa Do Mausami) were sown in separate plots and evaluated.Observations were recorded from five randomly choosen plants in all genotypes in each replication. The mean of five plants was taken for analysis. Data was recorded for estimation of heterosis on fruit length (cm), fruit girth (cm), Number of fruits per plant, Average fruit weight (g), Number of seeds per fruit, Seed index (g), TSS (^{0}Brix), Ascorbic acid content (mg/100g of fruit) and Fruit yield (q/ha). The statistical analysis of various parameters was done according to Panse and Sukhatme (1967).

Results and Discussion

Heterosis breeding has achieved greater importance in boosting the yield and augmenting quality traits of many cucurbitaceous vegetables. The superiority of F_1 over the mean of the parents or over the better parent or the standard check is termed as 'Heterosis' (Hayes *et al*., 1955).The analysis of variance was carried out to test the significance of differences among genotypes for all the character. Highly significant differences for all the characters under study were observed among all the genotypes. The mean sum of squares due to parents showed significant differences for all the traits under study.

Highly significant differences were observed due to lines for all traits under study except fruit length (cm). Similarly, the variance due to testers was also found to be significantly different for all the characters except fruit girth (cm) and TSS (ºBrix).The observations on heterosis over mid parent, better parent and standard check for different parameters are presented in table 1, 2, 3, 4 and 5.

Fruit length is proportional to yield, hence positive significant heterosis is considered to be desirable in bitter gourd. Significant variation was observed in case of fruit length among the genotype and heterosis varied from -27.89 (IC-085611 × OBGCS-1) to 35.38% (Jaunpuri Green × OBGCS-1) over mid parent, from -30.15 (IC-085611 × OBGCS-1) to 34.20 % (Jaunpuri Green × OBGCS-1) over better parent, while for economic heterosis, it varied from -19.66 (IC-085611 × OBGCS-1) to 49.58 % (Katheri × OBGCS-1) over standard check. Among 28 cross combinations, 16, 12 and 20 crosses expressed significant positive heterosis over mid parent, better parent and standard parent respectively. In order of their performance, the cross combinations Jaunpuri Green × OBGCS-1, Katheri × BGCV-2 and Katheri × OBGCS-1 showed 35.38, 34.35 and 29.43 per cent respectively significant positive heterosis over mid parent, while the crosses Jaunpuri Green × OBGCS-1, Katheri × BGCV-2 and PN-4 × BGCV-2 exhibited significant positive heterosis of 34.20 , 31.18 and 21.80 per cent respectively over better parent, whereas Katheri × OBGCS-1, Jaunpuri Green × OBGCS-1 and PN-4 × OBGCS-2 were the best crosses which expressed 49.58, 47.26, 44.76 per cent respectively significant positive heterosis over standard check desirable for the trait under study.

Maximum positive and significant heterosis over mid parent for fruit girth was observed in F_1 hybrids Jaunpuri Green × OBGCS-1 (25.57 %) followed by PN-4 × OBGCS-2 (21.13 %) and Katheri × OBGCS-1 (20.48 %), whereas over better parent, the crosses Jaunpuri Green × OBGCS-1 (23.17 %) followed by PN-4 × OBGCS-2 (19.08 %) and Katheri × OBGCS-1 (16.40 %) expressed significant positive heterosis, while in case of commercial check, the maximum positive and significant heterosis was observed for crosses Jaunpuri Green × OBGCS-1 (26.39 %), Katheri × OBGCS-1 (19.44 %) and Jaunpuri Green × BGCV-2 (12.83 %). These results were in agreement with the results of Ranpise *et al.,* (1992); Rajeshwari and Natarajan (1999); Kushwaha and Maurya (2010); Patil *et al.,* (2012); and Thangamani and Pugalendhi (2013) in bitter gourd.

