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Estimation of Heterosis for Yield and Yield contributing Traits in Bitter gourd (*Momordica charantia* L.)

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ABSTRACT: Bitter gourd is a warm season versatile vegetable of the cucurbitaceae family and has economical, medicinal and horticultural importance. Heterosis is a significant phenomenon that increases the yield potential of the crop by taking advantage of the additive and dominant effects of genes for different traits present in the parents. Bitter gourd productivity in India is low due to a lack of suitable hybrids so exploitation of hybrid vigour is one of the finest options for increasing crop yield and production. The present study was carried out to develop 28 hybrids by crossing 7 lines and 4 testers in line × tester fashion. Hybrids were evaluated along with parents and checks in the randomized complete block design (RCBD) with two replications. Heterosis was observed for all the yield and yield attributing characters. IC-470550 × Preethi, Gy 3-1-1-1-2 × Phule Green Gold and IC-505623 × Preethi hybrids performed better for the yield and its related traits with maximum heterosis over the better parent and checks. These crosses can be exploited in crop improvement by generating transgressive segregants.

Keywords: Bitter gourd, Hybrids, Relative heterosis, Heterobeltiosis, Economic heterosis, Yield.

INTRODUCTION

Bitter gourd (*Momordica charantia* L.; 2n = 2x = 22) belongs to the cucurbitaceae family and also known variously as bitter melon, African pear, balsam pear, karela, African cucumber, bitter squash, cassilla, maiden apple and bitter cucumber (Morton, 1967). India and China are regarded as the probable primary center of origin and secondary centre of diversity, respectively (Rao *et al.*, 2018). Bitter gourd provides vitamins (Vitamin A and C) and minerals (P, Mg, Fe, Zn and Mn) along with various medicinal properties (Alam *et al.*, 2009; Bharathi *et al.*, 2012). This crop is grown in tropical and subtropical regions of the world and widely cultivated in India, China, Sri Lanka, Thailand, Philippines, Japan, Australia, Malaysia, Africa and South America (Singh, 1990). The immature fruits are more nutritious and used in the form of fried, stuffed, dried, canned and pickled (Alhariri *et al.*, 2018). It exhibits antimicrobial, antitumor, antileukemic, antihelminitic, antimutagenic, antioxidant, antidiabetic, anti-inflammatory, antiviral, hypocholesterolemic, hypotriglyceridemic, immunostimulant and insecticidal properties (Basch *et al.*, 2003; Grover and Yadav 2004). In India, bitter gourd productivity is low because of lack of suitable cultivars or hybrids, development of new races of pathogens, narrow genetic base, adverse abiotic factors and genetic drift in cultivars. Hence, there is a need for development of new varieties or hybrids with high yield and biotic and abiotic stress resistance on sustainable basis to ensure the nutritional and economical security of the growing population of the country. One of the fastest and most effective ways to boost crop yield and production is the exploitation of hybrid vigor. Hybrids offer many advantages like earliness, high yield, improved quality, uniformity, wider adaptability and also help in deployment of dominant genes for resistance to biotic and abiotic stress. The exploitation of hybrid vigour in any crop depends on the substantial heterosis for yield coupled with economical genetic mechanisms for producing hybrid seeds. Bitter gourd has monoecious and gynoecious sex expression which can be profitably utilized for the production of hybrid seeds at cheaper rate. Therefore, bitter gourd offers greater scope for exploitation of hybrid vigour on commercial scale to increase the productivity. Keeping in view the above facts, the present investigation was carried out to examine the extent of heterosis in 28 F_1 hybrids by using seven lines and four testers.

MATERIAL AND METHODS

In the present study, seven lines (IC-66023, IC-505623, IC-505621, IC-470550, IC-470556, Gy 3-1-1-1-2 and IC-398610) with each of the four testers (Pusa Aushadhi, Preethi, IC-50527 and Phule Green Gold) were crossed to develop 28 hybrids in line × tester fashion. The hybrids were evaluated along with parents and checks (Pusa Hybrid-2 and Vennela-43) in randomized complete block design (RCBD) with two replications at University of Horticultural Sciences, Bagalkot, Karnataka. Observations were recorded on vine length (m), internodal length (cm), number of primary branches per plant, fruit length (cm), fruit diameter (mm), average fruit weight (g), number of fruits per plant and total yield per plant (kg). Statistical analysis was performed using the INDOSTAT statistical package. Heterosis is the percentage of increase or decrease in the performance of F_1 hybrid with respect to yield and yield attributes over mid-parent (relative heterosis), superior parent (heterobeltiosis) and commercial check (economic heterosis). Heterosis was computed for yield and yield related characters using the formula as follows

Mid-parent heterosis (MPH) per cent = $\frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$

Where, F_1 = Mean value of F_1 hybrid

and $\overline{MP}$ = Average of two parents involved in the cross

Better parent heterosis (BPH) per cent = $\frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$

Where, $\overline{BP}$ = Mean value of superior parent of the particular cross

Standard parent heterosis (SPH) per cent = $\frac{\overline{F_1} - \overline{CC}}{\overline{CC}} \times 100$

Where, $\overline{CC}$ = Mean value of the commercial check

RESULTS AND DISCUSSION

The analysis of variance revealed the significant differences for all the traits studied across the genotypes. This clearly indicated the existence of sustainable heterosis in hybrids. Similar results were noticed by Laxuman (2005), Kumar *et al.* (2020b), Naik *et al.* (2020); Malve *et al.* (2021) in bitter gourd.

