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Exploitation of heterosis in bitter gourd for horticultural traits

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ABSTRACT

A field experiment was carried out at the Vegetable Experimental Field, College of Horticulture, Venkataramannagudem, Andhra Pradesh, during the Summer and *Kharif* seasons of 2022. Seven diverse parents, along with 21 hybrid combinations, were evaluated in a randomized complete block design with three replications. Several hybrids, including IC-44418 × IC-433630, IC-68314 × Special Boldar, and Preethi × Kashi Mayuri, demonstrated superior performance compared to standard checks in terms of days to first male and female flower appearance and days to first picking. Notably, IC-469512 × Special Boldar and Preethi × Special Boldar combinations exhibited significantly larger fruit diameters compared to Pragathi and Monarch. With regard to yield and its components, such as the number of fruits per plant and average fruit weight, the crosses IC-469512 × Special Boldar, Preethi × Special Boldar, and IC-433630 × IC-469512 emerged as the top performers. These promising hybrid combinations can be evaluated across diverse locations and seasons to confirm their potential and stability before considering them for release as new hybrids.

Key words: *Momordica charantia* L., Hybrid vigour, Yield, Earliness, Sex ratio.

INTRODUCTION

Bitter gourd, a crucial vegetable in tropical and subtropical regions, belongs to the Cucurbitaceae family and is known for its cross-pollinating nature and extensive heterozygosity. Singh *et al*. (16) emphasized its medicinal value attributed to phytochemicals such as dietary fibre, minerals, vitamins, flavonoids, and antioxidants, especially notable for high levels of ascorbic acid and iron. The variability in bitter gourd's fruit and vegetative traits across India highlights its potential for harnessing hybrid vigour in cross-pollinated crops, aiming to develop high-quality, high-yielding cultivars desired globally. Leveraging heterosis in bitter gourd is crucial for creating economically viable variants with enhanced traits.

Bitter gourd's monoecious nature facilitates hybrid vigour utilization due to features like easy emasculation, high fruit-setting rates, abundant seed yield, and simple seed extraction methods, ensuring cost-effective F_1 hybrid seed production. Heterosis, or hybrid vigour, is the superior performance of F_1 hybrids compared to their parents, influenced by the number of heterozygous genes. Increased heterozygosity leads to more pronounced heterosis, as noted by East and Hayes (5), highlighting its significance in breeding programs. The predominant mating patterns in bitter gourd breeding are diallel or half-diallel, providing insights into the dominance relationship among parental lines. Diallelic cross analysis, utilizing the first filial generation (F_1) with or without reciprocals, helps estimate genetic parameters related to combining ability, including the distribution of dominant and recessive genes, the average degree of dominance, and presence of epistasis (Zongo *et al*., 20). Numerous improved bitter gourd hybrids have been created for global cultivation. For instance, Quamruzzaman *et al*. (14) observed substantial heterosis (86.1%) in a complete diallel cross involving 11 different bottle gourd parents. According to Behera *et al*. (5), crossing pure-line bitter gourds with superior combiners for yield and its components resulted in F_1 hybrids displaying heterosis in seed quality and yield traits. Understanding heterosis, which can manifest positively or negatively, is crucial in plant breeding to maximize yield. This study aimed to investigate heterosis in key horticultural traits.

MATERIALS AND METHODS

The study was conducted at the College of Horticulture, Dr Y.S.R. Horticultural University, Venkataramannagudem, West Godavari District, Andhra Pradesh, during the Summer and *kharif* seasons of 2022. The location falls under agro-climatic zone 10 at 34 m above M.S.L., known for its humid East Coast Plain and Hills (Krishna-Godavari zone) climate with an average annual rainfall of 900 mm. The area experiences hot and humid summers and

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pleasant winters. In this experiment, 21 single crosses were developed using a half-diallel fashion, crossing seven parental lines (Preethi, Kashi Mayuri, IC-44418, IC-433630, IC-68314, IC-469512, and Special Boldar) in all possible combinations, excluding reciprocals, assuming the absence of maternal effects. During the *kharif* seasons of 2022, these 21 hybrid combinations, along with their parental lines, were evaluated using a Randomized Complete Block Design with three replications. Heterosis, indicating the percentage change in mean F_1 performance compared to the standard checks, was calculated based on the formulae established by Jinks and Jones (9). Data were collected for various growth and yield traits, including plant height (cm), days to first male flower appearance, days to first female flower appearance, days to first picking, number of fruits per plant, average fruit weight (g), yield per plant (kg), fruit length (cm), fruit diameter (cm), internodal length (cm), seed per fruit, and sex ratio, from five randomly selected vines within each replication.

