



# Analysis of Heterosis and Heterobeltiosis for Earliness, Yield and Its Contributing Traits in Okra (*Abelmoschus esculentus* L. Moench)

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## Authors' contributions

This work was carried out in collaboration among all authors. Author PLC wrote the first draft of the manuscript. Author BK wrote the protocol, and designed the study and managed the analyses of the study. Author RK performed the statistical analysis. All authors read and approved the final manuscript.

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## ABSTRACT

Thirty-six F1 hybrids were generated from nine lines and four testers through line x tester mating design, these F1's along with 13 parents and 1 commercial check (Punjab-8) were evaluated to study the magnitude and direction of heterosis for growth and earliness over various characters in okra. Heterosis was studied to compare traits such as days to 50% flowering, days to picking, plant height, number of internodes, number of branches per plant, fruit length at commercial maturity and final maturity, number of fruits per plant, number of seeds per fruit, 100 seed weight, fruit weight, and yield per plant. Significant heterosis was found over better parent (Heterobeltiosis), mid parent

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and commercial checks for all the traits studied in desirable direction. The present study showed that the crosses L3 x T2 (19.04, 15.41, 8.28), L5 x T2 (41.90, 14.55, 7.47), L8 x T3 (23.75, 6.48, 8.46) recorded significant positive heterosis for yield per plant over mid parent, better parent and over standard check. Same hybrid L3 x T2 exhibited negative and highly significant heterosis for days to 50% flowering and days to first picking (-11.65,-12.00, -8.33) and (-11.79, -12.12, -15.94) respectively that are earliness character over mid parent, better parent and standard check. These hybrids may further be tested over various locations before release for commercial cultivation. High estimates of heterosis obtained in hybrid combinations revealed considerable genetic divergence among the parental lines and reveals good scope for commercial exploitation of heterosis in okra.

**Keywords:** Heterosis; Okra; better parent; mid parent; standard check; heterobeltiosis.

## 1. INTRODUCTION

Okra, which belongs to the Malvaceae family, is a plant with a chromosome number of  $2n = 8x = 72$  or  $144$ , and it is believed to have originated from Southeast Asia [1]. Okra (*Abelmoschus esculentus* L. Moench) is a valuable vegetable crop grown in tropical and subtropical regions around the world. It is very popular in India due to its ease of cultivation, consistent yield, and adaptability to varying moisture conditions. Tender okra fruits are eaten as a vegetable in India, Brazil, West Africa, and other places. Okra falls under the category of often cross-pollinated crops, with outcrossing rates ranging from 4 to 30%. Due to its monoadelphous stamen condition, large flowers that can be easily emasculated, and high level of seed production with a single pollination, it is a crop of significant interest to breeders and geneticists [2].

It is also available dehydrated and canned. As a fresh vegetable, okra has enormous export potential. The term heterosis refers to a phenomenon in which F<sub>1</sub> exhibits greater or lesser vigour than the parents. This phenomenon was dubbed the stimulus of heterozygosity by Shull in 1908 [3]. The presence of heterosis is common in plant species, but the degree of expression varies greatly. Vijayaraghavan and Warier, 1946 [4] were the first to report hybrid vigour in okra.

Studies have shown that the extent of significant heterosis is positively correlated with the diversity among parental materials [5-7]. Therefore, selecting appropriate parental genotypes with desirable economic traits is a crucial step in every hybridization program. A high-yielding genotype's superiority may or may not be passed down to its offspring. As a result, useful gene combinations in the form of high combining inbred determine the success of a breeding

programme. The selection of suitable parents is an important prerequisite for heterosis exploitation. The selection of parents solely based on phenotypic performance is not a sound procedure. As a result, it is critical that parents be chosen based on their ability to combine. In the current study, the line x tester mating design was used to assess genetic potentialities. The degree of heterosis provides a foundation for genetic diversity and a guide for selecting desirable parents for developing superior F<sub>1</sub> hybrids to exploit hybrid vigour and for developing gene pools for future breeding programmes. With this in mind, the current study was carried out to determine the magnitude of heterosis for fruit yield and its attributes traits in okra.

## 2. MATERIALS AND METHODS

The current study, titled "Analysis of Heterobeltiosis and Heterosis for Earliness, Yield and its contributing traits in okra (*Abelmoschus esculentus* L.)," was carried out at the LPU agriculture research farm during the summer and kharif seasons of 2022. The experiment took place on black cotton soil. The experimental material included 13 parents (9 lines and 4 testers), 36 F<sub>1</sub> hybrids, and one commercial check (Punjab-8)- Plants are medium tall with splashes of purple pigmentation present on the stem. Leaves are lobed and less serrated. Leaves, stem and petiole are less hairy. Fruits are thin, long, dark green and five ridged. It has resistance to yellow vein mosaic virus and tolerant to jassid and borer. It is suitable for processing. Average marketable yield is 55 q/acre. It is suitable for February-March as well as June-July sowings. Materials used in the breeding programme tabulated in Table 1. Heterosis was studied to compare traits such as days to 50% flowering, days to picking, plant height, number of internodes, number of

branches per plant, fruit length, number of fruits per plant, number of seeds per fruit, 100 seed weight, fruit weight, and yield per plant. Thirty-six crosses were built during the summer of 2022. The materials listed above (50) were used in the experiment to study heterosis. A Randomized Block Design with three replications was then used to evaluate this material. Panse and Sukhatme's [8] analysis of variance (ANOVA) for Randomized Block Design was used (1985). Fonseca and Peterson [9] and Meredith and Bridge [10] provided methods for calculating heterobeltiosis and standard heterosis, respectively.