A. Vine length

The range of heterosis over the mid parent was from -18.74% (IC-398610 × Pusa Aushadhi) to 145.80% (IC-505621 × IC-50527). The heterosis ranged from -37.70% (IC-505621 × Preethi) to 112.54% (IC-505621 × IC-50527) and -31.84% (IC-505621 × Preethi) to 21.51% (IC-505621 × IC-50527) over the better and best parents, respectively. The cross IC-505621 × IC-50527 had the highest heterosis of 63.43% and 62.09%, while the lowest heterosis of -8.32% and -9.08% was observed in IC-505621 × Preethi cross over Pusa Hybrid-2 and Vennela-43. Significant positive heterosis over mid parent, better parent, best parent and commercial checks was exhibited for 12 crosses, 3 crosses, 2 crosses and 14 crosses among the 28 crosses. The crosses IC-505621 × IC-50527 and IC-505621 × Phule Green Gold performed well and the highest heterosis was noticed for this trait when compared to better parent and commercial checks (Table 1). The heterotic range was similar to the observations of Kumar (2014); Verma *et al.* (2016); Kumar (2018); Kumari *et al.* (2020); Khairiya *et al.* (2023) in gourds.

B. Internodal length

The magnitude was varied widely from -23.64% (IC-505623 × IC-50527) to 25.19% (Gy 3-1-1-1-2 × Phule Green Gold) for relative heterosis, -29.50% (IC-505623 × Preethi) to 16.74% (Gy 3-1-1-1-2 × Phule Green Gold) for heterobeltiosis and -29.54% (IC-505623 × IC-50527) to 22.17% (IC-505621 × IC-50527) for best parent heterosis. Standard heterosis over Pusa Hybrid-2 varied from -20.51% (IC-505623 × IC-50527) to 37.82% (IC-505621 × IC-50527), while over Vennela-43 it ranged from -34.32% (IC-505623 × IC-50527) to 13.88% (IC-505621 × IC-50527). Negative heterosis is desirable and significant was found for 4 hybrids over better parent, 3 hybrids over best parent, 5 hybrids over mid parent and check Vennela-43. In comparison to other hybrids, IC-505623 × IC-50527, IC-505623 × Preethi and IC-505623 × Phule Green Gold displayed the better parental and commercial heterosis over Vennela-43 as well as the lowest internodal length (Table 1). These results are in line with the findings of Mohan (2005); Talekar *et al.* (2013); Kumar (2016); Mishra and Singh (2018b); Mishra (2019); Khairiya *et al.* (2023) in gourds.

C. Number of primary branches per plant

The degree of the mid, better and best parental heterosis was -25.49% (IC-470556 × Phule Green Gold) to 30.96% (IC-505623 × Preethi), -29.63% (IC-470556 × Phule Green Gold) to 30.96% (IC-505623 × Preethi) and -18.18% (IC-66023 × Pusa Aushadhi and IC-470550 × Pusa Aushadhi) to 45.46% (IC-66023 × IC-50527 and IC-470556 × IC-50527), respectively. The degree of the standard parental heterosis for Pusa Hybrid-2 was -25.00% (IC-66023 × Pusa Aushadhi and IC-470550 × Pusa Aushadhi) to 33.33% (IC-66023 × IC-50527 and IC-470556 × IC-50527). The number of cross combinations found significant in positive direction for mid parent, better parent, best parent and Pusa Hybrid-2 was three, one, two and two, respectively. IC-505623 × Preethi showed considerable heterosis in relation to better parent and IC-66023 × IC-50527 and IC-470556 × IC-50527 showed standard parental heterosis coupled with greater number of primary branches production (Table 2). Similar results were noticed by Mohan (2005), Sridhar (2012), Kumar (2016); Mishra and Singh (2018); Shetty (2019); Kumar *et al.* (2020); Singh *et al.* (2020); Al-asadi and Al-jebory (2021); Khairiya *et al.* (2023) in gourds.

D. Fruit length

The magnitude was varied widely from -29.67% (IC-505621 × Preethi) to 32.66% (IC-505623 × Phule Green Gold) for mid parental heterosis, -33.15% (IC-505621 × Preethi) to 26.17% (IC-505623 × Phule Green Gold) for better parental heterosis, -25.69% (Gy 3-1-1-1-2 × IC-50527) to 34.38% (IC-470550 × Preethi) for best parental heterosis, -14.47% (Gy 3-1-1-1-2 × IC-50527) to 54.68% (IC-470550 × Preethi) over check Pusa Hybrid-2 and -32.89% (Gy 3-1-1-1-2 × IC-50527) to 21.37% (IC-470550 × Preethi) over check Vennela-43. Significant positive heterosis over mid parent, best parent and Pusa Hybrid-2 was exhibited for 4 crosses, 2 crosses and 7 crosses, while 1 cross each for better parent and Vennela-43 was found significant among the 28 crosses. The hybrids of cross combination IC-505623 × Phule Green Gold and IC-470550 × Preethi exhibited highest fruit length along with significant heterosis over better parent and commercial checks (Table 2).