The more the number of fruits per plant, the more will be the total yield; thus positive significant heterosis is considered desirable. Genotypes differed significantly among themselves for number of fruits per plant and the extent of heterosis ranged from -16.63 (Meghna × OBGCS-2) to 49.47 % (Katheri × OBGCS-1) over mid parent, while it varied from -29.17 (IC-085612 × BGCV-2) to 37.07 % (Katheri × OBGCS-1) over better parent and from -22.08 (IC-085612 × OBGCS-1) to 34.23 % (Katheri × BGCV-2)over commercial check for number of fruits per plant. In order of their performance, the cross combinations Katheri × OBGCS-1, IC-085611× OBGCS-1 and Katheri × BGCV-2 showed 49.47, 28.57, 28.16 per cent respectively significant positive heterosis over mid parent whereas the crosses Katheri × OBGCS-1, IC-085611× OBGCS-1 and Katheri × Shaktigopal Local expressed significant positive heterosis 37.07, 28.05, 25.67 per cent respectively over better parent and the crosses Katheri × BGCV-2, Katheri × OBGCS-1 and Katheri × Shaktigopal Local expressed 34.23, 32.97, 26.66 per cent significant heterosis respectively over standard parent for number of fruits per plant. Similar result were also found by Sundaram (2007); and Behera *et al.,* (2009).Regarding the average fruit weight, 10 cross combinations showed desired significant positive heterosis over mid parent, 4 crosses over better parent and 7 crosses over standard parent. The range of heterosis was from -34.29 (IC-085611 × OBGCS-1) 23.82 % (Jaunpuri Green × BGCV-2) over mid parent, from -45.31 (IC-085611 × OBGCS-1) to 23.10 % (Jaunpuri Green × BGCV-2) over better parent and from -44.88 (IC-085611 ×

Shaktigopal Local) to 28.48 % (Preethi × OBGCS-1) over commercial check. Heterosis in the positive direction is considered desirable for average fruit weight in bitter gourd. The top three cross combinations were Jaunpuri Green × BGCV-2, Preethi × OBGCS-2 and Katheri × BGCV-2 showing 23.82, 16.99 and 16.02 per cent respectively significant positive heterosis over mid parent while the crosses Jaunpuri Green × BGCV-2, PN-4 × Shaktigopal Local and Meghna × OBGCS-2 showed significant positive heterosis 23.10, 11.62 and 10.75 per cent respectively over better parent and the crosses Preethi × OBGCS-1, Preethi × OBGCS-2 and Katheri × OBGCS-2 expressed 28.48, 18.98 and 11.43 per cent respectively significant positive heterosis over standard parent. Significant heterosis in positive direction was also reported by Ranpise *et al.,* (1992); Sundaram (2007); Behera *et al.,* (2009); Sundharaiya and Arumugam (2011); and Kushwaha and Maurya (2010) in bitter gourd.

From consumer point of view, less number of seed is preferable; thus negative significant heterosis is considered desirable in case of number of seeds per fruit.

According to the performance of the crosses, the three best cross combinations for this trait were IC-085611 × BGCV-2, Preethi × BGCV-2 and Preethi × Shaktigopal Local which showed -36.88, -26.08 and -29.31 per cent respectively significant negative heterosis over mid parent, whereas the crosses IC-085611 × BGCV-2, Preethi × BGCV-2 and Preethi × Shaktigopal Local expressed significant negative heterosis -35.59, -21.32 and -9.71 per cent respectively over better parent while the crosses Preethi × Shaktigopal Local, IC-085612 × BGCV-2 and IC-085611- × BGCV-2 expressed -27.52, -21.10 and -12.84 per cent respectively significant negative heterosis over standard parent. Regarding seed index, out of 28 F_1 hybrids, the cross combinations IC-085612 × Shaktigopal Local, Preethi × Shaktigopal Local and Jaunpuri Green × Shaktigopal Local showed -15.33, -11.28 and -1.32 per cent respectively significant negative heterosis over mid parent in order of their ranking while the crosses Preethi × Shaktigopal Local, IC-085612 × Shaktigopal Local and Katheri × Shaktigopal Local expressed -19.80, -17.66 and -13.67 per cent respectively significant negative heterosis over standard check. The present findings are similar to the findings of Thangamani and Pugalendhi (2013) in bitter gourd.

The magnitude of heterosis of F_1 for total soluble solid ranged from -28.92 (IC-085612 × OBGCS-1) to 26.36 % (Meghna × BGCV-2) over mid parent and was from -30.14 (IC-085612 × OBGCS-1) to 12.69 % (Meghna × BGCV-2) over better parent and the range for standard heterosis for total soluble solid was from -13.79 (Meghna × OBGCS-1) to 30.10 % (Meghna × BGCV-2, Katheri × OBGCS-2) over standard check. In order of their performance, the cross combinations Meghna × BGCV-2, Meghna × OBGCS-2 and Jaunpuri Green × Shaktigopal Local expressed 26.36, 20.33 and 13.47 % respectively significant positive heterosis over mid parent, while crosses Meghna × BGCV-2, Meghna × OBGCS-2 and Katheri × OBGCS-2 displayed significant positive heterosis 12.69, 6.62 and 4.86 % respectively over better parent and the crosses Meghna × BGCV-2 and Katheri × OBGCS-2, Meghna × OBGCS-2 and Katheri × Shaktigopal Local showed 30.10, 25.00 and 23.28%, respectively positive and significant heterosis over standard parent.

