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Heterosis Studies for Growth, Flower and Yield Characters in Bitter gourd (*Momordica charantia* L.)

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ABSTRACT: Bitter gourd (*Momordica charantia* L.) also known as balsam pear or karela, is an easily cultivated plant belongs to the family Cucurbitaceae. It is a native of tropical Asia, more especially of Indo Burma, which includes East India and South China. Despite the crop potential, economic and its medicinal use the present study was undertaken using twelve lines and three testers to develop 36 F_1 hybrids in L × T (Line × Tester) pattern. Evaluation of hybrids along with their parents revealed that the cross combinations Katahi Vaibhav × Preethi, Green Long × Preethi and Katahi Vaibhav × Co-1showed highest positive heterosis, which were supercilious for earliness and yield parameters whereas, IC505640-2 × Co-1 and Green Long × Preethi expressed superior for quality parameters resulting as best hybrids. Based on its yield potential and favoured earliness characteristics, the Katahi Vaibhav × Preethi hybrid was chosen as the best hybrid out of 36 cross combinations, with a yield of 14.32 t/ha. Hence the best hybrids are recommended for commercial exploitation of heterosis.

Keywords: Bitter gourd, hybrids, *per se* performance, Heterosis, Better parent heterosis, Standard heterosis.

INTRODUCTION

The common cucurbit vegetable known as the bitter gourd (*Momordica charantia* L.) belongs to the Cucurbitaceae family. It is a native of tropical Asia, more especially of Indo Burma, which includes East India and South China. China, Malaysia, India, tropical Africa and North and South America are all home to bitter gourd. The annual and perennial climber species in the *Momordica* genus includes the widely cultivated *Momordica charantia*. It has 22 chromosomal groups and is a diploid. The Latin word *momordica,* which means "to bite," relates to the leaf of the bitter melon plant, which has jagged edges and looks as though it has been bit. Because every part of the plant is bitter, it is also known as the "bitter melon" or "bitter gourd." Other names for it include Nigauri or Goya in Japanese, Balsam pear in English, Karela in Hindi and Haagalakaayi in Kannada.Momordicin, an alkaloid distinct from the cucurbitac in present in other cucurbits, gives the immature tuberculate fruits the distinct bitter flavor. A common cucurbitac in triterpenoid called 'charatin' has a significant impact on lowering blood sugar levels. In addition to being a cheap source of protein and minerals, the fruits are also high in iron (1.8 mg), calcium (20 mg), phosphorous (55 mg), vitamin A (210 IU) and vitamin C (88 mg/100 g), (Aykryod, 1963). Tender vine tips are a rich source of vitamin A. It has twice as much calcium and beta-carotene as broccoli and spinach (Bhatt *et al*., 2017).

Bitter gourd extract has antioxidant, antibacterial, antiviral, anti-hepatotoxic, and anti-ulcerogenic properties. Blood sugar levels may also be lowered as a result (Welhinda *et al*., 1986; Raman and Lau 1996). Recently, bitter gourd was found to have anti-cancerous properties. According to Dia and Krishnan (2016), the new BG-4 peptide from *Momordica charantia* L. encourages apoptosis in human colon cancer. According to ethno-medical accounts, *M. charantia* is used in folkloric medicine to cure ulcers, diabetes and infections (Gurbuz *et al*., 2000; Scartezzini and Speroni 2000; Beloin *et al*., 2005), while the root decoctions have abortifacient properties, leaf and stem decoctions are used to cure dysentery, rheumatism and gout (Subratty *et al*., 2005).

Bitter gourd is a herbaceous fast growing annual climber which is monoecious and grows up to 5 meter height with thin stems, tendrils and long tap root system with the duration of 100-120 days. Vine bearing yellow-coloured flowers, while pistillate flowers are solitary, short or long pedunculate and staminate flowers have five stamens. On the leaf axil, pistillate and staminate flowers were produced. The bitter gourd pistillate flower is made up of a columnar, hollow style, an inferior ovary and a three-lobed, moist stigma (Deyto and Cervancia 2009). Due to its monoecious character, it is highly cross-pollinated which bears pistillate and staminate flowers on different nodes on the same plant and high degree of heterozygosity. Gynoecious sex form (bears only female flowers) also reported in India (Ram *et al*., 2006). Anthesis typically occurs between 3:30 am to 7:30 am, when flowers are completely open and pollen viability is lost relatively rapidly. Prior to or following flower opening, the stigma is typically responsive for one day before drying out and turning brown (Rasco and Castillo 1990).

By employing the recognized practical tool of heterosis breeding, breeders can improve yield and other economic characteristics. Not every hybridization leads to the development of hybrid vigor. Heterozygous offspring can only be born to a particular set of parents. Therefore, in order to construct an effective heterosis breeding program in bitter gourd, it is required to specify the genetic type and quantity of quantitatively inherited traits as well as the predicted prepotency of parents in hybrid combinations. Therefore, in order to choose superior parents, one must be aware of both the general combining ability (gca) effects, which aid in parent selection and the specific combining ability (sca) effects, which aid in hybrid identification. The information obtained by this method would greatly facilitate the understanding of the degree of heterosis in F_1 hybrids. This heterosis and combining ability study aids in identifying the ideal parental combinations based on strong GCA and SCA.