### 2.1 Estimation of Heterosis

The estimation of heterosis was estimated in relation to mid-parent, better parent and standard check hybrid values. They were thus, calculated as per cent increase or decrease in hybrid (F1) over its better parent (BP) and standard check (SC) values in the desirable direction was calculated using the following formula given by Fonseca and Patterson [9].

$$\text{Heterosis over mid parent (MP) } MP\% = \frac{F1 - MP}{MP} \times 100$$

Where,

F1 = Mean performance of F1 hybrid  
MP = Mean performance of mid parent

$$\text{Heterosis over Better parent (BP) } BP\% = \frac{F1 - BP}{BP} \times 100$$

Where,

F1 = Mean performance of F1 hybrid  
BP = Mean performance of better parent.

$$\text{Heterosis over standard check (SH) } SH\% = \frac{F1 - SC}{SC} \times 100$$

Where,

F1 = Mean performance of F1 hybrid  
SH = Mean performance of standard check

### 3. RESULTS AND DISCUSSION

The phenomenon of heterosis is nowadays used as an important and efficient tool for achieving higher yields [11]. Analysis of variance for 12 traits (Table 2), demonstrated that both parents and their hybrids differed significantly among themselves indicating the existence of high genetic variability in the experimental population. The heterosis of crosses for different traits was mentioned in Table 3.

Days to 50% flowering and days to first picking 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. Hence, negative heterosis is highly desirable for all these two attributes of earliness.

Days to 50% flowering and Days to First Picking both were observed to have significant and negative heterosis, reflecting the earliness in flowering and fruit maturity, respectively. Such traits are preferable by the farmers for their economic sustainability (Owusu, 2015) (Table 3). For days to 50% flowering, the crosses L3 x T1 (-9.80, -11.54, -4.17), L3 x T2 (-11.65, -12.00, -8.33), L4 x T4 (-8.80, -12.98, -5.00), L9 x T2 (-8.80, -9.52, -5.00), L9 x T3 (-10.16, -11.54, -4.17) showed negative significant heterosis over mid, better parent and standard check, respectively (Table 3).

**Table 1. Material used in breeding program**

SN	Female (Lines)	Male (Tester)	Commercial check
1	9428 (L1)	9450 (T1)	Punjab 8
2	212 (L2)	212 (T2)	
3	1979 (L3)	551 (T3)	
4	8185 (L4)	552 (T4)	
5	4922 (L5)		
6	4008 (L6)		
7	4009 (L7)		
8	3033 (L8)		
9	2535 (L9)		

Table 2. Analysis of variance of various characters

Source of Variation	Df	Days to 50% Flowering	Days to First Picking	Plant Height	Number of Internodes	Number of Branches	Fruit Length (Commercial Maturity)
Replication	2	0.19	1.45	0.67	0.03	0.13	0.01
Genotypes	49	14.45**	34.59**	831.14**	5.95**	2.72**	3.61**
Cross	35	17.44**	37.76**	876.15**	6.49**	2.96*	4.01*
Line(c)	8	30.38**	50.31**	567.22**	4.09*	0.63*	5.50*
Tester(c)	3	6.28**	14.31**	730.31**	3.34*	0.35	1.73*
L x T (c)	24	14.52**	36.51**	997.36**	7.68**	4.06*	3.80*
Parent	12	6.52**	27.36**	826.35**	4.81*	2.34*	2.02*
Error	98	0.59	1.09	0.30	0.01	0.17	0.03
Source of Variation	Df	Fruit Length (Final Maturity)	Number of Fruits per Plant	Number of Seeds per Fruit	100 Seed Weight	Fruit Weight	Yield per Plant
Replication	2	0.01	0.61	0.06	0.00	0.04	26.70
Genotypes	49	3.61**	20.75**	7.82**	2.26**	4.92**	8642.50**
Cross	35	4.01*	22.70**	8.20**	2.29*	4.36*	8646.86**
Line(c)	8	5.50*	25.02**	2.66*	1.15*	3.76*	7038.58**
Tester(c)	3	1.73*	9.02**	8.80**	9.51**	0.74	2731.13**
L x T (c)	24	3.80*	23.64**	9.97**	1.77*	5.01**	9922.41**
Parent	12	2.02*	18.23**	7.10**	2.54*	6.62**	9503.69**
Error	98	0.03	0.82	0.05	1.15	0.04	110.70

\*Significant at 5 per cent level, \*\* Significant at 1 per cent level

**Table 3. Estimation of heterosis over mid parent, heterobeltiosis and standard heterosis of various characters in okra**

