Journal of Applied Horticulture, 26(1): 78-82, 2024
https://doi.org/10.37855/jah.2024.v26i01.15
Journal of Applied Horticulture
ISSN: 0972-1045

Development of hybrids in bitter gourd for charantin and other qualitative traits

B. Srinivasulu[1], S.S. Vijaya Padma[2], L. Naram Naidu[3], Ch. Kiran Kumar[4] and V. Sekhar[5]

*[1]Department of Vegetable Science, C.O.H., V.R. Gudem, Andhra Pradesh. [2]Department of Horticulture, C.O.H., Chinalataripi, Andhra Pradesh.[3]Department of Horticulture, Dr. Y.S.R. Horticultural University, Andhra Pradesh. [4]Department of Soil Science and Agronomy, C.O.H., Parvathipuram, Andhra Pradesh. [5]Department of agricultural statistics, C.O.H., V.R. Gudem, Andhra Pradesh. *E-mail: bsvas333@gmail.com*

Abstract

Commercial exploitation of bitter gourd hybrids is primarily focused on yield, while limited research has been conducted on the quality aspects of this crop. The study was conducted during the *Summer* and *Kharif* seasons of 2022 to identify superior hybrids compared to the standard checks in terms of significant quality traits. A total of 21 crosses were produced by crossing seven genetically distinct parents in a half diallel mating pattern during the *summer* of 2022. A total of 7 parents, 21 F1 hybrids, and 2 checks were assessed using a randomized complete block design with three replications during the *Kharif* season of 2022. The crosses, *viz*., Kashi Mayuri x IC-44418 and IC-44418 x IC-68314 have shown better performance in terms of quality aspects such as TSS. On the other hand, Kashi Mayuri x Special Boldar and IC-44418 x Special Boldar were found to be superior than commercial checks, Pragathi and Monarch for vitamin-C. Significantly greater heterosis for iron content was observed in the crosses *viz*., Kashi Mayuri x IC-469512, IC-433630 x IC-469512, and Kashi Mayuri x Special Boldar. Charantin, known for its antidiabetic properties, is a significant quality character present in fruits. The hybrids *viz*., IC-44418 x IC-68314, IC-433630 x IC-68314, and IC-68314 x IC-469512 demonstrated a significant increase in charantin heterosis. The superior cross combinations identified in this study warrant further evaluation to assess their potentiality and stability for commercial release as hybrids or varieties.

Key words: Charantin, TSS, vitamin-C, iron, quality and *Momordica charantia* L.

Introduction

Bitter gourd (*Momordica charantia* L.) is one of the most important cucurbitaceous vegetable crops grown throughout the country. It is commonly known as bitter melon, karela and balsam pear, *etc*. It is believed to be originated in tropical Asia, particularly eastern India. It belongs to the Cucurbitaceae family, subfamily-Cucurbitodeae, tribe-Joliffeae and subtribe-Thalithaneae with chromosome number 2n=2x=22. It is an indigenous tropical vegetable crop with versatile importance as a vegetable and traditional medicine. The fruits are usually consumed fresh but can also be dried and pickled (Pradhan *et al*., 2021). It is a large genus comprising nearly 23 species in Africa alone.

The highest species diversity is found in Africa and South East Asian countries. Recently six species closely related to bitter gourd have been reported in India: four dioecious and two monoecious. Monoecious species include *M. charantia* and *M. balsamina*, while dioecious species include *M. dioica*, *M. sahyadrica*, *M. cochhinchinensis*, and *M.subangulata* (Joseph and Antony, 2007). Apart from *M. charantia*, other species of genus *Momordica* namely *Momordica balsamina*, *M. dioica*, *M. cymbalaria* and *M. cochinchinensis* are consumed for medicinal and nutritional properties (Bharathi and John, 2013).