E. Fruit diameter

The degree of heterosis over the mid parent was from -25.73% (IC-505623 × IC-50527) to 35.17% (Gy 3-1-1-1-2 × Phule Green Gold). The heterosis ranged from -32.65% (IC-470550 × Phule Green Gold) to 27.87% (IC-505623 × Preethi) and -11.84% (IC-505623 × IC-50527) to 59.48% (IC-470550 × Preethi) over the better and best parents, respectively. The cross IC-470550 × Preethi had the highest heterosis of 38.52% and 43.51%, while the lowest heterosis of -23.43% and -20.67% was observed in IC-505623 × IC-50527 cross over Pusa Hybrid-2 and Vennela-43 checks. Significant positive heterosis over better parent, best parent and commercial checks over Vennela-43 was expressed for 1 cross, 12 crosses and 4 crosses, whereas 3 crosses each for mid parent and Pusa Hybrid-2 check was significant among the 28 crosses. The crosses IC-505623 × Preethi and IC-470550 × Preethi performed well and the highest heterosis was noticed for this trait when compared to better parent and commercial checks (Table 3).

F. Average fruit weight

The magnitude was varied widely from -68.21% (IC-505621 × Preethi) to 83.27% (Gy 3-1-1-1-2 × Phule Green Gold) for relative heterosis, -71.58% (IC-505621 × Preethi) to 81.01% (Gy 3-1-1-1-2 × Phule Green Gold) for heterobeltiosis and -53.52% (IC-470556 × Pusa Aushadhi) to 34.37% (IC-470550 × Preethi) for best parent heterosis. Standard heterosis over Pusa Hybrid-2 varied from -29.10% (IC-470556 × Pusa Aushadhi) to 104.99% (IC-470550 × Preethi), while over Vennela-43 it ranged from -30.14% (IC-470556 × Pusa Aushadhi) to 101.98% (IC-470550 × Preethi). Positive heterosis is desirable and significant was found for 7 hybrids over mid parent, 3 hybrids over better parent, 6 hybrids over best parent and 20 hybrids over commercial checks. In comparison to other hybrids, IC-470550 × Preethi and Gy 3-1-1-1-2 × Phule Green Gold exhibited maximum fruit weight and significant heterosis over commercial check hybrids and better parent (Table 3).

G. Number of fruits per plant

The cross IC-470556 × IC-50527 exhibited highest heterosis of 76.89% and 71.88%, on the other hand IC-470550 × Pusa Aushadhi exhibited lowest heterosis of -57.98% and -60.58% over mid parental and better parental value, respectively. Wide range of heterosis over commercial hybrid Pusa Hybrid-2 (-36.47% in IC-470550 × Pusa Aushadhi to 95.28% in IC-470550 × Preethi) and over Vennela-43 (-20.59% in IC-470550 × Pusa Aushadhi to 144.11% in IC-470550 × Preethi) was recorded. Positive heterosis with significance was observed in 10 crosses, 6 crosses, 7 crosses and 14 crosses with respect to mid parent, better parent, checks Pusa Hybrid-2 and Vennela-43. The top performing hybrids such as IC-470550 × Preethi, IC-505623 × IC-50527 and IC-66023 × Pusa Aushadhi showed significant heterosis in comparison with the commercial checks. IC-470556 × IC-50527, IC-66023 × IC-50527 and Gy 3-1-1-1-2 × IC-50527 showed significant heterosis in comparison with the better parent by producing more fruits from a plant (Table 4).

H. Total yield per plant

The cross combination IC-470550 × IC-50527 exhibited the lowest heterosis of -65.35% and -76.24%, whereas Gy 3-1-1-1-2 × Phule Green Gold exhibited the highest heterosis of 176.54% and 131.17% over mid parent and better parent. The extent of heterosis observed with respect to best parent, checks Pusa Hybrid-2 and Vennela-43 was -75.66% (IC-470550 × IC-50527) to 95.92% (IC-470550 × Preethi), -78.22% (IC-470550 × IC-50527) to 75.27% (IC-470550 × Preethi) and -62.87% (IC-470550 × IC-50527) to 198.82% (IC-470550 × Preethi), respectively. Heterosis in positive direction is desirable and significance was found for ten hybrids, six hybrids and seven hybrids in relation to mid parent, better parent and check Vennela-43. Two crosses each for the best parent and check Pusa Hybrid-2 was found to be significant among the 28 hybrids. The two hybrids IC-470550 × Preethi and Gy 3-1-1-1-2 × Phule Green Gold exhibited significant positive heterosis over the better parent and commercial checks with maximum yield per plant (Table 4). The tester Preethi has inherent potential for bearing bigger, longer and wider fruits and line IC-470550 has produced more number of fruits and highest yielding ability. Therefore, the cross combination IC-470550 × Preethi exhibited the superior performance for the yield related traits like fruit length, fruit diameter, average fruit weight, number of fruits per plant and fruit yield per plant. It can be concluded that heterosis breeding should be adopted in such cross combinations which is showing more heterotic response. In the present investigation, wide range of heterosis was recorded over the mid parent, better parent, best parent and over the commercial checks for all the yield attributing traits. The results were in accordance with the findings of Thangamani and Pugalendhi (2013); Mahboob (2014); Kumar (2014); Rao *et al.* (2017); Alhariri *et al.* (2018); Badni (2018); Acharya *et al.* (2019); Shetty (2019); Singh *et al.* (2020); Naik (2020); Al-asadi and Al-jebory (2021); Singh *et al.* (2022); Khairiya *et al.* (2023); Chandramouli *et al.* (2023) in gourds.