SN	Genotypes	Days to 50% Flowering			Days to First Picking			Plant Height		
		MPH	BPH	SH1	MPH	BPH	SH1	MPH	BPH	SH1
1	L1 x T1	-3.50 **	-4.62 **	3.33 *	-4.63 **	-11.84 **	-2.90 ns	51.73 **	37.53 **	19.82 **
2	L1 x T2	5.98 **	4.72 **	10.83 **	14.18 **	12.88 **	7.97 **	-13.81 **	-27.12 **	-8.13 **
3	L1 x T3	4.28 **	3.08 *	11.67 **	7.35 **	2.10 ns	5.80 **	-15.22 **	-17.74 **	-23.80 **
4	L1 x T4	2.44 ns	-0.79 ns	5.00 **	6.25 **	5.43 **	-1.45 ns	57.95 **	49.54 **	30.28 **
5	L2 x T1	-6.20 **	-6.92 **	0.83 ns	-9.47 **	-15.13 **	-6.52 **	-15.20 **	-32.24 **	-19.78 **
6	L2 x T2	9.52 **	7.81 **	15.00 **	15.47 **	15.04 **	10.87 **	-27.81 **	-30.01 **	-11.77 **
7	L2 x T3	3.88 **	3.08 *	11.67 **	4.35 **	0.70 ns	4.35 *	-12.81 **	-22.29 **	-8.01 **
8	L2 x T4	14.17 **	10.16 **	17.50 **	15.38 **	12.78 **	8.70 **	12.24 **	-6.98 **	10.12 **
9	L3 x T1	-9.80 **	-11.54 **	-4.17 **	-10.95 **	-17.11 **	-8.70 **	10.20 **	5.22 **	-18.09 **
10	L3 x T2	-11.65 **	-12.00 **	-8.33 **	-11.79 **	-12.12 **	-15.94 **	-12.38 **	-29.13 **	-10.67 **
11	L3 x T3	-1.96 ns	-3.85 **	4.17 **	-0.00 ns	-4.20 *	-0.72 ns	69.44 **	55.92 **	44.43 **
12	L3 x T4	-0.82 ns	-3.20 *	0.83 ns	0.78 ns	-0.76 ns	-5.80 **	11.75 **	11.75 **	-13.00 **
13	L4 x T1	-2.68 *	-3.05 *	5.83 **	-12.96 **	-13.82 **	-5.07 **	13.80 **	13.66 **	-19.31 **
14	L4 x T2	-0.39 ns	-3.05 *	5.83 **	-3.20 *	-8.72 **	-1.45 ns	-29.36 **	-44.79 **	-30.41 **
15	L4 x T3	-8.05 **	-8.40 **	0.00 ns	-14.38 **	-16.11 **	-9.42 **	28.66 **	13.63 **	5.25 **
16	L4 x T4	-8.80 **	-12.98 **	-5.00 **	-7.97 **	-14.77 **	-7.97 **	-4.33 **	-8.54 **	-28.80 **
17	L5 x T1	1.15 ns	0.76 ns	10.00 **	-2.33 ns	-3.29 ns	6.52 **	30.19 **	17.83 **	3.01 **
18	L5 x T2	2.75 *	-0.00 ns	9.17 **	1.78 ns	-4.03 *	3.62 *	-3.06 **	-17.91 **	3.47 **
19	L5 x T3	3.45 **	3.05 *	12.50 **	1.37 ns	-0.67 ns	7.25 **	8.59 **	5.53 **	-2.24 **
20	L5 x T4	-6.40 **	-10.69 **	-2.50 ns	-16.67 **	-22.82 **	-16.67 **	58.74 **	50.05 **	31.17 **

\*Significant at 5 per cent level, \*\* Significant at 1 per cent level

Table 3. Contd....

SN	Genotypes	Days to 50% Flowering			Days to First Picking			Plant Height		
		MPH	BPH	SH1	MPH	BPH	SH1	MPH	BPH	SH1
21	L6 x T1	-0.78 ns	-2.31 ns	5.83 **	-18.06 **	-22.37 **	-14.49 **	45.98 **	15.39 **	40.66 **
22	L6 x T2	-0.00 ns	-0.79 ns	4.17 **	-4.48 **	-5.88 **	-7.25 **	-23.51 **	-24.76 **	-5.17 **
23	L6 x T3	-2.34 ns	-3.85 **	4.17 **	-5.38 **	-7.69 **	-4.35 *	-27.42 **	-36.14 **	-22.15 **
24	L6 x T4	6.94 **	3.97 **	9.17 **	7.98 **	4.41 *	2.90 ns	7.93 **	-11.57 **	7.79 **
25	L7 x T1	-3.97 **	-6.92 **	0.83 ns	-4.66 **	-12.50 **	-3.62 *	-4.48 **	-13.42 **	-24.57 **
26	L7 x T2	-1.63 ns	-2.42 ns	0.83 ns	-5.79 **	-7.58 **	-11.59 **	-9.16 **	-23.19 **	-3.18 **
27	L7 x T3	4.76 **	1.54 ns	10.00 **	8.89 **	2.80 ns	6.52 **	-10.98 **	-13.63 **	-19.99 **
28	L7 x T4	9.54 **	8.20 **	10.00 **	17.32 **	17.32 **	7.97 **	59.28 **	50.80 **	31.39 **
29	L8 x T1	-3.76 **	-5.88 **	6.67 **	-6.16 **	-9.87 **	-0.72 ns	-25.74 **	-42.03 **	-26.85 **
30	L8 x T2	-5.38 **	-9.56 **	2.50 ns	-5.88 **	-8.57 **	-7.25 **	7.71 **	7.65 **	35.83 **
31	L8 x T3	-4.51 **	-6.62 **	5.83 **	-6.71 **	-7.69 **	-4.35 *	-35.15 **	-43.77 **	-29.06 **
32	L8 x T4	0.39 ns	-5.88 **	6.67 **	3.37 *	-1.43 ns	0.00 ns	-20.91 **	-36.05 **	-19.31 **
33	L9 x T1	-1.56 ns	-3.08 *	5.00 **	-13.04 **	-14.47 **	-5.80 **	14.41 **	7.34 **	-13.26 **
34	L9 x T2	-8.80 **	-9.52 **	-5.00 **	-8.24 **	-12.93 **	-7.25 **	1.76 **	-16.50 **	5.25 **
35	L9 x T3	-10.16 **	-11.54 **	-4.17 **	-22.07 **	-23.13 **	-18.12 **	-17.90 **	-23.14 **	-28.80 **
36	L9 x T4	6.12 **	3.17 *	8.33 **	2.19 ns	-4.76 **	1.45 ns	29.85 **	27.46 **	3.01 **
	SE±	0.54	0.63	0.6	0.75	0.86	0.77	0.22	0.26	0.5