Standard heterosis was expressed as per cent increase or decrease observed in F_1 over standard check.

$$\text{Standard heterosis (\%)} = \frac{F_1 - SC}{SC} \times 100$$

F_1 = Mean value of F_1
SC = Mean value of standard check

Standard heterosis for each cross was calculated as percentage deviation from the standard check values given by Hayes *et al*. (7).

RESULTS AND DISCUSSION

Tables 1 to 3 present detailed information on heterosis for different parameters, along with corresponding data for standard checks.

Table 1. Estimates of standard heterosis (S.H.) for plant height, internodal length and days to 1st male flower appearance and days to 1st female flower appearance in bitter gourd.

Cross combination	Vine length (cm)		Internodal length (cm)		Days to 1st male flower appearance		Days to 1st female flower appearance	
	Standard heterosis		Standard heterosis		Standard heterosis		Standard heterosis	
	Pragathi	Monarch	Pragathi	Monarch	Pragathi	Monarch	Pragathi	Monarch
Preethi × Kashi Mayuri	-4.33	-5.62*	6.9**	1.94	-9.39**	-8.32**	1.78	9.58**
Preethi × IC-44418	-8.13**	-9.37**	30.5**	24.45**	-6.17**	-5.06*	-2.91	4.53
Preethi × IC-433630	-3.42	-4.72*	5.59*	0.69	0.85	2.05	6.47**	14.63**
Preethi × IC-68314	1.45	0.08	27.31**	21.4**	-2.51	-1.36	-8.69**	-1.6
Preethi × IC-469512	8.68**	7.21**	30.43**	24.38**	11.32**	12.64**	6.43**	14.59**
Preethi × Special Boldar	11.54**	10.04**	35.58**	29.29**	-5.34**	-4.21*	2.31	10.16**
Kashi Mayuri × IC-44418	-1.72	-3.04	-6.03**	-10.39**	-3.77*	-2.63	-3.61	3.78
Kashi Mayuri × IC-433630	2.66	1.28	26.43**	20.57**	-0.9	0.28	-2.22	5.27*
Kashi Mayuri × IC-68314	4.01	2.61	2.9	-1.87	-3.46	-2.31	4.12	12.1**
Kashi Mayuri × IC-469512	10.18**	8.69**	29.56**	23.55**	9.58**	10.89**	2.11	9.94**
Kashi Mayuri × Special Boldar	16.01**	14.45**	50.69**	43.7**	-1.45	-0.28	3.95	11.92**
IC-44418 × IC-433630	-1.9	-3.22	31.37**	25.28**	-9.44**	-8.37**	-7.34**	-0.23
IC-44418 × IC-68314	2.57	1.19	-12.42**	-16.48**	1.32	2.52	-3.16	4.27
IC-44418 × IC-469512	7.13**	5.69*	-6.68**	-11.01**	6.12**	7.38**	4.45*	12.46**
IC-44418 × Special Boldar	14.03**	12.49**	10.68**	5.54**	1.87	3.08	1.45	9.22**
IC-433630 × IC-68314	3.81	2.41	-9.95**	-14.13**	1.05	2.25	-2.27	5.23*
IC-433630 × IC-469512	20.35**	18.72**	28.47**	22.51**	-2.62	-1.47	-9.14**	-2.1
IC-433630 × Special Boldar	15.94**	14.38**	-1.09	-5.68**	-7.39**	-6.29**	-4.79*	2.51
IC-68314 × IC-469512	14.16**	12.62**	28.03**	22.09**	13.32**	14.66**	6.78**	14.97**
IC-68314 × Special Boldar	23.57**	21.9**	-2.69	-7.2**	-8.17**	-7.08**	-11.43**	-4.64*
IC-469512 × Special Boldar	38.05**	36.19**	42.85**	36.22**	-3.01	-1.85	-9.4**	-2.46
Range	-8.13 to 38.05	-9.37 to 36.19	-12.42 to 50.69	-16.48 to 43.70	-9.39 to 13.32	-8.32 to 14.66	-11.43 to 6.78	-4.64 to 14.63