In India, the area under bitter gourd cultivation is 1.01 lakh ha, with an annual production of 12 lakh tonnes and productivity of 12.16 Mt/ha. Chhattisgarh, Telangana, Andhra Pradesh, Odisha, Madhya Pradesh, Uttar Pradesh and Bihar are the country's major bitter gourd producing states. In Andhra Pradesh, bitter gourd production is 1.09 lakh tonnes from 11,000 ha with a productivity of 14 t/ha (N.H.B. database, 2021-22).

The abundance of nutrients like vitamins, minerals, phytonutrients, antioxidants, polyphenols *etc*. make it a healthy vegetable, while the presence of phytonutrients like charantin, vicine and L-peptide makes it a traditional medicine for curing many ailments. It is an ancient medicinal vegetable crop due to different kinds of chemicals acting as antioxidants, antimicrobial, antidiabetic antiviral, anti-hepatotoxic and antiulcers. The bitter taste of fruits and other plant parts is due to the momordicine alkaloid. Bitter gourd fruits have antidiabetic properties due to the hypoglycaemic substance charantin, and they help reduce blood sugar (Goo *et al.*, 2016). A peptide designated charantin is a typical cucurbitane-type tri-terpenoid, which is highly effective in controlling blood glucose in relation to insulin resistance (Goo *et al.*, 2016). Thus, bitter gourd is considered a vegetable insulin in the medical community, where research is going on to find new effective plant sources for curing diabetes. However, research on evaluating bitter gourd for high charantin content has been less attempted.

The scope for utilization of heterosis largely depends on the direction and magnitude of heterosis. Heterosis is expressed as relative heterosis, heterobeltiosis and standard heterosis, depending on the criteria used to compare the performance of a hybrid. Heterosis is the superiority of a hybrid over its mid parent (relative heterosis) or over its better parent (heterobeltiosis)

or over the standard check (standard/economic/commercial heterosis). The relative heterosis will only help to understand the genetic status of the characters. However, from a practical point of view, standard heterosis is the most important of the three types of heterosis.

In bitter gourd, TSS, vitamin C, iron and charantin are the important quality parameters of fruit and heterosis in a positive direction would be desirable for these traits. In the present investigation, hybrids were tested for their superiority over mid-parent, better parent and standard checks for the important qualitative traits.

Materials and methods

The present investigation was conducted at the College of Horticulture, Dr.Y.S.R. Horticultural University, Venkataramannagudem, West Godavari District of Andhra Pradesh during Summer and Kharif 2022. At 34 m (112 ft) above mean sea level, the site has been identified to exist in Agro-climatic zone 10, Humid, East Coast Plain and Hills (Krishna-Godavari zone), with an average rainfall of 900 mm. The area has summers that are hot-humid and pleasant winters.

Mating design: Seven parental lines were crossed in all possible combinations excluding reciprocals in half-diallel fashion, resulting in 21 single crosses. The reciprocal crosses were avoided, presuming the absence of maternal effect in the experimental material. The seven parents included in the present study with their accession numbers are given in Table 1.

Table 1. List of parental lines and checks with their source

S. No.	Parents / Commercial checks	Source
1	Preethi	K.A.U., Thrissur, Kerala
2	Kashi Mayuri	I.I.V.R., Varanasi, Uttar Pradesh
3	IC-44418	NBPGR, Thrissur, Kerala
4	IC-68314	NBPGR, Thrissur, Kerala
5	IC-433630	NBPGR, Thrissur, Kerala
6	IC-469512	NBPGR, Thrissur, Kerala
7	Special Boldar	N.B.P.G.R., Thrissur, Kerala
8	Pragati (Commercial check)	East West Seeds, Andhra Pradesh
9	Monarch (Commercial check)	Hyveg seeds, Haryana

Crossing technique: The staminate and pistillate flower buds about to open in the following day were bagged separately with butter paper bags on the evening. On the next morning, pollen grains from the bagged staminate flowers were dusted on the bagged female flowers of the lines between 6.00 AM to 8.00 AM. The dusted pistillate flowers were covered with butter paper bags and labeled with details of the cross and the date of pollination. The paper covers were removed after 3-5 days after pollination to facilitate fruit development. In this crossing system, a total of 21 new cross-combinations were generated. The seeds were extracted from fully ripened fruits, dried, and stored in paper covers labeled with cross details.

