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RESEARCH ARTICLE

Heterosis for yield and yield-attributing traits in ridge gourd (*Luffa acutangula* (L.) Roxb.)

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Abstract

The present study was conducted to evaluate the performance and heterotic potential of 21 ridge gourd (*Luffa acutangula* L. Roxb.) hybrids for critical growth, flowering and yield-related traits. A comprehensive analysis revealed significant variability across all traits, indicating a broad genetic base suitable for effective selection and hybrid development. Among the parental lines, IC-344512 and Arka Prasan were superior for vine length, while IC-344652 and Kerala Local-3 were identified as sources for earliness. The hybrid Kerala Local-3 × Arka Sujat exhibited outstanding overall performance, recording the longest vine (5.54 m), the highest number of branches (7.84), early maturity (44.46 days to harvest) and a maximum yield of 6.96 kg/vine (36.18 t/ha). Furthermore, heterosis analysis revealed its significant superiority over commercial checks. The cross Bangalore Local-1 × Arka Prasan also emerged as a promising hybrid, notable for its early flowering and high fruit weight, making it ideal for short-duration cultivation. The expression of both positive and negative heterosis confirmed the roles of additive and non-additive gene actions. For instance, Bangalore Local-1 × Arka Prasan displayed highly desirable negative heterosis for earliness, while Kerala Local-3 × Arka Sujat showed remarkable mid-parent heterosis for yield per vine (133.30 %). Overall, this investigation successfully identified Kerala Local-3 × Arka Sujat and Bangalore Local-1 × Arka Prasan as elite hybrids that combine high yield potential with other desirable agronomic traits, thus validating heterosis breeding as a powerful strategy to enhance productivity in ridge gourd.

Keywords: Arka Prasan; mid parent; ridge gourd; standard check; variability

Introduction

Ridge gourd (*Luffa acutangula* L. Roxb.), a member of the Cucurbitaceae family with a chromosome number of 2n=26, originated in India. Ridge gourd, also known as ribbed gourd, Chinese okra and angled loofah, is widely cultivated across tropical regions for both edible and industrial purposes (1). Notably, the mature fruits' fibrous structure is processed into products such as bath sponges, mats and insulation materials. The *Luffa* species is valued for its nutritional properties, offering high moisture content and moderate levels of carbohydrates, minerals and vitamins while remaining low in calories. Per 100 g edible portion of fruit contains moisture (92.5 %), protein (0.5 g), fat (0.5 g), carbohydrates (3.4 g), energy (17 k cal), calcium (18 mg), vitamin C (5 mg), riboflavin (0.01 mg), phosphorus (26 mg), iron (0.5 mg) and carotene (33 µg) (2). It contains a gelatinous compound known as 'luffein', which holds significant medical value and is also used to identify trypsin inhibitors (3). Traditional medicine utilises various plant parts, with documented applications ranging from stomach remedies to conjunctivitis treatment (4). The seeds are recognised for their purgative and anthelmintic actions, contain compounds such as cucurbitacin and have shown antifungal and antiviral properties in recent studies (5, 6).

It is mainly grown during the spring, summer and rainy seasons. The crop exhibits substantial genetic diversity, particularly in fruit size, shape and maturation, presenting valuable opportunities for breeding programs. A wide genetic variation in morphological fruit characteristics is observed across different regions of India. In India, it is cultivated on approximately 24500 acres and produces 316925 tonnes (7). Ridge gourd is a deep-rooted climbing plant with simple, 5 to 7 lobed leaves. While typically monoecious, various sex forms have been reported (8). Staminate (male) flowers are borne in racemes and pistillate (female) flowers are solitary, both emerging from leaf axils. Anthesis begins in the evening and is influenced by environmental factors. The fruit is club-shaped with ten prominent ridges and contains numerous black, flattened seeds, with a thousand-seed weight of approximately 150-170 g (9). Given the crops' importance, there is a need to better understand the nature of gene action and heterosis for fruit yield and its contributing traits to support breeding programs. This will help in deciding the suitable breeding method in crop improvement.

Heterosis or hybrid vigour refers to the superior performance of hybrid offspring compared to their parents, manifested in enhanced growth rate, yield and stress tolerance (10). This advantage arises due to greater heterozygosity and favourable gene

interactions and is most pronounced in the first filial generation of hybrids, making heterosis a powerful tool for crop improvement in plant breeding. The present investigation is undertaken to elucidate the genetic mechanisms underlying yield and its associated traits in ridge gourd, to develop superior hybrids through line × tester mating design, thereby contributing to the advancement of sustainable agriculture.

Materials and Methods

The study on heterosis in ridge gourd was carried out at the Department of Horticulture, University of Agricultural Sciences, GKVK, Bengaluru, during *Kharif* 2024. Geographically, the place is located in the Eastern dry zone (Zone-5) of Karnataka state at 2° 58′ N latitude and 77° 35′ E longitude with an elevation of about 830 m above mean sea level. Meteorological data for the experimental period show that maximum temperatures ranged from 26.9 °C to 36 °C and minimum was ranged from 15.2 °C to 20.8 °C, while the average relative humidity varied between 34 % and 90 %. Twenty-one hybrids were developed using a line × tester mating design involving seven lines and three testers during January to May 2024. Seeds were sown at 1.5 m × 1.0 m. The statistical design followed for this experiment was a randomised block design with three replications. 7 lines and 3 testers' source of collection is presented in Table 1. The 21 hybrids, along with ten parents and two standard checks, were evaluated from June to September 2024 to assess the magnitude and direction of heterosis. Observations were recorded on twelve traits related to growth, flowering and yield.

Heterosis analysis

Data were recorded from five randomly selected plants of each hybrid and average was worked out for twelve traits *viz.,* vine length (m), number of primary branches, days to first female flower appearance, sex ratio, days to first harvest, fruit set (%) fruit length (cm), fruit diameter (cm), number of fruits per vine, average fruit weight (g), yield per vine (kg) and yield per hectare (t).

Sex ratio = Number of male flowers per vine / Number of female flowers per vine (Eqn. 1)

Fruit set (%) = Number of fruits per vine / Number of female flowers per vine (Eqn. 2)

Yield per hectare = Yield per vine × Number of plants per hectare (Eqn. 3)

Table 1. Source of collection of lines and testers

	Parents	Source of collection
	Lines	
L_1	IC-344652	CoH, Bangalore
L_2	IC-344512	CoH, Bangalore
L_3	Kolar Local-2	Kolar
L_4	Padmini	Dharwad
L_5	Bangalore Local-1	Bangalore
L_6	Kerala Local-3	Kerala
L_7	Raichur Local-2	Raichur
	Testers	
T_1	Kashi Kushi	IIVR, Varanasi
T_2	Arka Sujat	IIHR, Bangalore
T_3	Arka Prasan	IIHR, Bangalore

The efficiency of the F_1 hybrids was assessed based on heterosis over the mid-parent, better parent and standard check. The magnitude of heterosis was expressed as the percentage increase or decrease of the hybrid mean relative to the mid-parent (MP), better parent (BP) and standard check (SC), as per the formulas described in previous studies (11). The significance of relative heterosis, heterobeltosis and standard heterosis was statistically evaluated using a t-test.

$$\text{Mid parent heterosis (\%)} = \frac{F1 - MP}{MP} \times 100 \quad \text{(Eqn. 4)}$$

$$\text{Better parent heterosis (\%)} = \frac{F1 - BP}{BP} \times 100 \quad \text{(Eqn. 5)}$$

$$\text{Standard heterosis (\%)} = \frac{F1 - SC}{SC} \times 100 \quad \text{(Eqn. 6)}$$

Where, MP = Mean of mid parent, BP = Mean of better parent and SC = Mean of standard check.

