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Genetic Magnitude of Heterosis for Yield and Quality Traits in Bitter Gourd (*Momordica charantia* L.)

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A B S T R A C T

To magnitude of heterosis for yield and quality traits was carried out in bitter gourd during *Kharif*-2016, *Kharif*-2017 and *Kharif*-2018, with fifteen diversified genotypes, three testers and their commercial check (Pusa Do Mausami) to developed 45 hybrids (F_1s) following by the Line × Tester mating design using for various yield and quality traits at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, BHU, Varanasi (UP). The parental mean and heterosis revealed that the parents OBGCBR-2 and IC-085611 were the best genotype for improvement of fruit yield, combined with quality traits. Highest degree of heterosis for most of the traits *i.e.*, fruit yield and quality traits were registered in desired direction in the hybrid OBGCBR-2 × Jaunpuri Green and Green Jhalari × Jaunpuri Green. For number of fruit plant^{-1} and average fruit weight positive and significant heterosis observed in cross OBGCBR-2 × IC-085611 found to be superior cross over commercial check followed by Meghna × Jaunpuri Green for number of fruit plant^{-1} over relative parent and heterobeltiosis. Quality heterosis for ascorbic acid and iron content was found in the desired direction in cross OBGCBR-1 × Jaunpuri Green. The highest desirable and significant, heterobeltiosis for iron content and commercial check for TSS was observed in the hybrids OBGCBR-2 × IC-085611. Therefore, considering the performance of magnitude of heterosis, hybrid 'OBGCBR-2 × Jaunpuri Green' revealed favourable value for most of the important traits like yield and quality traits. It can be tested over the season and location for assessing stability for high yield and quality.

Introduction

Bitter gourd (*Momordica charantia* L.) has been identified as one of the promising cucurbitaceous crops cultivated throughout the country for vegetable, high nutritive value and medicinal properties. Wide range of diversity in respect of vegetative and fruit character is existent in India and abroad. However, some gynoecious lines, lost of varieties and hybrids have been achieved in bitter gourd. But, the demand is to be expected 193MT by the year 2030. It can be fulfilled by the developing high-yielding hybrids, earliness as well as stability in qualities.

Exploitation of heterosis is very easy due to the being monoecious nature in cross pollination crop provides immense scope for improvement of hybrid vigour in breeding programme and to accomplish the populations. This is also providing valuable genetic resources (as maternal plants) in breeding programs for the production of F_1 hybrids (Behera *et al.,* 2010).

Materials and Methods

The experiment was conducted at Vegetable Research Farm, Department of Horticulture, Banaras Hindu University, Varanasi (UP) during *Kharif*-2016, *Kharif*-2017 and *Kharif*-2018 in a randomized complete block design with three replications.

Evaluation, selection and hybridization of genotypes were done during *Kharif* season 2016. The best fifteen diversified lines *viz.,* OBGCBR-2, OBGCBR-1, VRFBG-1, VRFBG-2, VRFBG-3, OBGCS-2, OBGCS-4, OBGCS-5, OBGCV-2, Katehi, Sakhi Gopal, Green Jhalari, Kateri, Preethi, Meghna and; three testers *viz.,* IC-085611, IC-085612 and Jaunpuri Green were done by hand-pollinated with each other to produce all the possible combinations of 45 F_1 hybrid, combinations through line × tester mating fashion (Kempthorn, 1957) over the Commercial Check (Pusa Do Mausami).

The observations were recorded from five randomly selected plants for fourteen economically important traits, *viz.,* number of primary branches plant^{-1}, fruit length (cm), fruit diameter (mm), fruit circumference/girth (cm), average fruit weight (g), number of seeds fruit^{-1}, number of fruits plant^{-1}, fruit yield plant^{-1} (kg) and fruits yield ha^{-1} (q). Quality traits *i.e.,* ascorbic acid (mg 100g^{-1}), total chlorophyll content (mg 100g^{-1}), iron content (mg 100g^{-1}) and total soluble solid (^{0}Brix). Heterosis breeding technique in bitter gourd was first started by Pal and Singh (1946). Magnitude of heterosis signifies increased or decreased vigour of the F_1 hybrids and can be defined as the hybrid vigour or the superiority of the hybrids over mid-parent (MP), better parent (BP) and commercial check (SC) values (Shull, 1914) using the method of Turner (1953) and Hayes *et al.,* (1956) in bitter gourd.

Results and Discussion

The magnitude of heterosis was calculated as per cent increase or decrease in the performance of F_1 hybrid over relative parent, better parent and commercial check in respect of all the traits (Presented in Table: 1 to 7).

The heterosis for fruit yield and quality characters is important as they contribute towards productions and qualities. The crosses OBGCV-2 × IC-085612 and VRFBG-3 × IC-085612 registered significant positive heterosis over mid parent and better parent for number of primary branches plant^{-1}; similarly OBGCBR-2 × IC-085611 and OBGCBR-2 × Jaunpuri Green showed positive significant heterosis over the commercial check for this trait. Heterosis for plant height recorded positive significant heterosis in the cross OBGCS-4 × IC-085612 over mid parent, better parent and commercial check. Similar findings were reported by Rani *et al.,* (2014), Ranpise *et al.,* (1992) and Kumar *et al.,* (2011).

With respect to fruit length, cross combination OBGCV-2 × IC-085612 and OBGCBR-2 × Jaunpuri Green recorded positive significant heterosis over mid parent and better parent; while OBGCBR-2 × Jaunpuri Green showed significant positive heterosis over commercial check. For the trait, fruit diameter, crosses Green Jhalari × Jaunpuri Green registered significant positive heterosis over mid parent and better parent;

while none of the cross showed significant positive heterosis for this trait. In case of fruit circumference, Green Jhalari × Jaunpuri Green and OBGCBR-1 × Jaunpuri Green recorded significant positive heterosis over mid parent; whereas Meghna × IC-085611 and OBGCBR-2 × Jaunpuri Green revealed significant positive heterosis over the better parent; while OBGCS-2 × IC-085611 and OBGCBR-1 × Jaunpuri Green registered significant positive heterosis over the commercial check for this trait.