Statistical analysis: The resultant 21 hybrids and parents were evaluated during Summer and Kharif seasons of 2022 in a Randomized Complete Block Design with three replications. The data were recorded on five randomly selected vines from each replication for various traits like Charantin, TSS, Vitamin-C and Iron. Heterosis was calculated as the percentage increase or decrease of mean F_1 performance (F_1) over the means of the mid parent (MP), better parent (BP), and the standard checks (S.C.) following formulae given by Jinks and Jones (1958).

Biochemical analysis

Total soluble solids (°Brix): Total soluble solids in fruit juice were computed using Abbe's refractometer (0 -32 °Brix) at room temperature. The values were corrected at 100 ºC with the help of a temperature correlation chart and depicted as percent TSS of juice.

Vitamin-C content (mg 100 g^{-1}): Ten grams of bitter gourd sample was ground well with 3 percent metaphosphoric acid and the volume was made up to 100 mL with 3 percent metaphosphoric acid. The contents were shaken well and filtered through filter paper. 10 mL of the aliquot was taken and titrated against standard dye solution (2, 6-dichlorophenol indophenol dye) till the light pink colour persisted for at least 15 seconds (Sadasivam and Manickam, 1992). The vitamin-C content was estimated using the given formula and expressed as mg 100 g^{-1}.

$$\text{Vitamin-C content} = \frac{\text{Titre value} \times \text{dye factor} \times \text{volume made up}}{\text{Aliquot taken} \times \text{weight of the sample}}$$

Iron content (mg 100 g^{-1}): Two grams of sample was taken in a flask and then 2 mL of a di-acid mixture of nitric acid and per choleric acid in the ratio of 9:3 was added to it. The flask was then kept undisturbed overnight and the next day it was placed on a hot plate at 115-118 ºC for digestion till a watery transparent aliquot was obtain. The digested sample was then filtered and diluted with double distilled water to make the final volume up to 50 mL. Iron was then estimated by Versand method (Jackson, 1973).

Charantin content (mg 100g^{-1}): 0.5g of dried sample was refluxed for 2 hours in 20 mL of 80 percent methanol. This process was repeated thrice and the supernatant was collected in a 50 mL volumetric flask. Volume was made up to 50 mL with 80 percent methanol (Hlaing and Kyaw, 2005).

Results and discussion

Heterosis breeding has achieved greater importance in boosting the growth, earliness and yield contributing traits of many cucurbitaceous vegetables. The superiority of F_1 over the mean of the parents, the better parent, or the standard check is termed 'Heterosis' (Hayes *et al.*, 1955). The analysis of variance was carried out to test the significance of differences among genotypes for all the characters. The mean sum of squares due to parents showed significant differences for the traits studied. The data on heterosis over mid-parent, a better parent and standard checks for different parameters were presented in Tables 2 and 3.

Qualitative traits

TSS (°Brix): The relative heterosis and heterobeltiosis for total soluble solids as indicated by the data from Table 2, ranged from -42.46 and -56.57 (Preethi x IC-469512) to 38.37 and 16.19 percent (IC-469512 x Special Boldar) respectively. The range of standard heterosis over Pragathi varied from -46.10 (Preethi x IC-469512) to 22.87 percent (Kashi Mayuri x IC-44418), whereas the heterosis over Monarch ranged from -52.05(Preethi x IC-469512) to 9.31(Kashi Mayuri x IC-44418).