Results and Discussion

Significant variability was observed for sex ratio, fruit length, average fruit weight and yield per vine among the parents and hybrids for mean performance. Considerable variation in vine length was observed among the parental lines and hybrids (Table 2). Among the parents, IC-344512 (4.64 m) and Arka Prasan (4.60 m) recorded the longest vines, whereas Kashi Khushi (4.24 m) exhibited the shortest. Among the hybrids, Kerala Local-3 × Arka Sujat recorded the maximum vine length (5.54 m), which was statistically comparable with Bangalore Local-1 × Arka Prasan (5.51 m) and IC-344652 × Kashi Khushi (5.41 m). The shortest vine was recorded in Raichur Local-2 × Kashi Khushi (4.55 m). The superior performance of Kerala Local-3 × Arka Sujat indicates higher vegetative vigour and hybrid combination potential for vine growth, which could be attributed to heterotic expression for vine elongation. Significant differences were observed among parental lines for the number of primary branches (Table 2). Among the parents, Padmini (7.03) and Kolar Local-2 (6.57) recorded the highest number of branches, while Arka Prasan (6.17) had the lowest. Among hybrids, Kerala Local-3 × Arka Sujat (7.84) and Bangalore Local-1 × Arka Prasan (7.83) produced the maximum number of branches, whereas Raichur Local-2 × Kashi Khushi (6.34) recorded the lowest. Hybrids with higher branching could be advantageous for improved photosynthetic area and, consequently, better yield potential.

Early flowering genotypes are desirable for shortening the crop duration (Table 2). Among the parents, IC-344652 (35.56 days) and Kerala Local-3 (36.52 days) exhibited the earliest female flower appearance, while Arka Prasan (43.01 days) was the latest. Among hybrids, Bangalore Local-1 × Arka Prasan exhibited the earliest flowering (34.12 days), whereas Bangalore Local-1 × Kashi Khushi (41.87 days) recorded delayed flowering. The earliness observed in certain hybrids indicates dominance gene action, which can be exploited for developing short-duration cultivars. Kashi Khushi produced hermaphrodite flowers, which are a distinct floral expression (Table 2). Among the parents, IC-344652 had the lowest sex ratio (17.98), whereas Arka Prasan recorded the highest sex ratio (28.19). Among hybrids, Bangalore Local-1 × Arka Prasan showed the lowest sex ratio (16.99), while Kerala Local-3 × Arka Prasan recorded

Table 2. Mean performance of parents and hybrids for growth and flowering traits in ridge gourd

Parents	VL	NPB	DFFF	SR	DFH	FS
IC-344652	4.59	6.42	35.56	17.98	45.85	80.43
IC-344512	4.64	6.38	37.48	18.18	48.16	74.28
Kolar Local-2	4.47	6.57	38.87	18.08	49.15	75.29
Padmini	4.50	7.03	38.36	18.40	47.16	76.24
Bangalore Local-1	4.59	6.52	38.52	19.14	49.65	71.62
Kerala Local-3	4.52	6.34	36.52	18.72	48.47	77.05
Raichur Local-2	4.57	6.27	39.02	18.55	49.58	76.66
Kashi Khushi	4.24	6.22	37.21	1.00	53.66	92.42
Arka Sujat	4.50	6.52	41.88	27.18	50.00	67.78
Arka Prasan	4.60	6.17	43.01	28.19	53.05	65.92
Hybrids						
IC-344652 × Kashi Khushi	5.41	7.55	36.24	18.84	45.44	87.52
IC-344652 × Arka Sujat	5.20	7.37	37.90	20.80	47.88	70.80
IC-344652 × Arka Prasan	5.05	6.71	35.55	21.89	43.79	79.85
IC-344512 × Kashi Khushi	5.22	7.01	39.11	19.68	49.28	72.53
IC-344512 × Arka Sujat	5.38	7.51	39.43	19.34	49.30	70.51
IC-344512 × Arka Prasan	5.11	6.58	40.86	19.47	50.97	71.00
Kolar Local-2 × Kashi Khushi	4.80	6.53	39.22	19.12	49.52	63.11
Kolar Local-2 × Arka Sujat	5.34	7.42	40.68	21.22	50.83	74.48
Kolar Local-2 × Arka Prasan	5.31	7.40	37.64	22.90	47.31	79.66
Padmini × Kashi Khushi	5.07	6.73	34.82	19.82	45.38	85.82
Padmini × Arka Sujat	4.87	6.53	41.65	22.14	51.31	86.22
Padmini × Arka Prasan	5.04	6.73	39.87	19.68	50.10	76.53
Bangalore Local-1 × Kashi Khushi	4.99	6.57	41.87	20.66	52.30	71.35
Bangalore Local-1 × Arka Sujat	5.29	7.08	38.68	20.34	49.19	68.02
Bangalore Local-1 × Arka Prasan	5.51	7.83	34.12	16.99	45.11	86.67
Kerala Local-3 × Kashi Khushi	5.25	7.05	36.22	19.87	46.73	75.19
Kerala Local-3 × Arka Sujat	5.54	7.84	34.64	18.48	44.46	86.83
Kerala Local-3 × Arka Prasan	5.15	6.78	40.13	23.85	50.11	70.40
Raichur Local-2 × Kashi Khushi	4.55	6.34	41.79	22.46	52.03	76.05
Raichur Local-2 × Arka Sujat	5.24	7.05	41.23	19.67	51.11	72.77
Raichur Local-2 × Arka Prasan	5.41	7.52	41.68	20.87	52.37	73.20
Arka Vikram (Check-1)	5.20	7.04	40.04	21.54	48.9	84.95
Naga F1 Hybrid (Check-2)	5.23	7.23	41.25	20.45	49.3	80.43
S.Em±	0.06	0.99	0.52	0.81	0.51	1.54
CD (5 %)	0.18	0.28	1.49	2.32	1.47	4.39

VL- Vine length (m), **NPB**- Number of primary branches, **DFFF**- Days to first female flower appearance, **SR**- Sex ratio, **DFH**- Days to first harvest, **FS**- Fruit set (%)

the maximum sex ratio (23.85). Variation in sex ratio among crosses may be attributed to the differing genetic makeup influencing floral differentiation, which plays an important role in fruit set and yield. Earliness in harvest is an important commercial trait (Table 2). IC-344652 was the earliest parent to reach harvest (45.85 days), whereas Kashi Khushi was the delayed parent to reach harvest (53.66 days). Among hybrids, IC-344652 × Arka Prasan (43.79 days) and Kerala Local-3 × Arka Sujat (44.46 days) were the earliest to harvest, while Raichur Local-2 × Arka Prasan (52.37 days) was the late harvest. The early maturing hybrids may offer opportunities for staggered market supply and economic advantage.