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

Table 2. Estimates of standard heterosis (S.H.) for days to 1st picking, number of fruits per plant, average fruit weight and yield per plant in bitter gourd.

Cross combination	Days to 1st picking		No. of fruits per plant		Av. fruit weight (g)		Yield per plant (kg)	
	Standard heterosis		Standard heterosis		Standard heterosis		Standard heterosis	
	Pragathi	Monarch	Pragathi	Monarch	Pragathi	Monarch	Pragathi	Monarch
Preethi × Kashi Mayuri	-7.94**	-10.11**	30.83**	27.32**	0.69	5.73*	52.3**	35.9**
Preethi × IC-44418	-9.78**	-11.92**	42.36**	38.54**	2.91	8.07**	68.97**	50.77**
Preethi × IC-433630	-4.5	-6.75**	34.63**	31.02**	-6.97**	-2.31	44.25**	28.72**
Preethi × IC-68314	-6.34**	-8.55**	29.8**	26.32**	0.69	5.74*	50.57**	34.36**
Preethi × IC-469512	3.36	0.92	36.55**	32.88**	35.38**	42.17**	113.22**	90.26**
Preethi × Special Boldar	-0.3	-2.66	48.18**	44.2**	26.73**	-23.06**	25.29**	11.79**
Kashi Mayuri × IC-44418	5.78*	3.28	25.7**	22.33**	7.97**	13.39**	55.75**	38.97**
Kashi Mayuri × IC-433630	10.9**	8.28**	42.12**	38.31**	-1.68	3.25	60.92**	43.59**
Kashi Mayuri × IC-68314	12.36**	9.71**	19.06**	15.86**	9.6**	15.1**	50**	33.85**
Kashi Mayuri × IC-469512	-2.27	-4.58*	20.65**	17.41**	57.58**	65.49**	118.97**	95.38**
Kashi Mayuri × Special Boldar	1.93	-0.48	-0.36	-3.04	0.55	5.6*	16.09**	3.59
IC-44418 × IC-433630	15.84**	13.1**	12.03**	9.03**	1.35	6.43**	31.03**	16.92**
IC-44418 × IC-68314	-2.78	-5.08*	6.38*	3.53	11.26**	16.84**	36.21**	21.54**
IC-44418 × IC-469512	-7.21**	-9.41**	23.95**	20.62**	52.35**	59.99**	117.82**	94.36**
IC-44418 × Special Boldar	13.29**	10.61**	48.16**	44.17**	-28.17**	-24.57**	22.99**	9.74**
IC-433630 × IC-68314	-2.74	-5.04*	12.12**	9.11**	2.96	8.12**	33.33**	18.97**
IC-433630 × IC-469512	6.01*	3.51	30.23**	26.73**	63.25**	71.44**	144.83**	118.46**
IC-433630 × Special Boldar	-2.9	-5.23*	7.59**	4.70	-8.64**	-4.06	13.22**	1.03
IC-68314 × IC-469512	-1.63	-3.96	-0.14	-2.82	23.48**	29.67**	42.53**	27.18**
IC-68314 × Special Boldar	-10.47**	-12.59**	-5.7*	-8.23**	-14.33**	-10.04**	-7.47*	-17.44**
IC-469512 × Special Boldar	-5.57*	-7.8**	49.85**	45.83**	50.87**	58.43**	160.92**	132.82**
Range	-10.47 to 15.84	-12.69 to 13.01	-5.7 to 49.85	-8.23 to 45.83	-28.17 to 63.25	-24.57 to 71.44	-7.47 to 160.92	-17.44 to 132.82

