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Heterosis Studies in Okra (*Abelmoschus esculentus* L. Moench)

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A B S T R A C T

Heterosis is manifested through greater vigour of F_1 over their parents resulting into higher yields through their component characters and the study of heterosis would help in selection of heterotic crosses for commercial exploitation of F_1 hybrids in okra (*Abelmoschus esculentus* (L.) Moench). Forty five F_1s were developed by crossing 10 elite lines of okra in half diallel fashion during summer 2016. All 45 F_1s along with their 10 parents and one standard control (Nunhems hybrid Shakti) were evaluated in a randomized complete block design with three replicates during late *kharif* (July to October) 2016 at ICAR- Krishi Vigyan Kendra, Babbur Farm, Hiriyur, Chitradurga, Karnataka. The magnitude of heterosis varied from cross to cross for all the characters studied. The variance due to parents verses hybrids was highly significant (P=0.01) for plant height, number of branches per plant, first fruit producing node, fruit length, average fruit weight, number of fruits per plant and yield per plant. The results revealed wide range of heterotic pattern for different traits. For first fruit producing node, heterosis over better parent and standard control ranged from -25.44 to 54.32 and -9.03 to 43.32 respectively. For days to 50% flowering, heterosis over better parent and standard control ranged from -8.03 to 3.79 and -8.70 to 0.72 respectively and for total yield per plant, heterosis over better parent and standard control ranged from -32.66 to 83.78 and -0.13 to 168.55 respectively. Out of 45 F_1s, 44 F_1s crosses exhibit significant standard heterosis in any given direction for total yield per plant except cross IIHR-604 x IIHR-107 (-0.13%). The maximum positive significant heterosis was observed in cross IIHR-875 x IIHR-478 (83.78%) over better parent and (168.55%) over standard parent may be exploited for commercial cultivation.

Introduction

Okra (*Abelmoschus esculentus* (L.) Moench) an annual, often cross-pollinated crop belonging to the family Malvaceae, is an important crop of the tropics and subtropics of the world. The yield potential of okra is very low. However, it could be improved through hybridization. Marked heterosis of 38 to 71 percent has been reported in okra for yield and its components (Laxmiprasanna, 1996; Singh *et al.*, 1975). Under optimum crop production and protection management, the crops raised from F_1 hybrids show higher yield with added advantage of early maturing, uniformity, wider adaptability and tolerance to insect pests and diseases. Thus, heterosis breeding in okra for yield and quality with disease resistance offers quantum jump in yield in short period of time. Hybrid vigour in okra has been first reported by Vijayaraghavan and Warier (1946). For exploitation of heterosis, choice of suitable parents is an important pre-requisite. For exploitation of heterosis, choice of suitable parents is an important pre-requisite. Selection of parents on the basis of phenotypic performance alone is not a sound procedure. It is therefore essential that parents should be chosen on the basis of their combining ability. The half diallel mating design has been used in the present study to assess the genetic potentialities. The magnitude of heterosis provides a basis for genetical diversity and a guide for the choice of desirable parents for developing superior F_1 hybrids to exploit hybrid vigour and for building gene pools to be employed in future breeding programme. Keeping this in view, the present investigation was carried out to know magnitude of heterosis for fruit yield and its component traits in okra.

Materials and Methods

The experiment materials comprised of ten elite and nearly homozygous lines of okra namely IIHR -875, IIHR -478, IIHR- 604, IIHR- 567, IIHR- 182, IIHR- 595, IIHR- 562, IIHR- 347, IIHR- 444, IIHR-107 selected from the germplasm collected by ICAR-Indian Institute of Horticulture Research Institute, Bengaluru, Karnataka and were crossed in n(n - 1)/2 possible combinations during summer 2016 to generate the breeding material. The resulting 45 one way crosses along with their 10 counterpart parental lines and one standard control (Nunhems Hybrid Shakti) were evaluated in a randomized complete block design with three replicates. The experiment was conducted at the Experimental Farm, ICAR- Krishi Vigyan Kendra, Babbur Farm, Hiriyur, Chitradurga, Karnataka. The experiment was conducted during late *kharif* (July-October) 2016. The experimental site is situated in Central dry zone (Zone-4) 13°57’32” North latitude and 70°37’38” East longitude at 606 meters above Mean Sea Level (MSL). Among the agro-climatic zones of Karnataka, Hiriyur benefits of both South-West and North- East monsoons. The annual average rainfall for last 35 years is 567 mm per year. The maximum and minimum temperature in a year ranges between 31.49 °C and 20.91 °C, respectively. The annual relative humidity of location is 77.76 per cent and 61.74 per cent in morning and evening, respectively. The soil type of the experimental block was sandy clay loamy (montmorillonite) with a uniform fertility having soil pH range of 7.0 to 8.0. The experimental plots were ploughed repeatedly and land was brought to a fine tilth. Raised beds with inline drip and plastic mulching developed at 90 x 10 x 30 cm. Two to three seeds of each genotype per hill were dibbled at a distance of 15 cm apart and 60 cm between rows on the beds.