Many native cultivars or land races of bitter gourd that are grown in southern India have low yield potential. The focus of research is to increase production, uniformity and fruit quality through exploitation of heterosis using regionally adapted bitter gourd genotypes for commercial cultivation. With the aforementioned information, it can be highlighted that phenotypic diversity, heterosis and combining ability investigations are crucial for providing the data needed for any commercial varietal development effort.

MATERIAL AND METHODS

The present experiment was conducted at Kittur Rani Channamma College of Horticulture, Arabhavi, Belagavi district, Karnataka. The genotypes used in the present study comprised of twelve lines namely IC505640-1IC505640-2, IC505640-3, IC66023, IC470556-1, IC470555, IC65972-1, IC470553-2, Katahi Vaibhav, Green Long, Dharog Local and Monoecious, three testers namely Co-1, Preethi and Mysore Local which are of broad genetic base and all these genotypes were collected from various parts of Karnataka, Kerala, Tamil Nadu and New Delhi which were choosen based on their *per se* performance for yield attributes. These genotypes were crossed in line × tester pattern to obtain 36 hybrids and the obtained F_1's were grown in randomized block design with two replications along with two commercial checks (SW-814 and NS-1024). During experimentation all the necessary cultural practices were followed and plant protection measures were taken. The data on various earliness, flowering, yield and quality parameters were recorded from five randomly selected plants. The mean data was subjected to analysis in INDOSTAT 2.0 software to obtain heterosis percentage for various parameters. The heterosis was estimated from mean values, and its significance was tested using t-test.

RESULTS AND DISCUSSION

Positive or negative heterosis refers to the F_1 hybrids superiority or inferiority to their parents, respectively. Growth and yield factors can be manifested *via* positive heterosis. The earliest parameters are shown by the negative heterosis. Vine length varied greatly among genotypes, ranging from 182.56 cm (Green Long × Preethi) to 278.86cm (Katahi Vaibhav × Mysore Local) among crosses, from 174.42 cm (IC470555) to 281.06 cm (IC505640-2) among lines and from 208.12 cm (Co - 1) to 245.09 cm (Mysore Local) among testers The cross between IC5470555 and CO-1 showed the highest levels of heterosis over the better parent (30.29%) and commercial check (27.28%). Out of 36 crosses, one cross over better parent and one cross over commercial check, showed positive significant heterosis, which were found to be similar with the results of Talekar *et al*. (2013) ; Kumar *et al*. (2020). The usage of multiple genetic stocks as well as other environmental factors are attributed for the magnitude of heterosis being large in comparison to Laxuman *et al*. (2012) findings and low in comparison to Verma *et al*. (2016)'s.

At final harvest, there were 2.46 primary branches (IC470555) to 3.44 primary branches (Katahi Vaibhav) among lines, 2.40 primary branches (Preethi) to 3.29 primary branches (Co -1) among testers and 2.39 primary branches (IC505640-2 × Preethi) to 3.42 primary branches (IC66023 × Mysore Local) among hybrids. Both directions have a large amount of heterosis. The cross IC470555 × Preethi showed the most positive heterosis over better parent (28.80%), whereas the cross IC66023 × Mysore Local showed the highest positive heterosis over the commercial check (28.09%). Two crosses over better parent and four crosses over commercial check out of 36 crosses indicated positive significant heterosis. These results are in confirmation of the results of Singh *et al*. (2020). Different responses for number of branches per plant may be caused by the genotype vigour, genetic makeup and intrinsic traits.

Vegetable crops should take the earliness feature into account in order to maximise their potential economic yield. When determining earliness, characteristics like the days to 50 % flowering and days to the first fruit harvest are highly helpful. Negative heterosis is preferred for these traits. Days to 50 per cent flowering varied considerably among genotypes, ranging from 38.88 days for Katahi Vaibhav to 59.05 days for IC505640-3 among lines, from 42.18 days for Mysore Local to 47.21 days for Co - 1 among testers and from 35.09 days for Green Long × Preethi to 47.99 days for IC505640-2 × Co-1 among cross combinations. The cross between IC505640-3 × Co-1 had the highest magnitude of heterosis and the most significant negative heterosis over better parent (-20.05%) and the cross Katahi Vaibhav × Mysore Local over commercial check (-26.25%). Six of the 36 crosses over better parentand two of the crosses over commercial check exhibited negative and substantial heterosis for days to 50 per cent flowering, which was consistent with the findings of Dey *et al*. (2007), although the range of heterosis was slightly higher than that of Kumar *et al*. (2020); Kumari *et al*. (2020).

Significant differences were observed among the genotypes for days to first fruit harvest**.** It varied from 51.06 days (Katahi Vaibhav) to 73.53 days (IC65972-1) among lines, 55.73 days (Preethi) to 58.78 days (Co - 1) among testers and 42.08 days (Katahi Vaibhav × Mysore Local) to 60.23 days (IC66023 × Co - 1) among crosses. Both directions have a large amount of heterosis. IC65972-1 × Mysore Local showed the highest and most significant negative heterosis over better parent (-22.97%). The cross Katahi Vaibhav × Mysore Local showed the highest and most significant negative heterosis over commercial check (-22.83%). Eight crosses over better parent and five crosses over standard checkout of 36 crosses showed substantial and favourable heterosis for days to first fruit harvest which was in accordance with the work of Dey *et al*. (2007). The usage of several lines and testers is responsible for days to first fruit harvest.