\*Significant at 5 per cent level, \*\* Significant at 1 per cent level

Table 3. Contd....

Genotypes		Number of Internodes			Number of Branches			Fruit Length (Commercial Maturity)		
		MPH	BPH	SH1	MPH	BPH	SH1	MPH	BPH	SH1
1	L1 x T1	18.99 **	14.63 **	17.50 **	28.57 *	12.50 ns	0.00 ns	4.86 **	0.88 ns	-14.18 **
2	L1 x T2	-0.00 ns	-6.38 **	10.00 **	-4.35 ns	-26.67 **	22.22 ns	-6.09 **	-10.79 **	-15.67 **
3	L1 x T3	-3.53 **	-6.82 **	2.50 **	-50.00 **	-50.00 **	-55.56 **	-18.24 **	-18.71 **	-30.85 **
4	L1 x T4	26.58 **	21.95 **	25.00 **	-15.79 ns	-27.27 **	-11.11 ns	-13.07 **	-17.92 **	-21.39 **
5	L2 x T1	-10.59 **	-19.15 **	-5.00 **	20.00 ns	0.00 ns	0.00 ns	10.08 **	7.90 **	-11.69 **
6	L2 x T2	-6.38 **	-6.38 **	10.00 **	0.00 ns	-20.00 **	33.33 **	6.06 **	-1.05 ns	-6.47 **
7	L2 x T3	-9.89 **	-12.77 **	2.50 **	-29.41 **	-33.33 **	-33.33 **	-11.24 **	-12.43 **	-26.37 **
8	L2 x T4	10.59 **	-0.00 ns	17.50 **	-20.00 *	-27.27 **	-11.11 ns	-17.37 **	-23.38 **	-26.62 **
9	L3 x T1	15.79 **	15.79 **	10.00 **	23.08 ns	14.29 ns	-11.11 ns	12.98 **	9.14 **	-7.96 **
10	L3 x T2	-10.59 **	-19.15 **	-5.00 **	-36.36 **	-53.33 **	-22.22 ns	13.77 **	7.63 **	1.74 ns
11	L3 x T3	29.27 **	20.45 **	32.50 **	6.67 ns	-0.00 ns	-11.11 ns	1.62 ns	1.47 ns	-14.43 **
12	L3 x T4	-0.00 ns	-0.00 ns	-5.00 **	11.11 ns	-9.09 ns	11.11 ns	-2.21 *	-8.05 **	-11.94 **
13	L4 x T1	7.89 **	7.89 **	2.50 **	87.50 **	50.00 **	66.67 **	2.27 *	-2.03 ns	-15.92 **
14	L4 x T2	-3.53 **	-12.77 **	2.50 **	-60.00 **	-66.67 **	-44.44 **	-10.07 **	-14.21 **	-18.91 **
15	L4 x T3	7.32 **	-0.00 ns	10.00 **	0.00 ns	-10.00 ns	0.00 ns	4.54 **	3.48 **	-11.19 **
16	L4 x T4	-0.00 ns	-0.00 ns	-5.00 **	-14.29 ns	-18.18 ns	0.00 ns	3.56 **	-1.82 ns	-5.97 **
17	L5 x T1	7.32 **	-0.00 ns	10.00 **	150.00 **	150.00 **	66.67 **	20.52 **	17.09 **	-7.96 **
18	L5 x T2	-3.30 **	-6.38 **	10.00 **	-33.33 **	-53.33 **	-22.22 ns	-4.13 **	-14.47 **	-19.15 **
19	L5 x T3	-0.00 ns	-0.00 ns	10.00 **	-14.29 ns	-25.00 ns	-33.33 **	0.63 ns	-5.33 **	-20.40 **
20	L5 x T4	14.63 **	6.82 **	17.50 **	-5.88 ns	-27.27 **	-11.11 ns	18.89 **	5.45 **	1.00 ns

\*Significant at 5 per cent level, \*\* Significant at 1 per cent level

Table 3. Contd....