Five and 2 hybrids recorded significant positive heterosis, whereas 9 and 14 of the hybrids manifested significant negative heterosis over mid and better parent. Fourteen and five hybrids

Table 2. Estimates of relative heterosis (R.H.), heterobeltiosis (Hb) and standard heterosis (S.H.) for TSS and vitamin C in bitter gourd

No	Cross combinations	TSS (°Brix)				Vitamin-C content (mg 100 g^{-1})			
		RH	Hb	SH		RH	Hb	SH	
				Pragathi	Monarch			Pragathi	Monarch
1	Preethi x Kashi Mayuri	4.97**	4.57*	21.81**	8.36**	1.34	-1.92	18.94**	2.13
2	Preethi x IC-44418	-1.41	-1.4	14.01**	1.42	0.15	-1.51	15.61**	-0.73
3	Preethi x IC-433630	-3.86*	-8.23**	6.09*	-5.63*	9.68**	6.09**	20.38**	3.37
4	Preethi x IC-68314	6.25**	-0.92	14.54**	1.8	9.35**	3.77	17.76**	1.12
5	Preethi x IC-469512	-39.5**	-53.37**	-46.1**	-52.05**	13.49**	12.96**	28.19**	10.07**
6	Preethi x Special Boldar	-19.88**	-23.77**	-11.88**	-21.61**	2.24	-2.1	21.4**	4.24*
7	Kashi Mayuri x IC-44418	5.86**	5.48*	22.87**	9.31**	3.91*	2.25	24**	6.48**
8	Kashi Mayuri x IC-433630	7.07**	1.83	18.62**	5.52*	3.41*	-3.08	17.53**	0.92
9	Kashi Mayuri x IC-68314	-1.4	-8.42**	6.68**	-5.1*	-10.38**	-17.54**	0.98	-14.13**
10	Kashi Mayuri x IC-469512	18.55**	-8.88**	6.15*	-5.57*	-3.19	-6.71**	13.13**	-2.86
11	Kashi Mayuri x Special Boldar	-6.61**	-11.47**	3.13	-8.25**	7.00**	5.82**	31.22**	12.68**
12	IC-44418 x IC-433630	-0.46	-5.01*	9.87**	-2.26	6.96**	1.79	19.49**	2.60
13	IC-44418 x IC-68314	13.29**	5.62**	22.16**	8.68**	-2.41	-8.85**	7.00**	-8.12**
14	IC-44418 x IC-469512	27.72**	-1.58	13.83**	1.2	6.58**	4.33*	22.47**	5.16**
15	IC-44418 x Special Boldar	-4.59*	-9.25**	4.96*	-6.62**	7.62**	4.75*	29.9**	11.54**
16	IC-433630 x IC-68314	1.84	-0.62	4.43	-7.1**	22.19**	19.81**	27.04**	9.08**
17	IC-433630 x IC-469512	34.09**	6.97**	12.41**	0.00	7.96**	4.89*	17.93**	1.26
18	IC-433630 x Special Boldar	-13.32**	-13.61**	-9.22**	-19.24**	11.45**	3.38	28.19**	10.07**
19	IC-68314 x IC-469512	8.62**	-11.7**	-11.7**	-21.45**	3.71*	-1.15	11.14**	-4.57*
20	IC-68314 x Special Boldar	0.98	-1.13	3.19	-8.2**	-9.66**	-17.72**	2.03	-12.39**
21	IC-469512 x Special Boldar	45.27**	16.19**	21.28**	7.89**	6.6**	1.63	26.02**	8.21**
	Range	-42.26 to 38.37	-56.57 to 16.19	-46.10 to 22.87	-52.05 to 9.31	-10.25 to 21.83	-17.72 to 19.11	0.98 to 31.22	-14.13 to 12.68

**1% level of significance, *5% level of significance

Table 3. Estimates of relative heterosis (R.H.), heterobeltiosis (Hb) and standard heterosis (S.H.) for iron and charantin in bitter gourd