Table 1: Estimates of heterosis (%) over mid parent, better parent, best parent and commercial checks for vine length and internodal length in bitter gourd.

Sr. No.	Crosses	Vine length (m)						Internodal length (cm)					
		Mean	MP	BP	BTP	CC1	CC2	Mean	MP	BP	BTP	CC1	CC2
1.	IC-66023 × Pusa Aushadhi	3.18	25.66*	-14.35	-14.35	15.20	14.25	8.80	17.86*	15.79	20.01*	35.38**	11.87
2.	IC-66023 × Preethi	3.50	29.23*	-13.93	-5.84	26.65*	25.61*	7.33	-6.78	-9.84	0.00	12.82	-6.78
3.	IC-66023 × IC-50527	3.43	97.58**	61.55**	-7.64	24.23	23.20	6.40	-11.11	-15.79	-12.72	-1.54	-18.64*
4.	IC-66023 × Phule Green Gold	3.13	41.36**	1.62	-15.70	13.39	12.45	7.03	-4.74	-7.45	-4.08	8.21	-10.59
5.	IC-505623 × Pusa Aushadhi	3.45	-1.20	-7.18	-7.18	24.84	23.81	6.40	-9.00	-12.72	-12.72	-1.54	-18.64*
6.	IC-505623 × Preethi	3.42	-6.82	-15.98	-8.08	23.63	22.61	5.73	-22.86**	-29.50**	-21.81*	-11.79	-27.11**
7.	IC-505623 × IC-50527	3.43	27.36*	5.10	-7.63	24.24	23.22	5.17	-23.64*	-24.01*	-29.54**	-20.51	-34.32**
8.	IC-505623 × Phule Green Gold	3.60	13.38	10.19	-3.15	30.27*	29.19*	5.40	-22.30*	-24.65*	-26.36*	-16.92	-31.35**
9.	IC-505621 × Pusa Aushadhi	3.27	24.06*	-12.11	-12.11	18.22	17.24	8.40	9.09	4.13	14.55	29.23*	6.78
10.	IC-505621 × Preethi	2.53	-9.78	-37.70**	-31.84**	-8.32	-9.08	6.70	-17.28*	-17.62	-8.63	3.08	-14.83
11.	IC-505621 × IC-50527	4.52	145.80**	112.54**	21.51*	63.43**	62.09**	8.96	20.52*	11.06	22.17*	37.82**	13.88
12.	IC-505621 × Phule Green Gold	4.45	92.08**	44.32**	19.72*	61.03**	59.70**	7.03	-7.65	-12.81	-4.08	8.21	-10.59
13.	IC-470550 × Pusa Aushadhi	2.92	-16.47	-21.54*	-21.54*	5.54	4.67	7.07	-4.72	-5.78	-3.63	8.72	-10.17
14.	IC-470550 × Preethi	3.88	5.92	-4.50	4.48	40.53**	39.37**	8.17	4.48	0.42	11.37	25.65*	3.82
15.	IC-470550 × IC-50527	3.67	36.03**	12.26	-1.35	32.69*	31.60*	7.07	-1.17	-5.78	-3.63	8.72	-10.17
16.	IC-470550 × Phule Green Gold	3.50	10.24	7.15	-5.84	26.65*	25.61*	8.00	9.09	6.67	9.10	23.08*	1.70
17.	IC-470556 × Pusa Aushadhi	3.93	15.40	5.82	5.82	42.34**	41.16**	8.33	6.16	-0.40	13.64	28.20*	5.93
18.	IC-470556 × Preethi	3.63	1.39	-10.66	-2.26	31.46*	30.38*	6.90	-16.36*	-17.53*	-5.90	6.15	-12.29
19.	IC-470556 × IC-50527	3.50	33.97**	12.90	-5.84	26.65*	25.61*	7.50	-1.10	-10.36	2.28	15.38	-4.66
20.	IC-470556 × Phule Green Gold	2.83	-8.35	-8.60	-23.77*	2.53	1.69	7.50	-3.43	-10.36	2.28	15.38	-4.66
21.	Gy 3-1-1-1-2 × Pusa Aushadhi	3.38	-2.64	-8.97	-8.97	22.44	21.42	7.67	13.30	4.55	4.55	17.95	-2.54
22.	Gy 3-1-1-1-2 × Preethi	4.27	16.89*	4.92	14.78	54.39**	53.11**	6.97	-2.78	-14.34	-4.99	7.18	-11.43
23.	Gy 3-1-1-1-2 × IC-50527	3.17	18.19	-2.07	-14.81	14.58	13.64	6.73	3.59	-0.98	-8.18	3.59	-14.40
24.	Gy 3-1-1-1-2 × Phule Green Gold	3.78	19.77*	16.99	1.78	36.89**	35.76**	8.37	25.19*	16.74	14.09	28.72*	6.36
25.	IC-398610 × Pusa Aushadhi	3.00	-18.74*	-19.29*	-19.29*	8.56	7.66	7.40	-1.33	-3.48	0.91	13.85	-5.93
26.	IC-398610 × Preethi	3.63	-6.03	-10.65	-2.25	31.48*	30.40*	8.57	8.44	5.33	16.82	31.79**	8.90
27.	IC-398610 × IC-50527	3.10	7.04	-15.46	-16.60	12.18	11.25	7.20	-0.46	-6.08	-1.81	10.77	-8.47
28.	IC-398610 × Phule Green Gold	4.17	23.44*	13.62	12.09	50.77**	49.52**	8.37	12.81	9.13	14.09	28.72*	6.36
	MP	S. E. Difference	0.294					0.612					
		CD (0.05)	0.603					1.256					
		CD (0.01)	0.814					1.696					
	BP/BTP/Checks	S. E. Differnce	0.339					0.707					
		CD (0.05)	0.696					1.450					
		CD (0.01)	0.940					1.958					