SN	Genotypes	Number of Internodes			Number of Branches			Fruit Length (Commercial Maturity)		
		MPH	BPH	SH1	MPH	BPH	SH1	MPH	BPH	SH1
21	L6 x T1	24.71 **	12.77 **	32.50 **	0.00 ns	0.00 ns	-33.33 **	9.20 **	5.95 **	-11.44 **
22	L6 x T2	-6.38 **	-6.38 **	10.00 **	-14.29 ns	-40.00 **	0.00 ns	7.82 **	1.58 ns	-3.98 **
23	L6 x T3	-9.89 **	-12.77 **	2.50 **	100.00 **	75.00 **	55.56 **	17.21 **	16.86 **	-1.74 ns
24	L6 x T4	10.59 **	-0.00 ns	17.50 **	-41.18 **	-54.55 **	-44.44 **	-7.07 **	-12.99 **	-16.67 **
25	L7 x T1	1.27 **	-2.44 **	0.00 ns	16.67 ns	16.67 ns	-22.22 ns	3.30 **	-1.71 ns	-14.43 **
26	L7 x T2	-0.00 ns	-6.38 **	10.00 **	-4.76 ns	-33.33 **	11.11 ns	5.75 **	1.58 ns	-3.98 **
27	L7 x T3	-3.53 **	-6.82 **	2.50 **	57.14 **	37.50 **	22.22 ns	16.86 **	14.86 **	0.00 ns
28	L7 x T4	26.58 **	21.95 **	25.00 **	-17.65 ns	-36.36 **	-22.22 ns	-13.20 **	-17.14 **	-20.65 **
29	L8 x T1	-10.59 **	-19.15 **	-5.00 **	-6.67 ns	-22.22 ns	-22.22 ns	-3.19 **	-10.70 **	-16.92 **
30	L8 x T2	12.77 **	12.77 **	32.50 **	-50.00 **	-60.00 **	-33.33 **	-0.80 ns	-1.58 ns	-6.97 **
31	L8 x T3	-16.48 **	-19.15 **	-5.00 **	52.94 **	44.44 **	44.44 **	-0.28 ns	-5.08 **	-11.69 **
32	L8 x T4	-3.53 **	-12.77 **	2.50 **	50.00 **	36.36 **	66.67 **	-7.51 **	-8.83 **	-12.69 **
33	L9 x T1	3.80 **	-0.00 ns	2.50 **	0.00 ns	0.00 ns	-33.33 **	3.69 **	0.90 ns	-16.17 **
34	L9 x T2	-0.00 ns	-6.38 **	10.00 **	-14.29 ns	-40.00 **	0.00 ns	4.76 **	-1.58 ns	-6.97 **
35	L9 x T3	-10.59 **	-13.64 **	-5.00 **	28.57 *	12.50 ns	0.00 ns	21.13 **	20.41 **	1.24 ns
36	L9 x T4	11.39 **	7.32 **	10.00 **	52.94 **	18.18 ns	44.44 **	18.78 **	10.91 **	6.22 **
	SE±	0.06	0.07	0.11	0.29	0.34	0.35	0.12	0.13	0.14

\*Significant at 5 per cent level, \*\* Significant at 1 per cent level

Table 3 Contd....

SN	Genotypes	Fruit Length (Final Maturity)			Number of Fruits per Plant			Number of Seeds per Fruit		
		MPH	BPH	SH1	MPH	BPH	SH1	MPH	BPH	SH1
1	L1 x T1	3.45 **	0.63 ns	-10.61 **	6.06 *	-5.41 ns	2.94 ns	-0.00 ns	-1.31 **	-3.83 **
2	L1 x T2	-4.44 **	-7.96 **	-11.73 **	-17.88 **	-19.48 **	-8.82 **	0.22 ns	-0.85 **	-1.28 **
3	L1 x T3	-13.05 **	-13.42 **	-23.09 **	-28.36 **	-35.14 **	-29.41 **	-0.43 *	-0.87 **	-2.55 **
4	L1 x T4	-9.53 **	-13.27 **	-16.01 **	-27.14 **	-31.08 **	-25.00 **	4.62 **	3.93 **	1.28 **
5	L2 x T1	7.10 **	5.60 **	-8.75 **	3.33 ns	0.00 ns	-8.82 **	-0.66 **	-2.59 **	-3.83 **
6	L2 x T2	4.39 **	-0.78 ns	-4.84 **	-9.35 **	-18.18 **	-7.35 *	-0.86 **	-1.28 **	-1.70 **
7	L2 x T3	-8.00 **	-8.88 **	-19.74 **	8.20 *	6.45 ns	-2.94 ns	0.22 ns	-0.00 ns	-1.28 **
8	L2 x T4	-12.60 **	-17.31 **	-19.93 **	-26.56 **	-28.79 **	-30.88 **	-0.00 ns	-1.29 **	-2.55 **
9	L3 x T1	9.19 **	6.54 **	-5.96 **	9.52 **	1.47 ns	1.47 ns	5.38 **	5.38 **	-0.00 ns
10	L3 x T2	10.01 **	5.63 **	1.30 ns	2.07 ns	-3.90 ns	8.82 **	0.22 ns	-2.14 **	-2.55 **
11	L3 x T3	1.16 ns	1.05 ns	-10.80 **	-3.13 ns	-8.82 **	-8.82 **	7.05 **	5.19 **	3.40 **
12	L3 x T4	-1.61 *	-5.96 **	-8.94 **	5.97 *	4.41 ns	4.41 ns	0.67 **	-0.00 ns	-3.83 **
13	L4 x T1	1.61 *	-1.46 ns	-11.92 **	10.40 **	2.99 ns	1.47 ns	-0.66 **	-2.59 **	-3.83 **
14	L4 x T2	-7.34 **	-10.49 **	-14.15 **	-25.00 **	-29.87 **	-20.59 **	-0.43 *	-0.85 **	-1.28 **
15	L4 x T3	3.25 **	2.50 **	-8.38 **	-7.09 *	-11.94 **	-13.24 **	2.81 **	2.59 **	1.28 **
16	L4 x T4	2.60 **	-1.35 ns	-4.47 **	-5.26 ns	-5.97 ns	-7.35 *	-0.00 ns	-1.29 **	-2.55 **
17	L5 x T1	14.25 **	11.97 **	-5.96 **	26.61 **	18.97 **	1.47 ns	-0.00 ns	-2.55 **	-2.55 **
18	L5 x T2	-2.95 **	-10.68 **	-14.34 **	10.94 **	-7.79 **	4.41 ns	2.77 **	2.55 **	2.55 **
19	L5 x T3	0.44 ns	-3.81 **	-15.27 **	-8.11 *	-15.00 **	-25.00 **	-0.43 *	-1.28 **	-1.28 **
20	L5 x T4	13.54 **	4.04 **	0.74 ns	31.62 **	16.67 **	13.24 **	0.65 **	-1.28 **	-1.28 **