Significant variation was observed for fruit set percentage (Table 2). Kashi Khushi exhibited the highest fruit set (92.42 %), whereas Arka Prasan recorded the lowest fruit set (65.92 %) among parents. In hybrids, IC-344652 × Kashi Khushi showed the maximum fruit set (87.52 %), whereas Kolar Local-2 × Kashi Khushi exhibited the lowest fruit set (63.11 %). High fruit set in specific crosses indicates better pollen viability and favourable genetic combinations for fertilisation efficiency. Fruit length varied significantly among the genotypes (Table 3). Among parents, Kolar Local-2 (47.82 cm) and Kerala Local-3 (46.83 cm) produced longer fruits, whereas Kashi Khushi recorded the shortest fruits (13.93 cm). The hybrid IC-344512 × Arka Sujat recorded the longest fruits (50.73 cm), followed by Bangalore Local-1 × Arka Prasan (46.71 cm). Longer fruits are often preferred in market standards and the superior performance of IC-344512 × Arka Sujat suggests dominance of favourable alleles governing fruit elongation.

Among parents, Padmini recorded the highest fruit diameter (4.62 cm), followed by Kerala Local-3 (4.11 cm), with the smallest (Table 3). In hybrids, Kolar Local-2 × Kashi Khushi exhibited the maximum diameter (5.10 cm), while Raichur Local-2 × Arka Prasan recorded the minimum (3.25 cm). These results indicate additive and non-additive gene effects contributing to fruit girth in ridge gourd. The number of fruits per vine is directly related to yield potential (Table 3). Kashi Khushi (21.54) and IC-344652 (17.12) were superior among parents, while Arka Prasan (10.56) produced the least. In hybrids, Kerala Local-3 × Arka Sujat exhibited the highest number of fruits (22.93), whereas Kerala Local-3 × Arka Prasan recorded the lowest (13.94). The high fruit load in Kerala Local-3 × Arka Sujat indicates better fruit retention and hybrid vigour expression. Significant variation was noticed in average fruit weight among parents and hybrids (Table 3). Padmini exhibited the maximum fruit weight (262.35 g), while Kashi Khushi produced the minimum fruit weight (95.65 g). Among hybrids, Bangalore Local-1 × Arka Prasan (308.38 g) and Kerala Local-3 × Arka Sujat (303.52 g) recorded the highest fruit weight, whereas Kerala

Table 3. Mean performance of parents and hybrids for yield and yield attributing traits in ridge gourd

Parents	FL	FD	NFV	AFW	YPV	YPH
IC-344652	29.02	4.52	17.12	242.46	4.15	21.57
IC-344512	32.88	4.34	16.98	252.98	4.3	22.34
Kolar Local-2	47.82	4.32	16.34	256.81	4.22	21.92
Padmini	30.12	4.62	15.34	262.35	4.03	20.94
Bangalore Local-1	28.15	4.56	14.23	245.45	3.49	18.16
Kerala Local-3	46.83	4.11	15.11	242.34	3.66	19.1
Raichur Local-2	37.11	4.21	16.13	261.23	4.20	21.82
Kashi Khushi	13.93	4.25	21.54	95.65	2.06	10.73
Arka Sujat	33.96	4.27	10.88	212.34	2.31	12.01
Arka Prasan	45.78	4.12	10.56	232.56	2.55	13.28
Hybrids						
IC-344652 × Kashi Khushi	18.75	4.30	21.62	192.19	4.16	21.60
IC-344652 × Arka Sujat	40.23	3.70	15.25	264.33	4.03	20.97
IC-344652 × Arka Prasan	44.75	4.95	17.34	285.39	4.95	25.73
IC-344512 × Kashi Khushi	28.20	4.45	16.52	287.77	4.75	24.71
IC-344512 × Arka Sujat	50.73	4.60	18.45	294.75	5.44	28.27
IC-344512 × Arka Prasan	28.25	4.25	17.62	219.17	3.86	20.08
Kolar Local-2 × Kashi Khushi	22.75	5.10	15.77	198.28	3.13	16.25
Kolar Local-2 × Arka Sujat	40.12	4.70	16.44	191.14	3.14	16.33
Kolar Local-2 × Arka Prasan	25.80	4.25	16.37	218.19	3.57	18.57
Padmini × Kashi Khushi	23.25	4.20	20.23	225.20	4.41	22.95
Padmini × Arka Sujat	27.19	4.25	18.69	276.17	4.21	21.88
Padmini × Arka Prasan	29.80	4.72	19.12	197.65	5.28	27.46
Bangalore Local-1 × Kashi Khushi	23.72	5.04	15.87	196.15	3.20	16.31
Bangalore Local-1 × Arka Sujat	24.75	3.80	14.99	308.38	2.94	15.28
Bangalore Local-1 × Arka Prasan	46.71	4.30	22.34	176.35	6.86	35.81
Kerala Local-3 × Kashi Khushi	23.75	3.90	17.37	303.52	3.06	15.92
Kerala Local-3 × Arka Sujat	35.23	4.40	22.93	303.52	6.96	36.18
Kerala Local-3 × Arka Prasan	36.79	3.64	13.94	231.29	3.22	17.06
Raichur Local-2 × Kashi Khushi	23.50	4.85	16.33	197.16	3.22	16.74
Raichur Local-2 × Arka Sujat	38.73	3.60	18.43	176.73	3.25	16.93
Raichur Local-2 × Arka Prasan	33.97	3.25	16.22	242.10	3.93	20.42
Arka Vikram (Check-1)	37.80	4.8	18.6	256.6	4.77	24.81
Naga F1 Hybrid (Check-2)	32.75	3.65	18.36	231.34	4.25	22.1
S.Em±	0.40	0.07	0.40	2.41	0.09	0.48
CD (5 %)	1.15	0.19	1.14	6.90	0.27	1.39

FL- Fruit length (cm), **FD**- Fruit diameter (cm), **NFV**- Number of fruits per vine, **AFW**- Average fruit weight (g), **YPV**- Yield per vine (kg), **YPH**- Yield per hectare (t)

Local-3 × Kashi Khushi recorded the lowest (176.35 g). The heavier fruits reflect favourable hybrid combinations expressing heterosis for fruit size. Yield performance showed significant variability among genotypes (Table 3). Among parents, IC-344512 had the highest yield (4.30 kg/vine, 22.34 t/ha), while Kashi Khushi recorded the lowest (2.06 kg/vine, 10.73 t/ha). Among hybrids, Kerala Local-3 × Arka Sujat registered the maximum yield (6.96 kg/vine, 36.18 t/ha), while Bangalore Local-1 × Arka Sujat recorded the lowest (2.94 kg/vine, 15.28 t/ha). The superior yield performance of Kerala Local-3 × Arka Sujat was mainly due to its combination of longer vines, higher branching, more fruits per vine and heavier fruits, suggesting its potential as a promising hybrid for commercial exploitation in ridge gourd breeding programs.

Heterosis

Vine length

Kerala Local-3 × Arka Sujat recorded the maximum heterotic response in all the comparisons, showing 22.84 % heterosis over the mid-parent, 22.57 % over the better-parent, 6.54 % over Arka Vikram and 5.99 % over Naga F_1 hybrid (Table 4). Similar trends have also been documented in ridge gourd and in sponge gourd (12, 13).