Biometric data were recorded for 12 quantitative characters. Observations on the characters like plant height (cm), number of branches per plant, internodal length (cm), stem girth (mm), first fruit producing node, fruit length (cm), fruit diameter (mm), number of ridges per fruit and average fruit weight (g) were recorded on five randomly selected competitive plants, while the observations on the characters like days to 50% flowering, total number of fruits per plant and total yield per plant (g) were recorded on whole plot basis in each entry in each replicate. Relative heterosis, heterobeltiosis and standard heterosis were determined as percent increase (+) or decrease (-) of F_1 over mid parent (MP), better parent (BP) and standard control (SC) using the formulae (F_1-MP/MP × 100), (F_1-BP/BP × 100) and (F_1-SC/SC × 100), respectively (Singh, 1973). The statistical significance of heterosis, heterobeltiosis and standard heterosis was assessed by t-test (Wynne *et al.*, 1970).

Results and Discussion

The goal of okra hybrid breeding is to identify and then reliably reproduce superior hybrid genotypes. Virtually all commercial okra hybrids are made from crosses of inbred lines. Knowledge of heterotic groups from which to draw parental germplasm for hybrid combinations is limited.

Improvement of complex characters such as pod yield may be accomplished through the component approach of breeding. This method, in general, assumes strong associations of yield with a number of characters making up yield and simpler inheritance for these component characters.

Analysis of variance

Genotypes (Treatments)

ANOVA (Table 1) indicated significance of mean squares due to genotypes for almost all growth, earliness and yield parameters *viz*., plant height, intermodal length, number of branches per plant stem girth, first fruit producing node, days to 50% flowering, fruit length, fruit diameter, average fruit weight, number of ridges per fruit, number of fruits per plant and yield per plant.

This can be attributed to the fact that there were clear cut genotypic differences among the parents and their hybrids, which were phenotypically expressed.

Parents

Parents differed significantly, at P=0.01 among themselves for all the growth, earliness and yield parameters, *viz*., plant height, internodal length, number of branches per plant stem girth, first fruit producing node, fruit length, fruit diameter, average fruit weight, number of ridges per fruit, number of fruits per plant and yield per plant. Whereas days to 50 per cent flowering, the variance due to parents was significant at P=0.05.

Hybrids (Crosses)

There was highly significant differences (P=0.01) among the hybrids for all the growth, earliness and yield parameters studied.

Parents *vs*. Hybrids

The variance due to parents verses hybrids was highly significant (P=0.01) for plant height, number of branches per plant, first fruit producing node, fruit length, average fruit weight, number of fruits per plant and yield per plant. However, variance due to parent’s verses hybrids was not significant for internodal length, stem girth, days to 50 per cent flowering, fruit diameter and number of ridges per fruit. Similar results were obtained by Mehta *et al.*, 2007 and Hosamani *et al.*, 2008.

Heterosis

The number of crosses in present study displaying significantly positive and negative heterosis over the better parent and standard control (Nunhems hybrid Shakti) are presented in Table 2. There was huge amount of variation in heterotic effects as they varied differently for different characters. For plant height, heterosis over better parent and standard control ranged from -33.30 to 13.93 and -23.82 to 30.12 per cent respectively. For this trait, nine cross over better parent and 36 cross over standard control manifested significantly positive heterosis. Heterosis over better parent and standard control ranged from -22.03 to 20.01 and -19.79 to 15.91 per cent respectively for internodal length. For internodal length 21 cross over better parent and 11 cross over standard control manifested significantly negative heterosis.

For number of branches per plant, heterosis better parent and standard control ranged from -40.11 to 40.54 and -35.64 to 26.97 per cent respectively. For this trait, eight cross over better parent and four cross over standard control manifested significantly positive heterosis. For stem girth, heterosis over better parent and standard control ranged from -20.70 to 24.64 and -14.57 to 28.23 percent respectively. For this trait, seven cross over better parent and 18 cross over standard control manifested significantly positive heterosis.

For first fruit producing node, heterosis over better parent and standard control ranged from -25.44 to 54.32 and -9.03 to 43.32 percent respectively. For this trait, 15 cross over better parent and six cross over standard control manifested significant heterosis in desirable direction (negative). For days to 50% flowering, better parent and standard control ranged from -8.03 to 3.79 and -8.70 to 0.72 per cent respectively. For this trait, nine cross over better parent and nine cross over standard control manifested significantly negative heterosis.

For fruit length, better parent and standard control ranged from -25.40 to 24.30 and -25.24 to 13.53 respectively per cent (Table 3). For this trait, 10 cross over better parent and five cross over standard control manifested significantly positive heterosis. For fruit diameter, better parent and standard control ranged from -23.14 to 16.01 and -16.77 to 11.90 per cent respectively.