\*Significant at 5 per cent level, \*\* Significant at 1 per cent level

Table 3 Contd....

SN	Genotypes	Fruit Length (Final Maturity)			Number of Fruits per Plant			Number of Seeds per Fruit		
		MPH	BPH	SH1	MPH	BPH	SH1	MPH	BPH	SH1
21	L6 x T1	6.51 **	4.25 **	-8.57 **	13.79 **	13.79 **	-2.94 ns	3.98 **	2.62 **	-0.00 ns
22	L6 x T2	5.68 **	1.17 ns	-2.98 **	11.11 **	-2.60 ns	10.29 **	0.22 ns	-0.85 **	-1.28 **
23	L6 x T3	12.29 **	12.05 **	-1.30 ns	6.78 *	5.00 ns	-7.35 *	-3.04 **	-3.46 **	-5.11 **
24	L6 x T4	-5.15 **	-9.62 **	-12.48 **	-9.68 **	-15.15 **	-17.65 **	0.66 **	-0.00 ns	-2.55 **
25	L7 x T1	2.35 **	-1.24 ns	-10.80 **	0.00 ns	-1.67 ns	-13.24 **	2.00 **	1.33 **	-2.55 **
26	L7 x T2	4.20 **	1.17 ns	-2.98 **	2.19 ns	-9.09 **	2.94 ns	0.87 **	-0.85 **	-1.28 **
27	L7 x T3	12.11 **	10.72 **	0.00 ns	23.33 **	23.33 **	8.82 **	-1.09 **	-2.16 **	-3.83 **
28	L7 x T4	-9.65 **	-12.69 **	-15.46 **	9.52 **	4.55 ns	1.47 ns	5.31 **	5.31 **	1.28 **
29	L8 x T1	-2.29 **	-7.86 **	-12.66 **	-10.77 **	-19.44 **	-14.71 **	2.62 **	-0.00 ns	-0.00 ns
30	L8 x T2	-0.59 ns	-1.17 ns	-5.21 **	-2.01 ns	-5.19 ns	7.35 *	-2.35 **	-2.55 **	-2.55 **
31	L8 x T3	-0.20 ns	-3.73 **	-8.75 **	21.21 **	11.11 **	17.65 **	3.43 **	2.55 **	2.55 **
32	L8 x T4	-5.54 **	-6.54 **	-9.50 **	0.00 ns	-4.17 ns	1.47 ns	-1.95 **	-3.83 **	-3.83 **
33	L9 x T1	2.61 **	0.64 ns	-12.10 **	-10.24 **	-17.39 **	-16.18 **	-1.74 **	-4.64 **	-3.83 **
34	L9 x T2	3.46 **	-1.17 ns	-5.21 **	-13.70 **	-18.18 **	-7.35 *	-1.49 **	-2.11 **	-1.28 **
35	L9 x T3	15.07 **	14.59 **	0.93 ns	3.88 ns	-2.90 ns	-1.47 ns	1.71 **	0.42 ns	1.28 **
36	L9 x T4	13.65 **	8.08 **	4.66 **	6.67 *	4.35 ns	5.88 ns	-1.08 **	-3.38 **	-2.55 **
	SE±	0.12	0.13	0.14	0.64	0.74	0.73	0.16	0.19	0.17

\*Significant at 5 per cent level, \*\* Significant at 1 per cent level

Table 3 Contd....