Number of primary branches

Significant differences in heterosis were recorded among the 21 hybrids studied (Table 4). The cross Bangalore Local-1 × Arka Prasan showed the highest heterosis over the mid-parent (23.44 %). Kerala Local-3 × Arka Sujat showed the maximum heterosis over the better-parent (20.25 %) as well as over the standard checks Arka Vikram (11.36 %) and Naga F_1 hybrid (8.44 %). On the other hand, IC-344512 × Arka Prasan displayed the minimum heterosis over the mid-parent (4.84 %), Padmini × Kashi Khushi showed the lowest heterobeltosis (-4.27 %) and Raichur Local-2 × Kashi Khushi showed negative heterosis against both standard checks, Arka Vikram (-9.94 %) and Naga F_1 hybrid (-12.31 %). Similar trends have also been documented in sponge gourd (13). For vegetative parameters, Kerala Local-3 × Arka Sujat is a result of successfully combining complementary genes from genetically distinct parents, leading to the masking of negative traits, superior heterozygous gene combinations and favourable gene interactions. This results in a hybrid that is physiologically more efficient and robust in its vegetative growth.

Table 4. Estimation of heterosis (%) over mid-parent, better parent and standard check for vine length and number of primary branches in ridge gourd

Hybrids	Vine length (m)				Number of primary branches			
	MP	BP	Check-1	Check-2	MP	BP	Check-1	Check-2
IC-344652 × Kashi Khushi	21.16**	17.95**	4.04*	3.51*	19.49**	17.60**	7.24**	4.43*
IC-344652 × Arka Sujat	14.38**	13.30**	-0.06	-0.57	13.91**	13.04**	4.69*	1.94
IC-344652 × Arka Prasan	9.94**	9.78**	-2.88	-3.38	6.62**	4.52	-4.69*	-7.19**
IC-344512 × Kashi Khushi	16.14**	12.43**	0.32	-0.19	11.30**	9.87**	-0.43	-3.04
IC-344512 × Arka Sujat	17.72**	15.95**	3.46	2.93	16.49**	15.24**	6.72**	3.92
IC-344512 × Arka Prasan	10.53**	10.06**	-1.79	-2.30	4.84*	3.08	-6.58**	-9.04**
Kolar Local-2 × Kashi Khushi	8.85**	7.31**	-7.76**	-8.23**	2.11	-0.66	-7.24**	-9.68**
Kolar Local-2 × Arka Sujat	19.06**	18.67**	2.69	2.17	13.39**	12.93**	5.45*	2.67
Kolar Local-2 × Arka Prasan	17.02**	15.36**	2.05	1.53	16.17**	12.58**	5.11*	2.35
Padmini × Kashi Khushi	13.69**	10.87**	-2.56	-3.06	1.59	-4.27*	-4.45*	-6.96**
Padmini × Arka Sujat	7.31**	6.49**	-6.41**	-6.89**	-3.59	-7.07**	-7.24**	-9.68**
Padmini × Arka Prasan	10.00**	9.64**	-3.01	-3.51	2.02	-4.22	-4.40*	-6.92**
Bangalore Local-1 × Kashi Khushi	11.79**	8.79**	-3.97*	-4.46*	3.17	0.77	-6.68**	-9.13**
Bangalore Local-1 × Arka Sujat	16.32**	15.18**	1.67	1.15	8.59**	8.59**	0.57	-2.07
Bangalore Local-1 × Arka Prasan	19.91**	19.78**	5.96**	5.42**	23.44**	20.09**	11.22**	8.30**
Kerala Local-3 × Kashi Khushi	18.54**	16.22**	1.03	0.51	12.29**	11.20**	0.14	-2.49
Kerala Local-3 × Arka Sujat	22.84**	22.57**	6.54**	5.99**	21.93**	20.25**	11.36**	8.44**
Kerala Local-3 × Arka Prasan	12.87**	11.88**	-1.03	-1.53	8.48**	6.99**	-3.65	-6.18**
Raichur Local-2 × Kashi Khushi	2.09	-0.44	-12.50**	-12.95**	1.55	1.12	-9.94**	-12.31**
Raichur Local-2 × Arka Sujat	15.62**	14.73**	0.83	0.32	10.24**	8.13**	0.14	-2.49
Raichur Local-2 × Arka Prasan	17.92**	17.54**	3.97*	3.44	19.94**	19.94**	6.82**	4.01
S.Em ±	0.08	0.09	0.09	0.09	0.13	0.15	0.15	0.15
CD (5 %)	0.16	0.18	0.18	0.18	0.26	0.30	0.30	0.30
CD (1 %)	0.21	0.25	0.25	0.25	0.35	0.40	0.40	0.40

*Significant at $p = 0.05$, **Significant at $p = 0.01$, ***Significant at $p = 0.001$, **MP**-Mid parent, **BP**- Better parent, Check-1- Arka Prasan, Check 2- Naga F_1 hybrid

Days to first female flower appearance

For days to first female flowering, where negative heterosis is desirable as it reflects earliness, several hybrids showed promising result (Fig. 1). Among them, Bangalore Local-1 × Arka Prasan showed the maximum significant negative heterosis across all comparisons: -16.29 % over the mid-parent, -20.66 % over the better-parent, -14.78 % over Arka Vikram and -17.28 % over Naga F_1 hybrid. In contrast, Bangalore Local-1 × Kashi Khushi recorded the maximum positive heterosis, with 10.58 % over the mid-parent, 8.71 % over the better-parent and 4.56 % over Arka Vikram. From a breeding perspective, earliness is a critical target since it shortens the breeding cycle, enhances selection efficiency and facilitates the development of hybrids with wider adaptability. Thus, negative heterosis for this trait is regarded as highly beneficial. These observations corroborate the reports in ridge gourd (12, 14).

Sex ratio

For the sex ratio, where negative heterosis is considered favourable, a wide range of heterotic effects was observed among hybrids (Table 5). Bangalore Local-1 × Arka Prasan exhibited the highest significant negative relative heterosis (-28.21 %), heterobeltosis (-39.74 %) and standard heterosis against Arka Vikram (-21.12 %) and Naga F_1 hybrid (-16.92 %). Conversely, the most significant positive heterosis was observed in different crosses. The highest positive heterosis over mid-parent (129.73 %) and better-parent (21.06 %) was recorded in Raichur Local-2 × Kashi Khushi, while Kerala Local-3 × Arka Prasan showed the highest significant positive standard heterosis against checks, Arka Vikram (10.74 %) and Naga F_1 hybrid (16.64 %). Results indicate that the hybrid not only produced a more favourable sex ratio than the average of its parents but was significantly better than even the more favourable parent. This level of superiority strongly suggests the involvement of non-additive gene action, such as overdominance or epistasis. These observations are consistent with the results reported in sponge gourd and in musk melon (15, 16)

Fruit set

For the trait of fruit set, significant variation in heterosis was observed among the twenty-one hybrids (Table 5). The cross Bangalore Local-1 × Arka Prasan exhibited the highest significant positive heterosis over both the mid-parent (26.03 %) and better-parent (21.02 %). For standard heterosis, Kerala Local-3 × Arka Sujat showed the maximum positive standard heterosis against the Naga F_1 hybrid (7.99 %). In contrast, Kolar Local-2 × Kashi Khushi showed the most significant negative heterosis across all comparisons, with values of -24.74 % (vs. mid-parent), -31.72 % (vs. better-parent), -25.72 % (vs. Arka Vikram) and -21.52 % (vs. Naga F_1 hybrid). The better parent heterosis suggests the influence of non-additive gene effects. These results are consistent with previous findings that successfully identify valuable parental combinations for targeted hybrid breeding programs (13, 17).