The ultimate goal of any breeding programme is target to achieve maximization of marketable yield. Since yield is a complex and polygenically inherent trait, number of fruits per plant and average fruit weight are directly contributing to yield in brinjal breeding. The number of fruits per vine varied greatly between genotypes, ranging from 7.97 (IC65972-1× Co-1) to 31.56 (Katahi Vaibhav × Preethi) among hybrids, 13.20 (Mysore Local) to 17.65 (Preethi) among testers and 7.88(IC5470556-1) to 19.68 (Katahi Vaibhav) among lines. The degree of heterosis was significantly positive when compared to better parent and commercial check. The cross Katahi Vaibhav × Preethi showed the highest levels of heterosis over better parent (155.10%)and commercial check(172.71%). 16 crosses over the better parent and 19 crosses over commercial check showed substantial heterosis for the number of fruits per vine out of the total 36 crosses. The present results are in agreement with the earlier findings of Dey *et al*. (2007). The usage of several lines and testers is responsible for number of fruits per plant.

For fruit length, the genotypes varied greatly among one another. It varied from 6.28 cm (IC65972-1 × Mysore Local) to 18.58 cm (Monoecious × Preethi) among crosses, 8.15 cm (IC505640-2) to 16.07 cm (Katahi Vaibhav) among lines and 8.75 cm (Co - 1) to 11.58 cm (Preethi) among testers. The cross Katahi Vaibhav × Preethi showed the highest levels of heterosis over better parent (91.97%) and commercial check (55.01%). Of the 36 cross combinations, the fruit length exhibited a substantial positive heterosis for ten crosses over beteer parent and three crosses over commercial check. It was found similar with Ranpise *et al*. (1992); Laxuman *et al*. (2012). Different responses for fruit diameter may be caused by the genotype vigour, genetic makeup and intrinsic traits.

Fruit diameter varied significantly among the genotypes and which ranged from 28.17 mm (Katahi Vaibhav) to 43.18 mm (IC470556-1) among lines, 21.27 mm (Mysore Local) to 31.63 mm (Preethi) among testers and 21.97 mm (IC65972-1 × Preethi) to 35.84 mm (IC505640-3 × Mysore Local) among crosses. The amount of heterosis was considerable in both directions. The cross Katahi Vaibhav × Preethi had the most positive and significant heterosis over better parent (60.95%) and commercial check (78.23%). Of the 36 cross combinations,6 crosses over better parent and two crosses over commercial check showed significant positive heterosis, which is similar to the findings of Ranpise *et al*. (1992); Naik *et al*. (2020). Different responses for fruit diameter may be caused by the genotype vigour, genetic makeup and intrinsic traits.

For average fruit weight, genotypes differed considerably. It ranged between 26.83 g (IC470555) and 73.00g (IC470553-2) among lines, 25.17 g (Mysore Local) and 79.16 g (Preethi) among testers and 37.13 g (Dharog Local × Mysore Local) and 91.16 g (Katahi Vaibhav × Preethi) among hybrids. The hybrid IC66023 × Mysore Local has the highest heterosis of better parent (32.68%), followed by Katahi Vaibhav × Co-1 (17.22%). The hybrid Katahi Vaibhav × Preethi showed the most heterosis for commercial check (38.58%), followed by Green Long × Preethi (35.65%). Out of 36 cross combinations, 5 crosses showed positive and substantial heterosis for average fruit weight over better parent and 11 crosses over commercial check, which was consistent with Al-Mamun *et al*. (2015); Malviya *et al*. (2017). The usage of several lines and testers is responsible for the fluctuating average fruit weight.

Yield in any crop is the final product of different yield components. This ultimate produce in the plant is expressed through mutual balancing of characters. Fruit yield per plant varied greatly across genotypes, ranging from 0.75 kg (IC65972-1) to 1.91 kg (Katahi Vaibhav), 0.77 kg (Mysore Local) to 1.67 kg (Co-1) and 1.03 kg (Dharog Local × Mysore Local) to 2.72 kg (Katahi Vaibhav × Preethi) among crosses. The crosss IC470556-1 × Preethi showed the most positive and significant heterosis over better parent (49.37%). The cross Katahi Vaibhav × Preethi showed considerable positive heterosis over commercial check(100.00%). Among the 36 crosses, 22 crosses over better parent and 28 crosses over commercial check showed considerable positive heterosis. Similar results were also reported by Ranpise *et al*. (1992); Dey *et al*. (2007); Laxuman *et al*. (2012); Al-Mamun *et al*. (2015); Naik *et al*. (2020);

Malviya *et al*. (2017). Varied magnitude of heterosis for yield parameters is attributed to use of different lines and genetic stocks in different studies.