Regarding, average fruit weight, crosses OBGCBR-2 × Jaunpuri Green and Meghna × Jaunpuri Green exhibited highest significant positive heterosis over mid parent and better parent; whereas OBGCBR-2 × IC-085611 and OBGCS-2 × IC-085611 recorded significant positive heterosis over commercial check.

Number of seeds fruit^{-1} should be less to make it more acceptable to the consumer; however, more number of seed is desirable for vegetable breeder point of view. The cross OBGCBR-2 × IC-085611 found significant positive heterosis over mid parent, better parent and over the commercial check for number of seeds fruit^{-1}.

Highly significant positive heterosis observed in the cross Meghna × Jaunpuri Green over the mid parent and better parent; while OBGCBR-2 × IC-085611 exhibited significant positive heterosis over the commercial check for number of fruit plant^{-1}.

For the trait, fruit yield plant^{-1} in kg and fruit yield quintal hectare^{-1} estimated high degree of heterosis in the crosses OBGCBR-2 × Jaunpuri Green and Meghna × Jaunpuri Green over mid parent; OBGCV-2 × IC-085612 and OBGCBR-2 × Jaunpuri Green over the better parent; whereas, OBGCS-4 × IC-085611 and OBGCBR-2 × Jaunpuri Green over the commercial check for the traits. These findings are similar to the earlier reports of Lawande and Patil (1990), Miniraj *et al.*, (1993), Mishra *et al.*, (1994), Sundaram (2008), Yadav *et al.*, (2009), Thangamani *et al.*, (2011), Thangamani and Pugalendhi (2013); and Verma and Singh (2014).

Quality traits are immense and versatile factor in hybrid improvement in bitter gourd. For the trait, ascorbic acid, cross VRFBG-2 × IC-085611 recorded positive significant heterosis for relative parent and heterobeltiosis; whereas VRFBG-2 × IC-085611 and OBGCBR-2 × IC-085611 showed significant positive heterosis over commercial check.

Total chlorophyll content exhibited positive significant heterosis in the cross OBGCBR-2 × Jaunpuri Green and OBGCBR-1 × IC-085611 over mid parent; OBGCBR-2 × IC-085612 for heterobeltiosis; similarly highest positive significant heterosis was estimated in the cross OBGCBR-2 × Jaunpuri Green over the commercial check for this trait.

In case of iron content, cross OBGCV-2 × IC-085612 and OBGCS-4 × IC-085611 had recorded highest positive heterosis over relative parent; OBGCBR-2 × IC-085611 and OBGCBR-2 × Jaunpuri Green for heterobeltiosis; while not a single cross recorded positive heterosis over commercial check.

Regarding, total soluble solid, cross OBGCS-2 × Jaunpuri Green expressed positive significant heterosis for relative parent; cross OBGCS-2 × IC-085611 and OBGCS-2 × Jaunpuri Green over better parents; however cross OBGCBR-2 × IC-085611 and OBGCS-2 × Jaunpuri Green over commercial check for TSS. The similar statements have been reported by Sundaram (2008); Talekar *et al.*, (2013); Kumar *et al.*, (2011); Thangamani and Pugalendhi (2013); Verma and Singh (2014); and Mallikarjunarao *et al.*, (2018).

Table.1 Estimation of heterosis of 45 F_1 hybrids for number of primary branches plant^{-1} and plant height (m) in bitter gourd (*Momordica charantia* L.)

Crosses	Number of primary branches plant^{-1}			Plant height (m)		
	MPH	BPH	Std H	MPH	BPH	Std H
OBGCBR-2 × IC-085611	27.02**	20.60*	19.85 *	36.60**	31.18*	36.77**
OBGCBR-2 × IC-085612	2.88	-5.47	-6.05	22.23*	11.73	4.18
OBGCBR-2 × Jaunpuri Green	21.55 *	15.41	14.69*	32.17**	17.88	16.17
OBGCBR-1 × IC-085611	16.06	16.06	3.67	25.24 *	-0.52	22.37
OBGCBR-1 × IC-085612	23.65**	19.44	6.70	50.95**	34.08 **	25.02*
OBGCBR-1 × Jaunpuri Green	1.94	1.94	-8.93	24.42*	7.92	6.36
VRFBG-1 × IC-085611	-4.00	-7.69	-10.67	-10.74	-19.56	-1.05
VRFBG-1 × IC-085612	2.00	-5.13	-8.19	10.23	7.17	5.79
VRFBG-1 × Jaunpuri Green	-16.16	-19.38 *	-21.99*	7.18	7.09	5.71
VRFBG-2 × IC-085611	0.00	0.00	-10.67	-6.54	-9.74	11.02
VRFBG-2 × IC-085612	6.40	2.78	-8.19	12.12	1.69	16.49
VRFBG-2 × Jaunpuri Green	2.78	2.78	-8.19	-10.08	-16.36	-4.18
VRFBG-3 × IC-085611	35.24**	18.33	5.71	21.86 *	5.17	29.36*
VRFBG-3 × IC-085612	42.03**	28.17 **	6.70	10.53	8.20	0.88
VRFBG-3 × Jaunpuri Green	4.76	-8.33	-18.11*	25.48 **	19.59	17.86
OBGCS-2 × IC-085611	38.79**	27.22**	13.65	9.71	4.91	29.04*
OBGCS-2 × IC-085612	7.00	1.34	-15.63	-8.14	-15.91	-5.63
OBGCS-2 × Jaunpuri Green	15.15	5.56	-5.71	-0.99	-7.03	4.34
OBGCS-4 × IC-085611	18.38	5.56	-5.71	0.34	-14.19	5.55
OBGCS-4 × IC-085612	32.79**	22.21 *	1.74	58.49**	53.49 **	43.12**
OBGCS-4 × Jaunpuri Green	12.15	0.00	-10.67	16.31	9.71	8.13
OBGCS-5 × IC-085611	-8.33	-8.33	-18.11*	10.02	1.64	24.00
OBGCS-5 × IC-085612	22.44 *	18.28	5.66	-13.32	-17.90	-14.40
OBGCS-5 × Jaunpuri Green	2.78	2.78	-8.19	-14.00	-16.36	-12.79
OBGCV-2 × IC-085611	30.16**	13.89	1.74	-5.87	-17.20	1.85
OBGCV-2 × IC-085612	50.88**	36.15**	13.35	42.67**	42.55**	33.15**
OBGCV-2 × Jaunpuri Green	20.63*	5.56	-5.71	-20.54	-22.61	-23.73
Katehi × IC-085611	-6.76	-7.93	-15.63	-18.95 *	-19.88*	-1.45
Katehi × IC-085612	-9.19	-13.35	-20.60*	-11.65	-21.55 *	-5.71
Katehi × Jaunpuri Green	-12.24	-13.35	-20.60*	-26.96**	-33.53**	-20.11
Sakhi Gopal × IC-085611	3.97	-8.33	-18.11*	-30.91**	-36.10**	-21.40
Sakhi Gopal × IC-085612	14.70	4.32	-13.15	0.16	-5.23	-0.97
Sakhi Gopal × Jaunpuri Green	19.72 *	5.56	-5.71	-15.53	-17.94	-14.24
Green Jhalari × IC-085611	-12.21	-13.89	-23.08 *	-9.06	-23.22*	-5.55
Green Jhalari × IC-085612	-14.48	-15.80	-27.67**	8.86	3.88	-3.14
Green Jhalari × Jaunpuri Green	-17.87 *	-19.44	-28.04**	-6.67	-13.22	-14.48
Katheri × IC-085611	1.33	-2.56	-5.71	-19.76 *	-21.78 *	-3.78
Katheri × IC-085612	-0.76	-7.69	-10.67	-7.85	-17.15	-3.22
Katheri × Jaunpuri Green	-14.67	-17.95	-20.60*	-13.63	-20.39	-7.00
Preethi × IC-085611	7.69	0.00	4.22	-15.25	-18.57	0.16
Preethi × IC-085612	-17.94*	-26.19**	-23.08*	1.71	-7.31	5.07
Preethi × Jaunpuri Green	-25.38**	-30.71**	-27.79**	-2.96	-9.30	2.82
Meghna × IC-085611	2.41	-1.86	-12.33	-11.44	-22.56 *	-4.75
Meghna × IC-085612	-0.83	-1.64	-18.11*	3.56	2.93	-4.02
Meghna × Jaunpuri Green	30.00**	24.58*	11.29*	20.51*	36.57**	24.88*