* and ** indicates significance of values at $p = 0.05$ and $p = 0.01$, respectively
MP - Mid parent; BP - Better parent; BTP - Best parent ; CC1 (Pusa Hybrid-2); CC2 (Vennela-43) - Commercial checks

Table 2: Estimates of heterosis (%) over mid parent, better parent, best parent and commercial checks for number of primary branches per plant and fruit length in bitter gourd.

Sr. No.	Crosses	Number of primary branches per plant						Fruit length (cm)					
		Mean	MP	BP	BTP	CC1	CC2	Mean	MP	BP	BTP	CC1	CC2
1.	IC-66023 × Pusa Aushadhi	6.00	-17.24	-18.18	-18.18	-25.00*	-41.94**	19.10	12.24	5.91	5.91	21.91	-4.34
2.	IC-66023 × Preethi	6.50	-8.28	-9.35	-11.41	-18.79	-37.13**	17.83	-11.35	-26.41**	-1.11	13.83	-10.69
3.	IC-66023 × IC-50527	10.67	28.00*	12.28	45.46**	33.33*	3.22	16.50	8.08	3.12	-8.50	5.32	-17.36
4.	IC-66023 × Phule Green Gold	7.17	-11.34	-20.37	-2.26	-10.41	-30.64**	18.17	14.74	13.54	0.74	15.95	-9.02
5.	IC-505623 × Pusa Aushadhi	8.00	11.63	9.10	9.10	0.00	-22.58*	16.10	0.10	-10.72	-10.72	2.76	-19.37*
6.	IC-505623 × Preethi	9.17	30.96*	30.96*	25.01	14.59	-11.29	17.10	-10.86	-29.44**	-5.18	9.15	-14.36
7.	IC-505623 × IC-50527	9.33	13.13	-1.75	27.28	16.67	-9.68	16.70	16.51	14.91	-7.39	6.59	-16.36
8.	IC-505623 × Phule Green Gold	7.33	-8.33	-18.52	0.01	-8.33	-29.03**	19.77	32.66**	26.17*	9.61	26.17*	-1.00
9.	IC-505621 × Pusa Aushadhi	9.00	17.39	12.50	22.73	12.50	-12.90	22.40	12.38	2.60	24.21*	42.98**	12.19
10.	IC-505621 × Preethi	7.00	-6.67	-12.50	-4.54	-12.50	-32.26**	16.20	-29.67**	-33.15**	-10.17	3.40	-18.87*
11.	IC-505621 × IC-50527	7.00	-20.00*	-26.32*	-4.54	-12.50	-32.26**	20.13	10.73	-7.78	11.64	28.51*	0.83
12.	IC-505621 × Phule Green Gold	7.00	-17.65	-22.22	-4.54	-12.50	-32.26**	18.73	-0.09	-14.20	3.88	19.57	-6.18
13.	IC-470550 × Pusa Aushadhi	6.00	-16.28	-18.18	-18.18	-25.00*	-41.94**	16.03	-11.50	-11.90	-11.09	2.34	-19.70*
14.	IC-470550 × Preethi	8.00	14.29	14.29	9.10	0.00	-22.58*	24.23	14.22	0.00	34.38**	54.68**	21.37*
15.	IC-470550 × IC-50527	8.00	-3.03	-15.79	9.10	0.00	-22.58*	16.17	-1.22	-11.17	-10.35	3.19	-19.03*
16.	IC-470550 × Phule Green Gold	6.67	-16.67	-25.93*	-9.09	-16.67	-35.49**	17.37	2.56	-4.58	-3.70	10.85	-13.02
17.	IC-470556 × Pusa Aushadhi	6.83	-10.87	-14.59	-6.82	-14.59	-33.88**	13.97	-15.78	-22.55*	-22.55*	-10.85	-30.05**
18.	IC-470556 × Preethi	8.00	6.67	0.00	9.10	0.00	-22.58*	17.77	-9.74	-26.68**	-1.48	13.40	-11.02
19.	IC-470556 × IC-50527	10.67	21.90*	12.28	45.46**	33.33*	3.22	18.93	27.64*	25.11	4.99	20.85	-5.18
20.	IC-470556 × Phule Green Gold	6.33	-25.49*	-29.63*	-13.64	-20.84	-38.71**	17.97	16.67	14.68	-0.37	14.68	-10.02
21.	Gy 3-1-1-1-2 × Pusa Aushadhi	7.17	2.38	-2.27	-2.27	-10.42	-30.65**	20.27	30.75**	12.39	12.39	29.36*	1.50
22.	Gy 3-1-1-1-2 × Preethi	8.17	19.52	16.67	11.37	2.09	-20.97*	19.73	6.09	-18.57*	9.43	25.96*	-1.17
23.	Gy 3-1-1-1-2 × IC-50527	8.33	3.10	-12.28	13.64	4.17	-19.35*	13.40	-2.55	-7.80	-25.69*	-14.47	-32.89**
24.	Gy 3-1-1-1-2 × Phule Green Gold	8.00	2.13	-11.11	9.10	0.00	-22.58*	18.10	26.43*	15.53	0.37	15.53	-9.35
25.	IC-398610 × Pusa Aushadhi	6.83	-4.65	-6.82	-6.82	-14.59	-33.88**	14.60	-15.20	-19.04	-19.04	-6.81	-26.88**
26.	IC-398610 × Preethi	7.00	0.00	0.00	-4.54	-12.50	-32.26**	19.90	-2.05	-17.88*	10.35	27.02*	-0.34
27.	IC-398610 × IC-50527	7.17	-13.13	-24.56*	-2.26	-10.41	-30.64**	17.33	12.07	5.69	-3.88	10.63	-13.19
28.	IC-398610 × Phule Green Gold	8.67	8.34	-3.70	18.19	8.34	-16.13	14.77	-7.90	-9.96	-18.12	-5.75	-26.05**
MP	S. E. Difference	0.849						1.622					
	CD (0.05)	1.741						3.327					
	CD (0.01)	2.352						4.493					
BP/BTP/Checks	S. E. Difference	0.980						1.873					
	CD (0.05)	2.011						3.842					
	CD (0.01)	2.715						5.188					