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

In bitter gourd, maximum vine length is advantageous as it correlates with an increased number of flowering nodes and higher yields. Positive heterosis for vine length is desirable. In Table 1, standard heterosis for vine length ranged from -8.13 to -9.37% (Preethi × IC-44418) up to a significant 38.05 and 36.19% (IC-469512 × Special Boldar) compared to standard checks Pragathi and Monarch. Among the 21 hybrids studied, six exhibited significant positive standard heterosis when compared to Pragathi, while six showed notable negative heterosis. Conversely, compared to Monarch, 11 hybrids displayed significant negative heterosis, while four exhibited substantial positive heterosis. High vine length, observed in various hybrids, can be advantageous in increasing the number of fruits per plant and consequently, overall fruit yields. These findings are consistent with previous studies on bitter gourd by Bhatt *et al*. (3), Robindro *et al*. (15), and Mishra *et al*. (12), highlighting the intricate nature of plant heterosis and its impact on yield.

When comparing various hybrid combinations with Pragathi and Monarch, the range of standard heterosis for internodal length varied from -16.48 to 50.69%. Notably, compared to Pragathi, 14 hybrids displayed significant positive and negative standard heterosis, while compared to Monarch, 12 hybrids exhibited significant positive heterosis and 6 displayed significant negative heterosis. Negative heterosis for internodal length was desirable because shorter internodal length allows for higher fruit accommodation at a given plant height. These results align with similar findings on bitter gourd reported by Pushpendra *et al*. (13) and Amrita *et al*. (1).

In bitter gourd, early flowering is crucial. Desired negative heterosis was aimed for both days to first

Table 3. Estimates of standard heterosis (S.H.) for fruit length, fruit diameter, sex ratio and seeds per fruit in bitter gourd.

Cross combination	Fruit length (cm)		Fruit diameter (cm)		Sex ratio		Seeds per fruit	
	Standard heterosis		Standard heterosis		Standard heterosis		Standard heterosis	
	Pragathi	Monarch	Pragathi	Monarch	Pragathi	Monarch	Pragathi	Monarch
Preethi × Kashi Mayuri	27.34**	31.16**	20.15**	13.18**	-0.41	11.36**	76.74**	70.48**
Preethi × IC-44418	32.64**	36.61**	46.71**	38.2**	-18.08**	-8.4**	7.31**	3.5
Preethi × IC-433630	34.67**	38.71**	18.65**	11.76**	-8.93**	1.83	35.63**	30.82**
Preethi × IC-68314	27.05**	30.86**	43.21**	34.9**	4.01*	16.3**	41.65**	36.64**
Preethi × IC-469512	20.91**	24.54**	46.71**	38.2**	-25.56**	-16.76**	34.83**	30.05**
Preethi × Special Boldar	-7.84**	-5.07	52.37**	43.53**	-12.84**	-2.54	3.79	0.1
Kashi Mayuri × IC-44418	65.51**	70.47**	5.66	-0.47	-24.42**	-15.49**	37.38**	32.51**
Kashi Mayuri × IC-433630	46.1**	50.48**	42.13**	33.88**	-17.92**	-8.22**	71.77**	65.69**
Kashi Mayuri × IC-68314	25.11**	28.86**	15.57**	8.86**	-15.81**	-5.86**	47.5**	42.28**
Kashi Mayuri × IC-469512	36.25**	40.34**	45.63**	37.18**	-39.6**	-32.46**	37.52**	32.65**
Kashi Mayuri × Special Boldar	6.88*	10.08**	69.28**	59.45**	2.87	15.03**	55.05**	49.56**
IC-44418 × IC-433630	37.31**	41.43**	47.63**	39.06**	-21.52**	-12.24**	15.92**	11.82**
IC-44418 × IC-68314	22.67**	26.35**	-1.5	-7.22*	-6.6**	4.45*	25.36**	20.92**
IC-44418 × IC-469512	-1.09	1.87	4.91	-1.18	-40.71**	-33.7**	43.49**	38.41**
IC-44418 × Special Boldar	-25.21**	-22.97**	24.4**	17.18**	-25.5**	-16.69**	3.01	-0.64
IC-433630 × IC-68314	11.06**	14.39**	1.25	-4.63	-11.77**	-1.34	37.61**	32.73**
IC-433630 × IC-469512	1.1	4.23	44.46**	36.08**	-46.1**	-39.73**	50.86**	45.52**
IC-433630 × Special Boldar	-3.42	-0.52	11.16**	4.71	21.77**	36.17**	28.00**	23.46**
IC-68314 × IC-469512	-1.7	1.25	43.88**	35.53**	-4.99**	6.25**	51.64**	46.26**
IC-68314 × Special Boldar	-27.77**	-25.6**	9.41**	3.06	28.37**	43.54**	-17.87**	-20.78**
IC-469512 × Special Boldar	25.82**	29.59**	60.7**	51.37**	-50.27**	-44.39**	62.82**	57.06**
Range	-27.77 to 65.51	-25.60 to 70.47	-1.5 to 69.28	-7.22 to 59.45	-50.27 to 28.37	-44.39 to 43.54	-17.87 to 76.74	-20.78 to 70.48