Table.1 Estimates of heterosis over mid parent, better and standard parent for Fruit length (cm) and Fruit girth (cm)

Crosses	Fruit length(cm)			Fruit girth(cm)		
	MPH	BPH	SH	MPH	BPH	SH
PN-4 × BGCV-2	23.42 **	21.80 **	43.13 **	0	-6.58	-2.53
PN-4 × OBGCS-2	20.04 **	14.21 **	44.76 **	21.13 **	19.08 **	11.68 *
PN-4 × Shaktigopal Local	22.54 **	13.07 **	29.39 **	12.02 *	10.21	3.19
PN-4 × OBGCS-1	11.87 **	8.63 *	24.31 **	-2.41	-8.12	-5.72
IC-085612 × BGCV-2	8.32 *	6.52	25.18 **	1.54	-2.19	2.04
IC-085612 × OBGCS-2	1.01	-4.22	21.41 **	11.63 *	9.97	6.29
IC-085612 × Shaktigopal Local	5.65	-2.2	11.12 *	-5.37	-6.85	-9.97
IC-085612 × OBGCS-1	-1.1	-3.63	9.5	-1.19	-4.06	-1.55
IC-085611 × BGCV-2	12.47 **	11.27 **	30.76 **	-2.11	-11.20 *	-7.35
IC-085611 × OBGCS-2	9.75 **	4.67	32.67 **	0.46	-4.27	-10.21
IC-085611 × Shaktigopal Local	-5.86	-13.33 **	-0.32	11.34 *	6.2	-0.57
IC-085611 × OBGCS-1	-27.89 **	-30.15 **	-19.66 **	0.96	-7.72	-5.31
Jaunpuri Green × BGCV-2	4.29	0.84	18.50 **	11.15 *	8.14	12.83 *
Jaunpuri Green × OBGCS-2	-13.19 **	-19.02 **	2.64	-12.22 *	-14.40 *	-15.52 **
Jaunpuri Green × Shaktigopal Local	14.50 **	7.73	18.21 **	9.09	6.29	4.9
Jaunpuri Green × OBGCS-1	35.38 **	34.20 **	47.26 **	25.57 **	23.17 **	26.39 **
katheri × BGCV-2	34.35 **	31.18 **	61.78 **	-0.77	-3.76	0.41
katheri × OBGCS-2	21.72 **	20.07 **	52.19 **	10.82 *	8.42	6.29
katheri × Shaktigopal Local	-9.57 *	-19.31 **	-0.49	-7.5	-9.58	-11.36 *
katheri × OBGCS-1	29.43 **	21.29 **	49.58 **	19.06 **	16.40 **	19.44 **
Preethi × BGCV-2	21.71 **	17.80 **	38.43 **	7.23	2.82	7.27
Preethi × OBGCS-2	-8.47 *	-14.53 **	8.34	-0.09	-1.11	-5.31
Preethi × Shaktigopal Local	10.44 *	3.8	14.14 **	3.02	1.88	-2.45
Preethi × OBGCS-1	18.70 **	17.54 **	29.25 **	-11.12 *	-14.09 *	-11.85 *
Meghna × BGCV-2	0.51	-2.97	14.03 **	6.54	-5.01	-0.9
Meghna × OBGCS-2	-14.64 **	-20.49 **	0.78	13.31 *	6.01	-0.57
Meghna × Shaktigopal Local	-2.04	-7.7	0.96	10.62	3.58	-3.02
Meghna × OBGCS-1	10.14 *	9.35 *	19.60 **	20.48 **	8.2	11.03

*significant at p= 0.05, ** significant at p= 0.01

Table.2 Estimates of heterosis over mid parent, better and standard parent for Number of fruits per plant and Average fruit weight (g)