* and ** indicates significance of values at p = 0.05 and p = 0.01, respectively
MP - Mid parent; BP - Better parent; BTP - Best parent; CC1 (Pusa Hybrid-2) and CC2 (Vennela-43) - Commercial checks

Table 3: Estimates of heterosis (%) over mid parent, better parent, best parent and commercial checks for fruit diameter and average fruit weight in bitter gourd.

Sr. No.	Crosses		Fruit diameter (mm)						Average fruit weight (g)					
			Mean	MP	BP	BTP	CC1	CC2	Mean	MP	BP	BTP	CC1	CC2
1.	IC-66023 × Pusa Aushadhi		42.88	12.79	6.47	19.90	4.14	7.89	103.33	-4.53	-15.30*	-15.30*	29.21**	27.32**
2.	IC-66023 × Preethi		44.57	5.83	1.40	24.62	8.24	12.15	114.37	-26.77**	-47.51**	-6.26	43.01**	40.91**
3.	IC-66023 × IC-50527		42.87	3.04	-0.17	19.88	4.12	7.88	105.87	20.81**	12.07	-13.22*	32.38**	30.44**
4.	IC-66023 × Phule Green Gold		40.57	8.61	0.74	13.45	-1.47	2.09	101.27	11.31	7.20	-16.99**	26.63**	24.77**
5.	IC-505623 × Pusa Aushadhi		33.71	-13.25	-19.65	-5.74	-18.13	-15.18	67.33	-33.44**	-44.81**	-44.81**	-15.80	-17.04
6.	IC-505623 × Preethi		56.21	30.85**	27.87*	57.16**	36.50**	41.42**	156.03	4.64	-28.39**	27.90**	95.11**	92.25**
7.	IC-505623 × IC-50527		31.53	-25.73*	-26.58*	-11.84	-23.43*	-20.67	97.33	20.81**	20.46*	-20.22**	21.71*	19.92*
8.	IC-505623 × Phule Green Gold		45.09	18.03	7.46	26.07	9.50	13.45	140.73	67.72**	60.86**	15.36*	75.98**	73.40**
9.	IC-505621 × Pusa Aushadhi		47.07	4.52	-13.32	31.60*	14.30	18.43	162.47	10.62*	-5.40	33.17**	103.16**	100.17**
10.	IC-505621 × Preethi		47.17	-3.99	-13.13	31.88*	14.55	18.68	61.93	-68.21**	-71.58**	-49.23**	-22.56*	-23.69*
11.	IC-505621 × IC-50527		48.73	0.22	-10.26	36.25*	18.34	22.61	156.50	23.94**	-8.87*	28.28**	95.70**	92.82**
12.	IC-505621 × Phule Green Gold		44.53	0.36	-17.99	24.51	8.14	12.04	115.90	-10.58*	-32.51**	-5.00	44.93**	42.80**
13.	IC-470550 × Pusa Aushadhi		46.29	11.02	-2.81	29.44*	12.43	16.48	99.90	-22.23**	-25.95**	-18.11**	24.92**	23.09*
14.	IC-470550 × Preethi		57.04	24.55*	19.74	59.48**	38.52**	43.51**	163.93	-7.07*	-24.77**	34.37**	104.99**	101.98**
15.	IC-470550 × IC-50527		36.22	-20.02*	-23.95*	1.28	-12.03	-8.86	64.57	-40.13**	-52.14**	-47.08**	-19.26*	-20.45*
16.	IC-470550 × Phule Green Gold		32.08	-21.82*	-32.65**	-10.29	-22.08	-19.27	77.60	-30.21**	-42.48**	-36.39**	-2.96	-4.39
17.	IC-470556 × Pusa Aushadhi		36.41	-12.64	-23.50*	1.82	-11.57	-8.38	56.70	-49.06**	-53.52**	-53.52**	-29.10**	-30.14**
18.	IC-470556 × Preethi		35.40	-22.66*	-25.62*	-1.01	-14.02	-10.92	70.77	-55.57**	-67.52**	-41.99**	-11.51	-12.81
19.	IC-470556 × IC-50527		48.52	7.18	1.95	35.68*	17.84	22.09	109.90	21.15**	9.21	-9.92	37.42**	35.41**
20.	IC-470556 × Phule Green Gold		40.86	-0.39	-14.16	14.24	-0.78	2.80	86.53	-8.00	-14.01*	-29.07**	8.21	6.62
21.	Gy 3-1-1-1-2 × Pusa Aushadhi		38.98	-1.32	-9.85	8.98	-5.34	-1.93	115.77	9.37	-5.11	-5.11	44.76**	42.64**
22.	Gy 3-1-1-1-2 × Preethi		47.71	9.44	8.54	33.40*	15.87	20.05	124.80	-18.86**	-42.73**	2.30	56.06**	53.77**
23.	Gy 3-1-1-1-2 × IC-50527		44.59	3.48	3.14	24.68	8.29	12.20	74.77	-12.30	-16.65*	-38.72**	-6.51	-7.88
24.	Gy 3-1-1-1-2 × Phule Green Gold		52.50	35.17**	21.43	46.79**	27.49*	32.09*	162.37	83.27**	81.01**	33.09**	103.03**	100.05**
25.	IC-398610 × Pusa Aushadhi		49.95	20.08	5.31	39.67**	21.31	25.68*	110.27	-6.88	-9.62	-9.62	37.88**	35.86**
26.	IC-398610 × Preethi		45.26	-0.94	-4.57	26.56	9.92	13.89	126.30	-24.08**	-42.04**	3.52	57.93**	55.61**
27.	IC-398610 × IC-50527		47.74	5.64	0.65	33.48*	15.93	20.11	104.70	7.04	-8.82	-14.18*	30.92**	29.00**
28.	IC-398610 × Phule Green Gold		48.13	17.58	1.48	34.58*	16.89	21.10	106.57	5.34	-7.20	-12.65*	33.26**	31.30**
	MP	S. E. Difference	4.164						5.860					
		CD (0.05)	8.544						12.023					
		CD (0.01)	11.537						16.236					
	BP/BTP/Checks	S. E. Difference	4.808						6.766					
		CD (0.05)	9.865						13.883					
		CD (0.01)	13.322						18.747					

* and ** indicates significance of values at p = 0.05 and p = 0.01, respectively
MP - Mid parent; BP - Better parent ; BTP - Best parent; CC1 (Pusa Hybrid-2) and CC2 (Vennela-43) - Commercial checks

Table 4: Estimates of heterosis (%) over mid parent, better parent, best parent and commercial checks for number of fruits per plant and total yield per plant in bitter gourd.