For this trait, seven cross over better parent and four cross over standard control manifested positively significant heterosis. For average fruit weight, better parent and standard control ranged from -30.05 to 31.76 and -15.39 to 42.25 respectively. For this trait, 16 cross over better parent and 26 cross over standard control manifested significantly positive heterosis. For number of ridges per fruit, better parent and standard control ranged from -13.07 to 15.09 and -3.85 to 17.31 per cent respectively. For this trait, two cross over better parent and eight cross over standard control manifested significantly positive heterosis.

For number of fruits per plant, heterosis over better parent and standard control ranged from -24.14 to 48.91 and -4.35 to 98.55 per cent respectively. For this trait, 19 cross over better parent and 42 cross over standard control manifested significantly positive heterosis. For total yield per plant, better parent and standard control ranged from -32.66 to 83.78 and -0.13 to 168.55 respectively per cent. For this trait, 20 cross over better parent and 44 cross over standard control manifested positively significant heterosis. From the results of the heterosis studies, it is evident that none of the 45 F_1 hybrids of okra showed consistency in direction and degree of heterosis over three bases for all the characters studied. Some of them manifested positive heterosis while others exhibited negative heterosis, mainly due to varying extent of genetic diversity between parents of different cross combinations for the component characters. Significant heterosis was observed for all the growth, earliness and yield attributes. It is inferred that the magnitude of economic heterosis was higher for most of the growth and earliness characters under study.

In the present study, the estimates of relative heterosis, heterobeltiosis, and standard heterosis were found to be highly variable in direction and magnitude among crosses for all the characters under study. Weerasekara *et al.,* (2007) and Jindal *et al.,* (2009) also reported such a variation in heterosis for different characters. The manifestation of negative heterosis observed in some of the crosses for different traits may be due to the combination of the unfavorable genes of the parents.

Fig.1 *Per cent* standard heterosis of top three hybrids IIHR-875 x IIHR-478, IIHR-604 x IIHR-347 and IIHR-478 x IIHR-567 for 12 characters studied

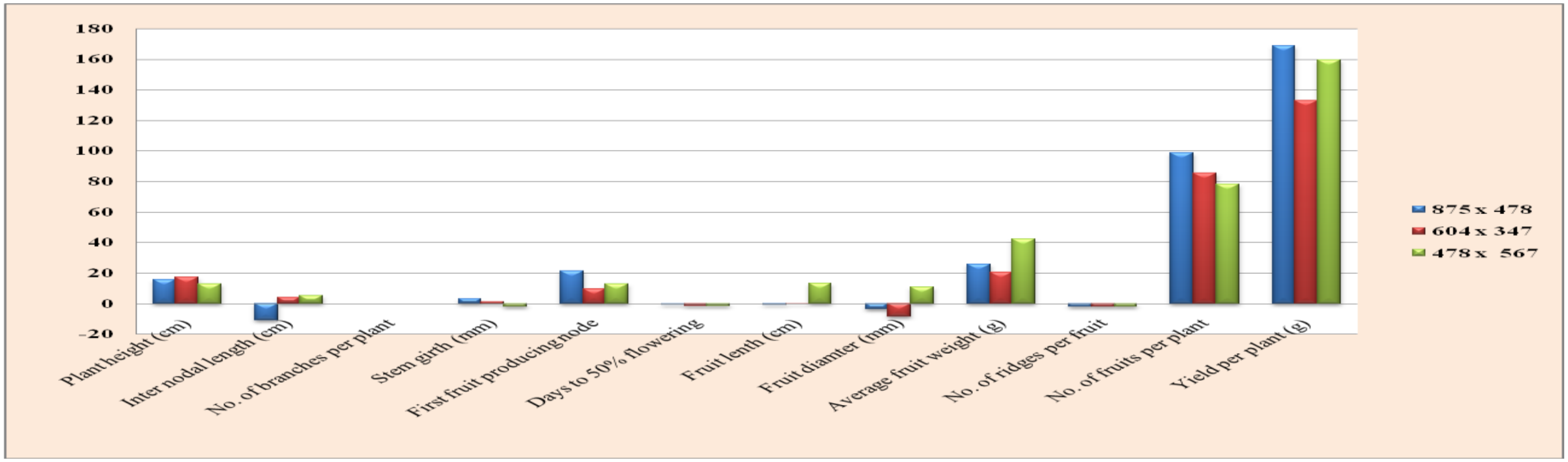

Table.1 Analysis of variance (mean sum of square) of combining abilities for twelve characters in a set of 10 X 10 half diallel crosses