Crosses	Number of fruit/plant			Average fruit weight(g)		
	MPH	BPH	SH	MPH	BPH	SH
PN-4 × BGCV-2	15.65 **	11.92 **	25.87 **	-1.28	-5.19	-18.16 **
PN-4 × OBGCS-2	4.58 *	4.35	9.78 **	1.52	0.36	-13.37 **
PN-4 × Shaktigopal Local	2.14	0	5.21 *	13.57 **	11.62 **	-3.65
PN-4 × OBGCS-1	20.34 **	6.45 **	11.99 **	-2.01	-10.79 **	-6.17 *
IC-085612 × BGCV-2	-16.04 **	-29.17 **	-20.35 **	14.40 **	-0.84	7.43 **
IC-085612 × OBGCS-2	23.92 **	7.68 **	12.78 **	-20.42 **	-29.23 **	-23.33 **
IC-085612 × Shaktigopal Local	7.17 **	-5.32 *	-4.57	-32.86 **	-40.60 **	-35.64 **
IC-085612 × OBGCS-1	-1.5	-3.7	-22.08 **	2	0.51	8.89 **
IC-085611 × BGCV-2	-3.58	-16.83 **	-6.47 *	-13.92 **	-19.10 **	-35.70 **
IC-085611 × OBGCS-2	3.47	-7.98 **	-3.63	-11.17 **	-18.77 **	-31.49 **
IC-085611 × Shaktigopal Local	18.17 **	6.89 **	7.73 **	-28.07 **	-33.87 **	-44.88 **
IC-085611 × OBGCS-1	28.54 **	28.05 **	4.42	-34.29 **	-45.31 **	-42.48 **
Jaunpuri Green × BGCV-2	-4.53 *	-11.31 **	16.25 **	23.82 **	23.10 **	-1
Jaunpuri Green × OBGCS-2	19.73 **	7.70 **	41.17 **	-5.85 *	-8.04 **	-22.44 **
Jaunpuri Green × Shaktigopal Local	18.78 **	5.05 **	37.70 **	0.89	-0.89	-17.38 **
Jaunpuri Green × OBGCS-1	9.52 **	-11.43 **	16.09 **	9.57 **	-3.32	1.68
katheri × BGCV-2	28.16 **	19.35 **	34.23 **	16.02 **	-0.29	10.25 **
katheri × OBGCS-2	10.56 **	6.48 **	11.51 **	14.33 **	0.77	11.43 **
katheri × Shaktigopal Local	28.07 **	25.67 **	26.66 **	-22.67 **	-32.18 **	-25.01 **
katheri × OBGCS-1	49.47 **	37.07 **	32.97 **	-11.76 **	-13.91 **	-4.81
Preethi × BGCV-2	8.19 **	-0.84	11.51 **	2.68	-14.39 **	1.93
Preethi × OBGCS-2	-6.36 **	-11.30 **	-7.10 **	16.99 **	-0.07	18.98 **
Preethi × Shaktigopal Local	-9.16 **	-12.36 **	-11.67 **	5.51 **	-10.31 **	6.78 **
Preethi × OBGCS-1	1.9	-5.05	-11.04 **	14.59 **	7.91 **	28.48 **
Meghna × BGCV-2	-7.40 **	-17.53 **	-7.26 **	-2.11	-3.55	-21.02 **
Meghna × OBGCS-2	-16.63 **	-23.34 **	-19.72 **	12.38 **	10.75 **	-6.59 **
Meghna × Shaktigopal Local	-6.19 **	-12.21 **	-11.51 **	-2.7	-3.55	-19.61 **
Meghna × OBGCS-1	9.16 **	4.85	-7.89 **	-9.63 **	-19.63 **	-15.47 **

*significant at p= 0.05, ** significant at p= 0.01

Table.3 Estimates of heterosis over mid parent, better and standard parent for Number of seeds per fruit and Seed index (g)