Sr. No.	Crosses	Number of fruits per plant						Total yield per plant (kg)					
		Mean	MP	BP	BTP	CC1	CC2	Mean	MP	BP	BTP	CC1	CC2
1.	IC-66023 × Pusa Aushadhi	25.50	50.00**	11.68	11.68	80.00**	125.01**	2.10	68.11**	13.88	13.88	1.88	73.69**
2.	IC-66023 × Preethi	14.83	13.40	-1.08	-35.03**	4.71	30.89	1.39	23.05	-13.43	-24.54	-32.49*	15.09
3.	IC-66023 × IC-50527	18.83	68.71**	68.66*	-17.52	32.94	66.18*	1.31	93.42*	86.85*	-28.86	-36.36*	-39.06
4.	IC-66023 × Phule Green Gold	11.00	-20.00	-32.65	-51.83**	-22.36	-2.95	0.85	-7.26	-28.15	-53.60**	-58.49**	-29.23
5.	IC-505623 × Pusa Aushadhi	15.50	-25.90*	-32.13*	-32.13*	9.39	36.74	1.01	-30.75	-45.24**	-45.24**	-51.01**	-16.47
6.	IC-505623 × Preethi	18.83	10.82	-0.85	-17.52	32.94	66.18*	2.37	77.31**	47.81*	28.84	15.27	96.51**
7.	IC-505623 × IC-50527	25.67	70.24**	35.13*	12.42	81.19**	126.49**	1.90	113.91**	76.97**	2.93	-7.92	56.99*
8.	IC-505623 × Phule Green Gold	14.17	-19.80	-25.42	-37.96**	0.00	25.00	1.48	30.82	24.32	-19.71	-28.17*	22.46
9.	IC-505621 × Pusa Aushadhi	19.17	5.03	-16.06	-16.06	35.30	69.13*	2.25	50.02**	22.40	22.40	9.50	86.69**
10.	IC-505621 × Preethi	20.33	41.89*	35.60	-10.95	43.53*	79.42**	1.04	-24.97	-35.30	-43.61**	-49.55**	-13.98
11.	IC-505621 × IC-50527	13.83	11.42	1.21	-39.43**	-2.38	22.03	1.42	52.49	22.19	-22.81	-30.94*	17.74
12.	IC-505621 × Phule Green Gold	16.66	11.11	2.04	-27.02*	17.62	47.03	1.48	26.21	24.84	-19.38	-27.87	22.97
13.	IC-470550 × Pusa Aushadhi	9.00	-57.98**	-60.58**	-60.58**	-36.47	-20.59	0.80	-56.88**	-57.40**	-56.35**	-60.95**	-33.43
14.	IC-470550 × Preethi	27.66	58.11**	38.33*	21.16	95.28**	144.11**	3.61	106.65**	91.23**	95.92**	75.27**	198.82**
15.	IC-470550 × IC-50527	9.16	-41.21*	-54.20**	-59.88**	-35.34	-19.17	0.45	-65.35**	-76.24**	-75.66**	-78.22**	-62.87*
16.	IC-470550 × Phule Green Gold	16.67	-8.25	-16.67	-27.01*	17.65	47.06	1.07	-30.63	-43.45**	-42.07*	-48.17**	-11.64
17.	IC-470556 × Pusa Aushadhi	13.00	-25.00	-43.07**	-43.07**	-8.24	14.70	0.74	-44.71*	-59.62**	-59.62**	-63.87**	-38.41
18.	IC-470556 × Preethi	17.66	31.69	17.80	-22.64	24.68	55.86*	1.04	-15.35	-35.30	-43.60**	-49.55**	-13.98