* Significant at p= 0.05, ** Significant at p= 0.01

Table.2 Estimation of heterosis of 45 F_1 hybrids for fruit length (cm) and fruit diameter (mm) in bitter gourd (*Momordica charantia* L.)

Crosses	Fruit length (cm)			Fruit diameter (mm)		
	MPH	BPH	Std H	MPH	BPH	Std H
OBGCBR-2 × IC-085611	42.96 **	32.49**	15.54*	6.99	-3.24	11.56
OBGCBR-2 × IC-085612	10.07	7.35	-6.39	22.66**	12.89	-0.75
OBGCBR-2 × Jaunpuri Green	46.92**	41.86**	23.71**	24.57**	19.35 *	-3.92
OBGCBR-1 × IC-085611	28.47**	17.34 *	5.64	3.95	-0.99	0.00
OBGCBR-1 × IC-085612	9.30	4.97	-5.50	9.40	2.31	3.34
OBGCBR-1 × Jaunpuri Green	-9.26	-13.71	-22.32**	13.23	1.74	2.76
VRFBG-1 × IC-085611	42.55**	41.72**	5.49	-6.24	-11.92	-8.39
VRFBG-1 × IC-085612	4.83	-1.07	-18.00*	-25.42**	-31.18**	-28.42**
VRFBG-1 × Jaunpuri Green	15.20	9.79	-10.86	-1.32	-12.47	-8.96
VRFBG-2 × IC-085611	-3.52	-4.32	-27.58**	8.33	2.31	5.21
VRFBG-2 × IC-085612	9.35	4.60	-13.30	-19.61**	-25.44**	-23.32**
VRFBG-2 × Jaunpuri Green	15.32	11.41	-9.54	19.71**	6.71	9.74
VRFBG-3 × IC-085611	6.89	4.37	-22.32**	13.29	11.81	2.20
VRFBG-3 × IC-085612	6.14	-1.52	-18.37*	10.04	9.36	-2.66
VRFBG-3 × Jaunpuri Green	36.96**	28.30**	4.17	14.20	8.74	-3.20
OBGCS-2 × IC-085611	29.00**	14.86	9.49	-3.16	-6.34	-14.40
OBGCS-2 × IC-085612	-1.43	-7.86	-12.17	14.11	12.48	-1.11
OBGCS-2 × Jaunpuri Green	-7.09	-13.97	-18.00*	-0.54	-3.39	-17.50*
OBGCS-4 × IC-085611	5.99	3.36	-23.07**	-22.07**	-24.32**	-26.60**
OBGCS-4 × IC-085612	26.82**	17.52	-2.59	-4.91	-9.36	-12.09
OBGCS-4 × Jaunpuri Green	0.53	-5.95	-23.63**	5.69	-3.29	-6.21
OBGCS-5 × IC-085611	7.45	5.80	-18.75*	-8.00	-12.47	-20.00*
OBGCS-5 × IC-085612	4.59	0.75	-16.49*	-2.32	-5.32	-16.76*
OBGCS-5 × Jaunpuri Green	15.70	12.56	-8.60	7.14	5.83	-12.67
OBGCV-2 × IC-085611	18.99 *	16.73	-13.11	5.41	-3.78	-12.05
OBGCV-2 × IC-085612	53.33 **	42.91**	18.45*	6.29	-1.23	-13.17
OBGCV-2 × Jaunpuri Green	11.26	4.70	-14.99*	12.14	8.63	-12.55
Katehi × IC-085611	4.75	-6.14	-11.80	5.69	3.32	-5.57
Katehi × IC-085612	8.03	1.66	-4.47	20.02 *	19.59 *	5.14
Katehi × Jaunpuri Green	6.50	-0.74	-6.73	24.24**	19.41 *	4.24
Sakhi Gopal × IC-085611	15.70	5.63	-21.38**	-4.38	-4.55	-12.45
Sakhi Gopal × IC-085612	12.63	10.27	-8.60	-7.22	-9.14	-16.67*
Sakhi Gopal × Jaunpuri Green	30.10**	14.30	-7.20	-3.27	-9.19	-16.71*
Green Jhalari × IC-085611	7.29	-3.97	-9.54	-2.28	-11.16	-18.80*
Green Jhalari × IC-085612	-8.59	-14.08	-19.07*	7.31	-0.70	-12.70
Green Jhalari × Jaunpuri Green	14.07	6.20	0.04	26.96**	22.45 *	-1.43
Katheri × IC-085611	14.91	13.75	-13.58	-7.85	-12.12	-19.68*
Katheri × IC-085612	-6.22	-10.13	-25.51**	9.90	6.79	-6.12
Katheri × Jaunpuri Green	-4.26	-7.33	-24.76**	13.87	12.20	-6.95
Preethi × IC-085611	33.31**	28.33**	3.23	3.27	-7.44	-15.40
Preethi × IC-085612	-3.96	-5.37	-21.57**	10.35	0.64	-11.52
Preethi × Jaunpuri Green	-4.58	-5.02	-22.88**	25.24**	18.97	-4.23
Meghna × IC-085611	38.06**	22.81**	17.32*	-18.80*	-25.33**	-31.75**
Meghna × IC-085612	-7.66	-13.77	-17.62*	10.19	3.16	-9.30
Meghna × Jaunpuri Green	29.37**	19.67 *	14.32	11.19	8.57	-12.60