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

male flower appearance and days to first female flower appearance. Among the 21 hybrids, seven showed negative heterosis compared to Pragathi, while six exhibited significant negative heterosis compared to Monarch for male flower appearance. Regarding days to the appearance of the first female flower, six hybrids displayed significantly negative standard heterosis compared to Pragathi and one compared to Monarch. Conversely, three hybrids exhibited notably positive standard heterosis compared to Pragathi and twelve compared to Monarch. Previous studies, including Thangamani *et al*. (17) and Robindro *et al*. (15), have highlighted the importance of early male and female flower appearance in bitter gourd hybrids.

For days to the first picking, standard heterosis showed significant variation. Compared to Pragathi, it ranged from -10.47 (IC-68314 × Special Boldar) to 15.8 (IC-44418 × IC-433630), while against Monarch, it ranged from -12.69 (IC-68314 × Special Boldar) to 13.10 (IC-44418 × IC-433630) (Table 2). Among the hybrids, six showed significant negative and positive standard heterosis compared to Pragathi, while ten displayed notable negative and four showed notable positive standard heterosis compared to Monarch. Previous research consistently highlights the superiority of this trait in bitter gourd hybrids by Mahamud *et al*. (11), Kandasamy (9), Verma *et al*. (19), and Gangadhararao *et al*. (6).

The increase in fruits per plant compared to Pragathi and Monarch ranged from -5.70 to -8.23% for IC-68314 × Special Boldar, reaching 49.85 to 45.83% for IC-469512 × Special Boldar. Among the hybrids, 18 showed significant positive heterosis compared to Pragathi and 16 compared to Monarch. One hybrid exhibited significant negative heterosis compared to both. Fruits per plant is a crucial yield trait, and positive heterosis is highly desirable.

Previous studies by Robindro *et al*. (15), Mishra *et al*. (12), and Puspendra *et al*. (16) similarly highlight its importance in bitter gourd hybrids.

Heterosis for average fruit weight ranged from -28.17 to -24.57 for IC-44418 × Special Boldar and 63.25 to 71.44 for IC-433630 × IC-469512, compared to Pragathi and Monarch. Among the 21 hybrids evaluated, 10 and 15 showed significantly positive heterosis, while four and three hybrids displayed positive heterosis. Fruit weight significantly influences overall fruit yield, impacting productivity. Heterosis in this trait, along with other fruit characteristics like length and diameter, provides a significant advantage for yield improvement. Previous studies consistently highlight the superiority of this trait in bitter gourd by Gangadhararao *et al*. (6) and Robindro *et al*. (15), emphasizing its crucial role in enhancing overall yield.