Source	d.f.	Plant height (cm)	Inter nodal length (cm)	No. of branches per plant	Stem girth (mm)	First fruit producing node	Days to 50% flowering	Fruit length (cm)	Fruit diameter (mm)	Average fruit weight (g)	No. of ridges per fruit	No. of fruits per plant	Yield per plant (g)
Replicates	2	0.39	1.78 **	1.42 **	0.65	0.01	37.98 **	0.34	2.23 **	0.84	0.57 **	49.32 **	**9275.55 ****
Treatments	54	727.47 **	3.24 **	0.87 **	10.71 **	1.56 **	3.93 **	5.01**	4.46 **	14.27 **	0.15 **	79.30 **	**38483.22 ****
Parents	9	822.46 **	4.50 **	1.04 **	8.79 **	2.32 **	2.01 *	3.34**	4.22 **	11.07 **	0.16 **	13.31 **	**15676.11 ****
Hybrids	44	717.18 **	3.05 **	0.84 **	11.33 **	1.41 **	4.41 **	5.35 **	4.61 **	14.60 **	0.15 **	88.78 **	**40219.54 ****
Parent Vs. Hybrids	1	324.95 **	0.01	0.77 **	0.51	1.72 **	0.10	5.17 **	0.01	28.71 **	0.00	256.02 **	**167349.10 ****
Error	**108**	**1.27**	**0.35**	**0.05**	**0.36**	**0.04**	**0.94**	**0.26**	**0.27**	**0.29**	**0.01**	**0.85**	**158.41**

*, **Significant at P ≤ 0.05 and P ≤ 0.01 levels probability, respectively.

Table.2 Estimation of better parent and standard heterosis of 10 X 10 half diallel crosses in okra for different characters

Sl. No.	Crosses	Plant height (cm)		Inter nodal length (cm)		No. of branches per plant		Stem girth (mm)		First fruit producing node		Days to 50% flowering	
		BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC
1	875 x 478	0.05	15.83 **	9.08	-10.55 *	32.58 **	20.06 **	-11.09 **	3.16	30.65 **	21.33 **	1.48	-0.72
2	875 x 604	13.93 **	30.12 **	-16.15 **	-14.72 **	33.98 **	21.32 **	2.77	10.71 **	54.32 **	43.32 **	0.00	-0.72
3	875 x 567	-2.12 **	28.81 **	20.01 **	15.91 **	13.66 *	2.92	4.67 *	10.78 **	-3.48	17.05 **	-0.73	-1.45
4	875 x 182	6.27 **	24.27 **	-4.31	-1.48	2.89	-2.82	-0.23	1.49	-0.05	13.07 **	1.49	-1.45
5	875 x 595	3.79 **	27.20 **	-17.46 **	-11.10 **	0.32	-9.15	2.94	4.72 *	4.08	13.78 **	3.79 *	-0.72
6	875 x 562	3.49 **	23.45 **	7.32	10.40 *	31.51 **	19.08 **	0.39	5.45 *	2.62	27.99 **	-0.73	-1.45
7	875 x 347	5.02 **	25.72 **	-10.09 *	-4.46	-26.19 **	-9.15	2.83	5.79 *	23.56 **	38.03 **	1.49	-1.45
8	875 x 444	-4.38 **	8.34 **	9.13	-6.49	-12.04	-20.35 **	-1.54	3.50	17.47 **	9.09 **	-5.15 **	-6.52 **
9	875 x 107	-1.42 *	11.69 **	7.19	14.00 **	-5.70	-14.61 *	0.73	2.48	-8.66 **	-4.16	3.79 *	-0.72
10	478 x 604	6.31 **	23.08 **	2.19	3.94	-25.93 **	-33.79 **	-1.08	14.78 **	4.08	-4.58	-1.46	-2.17
11	478 x 567	-14.21 **	12.90 **	9.00 *	5.27	2.29	-8.57	-15.60 **	-2.07	-6.76 **	13.07 **	-0.73	-1.45
12	478 x 182	2.84 **	20.26 **	-10.98 **	-8.35	4.54	-1.27	-8.97 **	5.63 *	-4.94	7.55 *	0.74	-1.45
13	478 x 595	-5.45 **	15.88 **	5.84	14.00 **	-21.24 **	-29.60 **	-14.34 **	-0.60	-10.33 **	-1.96	2.22	0.00
14	478 x 562	-0.11	19.15 **	4.73	7.74	2.29	-8.57	-0.66	15.27 **	-13.01 **	8.50 **	-1.46	-2.17
15	478 x 347	2.18 **	22.32 **	8.04 *	14.81 **	-40.11 **	-26.29 **	-15.19 **	-1.59	3.67	15.81 **	0.00	-2.17
16	478 x 444	-14.13 **	-0.58	0.68	-13.74 **	-18.63 **	-27.26 **	-11.15 **	3.10	17.81 **	-4.10	-0.74	-2.17
17	478 x 107	6.72 **	23.56 **	-0.08	6.26	-9.04	-18.70 **	-9.55 **	4.96 *	-6.00 *	-1.37	1.48	-0.72
18	604 x 567	-13.23 **	14.19 **	2.22	3.97	-12.42	-24.44 **	6.15 **	14.35 **	-10.14 **	8.97 **	0.73	0.00
19	604 x 182	-5.82 **	10.13 **	-12.89 **	-10.32 *	-11.24	-16.16 **	-13.66 **	-6.99 **	2.00	15.39 **	0.00	-0.72
20	604 x 595	-23.61 **	-6.38 **	-5.00	2.32	-2.62	-20.25 **	-20.70 **	-14.57 **	-13.37 **	-5.29	-5.11 **	-5.80 **
21	604 x 562	-14.31 **	2.22 **	-7.38	-4.72	-2.73	-20.35 **	-12.66 **	-5.91 *	-9.24 **	13.19 **	0.73	0.00
22	604 x 347	-2.01 **	17.30 **	-1.91	4.23	-34.89 **	-19.86 **	-5.92 **	1.35	-1.81	9.69 **	-0.73	-1.45