* Significant at p= 0.05, ** Significant at p= 0.01

Table.3 Estimation of heterosis of 45 F_1 hybrids for fruit circumference/girth (cm) and average fruit weight (g) in bitter gourd (*Momordica charantia* L.)

Crosses	Fruit circumference /girth (cm)			Average fruit weight (g)		
	MPH	BPH	Std H	MPH	BPH	Std H
OBGCBR-2 × IC-085611	17.52**	6.70	14.57*	49.82**	25.11 *	48.61**
OBGCBR-2 × IC-085612	1.98	-2.89	-0.91	25.63 *	20.31	4.63
OBGCBR-2 × Jaunpuri Green	8.30	19.93**	2.99	75.76**	70.46**	35.67**
OBGCBR-1 × IC-085611	-2.43	-3.50	0.00	38.05**	2.02	21.19
OBGCBR-1 × IC-085612	6.70	1.92	3.31	45.57**	20.31	4.63
OBGCBR-1 × Jaunpuri Green	20.89**	-5.68	15.40**	31.52*	15.68	-13.48
VRFBG-1 × IC-085611	-9.05	-10.63	-7.39	7.28	-16.27	-0.54
VRFBG-1 × IC-085612	-2.70	-6.46	-6.44	16.03	2.46	-10.89
VRFBG-1 × Jaunpuri Green	-1.87	-7.69	-7.66	20.90	14.31	-14.51
VRFBG-2 × IC-085611	8.42	0.83	4.49	-4.97	-29.34**	-16.07
VRFBG-2 × IC-085612	-1.95	-3.64	-11.07	-7.67	-23.12	-33.14**
VRFBG-2 × Jaunpuri Green	10.31	9.72	-2.22	48.39**	31.60**	-1.58
VRFBG-3 × IC-085611	-0.10	-0.46	3.90	-18.11 *	-19.87 *	-0.54
VRFBG-3 × IC-085612	0.03	-5.76	-1.63	-20.47 *	-32.37**	-16.06
VRFBG-3 × Jaunpuri Green	2.56	-5.41	-1.27	9.36	-12.37	8.76
OBGCS-2 × IC-085611	5.93	18.42**	18.21**	37.73**	16.40	38.26**
OBGCS-2 × IC-085612	-1.48	-5.59	-4.94	22.59	19.09	3.57
OBGCS-2 × Jaunpuri Green	-4.95	-10.86	-10.25	3.77	-0.78	-18.65
OBGCS-4 × IC-085611	-14.75**	-16.81**	-13.79*	-40.07**	-51.11**	-41.93**
OBGCS-4 × IC-085612	-0.14	-3.36	-4.67	39.36**	29.77 *	12.86
OBGCS-4 × Jaunpuri Green	-0.56	-5.84	-7.12	22.43	22.26	-8.30
OBGCS-5 × IC-085611	-13.30**	-14.16 *	-11.04	-8.48	-24.98 *	-10.89
OBGCS-5 × IC-085612	-11.63 *	-15.67**	-14.33*	-14.75	-20.15	-30.55*
OBGCS-5 × Jaunpuri Green	-3.54	-9.91	-8.48	7.93	7.11	-18.65
OBGCV-2 × IC-085611	-11.18 *	-16.52**	-13.49*	1.86	-13.66	2.56
OBGCV-2 × IC-085612	12.95 *	12.26	3.61	60.65**	56.59**	36.19**
OBGCV-2 × Jaunpuri Green	-1.57	-3.18	-11.75*	23.11	17.31	-3.13
Katehi × IC-085611	-6.62	-12.58 *	-9.41	2.49	-14.09	2.05
Katehi × IC-085612	2.78	1.72	-6.12	19.99	15.43	0.39
Katehi × Jaunpuri Green	13.79 *	12.39	1.59	32.84 *	28.24*	3.05
Sakhi Gopal × IC-085611	-12.65 *	-14.46 *	-11.36	-30.95**	-41.10**	-30.03*
Sakhi Gopal × IC-085612	0.83	-2.74	-3.40	-13.36	-14.91	-25.99*
Sakhi Gopal × Jaunpuri Green	-14.13 *	-18.95**	-19.50**	15.98	9.71	-7.99
Green Jhalari × IC-085611	-5.66	-15.75**	-12.70*	-23.22 *	-29.34**	-16.07
Green Jhalari × IC-085612	-0.03	-5.90	-13.15*	22.52 *	14.61	14.46
Green Jhalari × Jaunpuri Green	23.53**	18.83**	4.76	19.20	4.24	4.09
Katheri × IC-085611	-18.05**	-18.16**	-15.19*	-36.12**	-39.27**	-27.86*
Katheri × IC-085612	-6.80	-11.78*	-8.84	-10.29	-18.71	-12.96
Katheri × Jaunpuri Green	1.60	-5.86	-2.72	-12.81	-25.95 *	-20.72
Preethi × IC-085611	0.34	-2.41	1.13	41.68**	-3.20	14.98
Preethi × IC-085612	2.74	-0.23	-2.27	49.90**	12.46	-2.20
Preethi × Jaunpuri Green	-12.04 *	-16.44**	-18.14**	18.27	-6.45	-30.03*
Meghna × IC-085611	-15.40**	20.57**	-17.69**	4.19	-17.32	-1.79
Meghna × IC-085612	-6.21	-6.88	-14.06*	14.25	2.94	-10.48
Meghna × Jaunpuri Green	14.71 *	12.94 *	14.74*	69.52**	63.81**	22.51