Fruit yield per hectare varied greatly between genotypes, ranging from 3.98 t (IC65972-1) to 9.45 t (Katahi Vaibhav) among lines, 3.68 t (Mysore Local) to 9.96 t (Preethi) among testers and 4.78 t (Dharog Local × Mysore Local) to 14.32 t (Katahi Vaibhav × Preethi) among crosses. Maximum significant positive heterosis over better parent was seen in the cross IC66023 × Co-1(100.52%). The cross Katahi Vaibhav × Preethi has the most significant heterosis over commercial check (87.07%). Out of 36 crosses, 23 crosses over better parent and 9 crosses over commercial check, exhibited positive and substantial heterosis for fruit yield per hectare. These results were within range observed by Ranpise *et al*. (1992); Dey *et al*. (2007); Laxuman *et al*. (2012); Al-Mamun *et al*. (2015); Naik *et al*. (2020); Malviya *et al*. (2017).

Table 1: *Per se* performance of parents for growth and flowering parameters in bitter gourd.

Sr. No.	Genotypes	Vine length at final harvest (cm)	No. of primary branches at final harvest	Days to 50 % flowering	Days to first fruit harvest
	Lines				
1.	IC505640-1	215.41	2.59	44.68	54.86
2.	IC505640-2	281.06	3.21	46.53	57.32
3.	IC505640-3	251.55	3.42	59.05	70.52
4.	IC66023	233.33	2.57	47.43	55.95
5.	IC470556-1	201.91	3.21	48.71	61.16
6.	IC470555	174.42	2.46	56.51	70.00
7.	IC65972-1	186.55	3.32	61.71	73.53
8.	IC470553-2	256.97	3.11	56.78	71.02
9.	Katahi Vaibhav	265.68	3.44	38.88	51.06
10.	Green Long	258.05	3.32	49.23	54.79
11.	Dharog Local	218.55	3.19	52.24	58.85
12.	Monoecious	234.39	2.90	49.79	55.67
	Testers				
1	Co – 1	208.12	3.29	47.21	58.78
2	Preethi	240.80	2.40	42.96	55.73
3	Mysore Local	245.09	3.20	42.18	56.85
	Commercial checks				
1	SW-814	228.27	2.94	41.87	49.98
2	NS-1024	218.16	2.67	42.22	54.53
	S.Em±	17.43	0.15	3.22	2.87
	CD at 5%	49.47	0.44	9.13	8.13
	CD at 1%	65.91	0.59	12.17	10.84

Table 2: *Perse* performance of crosses for growth and flowering parameters in bitter gourd.

Sr. No.	Genotypes	Vine length at final harvest (cm)	No. of primary branches at final harvest	Days to 50 % flowering	Days to first fruit harvest
	Crosses				
1.	$L_1 \times T_1$	203.97	3.02	40.59	53.85
2.	$L_1 \times T_2$	263.50	2.99	45.27	58.33
3.	$L_1 \times T_3$	277.75	2.81	46.02	55.91
4.	$L_2 \times T_1$	236.52	2.98	47.99	59.87
5.	$L_2 \times T_2$	264.59	2.39	40.44	49.64
6.	$L_2 \times T_3$	213.32	3.08	35.58	48.94
7.	$L_3 \times T_1$	253.72	2.66	37.65	45.84
8.	$L_3 \times T_2$	183.50	2.57	42.12	53.12
9.	$L_3 \times T_3$	269.10	2.93	45.93	58.08
10.	$L_4 \times T_1$	197.79	3.14	45.08	60.23
11.	$L_4 \times T_2$	264.59	2.73	39.75	55.59
12.	$L_4 \times T_3$	226.97	3.42	41.87	53.83
13.	$L_5 \times T_1$	237.59	2.47	42.22	55.59
14.	$L_5 \times T_2$	231.20	3.29	38.7	49.98
15.	$L_5 \times T_3$	259.14	3.18	40.1	54.53
16.	$L_6 \times T_1$	271.16	2.81	43.28	54.18
17.	$L_6 \times T_2$	260.23	3.18	46.52	56.65
18.	$L_6 \times T_3$	194.71	3.11	44	54.53
19.	$L_7 \times T_1$	193.69	2.91	41.16	48.25
20.	$L_7 \times T_2$	194.71	2.89	42.57	48.25
21.	$L_7 \times T_3$	253.72	3.21	38.35	43.79
22.	$L_8 \times T_1$	183.50	2.60	43.64	54.89
23.	$L_8 \times T_2$	260.23	2.60	42.57	54.89

24.	$L_8 \times T_3$	253.72	2.53	41.51	54.89
25.	$L_9 \times T_1$	244.01	3.12	35.93	43.10
26.	$L_9 \times T_2$	254.80	2.47	40.81	46.53
27.	$L_9 \times T_3$	278.86	2.40	31.14	42.08
28.	$L_{10} \times T_1$	249.60	2.75	38.13	49.64
29.	$L_{10} \times T_2$	182.56	2.85	35.09	48.94
30.	$L_{10} \times T_3$	266.01	3.18	40.03	45.84
31.	$L_{11} \times T_1$	222.97	2.70	46.9	53.12
32.	$L_{11} \times T_2$	268.31	2.78	43.66	58.08
33.	$L_{11} \times T_3$	270.70	2.41	40.88	60.23
34.	$L_{12} \times T_1$	217.72	3.10	42.52	55.59
35.	$L_{12} \times T_2$	199.37	2.97	42.63	53.83
36.	$L_{12} \times T_3$	244.54	3.33	40.21	55.59

Table 3: Per cent heterosis over better parent (BP) and commercial checks (CC) for growth and flowering parameters in bitter gourd.