Crosses	Number of seed /fruit			Seed index (g)		
	MPH	BPH	SH	MPH	BPH	SH
PN-4 × BGCV-2	9.55 *	-16.29 **	17.89 **	42.70 **	26.95 **	28.18 **
PN-4 × OBGCS-2	67.76 **	62.07 **	29.36 **	9.96 *	8.33	9.38
PN-4 × Shaktigopal Local	81.49 **	74.86 **	40.37 **	25.76 **	16.16 **	17.29 **
PN-4 × OBGCS-1	25.55 **	13.43 **	4.59	32.86 **	31.77 **	33.04 **
IC-085612 × BGCV-2	-27.43 **	-43.97 **	-21.10 **	15.89 **	-0.2	8.72
IC-085612 × OBGCS-2	63.64 **	60.34 **	27.98 **	1.32	-3.78	4.83
IC-085612 × Shaktigopal Local	42.11 **	38.86 **	11.47 *	-15.33 **	-24.42 **	-17.66 **
IC-085612 × OBGCS-1	9.51 *	0.25	-7.57	21.33 **	15.96 **	26.33 **
IC-085611 × BGCV-2	-36.88 **	-38.11 **	-12.84 **	27.57 **	16.37 **	11.07 *
IC-085611 × OBGCS-2	-6.61	-25.76 **	0.46	6.51	5.14	3.01
IC-085611 × Shaktigopal Local	-2.55	-22.37 **	5.05	0.92	-4.31	-8.67
IC-085611 × OBGCS-1	-4.44	-19.66 **	8.72	34.63 **	32.01 **	31.09 **
Jaunpuri Green × BGCV-2	35.32 **	11.07 **	56.42 **	64.97 **	43.60 **	52.51 **
Jaunpuri Green × OBGCS-2	43.40 **	35.03 **	22.02 **	3.73	-0.29	5.9
Jaunpuri Green × Shaktigopal Local	55.38 **	46.70 **	32.57 **	-1.32	-10.92 *	-5.39
Jaunpuri Green × OBGCS-1	75.38 **	73.63 **	60.09 **	10.93 *	7.33	13.99 **
katheri × BGCV-2	15.77 **	1.63	43.12 **	44.08 **	39.37 **	17.34 **
katheri × OBGCS-2	22.66 **	7.33	14.22 **	31.73 **	22.47 **	19.99 **
katheri × Shaktigopal Local	43.00 **	25.43 **	33.49 **	1.72	0.91	-13.67 **
katheri × OBGCS-1	71.36 **	59.91 **	70.18 **	39.14 **	28.55 **	27.66 **
Preethi × BGCV-2	-26.08 **	-30.29 **	-1.83	29.24 **	18.01 **	12.39 *
Preethi × OBGCS-2	-4.48	-21.69 **	-2.29	33.40 **	31.54 **	28.88 **
Preethi × Shaktigopal Local	-29.31 **	-41.91 **	-27.52 **	-11.28 *	-15.80 **	-19.80 **
Preethi × OBGCS-1	-9.09 *	-20.96 **	-1.38	16.49 **	14.10 **	13.31 *
Meghna × BGCV-2	-7.88 *	-25.73 **	4.59	20.05 **	18.81 **	-4.54
Meghna × OBGCS-2	40.33 **	35.11 **	16.51 **	25.15 **	13.90 **	11.59 *
Meghna × Shaktigopal Local	15.15 **	11.17 *	-4.13	15.82 **	12.30 *	-3.93
Meghna × OBGCS-1	32.13 **	27.86 **	17.89 **	13.43 **	2.6	1.89

*significant at p= 0.05, ** significant at p= 0.01

Table.4 Estimates of heterosis over mid parent, better and standard parent for Total soluble solids (^{0}Brix) and Ascorbic acid content(mg/100 g)