Days to first harvest

For the trait of days to first fruit harvest, where negative heterosis signifies desirable earliness, significant variations were recorded

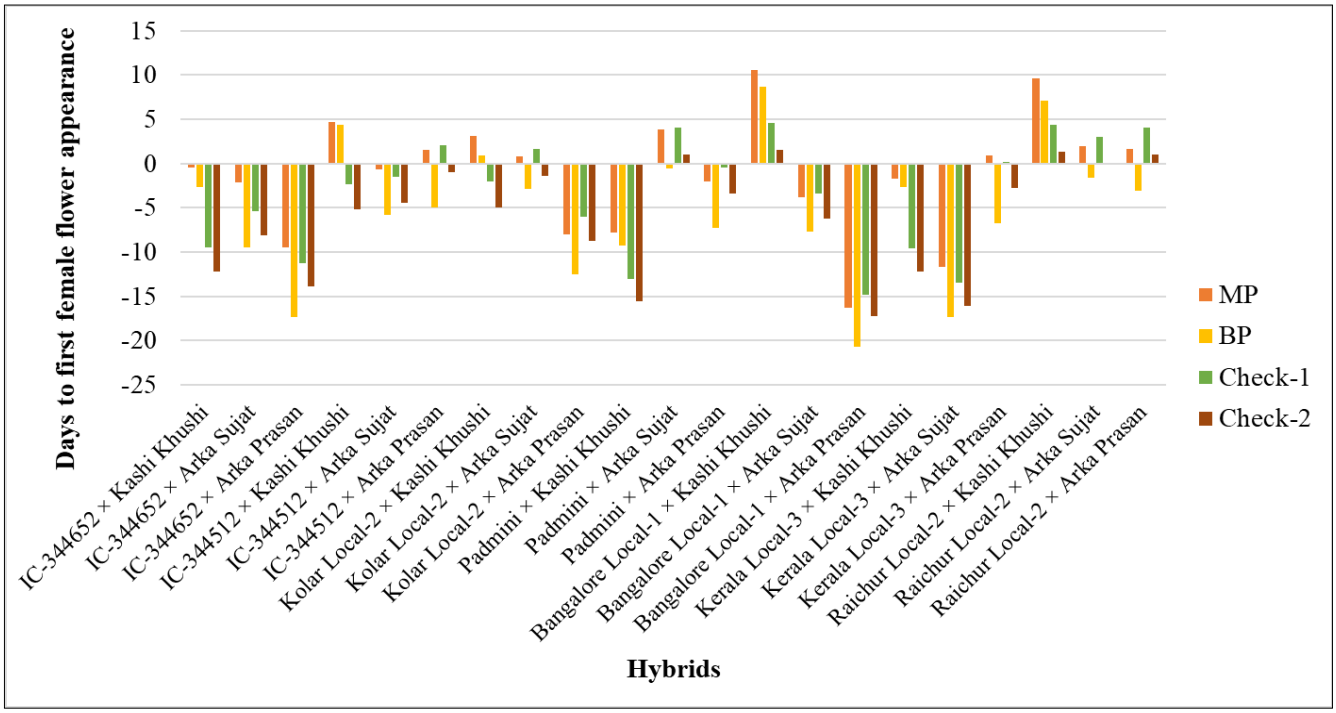

Fig. 1. Estimation of heterosis over mid-parent, better-parent and standard checks for days to first female flower appearance.

Table 5. Estimation of heterosis (%) over mid-parent, better parent and standard check for sex ratio and fruit set in ridge gourd

Hybrids	Sex ratio				Fruit set (%)			
	MP	BP	Check-1	Check-2	MP	BP	Check-1	Check-2
IC-344652 × Kashi Khushi	98.49**	4.76	-12.55*	-7.89	1.26	-5.31	3.02	8.84*
IC-344652 × Arka Sujat	-7.89	-23.48**	-3.45	1.70	-4.46	-11.97**	-16.62**	-11.95**
IC-344652 × Arka Prasan	-5.20	-22.37	1.61	7.03	9.11*	-0.73	-6.01	-0.70
IC-344512 × Kashi Khushi	105.18**	8.23	-8.65	-3.78	-4.99	-14.31**	-6.78	-1.51
IC-344512 × Arka Sujat	-14.71**	-28.82**	-10.20	-5.41	-0.73	-5.07	-17.00**	-12.31**
IC-344512 × Arka Prasan	-16.04**	-30.95**	-9.63	-4.81	1.29	-4.41	-16.42**	-11.70**
Kolar Local-2 × Kashi Khushi	100.42**	5.75	-11.23*	-6.50	-24.74**	-31.72**	-25.72**	-21.52**
Kolar Local-2 × Arka Sujat	-6.22	-21.92**	-1.49	3.77	4.12	-1.07	-12.33**	-7.37
Kolar Local-2 × Arka Prasan	-1.01	-18.76**	6.33	12.00*	12.82**	5.81	-6.23	-0.93
Padmini × Kashi Khushi	104.29**	7.70	-7.99	-3.08	1.76*	-7.15*	1.02	6.72
Padmini × Arka Sujat	-2.84	-18.52**	2.80	8.28	19.73**	13.08**	1.49	7.22
Padmini × Arka Prasan	-15.54**	-30.21**	-8.65	-3.78	7.66*	0.37	-9.92**	-4.83
Bangalore Local-1 × Kashi Khushi	105.13**	7.92	-4.10	1.01	-13.00**	-22.80**	-16.01**	-11.26**
Bangalore Local-1 × Arka Sujat	-12.16**	-25.14**	-5.56	-0.52	-2.40	-5.02	-19.93**	-15.40**
Bangalore Local-1 × Arka Prasan	-28.21**	-39.74**	-21.12**	-16.92**	26.03**	21.02**	2.02	7.79*
Kerala Local-3 × Kashi Khushi	101.59**	6.18	-7.74	-2.82	-11.27**	-18.64**	-11.49**	-6.49
Kerala Local-3 × Arka Sujat	-19.47**	-32.00**	-14.21*	-9.63	19.91**	12.69**	2.21	7.99*
Kerala Local-3 × Arka Prasan	1.70	-15.39**	10.74	16.64**	-1.52	-8.64*	-17.13**	-12.45**
Raichur Local-2 × Kashi Khushi	129.73**	21.06**	4.27	9.83	-10.04**	-17.72**	-10.48**	-5.42
Raichur Local-2 × Arka Sujat	-13.96**	-27.61**	-8.67	-3.80	0.77	-5.07	-14.34**	-9.50*
Raichur Local-2 × Arka Prasan	-10.70*	-25.96**	-3.10	2.07	2.68	-4.51	-13.83**	-8.96*
S.Em ±	1.03	1.19	1.19	1.19	2.56	2.96	2.96	2.96
CD (5%)	2.09	2.41	2.41	2.41	5.18	5.98	5.98	5.98
CD (1%)	2.80	3.23	3.23	3.23	6.93	7.99	7.99	7.99

*Significant at $p = 0.05$, **Significant at $p = 0.01$, ***Significant at $p = 0.001$, **MP**-Mid parent, **BP**- Better parent, Check-1- Arka Prasan, Check 2- Naga F_1 hybrid

Table 6. Estimation of heterosis (%) over mid-parent, better parent and standard check for days to first harvest and number of fruits per vine in ridge gourd