Sr. No.	Crosses	Vine length at final harvest (cm)		No. of primary branches at final harvest		Days to 50 % flowering		Days to first fruit harvest	
		BP	SH	BP	SH	BP	SH	BP	SH
1.	$L_1 \times T_1$	-5.31	-10.64	-8.22	2.73	-9.15	-3.05	-1.84	7.75
2.	$L_1 \times T_2$	9.43	15.44	15.25*	1.7	5.37	8.12	4.66	16.72**
3.	$L_1 \times T_3$	13.33	21.68	-12.48*	-4.43	9.10	9.92	-1.65	11.85*
4.	$L_2 \times T_1$	-15.85	3.62	-9.44	1.36	3.14	14.63	4.44	19.79**
5.	$L_2 \times T_2$	-5.86	15.91	-25.66**	-18.57**	-5.86	-3.4	-10.92	-0.69
6.	$L_2 \times T_3$	-24.10*	-6.55	-4.20	4.94	-15.65**	-15	-13.91**	-2.08
7.	$L_3 \times T_1$	0.86	11.15	-22.22**	-9.37	-20.25**	-10.07	-22.01**	-8.28
8.	$L_3 \times T_2$	-27.05*	-19.61	-24.85**	-12.44	-1.95	0.6	-4.68	6.29
9.	$L_3 \times T_3$	6.98	17.89	-14.47*	-0.34	8.89	9.7	2.16	16.21**
10.	$L_4 \times T_1$	-15.23	-13.35	-4.26	7.16	-4.51	7.68	7.64	20.52**
11.	$L_4 \times T_2$	9.88	15.91	6.23	-6.98	-7.47	-5.04	-0.25	11.22*
12.	$L_4 \times T_3$	-7.39	-0.57	6.71	16.52*	-0.73	0.97	-3.79	7.7
13.	$L_5 \times T_1$	14.16	4.09	-24.81**	-15.84*	-10.57	0.84	-5.42	11.22*
14.	$L_5 \times T_2$	-3.98	1.29	2.18	11.93	-9.92	-7.55	-10.31	9.23
15.	$L_5 \times T_3$	5.73	13.53	-1.09	8.35	-4.93	-4.22	-4.08	9.1
16.	$L_6 \times T_1$	30.29*	18.79	-14.31*	-4.09	-8.32	3.38	-7.82	8.4
17.	$L_6 \times T_2$	8.07	14.00	28.80**	8.18	8.28	11.12	1.65	13.35*
18.	$L_6 \times T_3$	-20.55	-14.70	-2.81	6.13	4.31	5.11	-4.08	9.1
19.	$L_7 \times T_1$	-6.93	-15.15	-12.48*	-0.85	-12.81**	-1.7	-17.91**	-3.46
20.	$L_7 \times T_2$	-19.14	-14.70	-13.08*	-1.53	-0.91	1.68	-13.42**	-3.46
21.	$L_7 \times T_3$	3.52	11.15	-3.31	9.54	-9.08	-8.4	-22.97**	-12.39*
22.	$L_8 \times T_1$	-28.59*	-19.61	-20.85**	-11.41	-7.56	4.24	-6.62	9.82
23.	$L_8 \times T_2$	1.27	14.00	-16.40*	-11.41	-0.91	1.68	-1.51	9.82
24.	$L_8 \times T_3$	-1.26	11.15	-21.06**	-13.80*	-1.59	-0.86	-3.45	9.82
25.	$L_9 \times T_1$	-8.15	6.90	-9.32	6.13	-7.59	-14.19	-15.59**	-13.77**
26.	$L_9 \times T_2$	-4.10	11.62	-28.24**	-16.01*	4.96	-2.52	-8.87	-6.9
27.	$L_9 \times T_3$	4.96	22.16	-30.28**	-18.40**	-19.90**	-25.63**	-17.58**	-15.81**
28.	$L_{10} \times T_1$	-3.27	9.35	-17.02**	-6.13	-19.23**	-8.92	-9.40	-0.69
29.	$L_{10} \times T_2$	-29.26*	-20.02	-14.01*	-2.73	-18.32**	-16.18	-10.68	-2.08
30.	$L_{10} \times T_3$	3.08	16.54	-4.07	8.52	-5.10	-4.4	-16.33**	-8.28
31.	$L_{11} \times T_1$	2.02	-2.32	-17.66**	-7.84	-0.66	12.03	-9.63	6.29
32.	$L_{11} \times T_2$	11.43	17.55	-12.70*	-5.11	1.63	4.3	4.2	16.21**
33.	$L_{11} \times T_3$	10.45	18.59	-24.80**	-17.89**	-3.08	-2.35	5.94	20.52**
34.	$L_{12} \times T_1$	-7.12	-4.62	-5.48	5.79	-9.93	1.56	-0.14	11.22*
35.	$L_{12} \times T_2$	-17.21	-12.66	2.59	1.19	-0.77	1.84	-3.31	7.7
36.	$L_{12} \times T_3$	-0.22	7.13	3.74	13.29*	-4.67	-3.95	-0.14	11.22*
	S.Em±	28.88	28.88	0.19	0.19	3.37	3.37	2.49	2.49
	CD at 5%	58.64	58.64	0.39	0.39	6.85	6.85	5.05	5.05
	CD at 1%	78.67	78.67	0.52	0.52	9.19	9.19	6.77	6.77

Note: * and ** indicate significance at values at p=0.05 and p=0.01, respectively
BP = Better parent; SH = Heterosis over commercial check (SW-814)

Table 4: *Per se* performance of parents for yield parameters in bitter gourd.