* Significant at p= 0.05, ** Significant at p= 0.01

Table.4 Estimation of heterosis of 45 F_1 hybrids for number of seeds fruit^{-1} and number of fruits plant^{-1} in bitter gourd (*Momordica charantia* L.)

Crosses	Number of seeds fruit^{-1}			Number of fruits plant^{-1}		
	MPH	BPH	Std H	MPH	BPH	Std H
OBGCBR-2 × IC-085611	58.06**	51.23**	39.63**	88.12 **	63.32**	46.01**
OBGCBR-2 × IC-085612	3.70	3.70	-4.26	43.92 **	42.65 **	-10.14
OBGCBR-2 × Jaunpuri Green	21.92 *	10.89	25.00*	93.49 **	76.94 **	31.46**
OBGCBR-1 × IC-085611	0.23	-8.50	-6.53	84.45 **	49.43 **	6.14
OBGCBR-1 × IC-085612	7.84	2.66	4.86	63.26 **	39.74 **	-13.52
OBGCBR-1 × Jaunpuri Green	-2.40	-6.98	4.86	89.18 **	74.40 **	-8.94
VRFBG-1 × IC-085611	5.44	-1.56	-4.26	53.04 **	26.50 *	-10.14
VRFBG-1 × IC-085612	3.41	0.78	-1.98	84.91 **	61.77 **	0.11
VRFBG-1 × Jaunpuri Green	16.16	8.19	21.96*	58.19 **	49.37 **	-22.0 **
VRFBG-2 × IC-085611	13.63	3.70	6.00	68.75 **	35.91 **	-3.46
VRFBG-2 × IC-085612	7.80	2.58	4.86	34.18 **	14.13	-29.37**
VRFBG-2 × Jaunpuri Green	-19.40 *	-23.15*	-13.37	40.69 **	28.80	-32.75**
VRFBG-3 × IC-085611	12.72	8.25	-0.84	1.67	1.19	-27.44**
VRFBG-3 × IC-085612	12.79	12.35	3.72	22.79 *	14.38	-17.98*
VRFBG-3 × Jaunpuri Green	-0.71	-10.01	1.44	51.01 **	30.49 **	-6.43
OBGCS-2 × IC-085611	25.91 **	7.05	26.90*	80.39 **	63.01 **	25.79**
OBGCS-2 × IC-085612	-7.03	-17.31	-1.98	33.77 **	28.86 *	-20.25**
OBGCS-2 × Jaunpuri Green	-3.40	-5.77	11.70	27.01 *	21.33	-30.43**
OBGCS-4 × IC-085611	8.33	5.56	-6.16	17.24	1.92	-27.60**
OBGCS-4 × IC-085612	-7.34	-9.05	-16.03	13.75	15.10	34.96**
OBGCS-4 × Jaunpuri Green	-3.90	-14.05	-3.12	28.80 *	28.48	-32.58**
OBGCS-5 × IC-085611	12.82	7.32	0.30	60.68 **	39.20 **	-1.13
OBGCS-5 × IC-085612	5.52	4.88	-1.98	16.32	7.07	-33.74**
OBGCS-5 × Jaunpuri Green	-8.24	-16.08	-5.40	49.90 **	49.64 **	-21.86**
OBGCV-2 × IC-085611	-17.98 *	-29.81**	-16.79	20.68 *	11.55	-20.77**
OBGCV-2 × IC-085612	11.71	-0.64	17.78	82.74 **	80.36 **	11.62
OBGCV-2 × Jaunpuri Green	-25.09**	-26.92**	-13.37	27.81 *	19.26	-28.11**
Katehi × IC-085611	7.95	-6.86	8.28	2.03	-6.91	-33.87**
Katehi × IC-085612	-2.73	-12.75	1.44	29.63 **	26.18 *	-12.91
Katehi × Jaunpuri Green	-16.38 *	-17.65	-4.26	14.82	8.58	-36.39**
Sakhi Gopal × IC-085611	3.23	-1.23	-8.81	11.21	1.53	-27.88**
Sakhi Gopal × IC-085612	-2.06	-2.06	-9.57	1.72	-0.93	-38.69**
Sakhi Gopal × Jaunpuri Green	-22.18 **	-29.22**	-20.21	12.55	6.36	-37.60**
Green Jhalari × IC-085611	16.86*	5.49	9.42	-2.22	-6.35	-33.48**
Green Jhalari × IC-085612	0.00	-5.49	-1.98	-15.86	-17.90	-46.61**
Green Jhalari × Jaunpuri Green	7.42	3.13	16.26	14.24	2.98	-33.03**
Katheri × IC-085611	-9.69	-24.42**	-5.40	9.26	8.59	-12.87
Katheri × IC-085612	-8.81	-20.78 *	-0.84	8.55	2.15	-28.33**
Katheri × Jaunpuri Green	-25.03**	-28.76**	-10.83	6.50	-7.12	-34.84**
Preethi × IC-085611	25.15 **	14.61	16.26	84.70**	45.64**	3.48
Preethi × IC-085612	-3.53	-7.87	-6.53	26.74 *	5.38	-34.79**
Preethi × Jaunpuri Green	-21.98 *	-25.88**	-16.45	65.42**	47.68**	-22.89**
Meghna × IC-085611	0.52	-10.36	-3.50	20.62	1.60	-27.83**
Meghna × IC-085612	1.45	-5.77	1.44	76.60**	13.04	-30.04**
Meghna × Jaunpuri Green	3.78	1.45	14.36	111.48**	104.22**	36.63**