SN	Genotypes	100 Seed Wt. (g)			Fruit Wt			Yield per Plant		
		MPH	BPH	SH1	MPH	BPH	SH1	MPH	BPH	SH1
1	L1 x T1	3.66 ns	-3.66 ns	-12.80 ns	-1.78 ns	-17.34 **	-5.85 **	1.93 ns	-22.03 **	-2.83 ns
2	L1 x T2	10.74 ns	1.75 ns	9.95 ns	-19.65 **	-30.84 **	-21.22 **	-33.32 **	-41.56 **	-27.17 **
3	L1 x T3	4.57 ns	-7.29 ns	8.53 ns	-25.00 **	-35.12 **	-26.10 **	-48.78 **	-59.30 **	-49.28 **
4	L1 x T4	-2.45 ns	-6.28 ns	-15.17 ns	-20.25 **	-32.12 **	-22.68 **	-42.97 **	-53.64 **	-42.22 **
5	L2 x T1	5.21 ns	-4.48 ns	-9.00 ns	26.03 **	22.49 **	0.98 ns	30.77 **	22.77 **	-7.62 *
6	L2 x T2	10.02 ns	3.51 ns	11.85 ns	9.04 **	8.88 **	-10.24 **	-0.67 ns	-10.51 **	-16.04 **
7	L2 x T3	-12.50 ns	-20.65 ns	-7.11 ns	25.18 **	24.63 **	3.66 *	35.90 **	34.26 **	1.02 ns
8	L2 x T4	-6.10 ns	-11.94 ns	-16.11 ns	-6.01 **	-7.40 **	-23.66 **	-31.36 **	-32.58 **	-47.41 **
9	L3 x T1	12.78 ns	-4.26 ns	6.64 ns	11.11 **	5.34 **	-8.54 **	21.37 **	6.17 ns	-6.46 *
10	L3 x T2	4.54 ns	2.98 ns	14.69 ns	18.04 **	14.89 **	-0.24 ns	19.04 **	15.41 **	8.28 **
11	L3 x T3	-26.14 **	-27.94 *	-15.64 ns	1.58 ns	-0.56 ns	-13.66 **	-2.94 ns	-11.02 **	-21.61 **
12	L3 x T4	-2.19 ns	-14.47 ns	-4.74 ns	16.08 **	11.52 **	-3.17 *	21.20 **	14.25 **	0.66 ns
13	L4 x T1	-17.29 ns	-29.79 **	-21.80 ns	3.35 *	0.59 ns	-17.32 **	13.00 **	2.56 ns	-16.92 **
14	L4 x T2	-5.40 ns	-6.81 ns	3.79 ns	0.89 ns	0.89 ns	-17.07 **	-24.56 **	-29.71 **	-34.06 **
15	L4 x T3	-5.39 ns	-7.69 ns	8.06 ns	6.49 **	5.87 **	-11.95 **	-1.09 ns	-5.72 ns	-23.63 **
16	L4 x T4	-14.84 ns	-25.53 *	-17.06 ns	16.99 **	15.43 **	-5.12 **	12.50 **	10.42 **	-10.56 **
17	L5 x T1	11.63 ns	6.67 ns	-9.00 ns	29.54 **	28.53 **	-0.00 ns	64.77 **	54.31 **	1.90 ns
18	L5 x T2	4.90 ns	-6.14 ns	1.42 ns	30.26 **	25.82 **	3.41 *	41.90 **	14.55 **	7.47 *
19	L5 x T3	20.37 ns	4.05 ns	21.80 ns	-2.90 *	-6.74 **	-22.44 **	-11.98 **	-21.43 **	-42.31 **
20	L5 x T4	19.10 ns	17.78 ns	0.47 ns	17.13 **	14.63 **	-8.29 **	51.30 **	31.56 **	2.62 ns

\*Significant at 5 per cent level, \*\* Significant at 1 per cent level

Table 3. Contd....

SN	Genotypes	100 Seed Wt. (g)			Fruit Wt			Yield per Plant		
		MPH	BPH	SH1	MPH	BPH	SH1	MPH	BPH	SH1
21	L6 x T1	7.10 ns	-2.97 ns	-7.11 ns	12.42 **	11.38 **	-11.71 **	28.64 **	26.86 **	-13.84 **
22	L6 x T2	12.09 ns	5.70 ns	14.22 ns	20.85 **	18.69 **	-2.44 ns	32.83 **	14.50 **	7.42 *
23	L6 x T3	11.80 ns	1.62 ns	18.96 ns	5.41 **	2.93 *	-14.39 **	12.69 **	8.46 *	-20.36 **
24	L6 x T4	1.06 ns	-5.45 ns	-9.48 ns	-0.77 ns	-1.22 ns	-20.98 **	-12.14 **	-17.82 **	-35.90 **
25	L7 x T1	-2.18 ns	-18.88 ns	-4.27 ns	-3.15 *	-10.82 **	-17.56 **	-3.62 ns	-13.27 **	-28.38 **
26	L7 x T2	-0.21 ns	-4.42 ns	12.80 ns	4.47 **	-1.32 ns	-8.78 **	5.81 *	-0.53 ns	-6.68 *
27	L7 x T3	0.81 ns	0.40 ns	18.48 ns	0.56 ns	-4.49 **	-11.71 **	22.57 **	15.78 **	-4.40 ns
28	L7 x T4	-7.29 ns	-20.88 ns	-6.64 ns	7.50 **	0.26 ns	-7.32 **	18.30 **	15.02 **	-5.02 ns
29	L8 x T1	5.88 ns	-5.71 ns	-6.16 ns	-10.96 **	-19.34 **	-22.68 **	-22.77 **	-36.35 **	-35.16 **
30	L8 x T2	-12.33 ns	-15.79 ns	-9.00 ns	3.29 **	-4.07 **	-8.05 **	0.18 ns	-3.78 ns	-1.99 ns
31	L8 x T3	10.28 ns	2.02 ns	19.43 ns	3.27 **	-3.56 **	-7.56 **	23.75 **	6.48 *	8.46 **
32	L8 x T4	5.18 ns	-3.33 ns	-3.79 ns	-2.36 ns	-10.43 **	-14.15 **	-3.75 ns	-15.02 **	-13.44 **
33	L9 x T1	12.30 ns	-0.00 ns	-0.47 ns	-8.17 **	-18.80 **	-17.80 **	-18.72 **	-33.30 **	-31.31 **
34	L9 x T2	-14.61 ns	-17.98 ns	-11.37 ns	-11.17 **	-19.52 **	-18.54 **	-22.70 **	-26.14 **	-23.93 **
35	L9 x T3	6.35 ns	-1.62 ns	15.17 ns	17.46 **	6.99 **	8.29 **	22.07 **	4.55 ns	7.68 *
36	L9 x T4	26.42 *	16.19 ns	15.64 ns	6.06 **	-5.06 **	-3.90 **	13.02 **	-0.69 ns	2.28 ns
	SE±	0.76	0.88	0.88	0.14	0.17	0.19	7.41	8.56	9.09