Economic heterosis for fruit yield ranged from -7.47 to 160.92 over Pragathi and -17.44 to 132.82 over Monarch. Among 21 hybrids, 20 and 18 exhibited significant positive heterosis compared to Pragathi and Monarch, respectively, with only one hybrid showing significant negative heterosis. Fruit yield heterosis is influenced by various yield attributing traits, including fruit characteristics like length, diameter, weight, and number of seeds. Previous studies by Singh *et al*. (16), Gangadhararao *et al*. (6), Robindro *et al*. (15), Amrita *et al*. (1), and Pushpendra *et al*. (13) have highlighted the superiority of this trait in bitter gourd.

Useful heterosis for fruit length ranged from -27.77 to 65.51% over Pragathi and -25.60 to 70.47% over Monarch among the hybrids (Table 3 and Fig 5). Notably, IC-68314 × Special Boldar and Kashi Mayuri hybrids displayed the lowest and highest levels of heterosis, respectively, compared to the checks. Among the 21 hybrids, three and two showed significant negative heterosis compared to the standard checks. Fruit length significantly contributes to overall yield, aligning with previous findings on cucumber by Bhutia *et al*. (4) and on bitter gourd by Bhatt *et al*. (3), Gangadhararao *et al*. (6), and Amrita *et al*. (1).

Standard heterosis for fruit diameter ranged from -1.50 to -7.22% to 69.28 to 59.45% compared to Pragathi and Monarch, respectively. Out of 21 hybrids, seventeen and fourteen displayed significant positive heterosis over Pragathi and Monarch, respectively. None were significantly inferior to Pragathi, though one showed negative heterosis compared to Monarch. Fruit diameter, critical for yield, showed superiority, consistent with earlier research on bitter gourd by Singh *et al*. (16), Kandasamy (9), and Amrita *et al*. (1).

Economic heterosis for seeds per fruit, compared to Pragathi, ranged from -17.87 to 76.74%, and compared to Monarch, it ranged from -20.78 to 70.74%. Out of 21 hybrids, 18 showed significant positive heterosis over Pragathi, while only one exhibited significant negative heterosis compared to Monarch. The importance of seeds per fruit in enhancing yield has been confirmed in prior studies on bitter gourd by Thangamani *et al*. (17).

For sex ratio, heterosis over Monarch ranged from -50.27 to 28.37%, and over Pragathi from -44.39 to 43.54%. Among 21 hybrids, 15 and 9 showed significant superiority over Pragathi and Monarch, respectively, while 2 and 7 were significantly inferior compared to Pragathi and Monarch. A lower sex ratio, indicating more female flowers, is advantageous for yield improvement, aligning with findings from Bhatt *et al*. (3) on bitter gourd.

In this study, favourable negative heterosis was observed for traits like days to the first male flower, days to the first female flower, internodal length, and days to the first fruit picking in specific hybrid combinations. Significant improvements in the number of fruits per plant and fruit yield per plant were noted in certain crosses over the checks. Notably, hybrids such as IC-68314 × Special Boldar, IC-433630 × IC-469512, and IC-469512 × Special Boldar displayed superiority in various growth and yield traits (Fig. 1 to Fig. 6). These promising hybrids will be tested further in multilocational trials before potential release as commercial varieties.

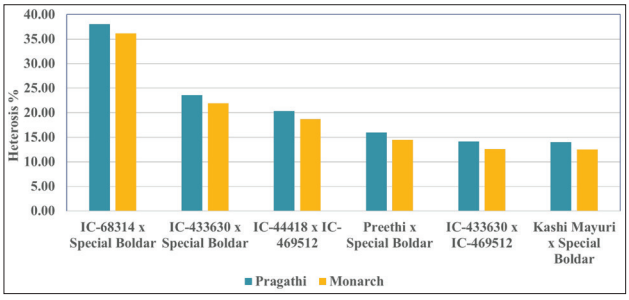

Fig. 1. Standard heterosis exhibited by superior hybrids over Pragathi and Monarch for plant height (cm).