Hybrids	Days to first harvest				Number of fruits per vine			
	MP	BP	Check-1	Check-2	MP	BP	Check-1	Check-2
IC-344652 × Kashi Khushi	-8.68**	-15.32**	-7.13**	-7.82**	11.86**	0.37	16.26**	17.76**
IC-344652 × Arka Sujat	-0.10	-4.25**	-2.14	-2.87	8.97*	-10.89**	-17.98**	-16.92**
IC-344652 × Arka Prasan	-11.44**	-17.45**	-10.49**	-11.16**	25.32**	1.30	-6.76*	-5.56
IC-344512 × Kashi Khushi	-3.20*	-8.16**	-0.74	-0.02	-14.24**	-23.32**	-11.18**	-10.04**
IC-344512 × Arka Sujat	0.45	1.39	0.78	0.02	32.46**	8.68*	-0.79	0.49
IC-344512 × Arka Prasan	0.72	-3.91**	4.19**	3.41*	28.01**	3.81	-5.23	-4.01
Kolar Local-2 × Kashi Khushi	-3.66**	-7.71**	1.23	0.47	-16.76**	-26.80**	-15.22**	-14.12**
Kolar Local-2 × Arka Sujat	2.53	1.66	3.90*	3.12*	20.75**	0.57	-11.61**	-10.48**
Kolar Local-2 × Arka Prasan	-7.42**	-10.82**	-3.30*	-4.02*	21.71**	0.16	-11.97**	-10.84**
Padmini × Kashi Khushi	-9.98**	-15.43**	-7.24**	-7.94**	9.73**	-6.07*	8.80**	10.20**
Padmini × Arka Sujat	5.63**	2.63	4.89**	4.10*	42.59**	21.86**	0.52	1.82
Padmini × Arka Prasan	0.00	-5.55**	2.41	1.64	47.69**	24.66**	2.83	4.16
Bangalore Local-1 × Kashi Khushi	1.24	-2.54	6.90**	6.09**	-11.27**	-26.32**	-14.66**	-13.56**
Bangalore Local-1 × Arka Sujat	-1.27	-1.61	0.55	-0.20	19.42**	5.36	-19.38**	-18.34**
Bangalore Local-1 × Arka Prasan	-12.16**	-14.97**	-7.80**	-8.49**	80.23**	56.97**	20.11**	21.66**
Kerala Local-3 × Kashi Khushi	-8.50**	-12.92**	-4.49**	-5.21**	-5.23	-19.37**	-6.61*	-5.41
Kerala Local-3 × Arka Sujat	-9.71**	-11.09**	-9.13**	-9.81**	76.43**	51.73**	23.28**	24.87**
Kerala Local-3 × Arka Prasan	-1.29	-5.55**	2.42	1.65	8.60*	-7.77	-25.06**	-24.09**
Raichur Local-2 × Kashi Khushi	0.78	-3.04*	6.34**	5.55**	-13.30**	-24.19**	-12.19**	-11.06**
Raichur Local-2 × Arka Sujat	2.64	2.21	4.46**	3.68*	36.47**	14.26**	-0.90	-.38
Raichur Local-2 × Arka Prasan	2.05	-1.28	7.05**	6.24**	21.56**	0.56	-12.78**	-11.66**
S.Em ±	0.65	0.75	0.75	0.75	0.50	0.58	0.58	0.58
CD (5 %)	1.32	1.52	1.52	1.52	1.02	1.18	1.18	1.18
CD (1 %)	1.76	2.03	2.03	2.03	1.36	1.57	1.57	1.57

*Significant at $p = 0.05$, **Significant at $p = 0.01$, ***Significant at $p = 0.001$, **MP**-Mid parent, **BP**- Better parent, Check-1- Arka Prasan, Check 2- Naga F_1 hybrid

among the twenty-one hybrids (Table 6). Bangalore Local-1 × Arka Prasan showed the negative mid-parent heterosis (-12.16 %). IC-344652 × Arka Prasan exhibited maximum negative better-parent heterosis (-17.45 %) and demonstrated the highest negative standard heterosis against both checks, Arka Vikram (-10.49 %) and Naga F_1 hybrid (-11.16 %). In contrast, the most significant positive heterosis was observed in Raichur Local-2 × Arka Prasan over Arka Vikram (7.05 %) and Naga F_1 hybrid (6.24 %). Here, positive heterosis indicated delayed harvest, which is undesirable for this trait. These findings are consistent with the results reported in bitter gourd and in ridge gourd (18, 19).

Number of fruits per vine

For the number of fruits per vine (Table 6), the cross Bangalore Local-1 × Arka Prasan exhibited the highest positive heterosis over the mid-parent (80.23 %) and the better-parent (56.97 %). Kerala Local-3 × Arka Sujat showed strong standard heterosis over both Arka Vikram (23.28 %) and the Naga F_1 hybrid (24.87 %), suggesting non-additive gene effects such as dominance and overdominance. Conversely, the most significant negative heterosis for mid-parent (-16.76 %) and better-parent (-26.80 %) performance was found in Kolar Local-2 × Kashi Khushi. For standard heterosis, the significant negative heterosis was recorded in Kerala Local-3 × Arka Prasan against both Arka Vikram (-25.06 %) and the Naga F_1 hybrid (-24.09 %). The substantial heterosis for the number of fruits per vine, a critical yield component, highlights the potential for significant genetic gains through hybridisation. The cross Bangalore Local-1 × Arka Prasan demonstrated exceptional better-parent heterosis, indicating powerful non-additive gene interactions. These findings agree with the research on ridge gourd (20).

Fruit length

The highest mid-parent heterosis was recorded in the IC-344512 × Kashi Khushi (63.22 %), followed by IC-344512 × Arka Sujat (51.79 %) (Table 7). In contrast, the maximum negative heterosis over the mid-parent was observed in Kolar Local-2 × Arka Prasan (-43.04 %). For better-parent heterosis, the most significant results were observed from the IC-344512 × Arka Sujat (49.37 %) and Kerala Local-3 × Kashi Khushi (49.29 %). The most significant negative heterobeltosis was recorded in the cross Kolar Local-2 × Kashi Khushi (-49.24 %). IC-344512 × Arka Sujat consistently displayed the maximum positive standard heterosis over both Arka Vikram (34.19 %) and the Naga F_1 hybrid (54.89 %). Conversely, IC-344652 × Kashi Khushi showed the largest negative standard heterosis against both Arka Vikram (-50.39 %) and the Naga F_1 hybrid (-42.74 %). These findings agree with the research conducted on ridge gourd (13, 21).

Fruit diameter

For fruit diameter, Kolar Local-2 × Kashi Khushi exhibited the highest positive heterosis over the mid-parent (18.94 %), the better-parent (17.98 %), Arka Vikram (6.25 %) and the Naga F_1 hybrid (39.63 %) (Table 7). Conversely, significant negative heterosis was also prevalent, with the cross Raichur Local-2 × Arka Prasan showing the most pronounced negative effects across all comparisons. This cross recorded values of -22.00 % (mid-parent), -22.86 % (better-parent), -32.24 % (vs. Arka Vikram) and -10.96 % (vs. Naga F_1 hybrid). These observations agree with findings in bitter gourd (7, 22). The findings for fruit length and diameter effectively illustrate the principle of heterosis breeding for targeted trait improvement. The high magnitude of heterosis in both positive and negative directions signifies that these traits are largely governed by non-additive gene

Table 7. Estimation of heterosis (%) over mid-parent, better parent and standard check for fruit length and fruit diameter in ridge gourd