No	Cross combinations	Iron content (mg 100 g^{-1})				Charantin content (mg 100 g^{-1})			
		RH	Hb	SH		RH	Hb	SH	
				Pragathi	Monarch			Pragathi	Monarch
1	Preethi x Kashi Mayuri	92.84**	18.18**	41.2**	93.33**	22.31**	8.16**	23.26**	-14.52**
2	Preethi x IC-44418	90.52**	44.6**	-24.72**	3.08	19.25**	9.71**	48.84**	3.23
3	Preethi x IC-433630	175.21**	95.88**	24.72**	70.77**	17.58**	2.00	58.14**	9.68**
4	Preethi x IC-68314	83.61**	51.35**	-37.08**	-13.85**	16.63**	-9.7**	87.6**	30.11**
5	Preethi x IC-469512	-10.81**	-46.77**	-25.84**	1.54	33.94**	21.67**	69.77**	17.74**
6	Preethi x Special Boldar	266.3**	148.76**	87.27**	156.41**	7.91**	2.0	16.28**	-19.35**
7	Kashi Mayuri x IC-44418	101.31**	44.51**	72.66**	136.41**	-9.72**	-25.71**	0.78	-30.11**
8	Kashi Mayuri x IC-433630	98.36**	52.04**	81.65**	148.72**	34.19**	5.00*	62.79**	12.9**
9	Kashi Mayuri x IC-68314	84.19**	24.14**	48.31**	103.08**	18.11**	-16.04**	74.42**	20.97**
10	Kashi Mayuri x IC-469512	78.87**	66.13**	131.46**	216.92**	29.01**	5.00*	46.51**	1.61
11	Kashi Mayuri x Special Boldar	125**	83.39**	119.1**	200**	35.25**	25.95**	27.91**	-11.29**
12	IC-44418 x IC-433630	90.29**	72.94**	10.11**	50.77**	16.27**	9**	68.99**	17.2**
13	IC-44418 x IC-68314	108.8**	87.77**	-2.25	33.85**	23.25**	1.87	111.63**	46.77**
14	IC-44418 x IC-469512	96.48**	34.95**	88.01**	157.44**	12.11**	10.56**	54.26**	6.99**
15	IC-44418 x Special Boldar	21.76**	2.99	-22.47**	6.15	11.76**	-2.29	32.56**	-8.06**
16	IC-433630 x IC-68314	64.41**	35.88**	-13.48**	18.46**	7.69**	-5.97**	95.35**	35.48**
17	IC-433630 x IC-469512	119.19**	59.68**	122.47**	204.62**	11.58**	6**	64.34**	13.98**
18	IC-433630 x Special Boldar	27.76**	17.91**	-11.24**	21.54**	3.93	-14**	33.33**	-7.53**
19	IC-68314 x IC-469512	47.41**	-4.3*	33.33**	82.56**	5.8**	-11.57**	83.72**	27.42**
20	IC-68314 x Special Boldar	157.69**	100**	50.56**	106.15**	-8.27**	-31.72**	41.86**	-1.61
21	IC-469512 x Special Boldar	85.69**	43.01**	99.25**	172.82**	58.2**	36.67**	90.7**	32.26**
	Range	-10.81 to 266.30	-46.77 to 148.76	-37.08 to 131.46	-13.85 to 216.92	-10.03 to 58.20	-31.46 to 36.67	0.78 to 111.63	-30.11 to 46.77

**1% level of significance, *5% level of significan

recorded significant positive heterosis over Pragathi and Monarch, whereas four and eleven hybrids exhibited negative heterosis over the standard checks, respectively (Table 2 and Fig. 1). The positive heterosis is desirable and useful for total soluble solids content. Superiority of this trait was observed by Jadhav *et al.* (2009), Murlee *et al.* (2009), Suresh (2009) and Talukdar *et al.* (2010) in bitter gourd.

Vitamin-C content (mg 100 g^{-1}): From Table 2, it was observed that the relative heterosis and heterobeltiosis for vitamin-C ranged from -10.25 and -21.83 (Kashi Mayuri x IC-68314) to 21.83 and 19.11 percent (IC-433630 x Ic-68314) respectively. The range of standard heterosis varied from 0.98 and -14.33 (Kashi Mayuri x IC-68314) to 31.22 and 12.68 percent (Kashi Mayuri x Special Boldar) over Pragathi and Monarch, respectively.