23	604 x 444	-33.30 **	-23.82 **	-1.20	0.49	-17.48 *	-32.42 **	-2.79	4.72 *	6.93 *	-1.96	-2.19	-2.9
24	604 x 107	-9.38 **	3.51 **	-10.74 **	-5.07	-21.40 **	-35.64 **	-14.67 **	-8.07 **	-10.53 **	-6.12	0.73	0.00
25	567 x 182	-22.03 **	2.61 **	-14.58 **	-12.05 **	-3.09	-8.47	-5.35 *	0.17	-9.90 **	9.27 **	0.00	-0.72
26	567 x 595	-5.15 **	24.82 **	-5.22	2.09	2.26	-11.78 *	-0.99	4.78 *	5.63 *	28.10 **	1.46	0.72
27	567 x 562	-12.11 **	15.67 **	-14.17 **	-11.71 **	8.35	-6.52	-4.14	1.45	-9.77 **	12.54 **	-5.11 **	-5.80 **
28	567 x 347	-12.93 **	14.59 **	-14.45 **	-9.10 *	-19.78 **	-1.27	0.17	6.01 *	-3.87	16.58 **	-7.30 **	-7.97 **
29	567 x 444	-22.81 **	1.58 *	-1.56	-4.93	-7.34	-20.06 **	7.73 **	14.02 **	-9.26 **	10.04 **	-7.30 **	-7.97 **
30	567 x 107	-25.66 **	-2.16 **	-12.81 **	-7.27	-16.14 *	-27.65 **	-0.86	4.93 *	-24.99 **	-9.03 **	-8.03 **	-8.70 **
31	182 x 595	-12.35 **	7.41 **	-2.04	5.51	-20.82 **	-25.22 **	-10.19 **	-12.32 **	-19.01 **	-8.38 **	0.75	-2.17
32	182 x 562	-4.40 **	14.03 **	-2.65	0.23	15.77 *	9.35	-6.23 **	-1.51	-10.29 **	11.88 **	-2.19	-2.90
33	182 x 347	-11.24 **	6.25 **	-10.91 **	-5.33	3.16	26.97 **	1.50	4.42	2.99	16.52 **	1.49	-1.45
34	182 x 444	-24.72 **	-11.98 **	-10.05 *	-7.39	-8.25	-13.34 *	-17.34 **	-13.11 **	-9.40 **	2.50	-1.47	-2.90
35	182 x 107	-0.90	15.88 **	-8.34 *	-2.52	3.40	-2.34	9.79 **	-0.68	-1.79	11.11 **	1.49	-1.45
36	595 x 562	-6.46 **	14.64 **	-21.74 **	-15.71 **	35.57 **	-1.66	8.61 **	14.08 **	-7.91 **	14.85 **	0.00	-0.72
37	595 x 347	-3.68 **	18.04 **	-8.10 *	-1.01	-10.60 *	10.03	24.64 **	28.23 **	0.80	12.60 **	-5.97 **	-8.70 **
38	595 x 444	-17.67 **	0.90	-14.10 **	-7.48	-4.37	-29.60 **	-12.53 **	-8.06 **	-12.34 **	-4.16	2.21	0.72
39	595 x 107	0.06	22.63 **	-7.61	-0.49	32.05 **	-13.34 *	7.91 **	5.36 *	-14.35 **	-6.36 *	2.27	-2.17
40	562 x 347	-3.88 **	15.06 **	-3.98	2.03	-24.84 **	-7.50	-11.92 **	-7.49 **	-18.01 **	2.26	0.73	0.00
41	562 x 444	-24.39 **	-9.81 **	-22.03 **	-19.79 **	13.36	-16.55 **	-18.20 **	-14.02 **	-25.44 **	-7.01 *	-8.03 **	-8.70 **
42	562 x 107	-6.17 **	11.92 **	-13.13 **	-7.62	40.54 **	1.95	-4.69 *	0.11	-11.62 **	10.22 **	-3.65 *	-4.35 *
43	347 x 444	-19.22 **	-3.30 **	-9.19 *	-3.51	-17.17 **	1.95	-17.04 **	-12.79 **	-16.86 **	-7.13 *	-1.47	-2.90
44	347 x 107	-11.17 **	6.33 **	-11.44 **	-5.82	-19.07 **	-0.39	-11.97 **	-9.44 **	-9.57 **	1.01	1.49	-1.45
45	444 x 107	-15.35 **	-11.13 **	-20.08 **	-15.01 **	-1.06	-27.17 **	-17.75 **	-13.54 **	-12.63 **	-8.32 **	-1.47	-2.90
	S.E.D	**0.92**	**0.92**	**0.48**	**0.48**	**0.20**	**0.20**	**0.49**	**0.49**	**0.17**	**0.17**	**0.79**	**0.79**
	C.D. 0.05	**1.86**	**1.86**	**0.97**	**0.97**	**0.39**	**0.39**	**0.99**	**0.99**	**0.35**	**0.35**	**1.60**	**1.60**
	C.D. 0.01	**2.42**	**2.42**	**1.28**	**1.28**	**0.51**	**0.51**	**1.29**	**1.29**	**0.45**	**0.45**	**2.08**	**2.08**