Sr. No.	Genotypes	Number of fruits per plant	Fruit length(cm)	Fruit diameter (cm)	Average Fruit weight (g)	Fruit yield per plant (kg)	Fruit yield per ha (tonnes)
	Lines						
1.	IC505640-1	10.71	8.45	28.23	66.35	0.71	4.98
2.	IC505640-2	12.82	8.15	30.97	76.43	0.98	8.48
3.	IC505640-3	12.16	11.83	27.19	45.20	0.55	4.91
4.	IC66023	8.08	10.26	28.68	34.96	0.37	4.32
5.	IC470556-1	7.88	11.89	43.18	34.33	0.27	8.03
6.	IC470555	10.89	9.02	32.85	26.83	0.29	4.21
7.	IC65972-1	15.00	9.70	29.95	45.79	0.69	3.98
8.	IC470553-2	13.16	15.01	32.89	73.00	0.96	4.83
9.	Katahi Vaibhav	19.68	16.07	28.17	69.34	1.37	9.45
10.	Green Long	16.86	14.93	33.27	71.56	1.21	8.58
11.	Dharog Local	13.80	13.13	30.66	55.32	0.77	8.01
12.	Monoecious	15.12	9.02	30.46	59.47	0.90	5.23
	Testers						
1	Co – 1	13.95	8.75	27.15	73.27	1.02	8.71
2	Preethi	17.65	11.58	31.63	79.16	1.39	9.96
3	Mysore Local	13.20	5.23	21.27	25.17	0.34	3.68
	Commercial checks						
1	SW-814	13.44	18.07	27.81	61.20	0.82	8.04
2	NS-1024	12.39	17.13	28.57	65.78	0.81	7.65
	S.Em±	0.60	0.75	2.17	1.55	0.05	0.27
	CD at 5%	1.69	2.14	6.15	4.40	0.13	0.77
	CDat 1%	2.25	2.85	8.20	5.87	0.17	1.02

Table 5: *Per se* performance of crosses for yield parameters in bitter gourd

Sr. No.	Genotypes	Number of fruits per plant	Fruit length (cm)	Fruit diameter (cm)	Average Fruit weight(g)	Fruit yield per plant(kg)	Fruit yield per ha (tonnes)
	Crosses						
1.	$L_1 \times T_1$	17.90	15.26	34.65	49.30	0.88	8.61
2.	$L_1 \times T_2$	18.34	15.77	33.18	54.71	1.01	8.45
3.	$L_1 \times T_3$	15.67	14.40	24.58	41.34	0.65	5.01
4.	$L_2 \times T_1$	23.20	12.22	24.65	76.48	1.77	8.52
5.	$L_2 \times T_2$	27.10	12.56	23.11	81.58	2.21	12.95
6.	$L_2 \times T_3$	25.30	13.62	29.26	55.37	1.40	7.56
7.	$L_3 \times T_1$	19.37	8.95	27.67	72.30	1.40	8.45
8.	$L_3 \times T_2$	9.54	10.51	29.94	76.40	0.73	6.49
9.	$L_3 \times T_3$	11.32	11.03	35.84	43.87	0.50	7.84
10.	$L_4 \times T_1$	12.26	10.92	31.00	62.98	0.77	7.45
11.	$L_4 \times T_2$	15.04	12.71	24.65	86.10	1.29	8.23
12.	$L_4 \times T_3$	23.24	9.15	33.04	57.28	1.33	7.98
13.	$L_5 \times T_1$	26.06	7.31	35.53	64.61	1.68	8.33
14.	$L_5 \times T_2$	17.55	15.36	26.37	76.58	1.34	12.48
15.	$L_5 \times T_3$	24.69	6.32	29.30	42.95	1.06	8.22
16.	$L_6 \times T_1$	15.62	13.54	33.38	77.78	1.21	7.77
17.	$L_6 \times T_2$	24.60	11.30	30.65	69.58	1.71	8.72
18.	$L_6 \times T_3$	14.95	16.23	35.78	42.25	0.63	5.12
19.	$L_7 \times T_1$	7.97	11.88	26.02	52.88	0.42	8.18
20.	$L_7 \times T_2$	9.33	9.41	21.97	61.19	0.57	4.89
21.	$L_7 \times T_3$	23.64	6.28	30.09	40.72	0.96	5.17
22.	$L_8 \times T_1$	18.94	10.52	29.44	57.36	1.11	8.28
23.	$L_8 \times T_2$	12.98	11.73	24.45	64.28	0.83	12.34
24.	$L_8 \times T_3$	17.25	11.15	25.38	40.92	0.70	7.92
25.	$L_9 \times T_1$	28.65	14.12	26.77	85.89	2.46	13.78
26.	$L_9 \times T_2$	31.56	13.59	28.75	91.16	2.87	14.32
27.	$L_9 \times T_3$	19.23	14.24	26.49	66.52	1.28	8.33
28.	$L_{10} \times T_1$	19.28	12.91	26.89	78.79	1.52	8.29
29.	$L_{10} \times T_2$	29.78	8.16	25.61	89.23	2.66	14.10
30.	$L_{10} \times T_3$	17.34	12.78	31.24	61.02	1.06	5.87
31.	$L_{11} \times T_1$	9.16	11.72	27.24	67.73	0.62	12.12
32.	$L_{11} \times T_2$	24.48	13.45	31.82	61.43	1.50	7.68
33.	$L_{11} \times T_3$	22.94	16.50	31.06	37.13	0.85	4.78
34.	$L_{12} \times T_1$	22.37	10.25	29.30	62.70	1.40	8.21
35.	$L_{12} \times T_2$	18.16	18.58	34.95	68.34	1.24	8.29
36.	$L_{12} \times T_3$	21.38	15.54	30.09	55.10	1.18	7.87