Hybrids	Fruit length (cm)				Fruit diameter (cm)			
	MP	BP	Check-1	Check-2	MP	BP	Check-1	Check-2
IC-344652 × Kashi Khushi	-12.67**	-35.39**	-50.39**	-42.74**	-1.90	-4.86*	-10.28**	17.90**
IC-344652 × Arka Sujat	27.76**	18.47**	6.43**	22.85**	-15.81**	-18.20**	-22.86**	1.37
IC-344652 × Arka Prasan	19.65**	-2.24	18.38**	36.64**	14.62**	9.51**	3.27	35.71**
IC-344512 × Kashi Khushi	63.22**	16.18**	1.05	16.64**	3.57	2.46	-7.23**	21.92**
IC-344512 × Arka Sujat	51.79**	49.37**	34.19**	54.89**	6.85**	5.91**	-4.10*	26.03**
IC-344512 × Arka Prasan	-35.79**	-44.83**	-33.20**	-22.89**	0.43	-2.15	-11.40**	16.44**
Kolar Local-2 × Kashi Khushi	-22.54**	-49.24**	-39.82**	-30.53**	18.94**	17.98**	6.25**	39.63**
Kolar Local-2 × Arka Sujat	1.87	-10.47**	6.14**	22.51**	9.55**	8.87**	-1.95	28.86**
Kolar Local-2 × Arka Prasan	-43.04**	-43.64**	-31.75**	-21.22**	0.71	-1.62	-11.40**	16.44**
Padmini × Kashi Khushi	5.57*	-22.81**	-38.50**	-29.01**	-5.30**	-9.09**	-12.44**	15.07**
Padmini × Arka Sujat	-18.27**	-22.89**	-30.73**	-20.04**	-4.35**	-8.01**	-11.40**	16.44**
Padmini × Arka Prasan	-21.47**	-34.90**	-21.17**	-9.01**	8.09**	2.24	1.53	29.41**
Bangalore Local-1 × Kashi Khushi	12.76**	-15.73**	-37.25**	-27.56**	14.46**	10.61**	5.07*	38.08**
Bangalore Local-1 × Arka Sujat	-20.31**	-27.13**	-34.54**	-24.44**	-13.94**	-16.68**	-20.85**	4.02
Bangalore Local-1 × Arka Prasan	26.36**	2.03	23.56**	42.62**	-0.88	-5.63**	-10.35**	17.81**
Kerala Local-3 × Kashi Khushi	-21.82**	49.29**	-37.17**	-27.48**	-6.70**	-8.24**	-18.69**	6.85*
Kerala Local-3 × Arka Sujat	-5.37**	-18.38**	1.12	16.72**	5.05*	3.12	-8.27**	20.55**
Kerala Local-3 × Arka Prasan	-20.55**	-21.44**	-2.68	12.34**	-11.46**	-11.57**	-24.04**	-0.18
Raichur Local-2 × Kashi Khushi	-7.90**	-36.67**	-37.84**	-28.24**	14.61**	14.12**	1.11	32.88**
Raichur Local-2 × Arka Sujat	-36.04**	-38.75**	-39.88**	-30.61**	-15.17**	-15.70**	-25.02**	-1.46
Raichur Local-2 × Arka Prasan	-18.02**	-25.78**	-10.13**	3.74	-22.00**	-22.86**	-32.24**	-10.96**
S.Em ±	0.47	0.54	0.54	0.54	0.08	0.09	0.09	0.09
CD (5 %)	0.95	1.10	1.10	1.10	0.17	0.19	0.19	0.19
CD (1 %)	1.27	1.47	1.47	1.47	0.22	0.26	0.26	0.26

*Significant at $p = 0.05$, **Significant at $p = 0.01$, ***Significant at $p = 0.001$, **MP**-Mid parent, **BP**- Better parent, Check-1- Arka Prasan, Check 2- Naga F_1 hybrid

action.

Average fruit weight

Kerala Local-3 × Arka Sujat exhibited the highest heterosis over the mid parent (33.51 %) (Table 8), while Bangalore Local-1 × Arka Prasan showed the highest heterosis over the better parent (29.03 %) and maximum positive heterosis against the standard checks, Arka Vikram by 20.18 % and the Naga F_1 hybrid by 33.30 %. In contrast, significant negative heterosis was also observed. Raichur Local-2 × Arka Sujat showed maximum negative relative heterosis (-25.36 %) and heterobeltosis (-32.35 %). In contrast, Kerala Local-3 × Kashi Khushi exhibited the maximum negative heterosis when compared to the standard checks, with values of -31.27 % (vs. Arka Vikram) and -23.77 % (vs. Naga F_1 hybrid). These results are consistent with those reported in ridge gourd (20, 23).

Yield per vine

For yield per vine, Kerala Local-3 × Arka Sujat showed the highest heterosis over the mid-parent (133.30 %) and also standard heterosis against both Arka Vikram (45.91 %) and the Naga F_1 hybrid (63.76 %) (Table 8). Bangalore Local-1 × Arka Prasan showed the highest better-parent heterosis (96.28 %). In contrast, significant negative better-parent heterosis was seen in Kolar Local-2 × Kashi Khushi (-25.85 %). For standard heterosis, the maximum negative heterosis was recorded in Bangalore Local-1 × Arka Sujat against both Arka Vikram (-38.43 %) and the Naga F_1 hybrid (-30.90 %). These results are consistent with the findings in bitter gourd and in ridge gourd (24, 25).

Yield per hectare

The cross Kerala Local-3 × Arka Sujat showed maximum mid-parent heterosis (133.22 %) and standard heterosis over Arka Vikram (45.95 %) and the Naga F_1 hybrid (63.72 %) (Fig. 2). Similarly, Bangalore Local-1 × Arka Prasan exhibited the highest better-parent heterosis (97.17 %). In contrast, Kolar Local-2 × Kashi Khushi exhibited significant negative better-parent heterosis (-25.89 %) and Bangalore Local-1 × Arka Sujat, which exhibited maximum negative standard heterosis over both checks, Arka Vikram (-38.35 %) and the Naga F_1 hybrid (-30.85 %). Maximum standard heterosis for yield per hectare was reported in cucumber (26, 27).

The significant positive heterosis recorded for average fruit weight, yield per vine and yield per hectare demonstrates the substantial potential for enhancing ridge gourd productivity through hybrid breeding. This marked improvement in overall yield can be attributed to the synergistic accumulation of favourable heterotic effects from its primary components, namely fruit number and fruit weight. The high magnitude of better parent heterosis strongly indicates the predominance of non-additive gene action in governing these complex traits. Therefore, the identification of these specific crosses provides a direct and valuable resource for commercial hybrid development programs. Conversely, the significant negative heterosis in certain combinations highlights the

Table 8. Estimation of heterosis (%) over mid-parent, better parent and standard check for average fruit weight and yield per vine in ridge gourd