Thirteen and nine hybrids recorded significant positive heterosis, whereas 2 and 3 of the hybrids manifested significant negative heterosis over mid and better parent. Of the 21 hybrids, 19 and 9 hybrids have recorded significant positive heterosis over Pragathi and Monarch. None of the hybrids recorded significant negative standard heterosis over the Pragathi, whereas three hybrids recorded significant negative heterosis over the Monarch (Table 2 and Fig. 2). The heterosis in a positive direction is desirable and useful for ascorbic acid content. The superiority of this trait was observed by Thangamani *et al.* (2011), Talekar *et al.* (2013), Lalwani *et al.* (2014) and Bhatt *et al.* (2017).

Iron content (mg 100 g^{-1}): A perusal of the data on heterosis for iron content (Table 3 and Fig. 3) indicated an increase over mid and better parent value in the range of -10.81 and -46.77 (Preethi x IC-469512) to 266.30 and 148.76 percent (Preethi x Special Boldar) respectively. The standard heterosis over Pragathi was in the range of -37.08 (Preethi x IC-68314) to 131.46 (Kashi Mayuri x IC-469512) percent, whereas the standard heterosis over Monarch was in the range of -13.85 to 216.92.

Among 21 hybrids studied, 20 and 18 hybrids have shown significant positive relative heterosis and heterobeltiosis, respectively, whereas significant negative relative heterosis and heterobeltiosis were observed in only one and two hybrids, respectively. Fourteen and seven hybrids were significantly superior by exhibiting significant positive heterosis over check Pragathi whereas 6 and 1 were significantly inferior by exhibiting significant negative heterosis over check Monarch. For Iron content, heterosis in positive direction is most desirable. Similar results are reported by workers like Amrita *et al.* (2020) and Bajrang *et al.* (2020) in bitter gourd.

Charantin content (mg 100 g^{-1}): The relative heterosis as indicated by the data from Table 3 ranged from -10.03 (Kashi Mayuri x IC-44418) to 58.20 percent (IC-68314 x Special boldar) while heterobeltiosis ranged from -31.46 (IC-68314 x Special Boldar) to 36.67 (IC-469512 x Special Boldar) respectively. The range of standard heterosis varied from 0.78 and -30.11 (Kashi Mayuri x IC-44418) to 111.63 and 46.77 percent (IC-44418 x IC-68314) over the checks Pragathi and Monarch.

Eighteen and ten hybrids recorded significant positive heterosis whereas 2 and 7 of the hybrids manifested significant negative heterosis over mid and better parent. Among the 21 hybrids, 19 were observed as superior over Pragathi and none of the hybrids exhibited significant negative heterosis over Pragathi whereas 11 hybrids recorded significant positive heterosis and six hybrids were exhibited significant negative heterosis over Monarch (Table 3 and Fig. 4). The charantin is an important quality attribute and antidiabetic in nature. It reduces the blood glucose levels in the human body and works like an insulin compound. In this regard, positive heterosis is desirable.

Quality characteristics are very important in any crop because they impart nutritional quality. In the present study, the hybrids exhibited significant variation in quality characteristics like TSS, vitamin C, iron, and charantin. For TSS content in the fruits, the hybrids Kashi Mayuri x IC-44418 and IC-44418 x IC-68314 have exhibited significant positive heterosis over the standard checks. Kashi Mayuri x Special Boldar and IC-44418 x Special Boldar were superior to the checks Pragathi and Monarch for the trait Vitamin-C. Iron is also found appreciable in hybrids like Kashi Mayuri x IC-469512, IC-433630 x IC-469512 and Kashi Mayuri

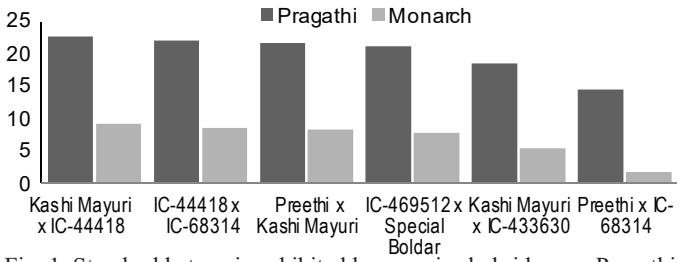

Fig. 1. Standard heterosis exhibited by superior hybrids over Pragathi and Monarch for TSS (°Brix).