Table 6: Per cent heterosis over better parent (BP) and commercial checks (CC) for yield parameters in bitter gourd.

Sr. No.	Crosses	Number of fruits per vine		Fruit length (cm)		Fruit diameter(cm)		Average fruitweight(g)		Fruityield per plant(kg)		Fruityieldperha (tonnes)	
		BP	SH	BP	SH	BP	SH	BP	SH	BP	SH	BP	SH
1.	$L_1 \times T_1$	108.10**	61.44**	-13.78**	-3.18**	-11.46	-10.14	-32.71**	-19.44**	5.99	21.65**	28.32**	7.09
2.	$L_1 \times T_2$	135.14**	82.41**	-14.17**	-3.63**	4.88	19.29	-30.89**	-10.60**	0.63	9.28*	21.48**	5.16
3.	$L_1 \times T_3$	112.70**	65.01**	-11.23**	-0.36	-12.93	-11.63	-37.70**	-32.45**	0.9	-23.02**	0.6	-37.69**
4.	$L_2 \times T_1$	38.49*	38.49*	-10.81**	0.18	-20.41	-11.36	0.07	24.97**	9.36*	28.52**	0.47	5.97
5.	$L_2 \times T_2$	-23.47	-23.47	-18.67**	-8.69**	-26.94*	-16.9	3.06	33.30**	27.49**	49.83**	52.77**	61.13**
6.	$L_2 \times T_3$	64.15**	64.15**	-14.94**	-4.48**	-5.52	5.21	-27.55**	-9.53**	-32.16**	-20.27**	-10.85*	-5.97
7.	$L_3 \times T_1$	-0.36	3.12	-7.80**	3.49**	1.75	-0.52	-1.32	18.14**	3.59	18.90**	26.01**	5.16
8.	$L_3 \times T_2$	32.88*	37.52*	-18.60**	-8.60**	-5.33	7.68	-3.49	24.84**	2.53	11.34*	-6.75	-19.28**
9.	$L_3 \times T_3$	-23.1	-20.42	-5.61**	5.96**	-3.99	-6.13	-2.94	-28.32**	24.11**	-4.47	59.67**	-2.49
10.	$L_4 \times T_1$	90.84**	68.20**	-9.21**	1.93*	8.11	11.47	-14.04**	2.91	34.13**	53.95**	100.52**	67.35**
11.	$L_4 \times T_2$	105.36**	81.00**	-18.89**	-8.96**	-22.07*	-11.36	8.77**	40.69**	-2.53	5.84	18.25**	2.36
12.	$L_4 \times T_3$	75.95**	55.08**	-8.34**	2.91**	15.22	18.81	32.68**	-6.41	48.47**	5.09	84.72**	-0.75
13.	$L_5 \times T_1$	6.04	3.83	-12.97**	-2.28**	-17.01	-8.22	-11.82**	5.57	13.17**	29.90**	3.74	3.61
14.	$L_5 \times T_2$	23.47	20.9	-19.18**	-9.27**	-16.63	-5.18	-3.26	25.13**	49.37**	62.20**	71.61**	71.39**
15.	$L_5 \times T_3$	44.55**	41.54*	-17.64**	-7.53**	-4.75	5.34	-0.50	-29.81**	9.22*	5.84	2.37	2.24
16.	$L_6 \times T_1$	12.18	-3.76	-16.22**	-5.91**	1.6	20.03	6.16*	27.09**	-17.37**	-5.15	15.80**	-3.36
17.	$L_6 \times T_2$	62.07**	39.05*	-17.60**	-7.48**	-6.71	10.21	-12.10**	13.69**	25.95**	36.77**	25.29**	8.46
18.	$L_6 \times T_3$	47.72*	26.74	-10.71**	0.27	-12.13	3.81	-2.12	-30.96**	46.84**	-20.27**	21.62*	-36.32**
19.	$L_7 \times T_1$	92.37**	51.88**	-5.68**	5.91**	-13.14	-6.44	-27.83**	-13.59**	-10.18**	3.09	21.91**	1.74
20.	$L_7 \times T_2$	33.02	5.02	-17.86**	-7.75**	-30.52**	-20.98	-22.70**	-0.02	-33.23**	-27.49**	-29.74**	-39.18**
21.	$L_7 \times T_3$	19.97	-5.28	-13.56**	-2.96**	0.45	8.2	-11.07*	-33.46**	53.25**	-18.90**	29.90**	-35.70**
22.	$L_8 \times T_1$	7.35	7.07	-14.20**	-3.63**	-10.48	5.86	-21.71**	-6.27	-0.9	13.75**	23.40**	2.99
23.	$L_8 \times T_2$	82.89**	82.41**	-5.86**	5.69**	-25.63*	-12.06	-18.80**	5.03	44.30**	56.70**	77.30**	53.48**
24.	$L_8 \times T_3$	65.59**	65.15**	-17.33**	-7.17**	-22.82*	-8.74	-43.95**	-33.14**	35.55**	-1.72	63.98**	-1.49
25.	$L_9 \times T_1$	84.33**	81.52**	-13.74**	-3.14**	-4.97	-3.74	17.22**	40.34**	19.37**	56.70**	31.99**	55.22**