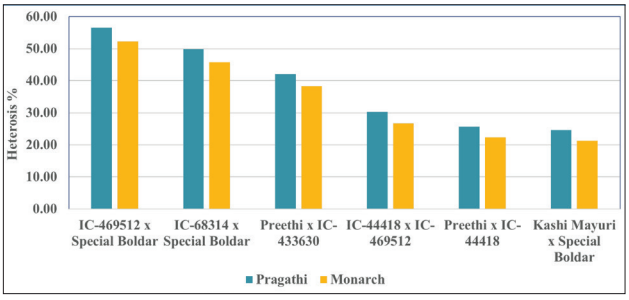

Fig. 2. Standard heterosis exhibited by superior hybrids over Pragathi and Monarch for number of fruits per plant.

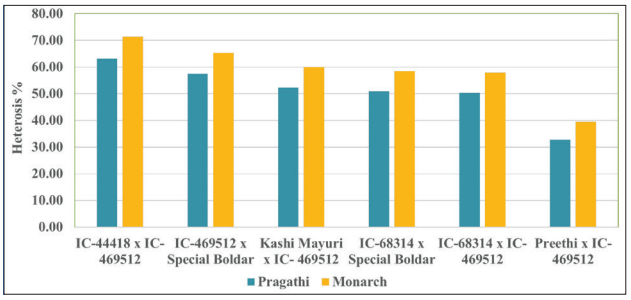

Fig. 3. Standard heterosis exhibited by superior hybrids over Pragathi and Monarch for average fruit weight (g).

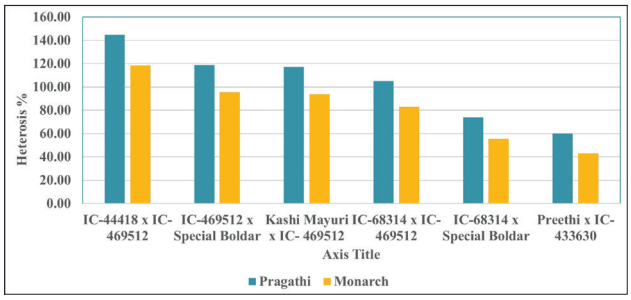

Fig. 4. Standard heterosis exhibited by superior hybrids over Pragathi and Monarch for yield per plant (kg).

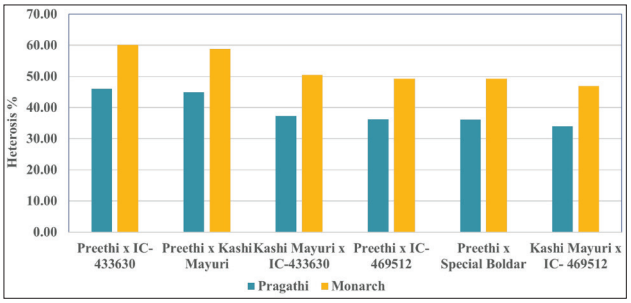

Fig. 5. Standard heterosis exhibited by superior hybrids over Pragathi and Monarch for fruit length (cm).

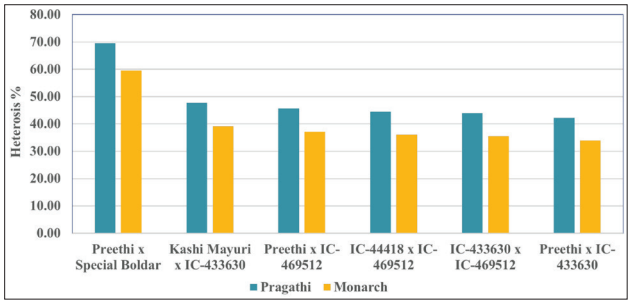

Fig. 6. Standard heterosis exhibited by superior hybrids over Pragathi and Monarch for fruit diameter (cm).

AUTHORS' CONTRIBUTION

Conceptualization of research (BS, SSVP, LN, MPR); Designing of the experiments (BS, CKK); Contribution of experimental materials (SSVP, BS); Execution of field/lab experiments and data collection (BS, MPR); Analysis of data and interpretation (BS, VS); Preparation of the manuscript (BS, SSVP, CKK).

DECLARATION

The authors declare that they do not have any conflict of interest.

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