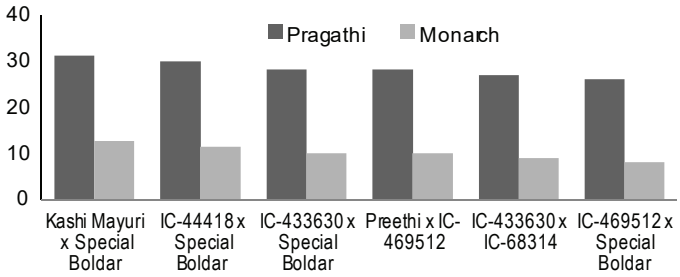

Fig. 2. Standard heterosis exhibited by superior hybrids over Pragathi and Monarch for vitamin-C content (mg 100 g^{-1}).

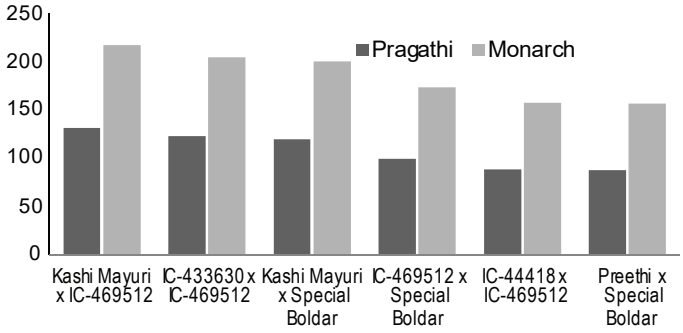

Fig. 3. Standard heterosis exhibited by superior hybrids over Pragathi and Monarch for iron content (mg 100 g^{-1}).

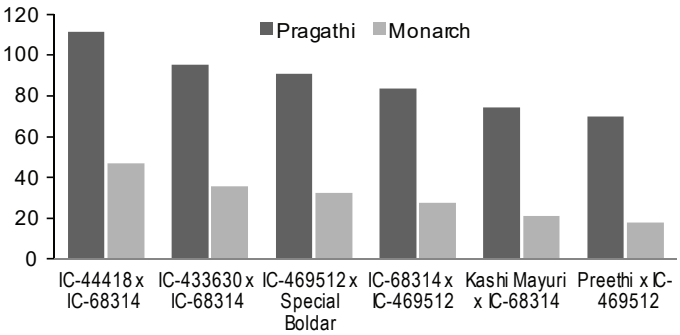

Fig. 4. Standard heterosis exhibited by superior hybrids over Pragathi and Monarch for charantin content (mg 100 g^{-1}).

x Special Boldar, which were also identified as superior over the checks. For the antidiabetic compound like charantin, IC-44418 x IC-68314, IC-433630 x IC-68314 and IC-68314 x IC-469512 were exhibited significant standard heterosis over the Pragathi and Monarch. The hybrids/cross combinations, identified as better performers over standard checks are to be further tested/evaluated under multilocational trails and seasons before being released as varieties or hybrids for commercial purposes.

Acknowledgement

We are very grateful for the facilities provided by the Division of Vegetable Science, Division of Plant Breeding and Genetics, Dr. Y.S.R. Horticultural University, Venkataramannagudem, Andhra Pradesh, for conduct of the research programme.

References

Amrita, K., S. Sangeeta, K. Randhir, K. Chandan, V.K. Singh and M. Haque, 2020. Estimation of heterosis for yield and quality traits in bitter gourd (*Momordica charantia* L.). *Int. J. Curr. Microbiol. Appl. Sci*., 9: 1614-1623.