19.	IC-470556 × IC-50527	20.33	76.89**	71.88**	-10.95	43.53*	79.41**	1.58	104.00**	86.27*	-14.16	-23.21	30.92
20.	IC-470556 × Phule Green Gold	16.67	18.37	2.06	-27.01*	17.65	47.06	1.17	14.43	-1.96	-36.68*	-43.35**	-3.42
21.	Gy 3-1-1-1-2 × Pusa Aushadhi	24.83	43.94**	8.75	8.75	75.27**	119.09**	1.89	43.20*	2.66	2.66	-8.15	56.59*
22.	Gy 3-1-1-1-2 × Preethi	18.33	37.52*	22.26	-19.71	29.41	61.77*	1.71	41.99*	6.34	-7.31	-17.08	41.37
23.	Gy 3-1-1-1-2 × IC-50527	19.17	67.93**	64.29*	-16.06	35.29	69.12*	1.11	47.74	38.69	-39.82*	-46.16**	-8.22
24.	Gy 3-1-1-1-2 × Phule Green Gold	23.83	70.24**	45.93*	4.37	68.21**	110.27**	2.75	176.54**	131.17**	49.29**	33.56*	127.71**
25.	IC-398610 × Pusa Aushadhi	20.00	13.21	-12.41	-12.41	41.18	76.48**	1.72	13.09	-6.45	-6.45	-16.31	42.68
26.	IC-398610 × Preethi	13.33	-3.01	-11.08	-41.61**	-5.88	17.65	1.49	5.85	-7.34	-19.23	-27.74	23.19
27.	IC-398610 × IC-50527	14.50	22.57	16.00	-36.50**	2.35	27.94	1.21	26.89	0.36	-34.32*	-41.24**	0.17
28.	IC-398610 × Phule Green Gold	17.00	17.93	4.10	-25.55*	20.00	50.00	1.44	20.72	19.92	-21.52	-29.79*	19.70
	MP — S. E. Difference	2.410						0.245					
	MP — CD (0.05)	4.946						0.502					
	MP — CD (0.01)	6.679						0.678					
	BP/BTP/Checks — S. E. Difference	2.783						0.283					
	BP/BTP/Checks — CD (0.05)	5.711						0.580					
	BP/BTP/Checks — CD (0.01)	7.712						0.783					

* and ** indicates significance of values at p = 0.05 and p = 0.01, respectively

MP - Mid parent; BP - Better parent; BTP - Best parent; CC1 (Pusa Hybrid-2) and CC2 (Vennela-43) - Commercial checks

CONCLUSIONS

Cross combinations such as IC-470550 × Preethi, Gy 3-1-1-1-2 × Phule Green Gold and IC-505623 × Preethi were best performing for the yield and its related traits with maximum heterosis and can be exploited for crop improvement. It can be concluded that heterosis can be exploited for commercial cultivation in these cross combinations.

FUTURE SCOPE

The crosses IC-470550 × Preethi, Gy 3-1-1-1-2 × Phule Green Gold and IC-505623 × Preethi can be further assessed for their stability to confirm their potentiality and also their adaptability to different agro-climatic conditions.

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