* Significant at p= 0.05, ** Significant at p= 0.01

Table.5 Estimation of heterosis of 45 F_1 hybrids for fruits yield plant^{-1} (kg) and fruits yield ha^{-1} (q) in bitter gourd (*Momordica charantia* L.)

Crosses	Fruits yield plant^{-1} (kg)			Fruits yield ha^{-1} (q)		
	MPH	BPH	Std H	MPH	BPH	Std H
OBGCBR-2 × IC-085611	38.34**	29.74**	23.61*	38.36**	29.75**	23.56 *
OBGCBR-2 × IC-085612	9.44	8.84	-9.20	9.47	8.89	-9.21
OBGCBR-2 × Jaunpuri Green	41.76 **	35.85**	33.34**	41.85 **	35.93 **	33.33**
OBGCBR-1 × IC-085611	29.07 **	7.91	2.82	29.15 **	7.97	2.81
OBGCBR-1 × IC-085612	23.91 *	10.04	-9.20	23.96 *	10.07	-9.21
OBGCBR-1 × Jaunpuri Green	10.50	1.52	-22.37*	10.58	1.59	-22.36*
VRFBG-1 × IC-085611	4.84	-8.61	-12.92	4.85	-8.61	-12.97
VRFBG-1 × IC-085612	3.73	-3.61	-20.46*	3.76	-3.60	-20.48*
VRFBG-1 × Jaunpuri Green	4.27	0.43	-23.20*	4.46	0.61	-23.11*
VRFBG-2 × IC-085611	-5.28	-20.43*	-24.19**	-5.28	-20.44*	-24.24**
VRFBG-2 × IC-085612	-13.95	-23.19*	-36.62**	-13.93	-23.19 *	-36.64**
VRFBG-2 × Jaunpuri Green	22.11	12.78	-13.75	22.24	12.90	-13.72
VRFBG-3 × IC-085611	-8.10	-8.70	-13.01	-8.00	-8.60	-12.97
VRFBG-3 × IC-085612	-14.12	-19.38*	-24.19**	-14.14	-19.39 *	-24.24**
VRFBG-3 × Jaunpuri Green	9.91	-0.35	-6.30	10.09	-0.20	-6.20
OBGCS-2 × IC-085611	30.27**	20.87 *	15.16	30.47**	20.99 *	15.21
OBGCS-2 × IC-085612	9.80	9.14	-9.94	9.87	9.14	-9.98
OBGCS-2 × Jaunpuri Green	-6.55	-9.45	-26.18**	-6.37	-9.23	-26.12**
OBGCS-4 × IC-085611	-32.51**	-40.26**	43.08**	-32.41**	-40.17**	43.03**
OBGCS-4 × IC-085612	24.12 *	17.27	-3.23	24.19 *	17.32	-3.23
OBGCS-4 × Jaunpuri Green	8.68	6.50	-18.56*	8.69	6.51	-18.61*
OBGCS-5 × IC-085611	-9.22	-16.52	-20.46*	-9.19	-16.50	-20.48*
OBGCS-5 × IC-085612	-19.63 *	-20.88	-34.71**	-19.65 *	-20.91	-34.76**
OBGCS-5 × Jaunpuri Green	-5.51	-7.56	-26.10**	-5.48	-7.53	-26.12**
OBGCV-2 × IC-085611	0.37	-6.26	-10.69	0.40	-6.24	-10.71
OBGCV-2 × IC-085612	37.71**	37.58**	13.75	37.73**	37.61**	13.71
OBGCV-2 × Jaunpuri Green	7.03	3.01	-14.83	7.08	3.05	-14.85
Katehi × IC-085611	-1.24	-6.61	-11.02	-1.26	-6.63	-11.09
Katehi × IC-085612	4.80	3.32	-12.26	4.82	3.34	-12.29
Katehi × Jaunpuri Green	11.09	5.56	-10.36	11.16	5.63	-10.36
Sakhi Gopal × IC-085611	-26.29**	-31.13**	-34.38**	-26.24**	-31.10**	-34.39**
Sakhi Gopal × IC-085612	-17.09	-17.22	-31.48**	-17.00	-17.10	-31.46**
Sakhi Gopal × Jaunpuri Green	2.50	-1.40	-18.39*	2.60	-1.28	-18.38 *
Green Jhalari × IC-085611	-17.68 *	-20.43*	-24.19**	-17.69*	-20.4 *	-24.24**
Green Jhalari × IC-085612	14.26	10.16	-2.07	14.32	10.22	-2.07
Green Jhalari × Jaunpuri Green	9.32	1.68	-9.61	9.40	1.75	-9.60
Katheri × IC-085611	-28.95**	-29.48**	-32.81**	-28.92**	-29.44**	-32.81**
Katheri × IC-085612	-11.51	-16.86	-21.96*	-11.50	-16.84	-21.99*
Katheri × Jaunpuri Green	-15.08	-22.95 *	-27.67**	-14.97	-22.85 *	-27.62**
Preethi × IC-085611	30.37**	3.22	-1.66	30.33**	3.23	-1.70
Preethi × IC-085612	24.30 *	4.02	-14.17	24.29 *	4.06	-14.17
Preethi × Jaunpuri Green	-0.63	-14.19	-34.38**	-0.62	-14.14	-34.39**
Meghna × IC-085611	2.41	-9.57	-13.84	2.43	-9.55	-13.87
Meghna × IC-085612	2.61	-3.31	-20.22*	2.71	-3.23	-20.18*
Meghna × Jaunpuri Green	38.91**	35.75 **	3.81	38.96 **	35.80**	3.77

* Significant at p= 0.05, ** Significant at p= 0.01

Table.6 Estimation of heterosis of 45 F_1 hybrids for ascorbic acid (mg $100g^{-1}$) and total chlorophyll content (mg $100g^{-1}$) in bitter gourd (*Momordica charantia* L.)