\*Significant at 5 per cent level, \*\* Significant at 1 per cent level

For days to first picking, total 14 crosses showed negative significant heterosis over mid and better parent along with standard check. The crosses L2 x T1 (-9.47, -15.13, -6.52), L3 x T1 (-10.95, -17.11, -8.70), L3 x T2 (-11.79, -12.12, -15.94), L4 x T4 (-7.97, -14.77, -7.97), L5 x T4 (-16.67, -22.82, -16.67), L6 x T1 (-18.06, -22.37, -14.49), L6 x T2 (-4.48, -5.88, -7.25), L6 x T3 (-5.38, -7.69, -4.35), L7 x T1 (-4.66, -12.50, -3.62), L7 x T2 (-5.79, -7.58, -11.59), L9 x T2 (-8.24, -12.93, -7.25), L9 x T3 (-22.07, -23.13, -18.12) recorded significant negative heterosis over mid and better parent and over standard check (Table 3).

For plant height, total 9 crosses exhibited positive and significant heterosis over mid and better parent along with over standard check. The crosses L1 x T1 (51.73, 37.53, 19.82), L1 x T4 (57.95, 49.54, 30.28), L3 x T3 (69.44, 55.92, 44.43), L4 x T3 (28.66, 13.63, 5.25), L5 x T1 (30.19, 17.83, 3.01), L5 x T4 (58.74, 50.05, 31.17), L6 x T1 (45.98, 15.39, 40.66), L7 x T4 (59.28, 50.80, 31.39), L9 x T4 (29.85, 27.46, 3.01) recorded positive and significant heterosis over mid and better parent along with over standard check. These results were in agreement with Yadav et al. [11]; Hadiya et al. [12]; Shwetha et al. [13] and Shinde et al. [14].

For number of internodes, the crosses L1 x T1 (18.99, 14.63, 17.50), L1 x T4 (26.58, 21.95, 25.00), L3 x T3 (29.27, 20.45, 32.50), L5 x T4 (14.63, 6.82, 17.50), L6 x T1 (24.71, 12.77, 32.50), L7 x T4 (26.58, 21.95, 25.00), L9 x T4 (11.39, 7.32, 10.00) recorded positive and significant heterosis over mid and better parent along with over standard check.

For number of branches per plant, the crosses L4 x T1 (87.50, 50.00, 66.67), L5 x T1 (150.00, 150.00, 66.67), L6 x T3 (100.00, 75.00, 55.56), L8 x T3 (52.94, 44.44, 44.44), L8 x T4 (50.00, 36.36, 66.67) recorded positive and significant heterosis over mid and better parent along with over standard check. Result in favour with Rynjah et al. [15].

For fruit length at commercial maturity, the cross L9 x T4 (18.78, 10.91, 6.22) recorded positive and significant heterosis over mid and better parent along with over standard check. The same hybrid also recorded positive and significant heterosis over mid and better parent along with over standard check for fruit length at final maturity. These results are similar to results

obtained by Kapadia et al. [16]; Bhatt et al. [17] and Prakash et al. [18].

For number of fruits per plant, the cross L5 x T4 (31.62, 16.67, 13.24) exhibited positive and significant heterosis over mid and better parent along with over standard check. For number of seeds per fruit, the crosses L3 x T3 (7.05, 5.19, 3.40), L4 x T3 (2.81, 2.59, 1.28), L7 x T4 (5.31, 5.31, 1.28) exhibited positive and significant heterosis over mid and better parent along with over standard check.

For fruit weight, the cross L9 x T3 (17.46, 6.99, 8.29) exhibited positive and significant heterosis over mid and better parent along with over standard check. For yield per plant, the cross L3 x T2 (19.04, 15.41, 8.28), L5 x T2 (41.90, 14.55, 7.47), L6 x T2 (32.83, 14.50, 7.42), L8 x T3 (23.75, 6.48, 8.46) exhibited positive and significant heterosis over mid and better parent along with over standard check (Table 3). These results are in accordance with Yadav et al. [11]; Shinde et al. [14]; Vekariya et al. [16]; Nanthakumar et al. [19] and Kerure and Pitchaimuthu, 2018-19 [20,21].

#### 4. CONCLUSION

The phenomenon of heterosis is used as an important tool for achieving better yields in plants. Negative heterosis is useful for earliness for both days to 50% flowering and days to first picking, which is a good trait for farmer point of view, which gives earlier maturity, as well as early fruit picking. Rest all traits exhibited significant in positive direction contributing for yield traits. The present study showed that the crosses L3 x T2, L5 x T2, L8 x T3 recorded significant positive heterosis for yield per plant over mid parent, better parent and over standard check. These hybrids may further be tested over various locations before release for commercial cultivation. On an average, okra displays heterosis for yield and its component traits studied. However, for each trait important differences exist among hybrids for the individual values of heterosis. Yield components should be considered to increase the yield through selections.

#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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