Crosses	Total soluble solid(^{0}Brix)			Ascorbic acid content (mg/100 g)		
	MPH	BPH	SH	MPH	BPH	SH
PN-4 × BGCV-2	7.95 *	-3.73	11.21 **	-19.30 **	-25.71 **	-15.53 **
PN-4 × OBGCS-2	-2.07	-13.24 **	1.72	9.11 **	-9.84 **	-13.76 **
PN-4 × Shaktigopal Local	-5.35	-16.67 **	-0.86	11.99 **	1.1	-3.30 **
PN-4 × OBGCS-1	4.07	-9.22 **	10.34 *	-0.85	-9.87 **	-13.80 **
IC-085612 × BGCV-2	-9.29 **	-13.01 **	9.48 *	0.89	0.37	14.13 **
IC-085612 × OBGCS-2	-20.57 **	-23.29 **	-3.45	-26.63 **	-42.96 **	-35.81 **
IC-085612 × Shaktigopal Local	-18.31 **	-20.55 **	0	-7.28 **	-21.90 **	-12.11 **
IC-085612 × OBGCS-1	-28.92 **	-30.14 **	-12.07 **	-11.03 **	-24.59 **	-15.13 **
IC-085611 × BGCV-2	-4.8	-5.84	11.21 **	12.08 **	-1.2	12.35 **
IC-085611 × OBGCS-2	1.1	0.73	18.97 **	-9.92 **	-22.55 **	-32.80 **
IC-085611 × Shaktigopal Local	-23.64 **	-23.91 **	-9.48 *	6.04 **	0.1	-13.15 **
IC-085611 × OBGCS-1	-2.88	-4.26	16.38 **	-2.63 **	-7.42 **	-19.66 **
Jaunpuri Green × BGCV-2	-7.88 *	-17.16 **	-4.31	-4.39 **	-8.59 **	3.94 **
Jaunpuri Green × OBGCS-2	-2.88	-13.24 **	1.72	4.35 **	-16.42 **	-13.31 **
Jaunpuri Green × Shaktigopal Local	13.47 **	0.72	19.83 **	-26.30 **	-35.78 **	-33.39 **
Jaunpuri Green × OBGCS-1	-16.13 **	-26.24 **	-10.34 *	38.06 **	21.10 **	25.60 **
katheri × BGCV-2	-23.02 **	-25.69 **	-7.76	3.71 **	0.37	14.13 **
katheri × OBGCS-2	7.86 *	4.86	30.17 **	31.23 **	4.12 **	10.77 **
katheri × Shaktigopal Local	1.42	-0.69	23.28 **	-12.18 **	-24.29 **	-19.46 **
katheri × OBGCS-1	-20.70 **	-21.53 **	-2.59	3.85 **	-9.90 **	-4.14 **
Preethi × BGCV-2	9.17 *	-2.24	12.93 **	21.30 **	10.21 **	25.32 **
Preethi × OBGCS-2	-9.92 **	-19.85 **	-6.03	-10.99 **	-25.59 **	-30.86 **
Preethi × Shaktigopal Local	9.84 **	-2.9	15.52 **	10.07 **	0.66	-6.46 **
Preethi × OBGCS-1	-8.50 *	-19.86 **	-2.59	-15.01 **	-21.73 **	-27.27 **
Meghna × BGCV-2	26.36 **	12.69 **	30.17 **	19.75 **	5.05 **	19.45 **
Meghna × OBGCS-2	20.33 **	6.62	25.00 **	-21.62 **	-32.29 **	-41.91 **
Meghna × Shaktigopal Local	-8.64 *	-19.57 **	-4.31	-10.52 **	-15.08 **	-27.15 **
Meghna × OBGCS-1	-18.70 **	-29.08 **	-13.79 **	-3.46 **	-7.71 **	-20.83 **

*significant at p= 0.05, ** significant at p= 0.01

Table.5 Estimates of heterosis over mid parent, better and standard parent for Total fruit yield (q/ha)

Crosses	Total fruit yield(q/ha)		
	MPH	BPH	SH
PN-4 × BGCV-2	14.00 **	13.14 **	2.68
PN-4 × OBGCS-2	6.39 **	4.97 *	-4.73 *
PN-4 × Shaktigopal Local	16.18 **	11.85 **	1.51
PN-4 × OBGCS-1	19.34 **	15.62 **	4.93 *
IC-085612 × BGCV-2	-0.15	-3.38	-13.63 **
IC-085612 × OBGCS-2	0.01	-2.66	-14.02 **
IC-085612 × Shaktigopal Local	-26.01 **	-26.17 **	-38.00 **
IC-085612 × OBGCS-1	1.62	0.74	-14.28 **
IC-085611 × BGCV-2	-18.36 **	-33.16 **	-40.25 **
IC-085611 × OBGCS-2	-9.12 **	-25.25 **	-33.97 **
IC-085611 × Shaktigopal Local	-15.71 **	-29.26 **	-40.59 **
IC-085611 × OBGCS-1	-15.39 **	-29.37 **	-39.90 **
Jaunpuri Green × BGCV-2	20.57 **	13.37 **	15.10 **
Jaunpuri Green × OBGCS-2	15.33 **	7.84 **	9.48 **
Jaunpuri Green × Shaktigopal Local	22.67 **	12.07 **	13.78 **
Jaunpuri Green × OBGCS-1	26.49 **	16.25 **	18.03 **
katheri × BGCV-2	50.52 **	37.99 **	47.98 **
katheri × OBGCS-2	27.06 **	15.86 **	24.24 **
katheri × Shaktigopal Local	-0.63	-11.41 **	-4.99 *
katheri × OBGCS-1	31.62 **	18.03 **	26.57 **
Preethi × BGCV-2	7.82 **	1.96	2.26
Preethi × OBGCS-2	5.31 *	-0.97	-0.67
Preethi × Shaktigopal Local	-6.99 **	-14.55 **	-14.30 **
Preethi × OBGCS-1	10.98 **	2.57	2.87
Meghna × BGCV-2	-9.21 **	-18.12 **	-26.81 **
Meghna × OBGCS-2	-6.37 **	-15.11 **	-25.01 **
Meghna × Shaktigopal Local	-8.72 **	-15.31 **	-28.88 **
Meghna × OBGCS-1	-0.82	-8.55 **	-22.18 **
*significant at p= 0.05, ** significant at p= 0.01			