*, **Significant at $P \leq 0.05$ and $P \leq 0.01$ levels probability, respectively.

Table.3 Estimation of better parent and standard heterosis of 10 X 10 half diallel crosses in okra for different characters

Sl. No.	Hybrids	Fruit length (cm)		Fruit diameter (mm)		Average fruit weight (g)		No. of ridges per fruit		No. of fruits per plant		Yield per plant (g)	
		BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC
1	875 x 478	8.53 **	-0.88	0.02	-3.52	20.55 **	25.88 **	-13.07 **	-1.92	48.91 **	98.55 **	83.78 **	168.55 **
2	875 x 604	3.52	-0.79	3.79	-3.21	29.58 **	16.02 **	-5.11 **	7.05 **	20.69 **	52.17 **	65.83 **	80.14 **
3	875 x 567	-0.13	-13.94 **	10.49 **	5.68 *	6.40 *	23.69 **	-12.50 **	-1.28	3.33	34.78 **	9.57 **	73.80 **
4	875 x 182	-1.25	-14.90 **	5.06 *	-4.73*	-2.12	1.14	-3.98 *	8.33 **	7.14 **	30.43 **	4.63	38.12 **
5	875 x 595	2.85	0.83	-3.60	6.19 **	8.71 **	20.18 **	-7.95 **	3.85 *	10.34 **	39.13 **	28.82 **	82.04 **
6	875 x 562	12.02 **	-1.22	6.24 *	-4.39	30.22 **	16.68 **	3.41 *	16.67 **	1.22	20.29 **	37.77 **	49.99 **
7	875 x 347	-18.94 **	-17.60 **	-0.30	-9.93 **	-20.04 **	-11.78 **	-13.07 **	-1.92	46.74 **	95.65 **	15.87 **	77.61 **
8	875 x 444	-0.76	-14.48 **	1.79	-3.16	-16.81 **	2.89	-10.23 **	1.28	11.90 **	36.23 **	-7.92 **	46.70 **
9	875 x 107	20.58 **	5.27	2.02	-2.87	2.28	8.14 **	-10.80 **	* 0.64	26.92 **	43.48 **	37.79 **	61.55 **
10	478 x 604	2.3	-1.96	-13.72 **	-16.77 **	9.12 **	13.94 **	-0.64	-0.64	3.26	37.68 **	17.18 **	71.23 **
11	478 x 567	24.30 **	13.53 **	15.00 **	10.94 **	22.37 **	42.25 **	0.00	-1.92	33.70 **	78.26 **	63.61 **	159.53 **
12	478 x 182	8.18 *	-1.19	0.11	-3.44	22.68 **	28.11 **	0.00	-1.28	1.09	34.78 **	25.54 **	83.45 **
13	478 x 595	3.35	1.33	-16.13 **	-7.62 **	14.46 **	26.53 **	1.31	-0.64	2.17	36.23 **	25.62 **	83.56 **
14	478 x 562	6.83 *	-2.43	-0.11	-3.64	5.45	10.11 **	0.64	* 0.64	30.43 **	73.91 **	33.87 **	95.62 **
15	478 x 347	7.44 **	9.21 **	-3.95	-7.35 **	10.73 **	22.18 **	-2.58	-3.21	-5.43 *	26.09 **	3.58	58.77 **
16	478 x 444	-2.79	-11.21 **	16.01 **	11.90 **	1.10	25.04 **	15.09 **	17.31 **	-15.22 **	13.04 **	-5.37 **	50.76 **
17	478 x 107	16.84 **	6.71 *	0.62	-2.94	13.54 **	20.05 **	1.30	0.00	0.00	33.33 **	19.20 **	74.18 **
18	604 x 567	-4.32	-8.31 **	-3.13	-7.35 **	-0.55	15.61 **	-3.21	-3.21	4.44	36.23 **	0.34	59.16 **
19	604 x 182	10.71 **	6.10 *	7.64 **	0.37	31.76 **	36.14 **	-1.28	-1.28	-13.79 **	8.70 **	20.02 **	58.43 **
20	604 x 595	-10.52 **	-12.27 **	-23.14 **	-15.34 **	2.85	13.70 **	-1.92	-1.92	-6.90 **	17.39 **	1.79	43.83 **
21	604 x 562	4.49	0.14	3.01	-3.95	17.29 **	2.45	3.21	3.21	0.00	26.09 **	19.76 **	30.38 **
22	604 x 347	-1.84	-0.23	-1.64	-8.28 **	9.17 **	20.45 **	-1.92	-1.92	39.13 **	85.51 **	52.04 **	133.05 **