Crosses	Ascorbic acid (mg $100g^{-1}$)			Total chlorophyll content (mg $100g^{-1}$)		
	MPH	BPH	Std H	MPH	BPH	Std H
OBGCBR-2 × IC-085611	14.31**	10.58	21.85**	**18.16 ****	8.69	1.92
OBGCBR-2 × IC-085612	-4.99	-10.14	-0.98	**22.06 ****	21.28 **	-3.28
OBGCBR-2 × Jaunpuri Green	-2.43	-7.32	2.12	**27.24 ****	**14.63 ***	12.56*
OBGCBR-1 × IC-085611	8.44	2.77	5.86	**26.91 ****	**16.04 ***	8.82
OBGCBR-1 × IC-085612	-1.36	-4.37	-6.05	4.45	3.12	-17.76**
OBGCBR-1 × Jaunpuri Green	-4.46	-7.79	-8.58	3.28	-7.49	-9.16
VRFBG-1 × IC-085611	-3.55	-15.20 *	-12.66*	-29.85 **	-33.08**	-30.88**
VRFBG-1 × IC-085612	0.13	-10.13	-11.70	-1.48	-12.71 *	-9.84
VRFBG-1 × Jaunpuri Green	1.69	-9.09	-9.87	-8.03	-10.30	-7.35
VRFBG-2 × IC-085611	26.48**	18.57 **	22.13**	-0.86	-2.77	-8.82
VRFBG-2 × IC-085612	21.71**	16.68 **	14.63*	-1.46	-7.15	-16.29**
VRFBG-2 × Jaunpuri Green	8.18	3.26	2.38	-11.71*	-15.32 *	-16.86**
VRFBG-3 × IC-085611	9.46	8.75	12.02*	-11.27 *	-13.16 *	-14.93 *
VRFBG-3 × IC-085612	1.47	-0.24	1.43	9.10	-1.04	-3.05
VRFBG-3 × Jaunpuri Green	-4.88	-6.06	-4.49	-11.19 *	-11.29	-12.90*
OBGCS-2 × IC-085611	14.59**	10.77	14.10*	15.29 *	6.88	0.23
OBGCS-2 × IC-085612	1.98	0.89	-0.88	10.54	10.31	-11.65*
OBGCS-2 × Jaunpuri Green	-7.32	-8.72	-9.50	-20.94 **	-28.23**	-29.52**
OBGCS-4 × IC-085611	-0.08	-3.48	-0.58	7.32	3.50	-2.94
OBGCS-4 × IC-085612	2.93	1.75	-0.03	-2.78	-6.88	-18.89**
OBGCS-4 × Jaunpuri Green	-10.08	-11.51	-12.27*	-16.61 **	-21.31**	-22.74**
OBGCS-5 × IC-085611	-10.81*	-16.31**	-13.80*	-7.80	-12.72 *	-8.37
OBGCS-5 × IC-085612	-5.57	-9.39	-10.98	4.35	-8.19	-3.62
OBGCS-5 × Jaunpuri Green	-1.32	-5.73	-6.53	-12.25 *	-15.09**	-10.86
OBGCV-2 × IC-085611	5.28	-0.74	2.24	-2.14	-8.15	-1.81
OBGCV-2 × IC-085612	9.71	5.79	3.93	9.94	-4.02	2.60
OBGCV-2 × Jaunpuri Green	4.02	-0.14	-0.99	-10.54 *	-14.18 *	-8.26
Katehi × IC-085611	3.31	-2.09	0.85	-8.35	-10.01	-15.61**
Katehi × IC-085612	-5.48	-8.37	-9.98	-20.35 **	-25.03**	-32.24**
Katehi × Jaunpuri Green	-1.17	-4.62	-5.43	-13.26 *	-16.71**	-18.21**
Sakhi Gopal × IC-085611	6.87	5.58	11.44	3.26	-6.27	-12.10*
Sakhi Gopal × IC-085612	2.70	-0.85	4.65	**18.61 ****	16.17 *	-7.35
Sakhi Gopal × Jaunpuri Green	-9.03	-11.79 *	-6.89	-7.12	-17.40**	-18.89**
Green Jhalari × IC-085611	-7.09	-9.22	-6.49	**20.23 ****	14.72 *	7.58
Green Jhalari × IC-085612	-2.92	-2.94	-4.60	**13.17 ***	9.56	-6.67
Green Jhalari × Jaunpuri Green	-2.62	-3.04	-3.87	0.31	-6.34	-8.03
Katheri × IC-085611	15.73**	12.20 *	15.57*	-6.31	-6.59	-11.88*
Katheri × IC-085612	-2.00	-2.77	-4.47	-15.14 *	-21.70**	-26.13**
Katheri × Jaunpuri Green	-8.54	-9.66	-10.43	-8.70	-10.48	-12.10*
Preethi × IC-085611	6.16	0.59	3.61	0.07	-7.48	-13.24*
Preethi × IC-085612	21.90**	18.14 **	16.07**	**18.38 ****	18.30 *	-5.66
Preethi × Jaunpuri Green	1.62	-1.94	-2.78	6.49	-3.57	-5.32
Meghna × IC-085611	-5.18	-5.42	-2.09	-18.45**	-21.67 **	-20.25**
Meghna × IC-085612	-3.46	-5.92	-2.61	-0.19	-11.00	-9.39
Meghna × Jaunpuri Green	10.55*	8.22	13.42*	3.51	1.67	3.51

* Significant at p= 0.05, ** Significant at p= 0.01

Table.7 Estimation of heterosis of 45 F_1 hybrids for iron content (mg $100g^{-1}$) and total soluble solids (^{0}Brix) in bitter gourd (*Momordica charantia* L.)