Regarding ascorbic acid, in order of their merit the cross combinations Jaunpuri Green × OBGCS-1, Katheri × OBGCS-2 and Preethi × BGCV-2 showed 38.06, 31.23 and 21.30 % respectively significant positive heterosis over mid parent, while the crosses Jaunpuri Green × OBGCS-1, Preethi × BGCV-2 and Meghna × BGCV-2 showed significant heterosis 21.10, 10.21 and 5.05 % respectively over better parent whereas the crosses Jaunpuri Green × OBGCS-1, Preethi × BGCV-2 and Meghna × BGCV-2 expressed 25.6, 25.32 and 19.45 % respectively significant and positive heterosis over standard parent. Out of 28 crosses 12 crosses showed significant positive heterosis over mid parent, 4 crosses over mid parent and 8 crosses recorded significant positive heterosis over standard check for the trait under study. Similar findings were also reported by Thangamani and Pugalendhi (2013); and Mallikarjunarao *et al.,* (2018).

Highly significant positive heterosis is considered desirable in case of total fruit yield. The total fruit yield (q/ha) varied significantly among all the genotypes under study. Fourteen out of 28 crosses showed significant positive heterosis over mid parent, 11 over better parent and 8 crosses over standard parent. The magnitude of heterosis observed in F_1 hybrids for fruit yield (q/ha) ranged from -26.01 (IC-085612 × Shaktigopal Local) to 50.52 % (Katheri × BGCV-2) over mid parent and the top three crosses showing maximum significant relative heterosis were cross Katheri × BGCV-2 (50.52 %) followed by Katheri × OBGCS-1 (31.62 %) and Katheri × OBGCS-2 (27.06 %) while per cent heterobeltiosis varied from 37.99 % (Katheri × BGCV-2) to -33.16 % (IC-085611 × BGCV-2) and the three best crosses exhibiting significant positive heterobeltiosis were cross Katheri × BGCV-2 (37.99 %), Katheri × OBGCS-1 (18.03 %) and Katheri × OBGCS-2 (15.86 %). The range of heterosis over commercial check was -40.59 (IC-085611 × Shaktigopal Local) to 47.98 % (Katheri × BGCV-2) among which the cross Katheri × BGCV-2 (47.98 %) exhibited maximum significant heterosis over standard check followed by Katheri × OBGCS-1 (26.57 %) and Katheri × OBGCS-2 (24.24 %) for total fruit yield (q/ha). Similar results were also found by Lawande and Patil (1990); Jadhav *et al.,* (2009); Thangamani and Pugalendhi (2013); Verma and Singh (2014); Kandasamy (2015); and Tiwari *et al.,* (2016).

From the present investigation, it was found that in case of traits like fruit length and fruit girth, the cross Jaunpuri Green × OBGCS-1 exhibited highly significant and positive heterosis over mid parent, better parent as well as standard check.Regarding the quality parameters such as TSS, the top performing hybrids recorded with higher value of mean and high percentage of heterosis were Meghna × BGCV-2 followed by Meghna × OBGCS-2 whereas, for ascorbic acid content the hybrids Jaunpuri Green × OBGCS-1 followed by Preethi × BGCV-2 showed highest heterosis for the trait over mid parent, better parent as well as commercial check. The hybrid Katheri × BGCV-2 was to be best cross combination over mid, better and standard parent heterosis in case of total fruit yield. Thus, the hybrids exhibiting significant heterosis in desirable direction for yield and its other quality traits should be further evaluated and can be exploited for commercial cultivation.

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