Bajrang, K., K.S. Anand, P. Prachi, M. Diksha, A.K. Pal and K.S. Binod, 2020. Line × Tester analysis for estimation of heterosis in bitter gourd (*Momordica charantia* L.). *J. Pharmacogn. Phytochem.*, 9: 486-490.

Bhatt, L., S.P. Singh, A.K. Soniand M.K. Samota, 2017. Studies on heterosis in bitter gourd (*Momordica charantia*L.). *Int. J. Curr. Microbiol. Appl. Sci*., 6: 4069-4077.

Bharathi, L.K. and K.J. John, 2013. *Momordica Genus in Asia-An Overview* (p.147). New York: Springer.

Goo, K.S., S. Ashari, N. Basuki and A.N Sugiharto, 2016. The bitter gourd (*Momordica charantia* L.) morphological aspects, charantin and vitamin-C contents. *J. Agric. Vet. Sci.,* 9: 2319-2322.

Hayes, H.K., E.R. Immerand D.C. Smith, 1955. *Methods of Plant Breeding*. McGraw-Hill publications in the agricultural sciences, New York. pp.551.

Hlaing, S. and H.A. Kyaw, 2005. Phytochemical studies in *Momordica*sps. Linn. and extraction and isolation of charantin from the fruit of *Momordica charantia* L. *J. Myanmar Acad. Arts Sci.,* 3: 225-236.

Jackson, M.L.1973. *Soil Chemical Analysis*. Prentice – Hall of India Private Limited, New Delhi.

Jadhav, K.A., B.V. Garad, S.S. Dhumal, D.B. Kshirsagar, B.T. Patil and K.G. Shinde, 2009. Heterosis in bitter gourd (*Momordica charantia* L.). *Agric. Sci. Dig.,* 29: 7-11.

Jinks, J.L. and R.M. Jones, 1958. Estimation of the components of heterosis. *Genetics*, 43: 223-234.

Lalwani, H.H., M.A. Vaddoria, K. Jyoti, D.R. Mehta and K.J. Jog, 2014. Heterosis and in breeding depression studies in bitter gourd for yield and related characters. *Progress. Res. J*., 9: 914-917.

Murlee, Y., C. Rashmi and D.B. Singh, 2009. Heterosis in bitter gourd (*Momordica charantia* L.). *J. Hortic. Sci.,* 4: 170-173.

N.H.B. Data Base. 2021-22. Published by *National Horticulture Board*. Department of Agriculture and Co-operation Government of India.

Pradhan., P., P. Tripathy, G.S. Sahu, B. Tripathy and S. Shyama, 2021. Assessment of genetic variability in F_4 segregating population of bitter gourd (*Momordica charantia* L.). *J. Pharmacogn. Phytochem.*, 10: 1452-1455.

Sadasivam, S. and A. Manickam, 1992. *Standard Methods of Biometrical Analysis*. Kalyani Publishers, New Delhi. 64-65.

Suresh, K. 2009. *Development of F_1 Hybrids in Bitter Gourd for Yield and Downy Mildew Resistance*. Ph. D.Diss.University of Agricultural Sciences, G.K.V.K., Banglore.

Talukdar, M.B., M.M. Rahman, M.K. Islam, K.A.M.M. Rahman and M.A. Hossen, 2010. Estimate of heterosis in bitter gourd. *J. Sher-e-Bangla Agric. Univ.,* 4: 73-79.

Thangamani, C., L. Pugalendhi, T. Sumath, C. Kavitha and V. Rajashree, 2011. Estimation of combining ability and heterosis for yield and quality characters in bitter gourd (*Momordica charantia*L.). *Electron. J. Plant Breed.*, 2: 62-66.

Talekar, N.S., M.A. Vaddoria and G.U. Kulkarani, 2013. Heterosis studies for quantitative traits in bitter gourd (*Momordica charantia* L.). *Progress. Res. J*., 8: 650-653.

Received: September, 2024; Revised: December, 2023; Accepted: January, 2024