23	604 x 444	-12.57 **	-16.21 **	-9.97 **	-14.35 **	-21.59 **	-3.02	-1.89	0.00	-9.20 **	14.49 **	-32.66 **	7.28 *
24	604 x 107	-6.53 *	-10.42 **	0.39	-4.42 *	-2.15	3.46	3.21	3.21	-24.14 **	-4.35	-14.82 **	-0.13
25	567 x 182	7.94 *	-11.55 **	-0.18	-4.52 *	-11.04 **	3.42	1.95	* 0.64	-13.33 **	13.04 **	-24.10 **	20.40 **
26	567 x 595	-12.81 **	-14.52 **	-10.92 **	-1.87	-9.17 **	5.58	2.61	* 0.64	-5.56 *	23.19 **	-16.07 **	33.14 **
27	567 x 562	-11.00 **	-21.52 **	-9.42 **	-13.37 **	-25.54 **	-13.44 **	-1.28	-1.28	13.33 **	47.83 **	-13.06 **	37.91 **
28	567 x 347	-10.06 **	-8.58 **	-8.78 **	-12.76 **	-4.52	10.99 **	-0.65	-1.28	-5.43 *	26.09 **	-7.36 **	46.96 **
29	567 x 444	5.30	-10.60 **	-2.10	-6.36 **	-6.39 **	15.78 **	-3.77 *	-1.92	13.33 **	47.83 **	11.39 **	77.46 **
30	567 x 107	1.52	-11.37 **	5.05 *	0.48	-18.21 **	-4.93	-0.65	-1.92	15.56 **	50.72 **	-0.78	57.39 **
31	182 x 595	10.86 **	8.69 **	-16.50 **	-8.03 **	16.34 **	28.61 **	0.65	-0.64	-18.39 **	2.90	-3.29	36.65 **
32	182 x 562	-15.22 **	-25.24 **	-2.49	-11.58 **	-16.99 **	-14.23 **	-1.92	-1.92	19.05 **	44.93 **	-6.16 **	23.87 **
33	182 x 347	-15.06 **	-13.67 **	0.32	-9.61 **	-8.93 **	0.48	0.65	0.00	30.43 **	73.91 **	21.94 **	86.90 **
34	182 x 444	2.76	-12.76 **	1.14	-3.78	-30.05 **	-13.49 **	-3.14	-1.28	0.00	21.74 **	-26.38 **	17.28 **
35	182 x 107	-3.02	-15.33 **	-2.57	-7.24 **	4.20	10.18 **	-0.65	-1.92	3.57	26.09 **	11.56 **	47.25 **
36	595 x 562	-8.56 **	-10.36 **	-16.00 **	-7.47 **	-6.51 *	3.35	0.00	0.00	3.45	30.43 **	-2.81	37.34 **
37	595 x 347	-6.71 *	-5.18	-9.85 **	-0.70	-8.30 **	1.38	-1.94	-2.56	3.26	37.68 **	-4.82 *	45.90 **
38	595 x 444	-6.34 *	-8.17 **	-10.47 **	-1.38	-5.52 *	16.86 **	-2.52	-0.64	3.45	30.43 **	-3.14	54.30 **
39	595 x 107	-9.05 **	-10.83 **	-9.31 **	-0.10	-6.77 *	3.06	-0.65	-1.92	24.14 **	56.52 **	16.24 **	64.25 **
40	562 x 347	-19.53 **	-18.21 **	-5.12 *	-14.29 **	-23.31 **	-15.39 **	-1.28	-1.28	7.61 **	43.48 **	-20.27 **	22.21 **
41	562 x 444	5.46	-7.00 *	-3.50	-8.20 **	-26.46 **	-9.04 **	-3.14	-1.28	25.00 **	52.17 **	-13.18 **	38.32 **
42	562 x 107	2.20	-9.88 **	-1.41	-6.14 **	-5.92 *	-0.53	0.00	0.00	10.98 **	31.88 **	10.95 **	30.08 **
43	347 x 444	-6.27 *	-4.73	0.20	-4.68 *	11.08 **	37.39 **	-5.66 **	-3.85 *	-10.87 **	18.84 **	-0.62	58.32 **
44	347 x 107	-25.40 **	-24.18 **	-12.43 **	-16.63 **	5.00	15.85 **	-1.29	-1.92	-21.74 **	4.35	-18.09 **	25.55 **
45	444 x 107	-0.64	-13.26 **	-0.52	-5.29 *	1.36	25.37 **	-5.03 **	-3.21	-9.52 **	10.14 **	-8.17 **	46.29 **
	S.E.D	**0.42**	**0.42**	**0.43**	**0.43**	**0.44**	**0.44**	**0.10**	**0.10**	**0.76**	**0.76**	**10.28**	**10.28**
	C.D. 0.05	**0.85**	**0.85**	**0.86**	**0.86**	**0.89**	**0.89**	**0.20**	**0.20**	**1.52**	**1.52**	**20.71**	**20.71**
	C.D. 0.01	**1.11**	**1.11**	**1.12**	**1.12**	**1.15**	**1.15**	**0.26**	**0.26**	**1.99**	**1.99**	**26.95**	**26.95**

*, **Significant at $P \leq 0.05$ and $P \leq 0.01$ levels probability, respectively.