26.	$L_9 \times T_2$	155.10**	151.21**	-13.17**	-2.55**	60.95**	83.06**	15.16**	48.95**	42.41**	86.94**	51.45**	78.11**
27.	$L_9 \times T_3$	6.91	5.28	-12.05**	-1.25	-5.96	-4.75	-4.07	8.69*	-1.57	29.21**	-11.90**	3.61
28.	$L_{10} \times T_1$	17.99	23.43	-8.34**	2.91**	27.29**	52.30**	7.53*	28.74**	-8.51*	18.21**	-3.38	3.11
29.	$L_{10} \times T_2$	103.63**	113.02**	-11.29**	-0.40	31.65**	57.52**	12.72**	45.80**	34.57**	73.88**	64.34**	75.37**
30.	$L_{10} \times T_3$	-18.63	-14.88	-9.53**	1.57*	-6.12	12.33	-14.73**	-0.29	-35.64**	-16.84**	-31.59**	-26.99**
31.	$L_{11} \times T_1$	-21.84	-19.75	6.78**	19.89**	-11.15	-2.03	-7.56*	10.67**	25.75**	44.33**	51.31**	50.75**
32.	$L_{11} \times T_2$	-18.8	-16.62	3.59**	16.31**	0.62	14.44	-22.40**	0.38	-7.91	8.36	-4.12	-4.48
33.	$L_{11} \times T_3$	57.66**	61.88**	4.37**	17.20**	1.29	11.69	-32.88**	-39.33**	-22.56**	-29.21**	-40.32**	-40.55**
34.	$L_{12} \times T_1$	-11.72	24.14	-3.12**	8.78**	-3.82	5.34	-14.43**	2.45	-0.6	14.09**	22.35**	2.11
35.	$L_{12} \times T_2$	0.21	40.91*	-2.47**	9.50**	-11.89	0.22	-13.67**	11.66**	15.82**	25.77**	19.11**	3.11
36.	$L_{12} \times T_3$	-14.23	20.6	-1.68*	10.39**	-1.21	8.2	-7.35*	-9.97**	10.16*	-3.09	50.48**	-2.11
	S.Em±	2.08	2.08	0.73	0.73	3.31	3.31	2.13	2.13	0.06	0.06	0.38	0.38
	CD at 5%	4.22	4.22	1.49	1.49	6.72	6.72	4.33	4.33	0.13	0.13	0.77	0.77
	CD at 1%	5.66	5.66	2.01	2.01	9.02	9.02	5.81	5.81	0.17	0.17	1.04	1.04

Note: * and** indicate significance at values at p=0.05 and p=0.01, respectively
BP = Better parent; SH= Heterosis over commercial check (SW-814)

CONCLUSIONS

Based on mean performance, the top promising crosses for marketable yield per plant were Katahi Vaibhav × Preethi (2.87 kg), Green Long × Preethi (2.66 kg) and Katahi Vaibhav × Co-1 (2.46 kg). The hybrids namely, Katahi Vaibhav × Preethi, Green Long × Preethi and Katahi Vaibhav × Co-1 were best for earliness and yield parameters, the hybrids namely IC505640-2 × Co-1 and Green Long × Preethi were best for quality parameters and also expressed significant and desirable best parent heterosis and standard heterosis for the major traits. Thus, these hybrids can be exploited in practical plan breeding for selection of better transgressive segregants and they may also be exploited through heterosis breeding programme in order to achieve hybrids with high fruit yield.

FUTURE SCOPE

The crosses Katahi Vaibhav x Preethi, Green Long × Preethi and Katahi Vaibhav × Co-1 were the superior hybrids selected for yield These crosses can be further assessed for their yield to confirm their potentiality and also their adaptability to different areas before exploiting them on commercial scale. The parents Katahi Vaibhav, Green Long, Co-1 and Preethi have produced good yield per plant and they can be used in identifying superior new heterotic combinations.

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