Crosses	Iron content (mg $100g^{-1}$)			Total soluble solids (^{0}Brix)		
	MPH	BPH	Std H	MPH	BPH	Std H
OBGCBR-2 × IC-085611	19.66**	18.67 *	6.11	30.31**	25.36 **	32.72**
OBGCBR-2 × IC-085612	-14.54 *	-15.44 *	-23.75**	-1.28	-5.03	0.54
OBGCBR-2 × Jaunpuri Green	16.17 *	17.43*	9.42	23.59**	20.74 *	27.83**
OBGCBR-1 × IC-085611	9.94	8.05	-5.81	-1.07	-4.64	0.54
OBGCBR-1 × IC-085612	-8.19	-10.33	-20.84**	-13.90	-17.01 *	-12.50
OBGCBR-1 × Jaunpuri Green	-9.78	-16.22 *	-17.74*	6.79	4.54	10.22
VRFBG-1 × IC-085611	-0.05	-4.31	-8.82	-2.24	-3.87	-2.72
VRFBG-1 × IC-085612	12.01	7.89	2.81	-8.57	-10.10	-9.02
VRFBG-1 × Jaunpuri Green	-2.64	-4.08	-5.81	2.90	2.79	4.02
VRFBG-2 × IC-085611	-3.06	-12.53	-23.75**	19.56 *	19.56 *	16.96
VRFBG-2 × IC-085612	-0.06	-10.33	-20.84**	-3.89	-3.89	-5.98
VRFBG-2 × Jaunpuri Green	1.19	-13.27	-14.83*	1.15	-0.43	0.54
VRFBG-3 × IC-085611	7.60	5.75	-7.82	-10.80	-13.78	-15.65
VRFBG-3 × IC-085612	-13.54	-15.55 *	-25.45**	6.32	2.78	0.54
VRFBG-3 × Jaunpuri Green	0.00	-7.14	-8.82	21.54**	15.72	16.85
OBGCS-2 × IC-085611	13.66 *	8.33	4.21	41.13**	29.44**	25.13**
OBGCS-2 × IC-085612	-15.81 *	-19.27**	-22.34**	12.05	2.78	0.54
OBGCS-2 × Jaunpuri Green	-24.54**	-25.31**	-26.65**	42.26**	28.63**	29.89**
OBGCS-4 × IC-085611	-2.77	-11.15	-22.55**	2.87	-0.56	-2.72
OBGCS-4 × IC-085612	22.05**	10.90	-2.10	16.78 *	12.89	10.43
OBGCS-4 × Jaunpuri Green	10.59	-4.08	-5.81	24.53**	15.72	16.85
OBGCS-5 × IC-085611	1.48	-5.63	-17.74*	2.78	2.78	0.54
OBGCS-5 × IC-085612	0.68	-6.92	-17.84*	6.11	6.11	3.80
OBGCS-5 × Jaunpuri Green	-9.72	-20.41**	-21.84**	11.10	9.36	10.43
OBGCV-2 × IC-085611	9.86	-10.34	-21.84**	15.88	6.22	3.91
OBGCV-2 × IC-085612	34.73**	9.42	-3.41	33.94**	22.78 *	20.11*
OBGCV-2 × Jaunpuri Green	11.11	-13.27	-14.83*	3.04	-6.89	-5.98
Katehi × IC-085611	-9.48	-19.89 *	-30.16**	-15.81 *	17.64 *	-15.76
Katehi × IC-085612	27.66**	12.37	-0.80	-6.03	-8.08	-5.98
Katehi × Jaunpuri Green	-3.03	-18.37**	-19.84**	-1.07	-1.70	0.54
Sakhi Gopal × IC-085611	-5.39	-10.23	-21.74**	-7.62	-15.76	-15.65
Sakhi Gopal × IC-085612	-15.76 *	-20.54**	-29.86**	10.12	2.78	0.54
Sakhi Gopal × Jaunpuri Green	-17.09 *	-25.51**	-26.85**	-5.79	-13.35	-12.50
Green Jhalari × IC-085611	6.33	4.56	-5.71	2.95	-0.52	4.35
Green Jhalari × IC-085612	5.56	4.44	-5.81	-0.80	-4.15	0.54
Green Jhalari × Jaunpuri Green	-3.19	-7.14	-8.82	-6.34	-8.08	-3.59
Katheri × IC-085611	-10.92	-15.55 *	-17.84*	29.44**	-25.44**	26.63**
Katheri × IC-085612	-11.34	-15.45 *	-17.74*	-8.33	-8.33	-10.33
Katheri × Jaunpuri Green	-15.84 *	-16.22 *	-17.74*	1.15	-0.43	0.54
Preethi × IC-085611	3.41	2.25	-8.82	2.64	-0.78	-2.93
Preethi × IC-085612	-4.01	-4.49	-14.83*	7.47	3.89	1.63
Preethi × Jaunpuri Green	-19.79**	-23.47**	-24.85**	4.58	-0.43	0.54
Meghna × IC-085611	-9.32	-15.52 *	-26.35**	16.41	6.78	4.46
Meghna × IC-085612	-2.94	-10.10	-20.64**	3.57	-5.00	-7.07
Meghna × Jaunpuri Green	13.58*	0.31	-1.50	25.60**	13.56	14.67

* Significant at p= 0.05, ** Significant at p= 0.01

Hence, through the heterosis breeding, it is useful to select promising hybrids having one in more importance characters like higher yield and quality traits in the F_1 hybrids. The hybrids OBGCBR-2 × IC-085611 and Meghna × Jaunpuri Green registered heterotic hybrids for most of the important trait like fruit yield. In order of merit *viz.*, OBGCBR-2 × Jaunpuri Green and OBGCBR-2 × IC-085611 were noted to be the top promising hybrids with respect to quality trait since they had showed significant and positive heterotic value.

These hybrids could be better utilized for intermating among superior segregants resulting from these heterotic hybrids and desirable progenies in later generations for further action.

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