Of the 12 characters under study, plant height, number of branches per plant and internodal length largely determine the fruit bearing surface and thus considered as growth attributes. Okra bears pods at almost all nodes on main stem and primary branches. Higher the plant height with more number of branches on the main stem, higher is the number of fruits per plant because of accommodation of more number of nodes for a given internodal length. Shorter distance between nodes accommodates more number of nodes on main stem, which will ultimately lead to higher fruit number and higher fruit production. Hence, positive heterosis is desirable for plant height and number of branches, while negative heterosis is desirable for internodal length to accommodate more number of nodes and to get higher fruit yield in okra. Appreciable amount of the crosses displayed positive standard heterosis for plant height (up to 30.12%), no. of branches per plant (up to 26.97%), internodal length (up to -19.79%). Ahmed *et al.,* (1999), Dhankar and Dhankar (2001) and Rewale *et al.,* (2003), Singh *et al.,* (2004), Weerasekara *et al.,* (2007) and Jindal *et al.,* (2009) also reported the similar projections for number of branches in okra. For internodal length, similar projections were also made by Rewale *et al.,* (2003), Singh *et al.,* (2004), and Jindal *et al.,* (2009).

However, days to 50% flowering and first fruit producing node are the indicators of earliness in okra. Early flowering not only gives early pickings and better returns but also widens fruiting period of the plant. Fruiting at lower nodes is helpful in increasing the number of fruits per plant as well as getting early yields. Negative heterosis is highly desirable for all these three attributes of earliness. In the present study, cross IIHR-562 x IIHR-444 exhibiting high negative heterosis over standard control for days to 50% flowering (-8.70%) out of 45 hybrids, 9 and 9 hybrids showed significant heterosis in desirable direction (negative)over better parent and over standard parent respectively. The cross IIHR-567 x IIHR-107 (Table 2) displaying high negative heterosis over standard control for first fruit producing node (-9.03%) among the 45 hybrids developed, 25 hybrids over better parent and 6 hybrids over standard parent showed significantly negative heterosis therefore, it is important to exploit heterosis for earliness in okra. Weerasekara *et al.,* (2007) and Jaiprakashnarayan *et al.,* (2008) also noticed heterosis in desirable direction for days to 50% flowering in okra. The negative estimates of heterobeltiosis and economic heterosis for earliness revealed the presence of genes for the development of earliness in okra. Mandal and Das (1991), Tippeswamy *et al.,* (2005) and Jindal *et al.,* (2009) also noticed desirable heterosis for first fruit producing node in okra.

Total number of fruits per plant and fruit length, width, and weight are considered to be associated directly with total yield per plant, for which positive heterosis is desirable. The trait fruit length exhibit high magnitude significant heterosis in both the direction of better parent and standard parent. Maximum positive and significant heterosis over better parent (24.30%) and over standard parent (13.53%) was observed in crosses IIHR-478 x IIHR-567. Among 45 hybrids developed, 10 hybrids over better parent and 5 hybrids over standard parent exhibited positive and significant heterosis. The trait fruit diameter exhibit high magnitude significant heterosis in both the better parent and standard parent. The cross IIHR-478 x IIHR-444 exhibited maximum positively significant heterosis over better parent (16.01%) and over standard parent (11.90%). Out of 45 hybrids, 7 and 4 hybrids showed positive and significant heterosis over better parent and over standard parent respectively. The trait average fruit weight exhibit high magnitude significant heterosis in both the direction better parent and standard parent. Positively significant heterosis is preferred for this trait. The cross IIHR-604 x IIHR-182, showed maximum positive significant heterosis over better parent (31.76%). Whereas, the cross IIHR-478 x IIHR-567 showed maximum significant heterosis over standard parent (42.25%). Among 45 hybrids, 13 hybrids over better parent and 26 hybrids over standard parent exhibited significant positive heterosis (Table 3). Similar results were also reported by Ahmed *et al.*, (1999), Weerasekara *et al.*, (2007) and Jaiprakashnarayan *et al.*, (2008) in okra.

The magnitude of heterosis for number of fruits per plant was significant in both the direction of better parent and where only positive direction was seen in standard parent. Maximum positive significant heterosis was observed in cross IIHR-875 x IIHR-478, 48.91 per cent over better parent and 98.55 per cent over standard parent. Majority of crosses exhibits positive and significant heterosis (Fig. 1). It can be recommended for commercial exploitation.

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