Hybrids	Average fruit weight (g)				Yield per vine (kg)			
	MP	BP	Check-1	Check-2	MP	BP	Check-1	Check-2
IC-344652 × Kashi Khushi	13.68**	-20.73**	-25.10**	-16.92**	33.80**	0.16	-12.86**	-2.20
IC-344652 × Arka Sujat	16.24**	9.02**	3.01*	14.26**	24.87**	-2.81	-15.44**	-5.10
IC-344652 × Arka Prasan	20.16**	17.71**	11.22**	23.36**	47.69**	19.28**	3.77	16.47**
IC-344512 × Kashi Khushi	65.09**	13.75**	12.15**	24.39**	49.48**	10.63**	-0.35	11.84**
IC-344512 × Arka Sujat	26.69**	16.51**	14.87**	27.41**	64.58**	26.53**	13.98**	27.92**
IC-344512 × Arka Prasan	-9.72**	-13.36**	-14.58**	-5.26**	12.80**	-10.09**	-19.01**	-9.10**
Kolar Local-2 × Kashi Khushi	12.51**	-22.79**	-22.73**	-14.29**	-0.42	-25.85**	-34.45**	-26.43**
Kolar Local-2 × Arka Sujat	-18.52**	-25.57**	-25.51**	-17.37**	-3.78	-25.53**	-34.17**	-26.12**
Kolar Local-2 × Arka Prasan	-10.79**	-15.00**	-14.93**	-5.64**	5.56	-15.26**	-25.09**	-15.92**
Padmini × Kashi Khushi	21.89**	-16.83**	-14.97**	-5.68**	44.94**	9.60**	-7.48*	3.84
Padmini × Arka Sujat	-5.12**	-14.16**	-12.24**	-2.65	32.88**	4.55	-11.74**	-0.94
Padmini × Arka Prasan	11.61**	5.27**	7.63**	19.38**	60.59**	31.21**	10.76**	24.31**
Bangalore Local-1 × Kashi Khushi	15.89**	-19.47**	-22.97**	-14.56**	15.30**	-8.30*	-32.84**	-24.63**
Bangalore Local-1 × Arka Sujat	-14.31**	-20.09**	-23.56**	-15.21**	1.21	-15.94**	-38.43**	-30.90**
Bangalore Local-1 × Arka Prasan	29.03**	25.64**	20.18**	33.30**	126.79**	96.28**	43.75**	61.33**
Kerala Local-3 × Kashi Khushi	4.35*	-27.23**	-31.27**	-23.77**	7.11	-16.23**	-35.78**	-27.92**
Kerala Local-3 × Arka Sujat	33.51**	25.24**	18.29**	31.20**	133.30**	90.34**	45.91**	63.76**
Kerala Local-3 × Arka Prasan	-2.59*	-4.56**	-9.86**	-.02	3.81	-11.85**	-32.42**	-24.16**
Raichur Local-2 × Kashi Khushi	10.49**	-24.53**	-23.16**	-14.78**	2.88	-23.27**	-32.49**	-24.24**
Raichur Local-2 × Arka Sujat	-25.36**	-32.35**	-31.12**	-23.60**	0.00	-22.48**	-31.80**	-23.45**
Raichur Local-2 × Arka Prasan	-1.94	-7.32**	5.65**	4.65**	16.35**	-6.43*	-17.68**	7.61*
S.Em ±	2.92	3.37	3.37	3.37	0.11	0.13	0.13	0.13
CD (5 %)	5.90	6.81	6.81	6.81	0.23	0.27	0.27	0.27
CD (1 %)	7.89	9.11	9.11	9.11	0.31	0.36	0.36	0.36

*Significant at $p = 0.05$, **Significant at $p = 0.01$, ***Significant at $p = 0.001$, **MP**-Mid parent, **BP**- Better parent, Check-1- Arka Prasan, Check 2- Naga F_1 hybrid

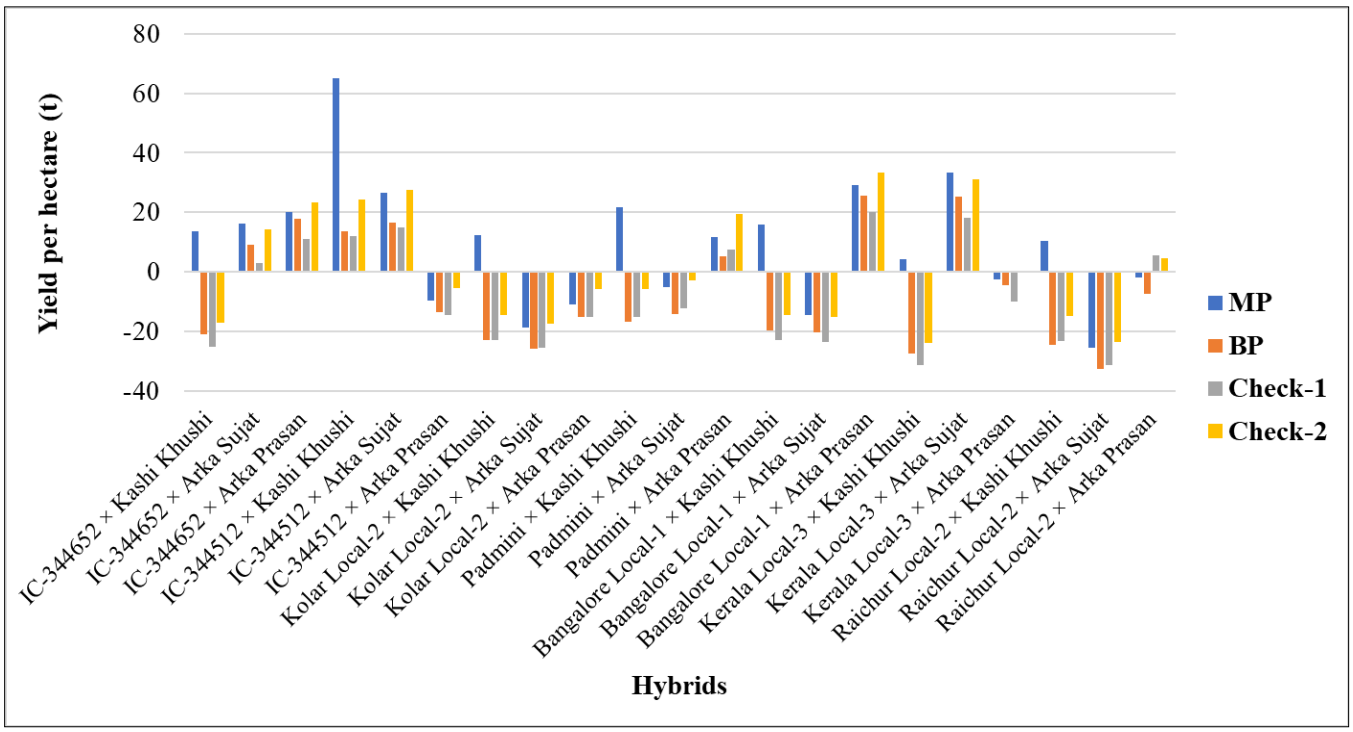

Fig. 2. Estimation of heterosis over mid-parent, better parent and standard checks for yield per hectare.

critical importance of parental selection and testing for combining ability to avoid unfavourable genetic pairings.

Conclusion

The study identified significant heterosis across multiple yield and quality-related traits among 21 ridge gourd hybrids. Among these, Kerala Local-3 × Arka Sujat and Bangalore Local-1 × Arka Prasan consistently exhibited superior performance in vegetative growth, flowering, fruit traits and yield potential. Positive heterosis was observed for yield and fruit quality traits, while desirable negative heterosis was recorded for earliness-related traits. These findings underscore the breeding value of the identified hybrids for improving productivity, earliness and quality. Their further evaluation could lead to the development of high-yielding, early maturing and well-adapted ridge gourd varieties.

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Authors' contributions

T conducted the field experiments, collected the primary data, performed the statistical analysis and drafted the original manuscript. KK reviewed and edited the manuscript and provided resources for the experiment. MS contributed to the conceptualisation, experimental planning and editing of the original manuscript. VSA and PVM designed and conceptualised the experiments. All authors read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflicts of interest to declare.

Ethical issues: None

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