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Heterosis for earliness and fruit yield in okra (*Abelmoschus esculentus* (L.) Moench)

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Abstract
The present investigation was conducted on heterosis for earliness related traits and fruit yield per plant in okra. Thirty-six F_1 hybrids were generated by half diallel (excluding reciprocals) mating design. These F_1 hybrids along with nine parents were evaluated in randomized block design with three replications during three seasons *viz.*, *Early kharif* 2021 (E_1), *Kharif* 2021 (E_2) and *Late kharif* 2021 (E_3). Analysis of variance revealed that mean square due to genotypes has significant for all the five traits in all the environments except days to first flowering in E_2. The highest heterobeltiosis was observed in AOL-12-59 x VRO-6 in E_1, EC 169513 x GO-2 in E_2 and HRB 108-2 x NOL-17-9 in E_3 for days to first flowering; HRB-55 x GO-2 in E_1, AOL-12-59 x NOL-17-9 in E_2 and HRB 108-2 x GO-2 in E_3 for days to first picking; HRB 108-2 x JOL-11-1 in E_1, IC 90107 x EC 169513 in E_2 and E_3 for days to last picking; IC 90107 x VRO-6 in E_1, AOL-12-59 x GO-2 in E_2 and IC 90107 x EC 169513 in E_3 for number of pickings and HRB 108-2 x AOL-12-59 in E_1 and E_3, EC 169513 x GO-2 for fruit yield per plant. The highest standard heterosis was observed in AOL-12-59 x GO-2 in E_1, EC 169513 x GO-2 in E_2 and AOL-12-59 x VRO-6 in E_3 for days to first flowering; HRB-55 x GO-2 in E_1, EC 169513 x GO-2 in E_2 and HRB 108-2 x GO-2 in E_3 for days to first picking; IC 90107 x VRO-6 in E_1, IC 90107 x EC 169513 in E_2 and E_3 for days to last picking; HRB 108-2 x JOL-11-1 and EC 169513 x AOL-12-59 in E_1, IC 90107 x EC 169513 and IC 90107 x GO-2 in E_2 and IC 90107 x JOL-11-1 in E_3 for number of pickings and EC 169513 x GO-2 in E_1, HRB 108-2 x AOL-12-59 for fruit yield per plant. The top five heterotic cross combinations *viz.*, HRB 108-2 x AOL-12-59, HRB 108-2 x HRB-55, EC 169513 x GO-2, IC 90107 x EC 169513 and HRB 108-2 x EC 169513 were identified as desirable heterosis for fruit yield and other earliness related traits in one or another environment in okra.

Keywords: Okra, heterosis, half diallel, growth, yield

Introduction
Okra [*Abelmoschus esculentus* (L.) Moench] commonly known as lady's finger belongs to the family Malvaceae. It is native to Tropical Asia. Okra is an allopolyploid with the most observed chromosome number of 2n=8x=130. It is an often cross pollinated crop. Okra fruit contains 90% water, 3% dietary fibre, 7% carbohydrates, 2% protein, good quantities of minerals, vitamin C and A and moderate contents of thiamin, folate and magnesium (Chopra *et al.*, 1956) [5]. During recent years, the commercial exploitation of hybrid vigour and selection of parents on the basis of combining ability have expanded a new alley in crop improvement. The term heterosis refers to a phenomenon in which F_1 shows increase or decrease in vigour over the parents. Shull (1908) [29] referred to this phenomenon as the stimulus of heterozygosity. The hybrid vigour in okra has been first reported by Vijayaraghavan and Warier (1946) [36]. The ease in emasculation, very high percentage of fruit setting and higher seed yield per cross indicate the possibilities of exploitation of its hybrid vigour. Exploitation of heterosis in okra has been recognized as a practical tool in providing the plant breeders a means of improving fruit yield and other important traits. For developing promising varieties through hybridization, the choice of parents is a matter of great concern to the plant breeders.

Materials and Methods
The experimental material consisted of nine parental lines *viz.*, IC 90107, HRB 108-2, EC 169513, AOL-12-59, NOL-17-9, JOL-11-1, HRB-55, GO-2 and VRO-6. These were crossed in diallel fashion excluding reciprocals during Summer, 2021. The resultant 36 F_1 hybrids along with nine parents and one check were evaluated in randomized block design with three replications at Instructional farm, Junagadh Agricultural University, Junagadh (Gujarat) with spacing of 60 x 30 cm during three seasons *Early kharif* 2021 (E_1), *Kharif* 2021 (E_2) and *Late kharif* 2021 (E_3).

The observations were recorded on five randomly selected plants from each plot for growth and fruit yield parameters *viz.*, days to first flowering, days to first picking, days to last picking, number of pickings and fruit yield per plant (g). The magnitude of heterosis was calculated as percentage increase or decrease of F_1 mean over the mean of better parent (BP) (Turner, 1953 and Hays *et al.*, 1955) [33, 7] and per cent superiority over standard check were calculated. The analysis of variance, for all the characters under study, was carried out by the method suggested by Panse and Sukhatme (1985) [17].

Results and Discussion

The analysis of variance carried out for different traits of okra are presented in Table 1. The analysis of variance revealed significant differences among genotypes for all traits (except days to first picking in E_2) indicating the presence of appreciable genetic variability among the genotypes. The mean square due to parents was significant for days to first picking and number of pickings in E1 as well as for days to last picking and fruit yield per plant in all the three environments. This indicates the existence of wide variability in the material studied and there is a good scope for identifying promising parents for these traits. The mean square due to hybrids was significant for all the five traits in all the environments (except number of pickings in E_2). The variance due to parents v/s hybrids as a group was significant in few instances only.

Early flowering is desirable trait for the development of early maturing variety. Heterobeltiosis was estimated for earliness. The heterosis over better parent for days to first flowering (Table 2) ranged from -16.67% (AOL-12-59 × GO-2) to 16.91% (HRB-108-2 × VRO-6) in E_1; -8.81% (AOL-12-59 × HRB-55) to 7.55% (IC 90107 × EC 169513) in E_2; -13.69% (HRB 108-2 × NOL-17-9) to 14.29% (HRB 108-2 × GO-2) in E_3. Heterobeltiosis was significant for seven crosses in E_1; three crosses in E_2; and five crosses in E_3 for this trait in desirable (negative) direction. Similar results are reported by Rewale *et al.* (2003b) [23], Nichal *et al.* (2006) [15], Patel *et al.* (2015) [20], Tiwari *et al.* (2015) [32], Bhatt *et al.* (2016) [2], Kumar and Chowdhary (2019) [11], Rynjah *et al.* (2020) [24] and Chavan *et al.* (2021) [4]. The magnitude of standard heterosis for this trait ranged from -15.49% (AOL-12-59 × GO-2) to 18.31% (HRB-55 × GO-2); -15.23% (EC 169513 × GO-2) to 13.25% (NOL-17-9 × HRB-55); and -13.77% (EC 169513 × JOL-11-1) to 14.97% (HRB-108-2 × GO-2) in E_1, E_2 and E_3, respectively. The heterosis over standard check (GJOH-4) was significant for eight, five and five crosses in E_1, E_2 and E_3, respectively for days to first flowering. These results are in conformity with the findings of Tiwari *et al.* (2015) [32], Bhatt *et al.* (2016) [2], Kumar and Chowdhary (2019) [11], Rynjah *et al.* (2020) [24] and Chavan *et al.* (2021) [4] in okra.

For days to first picking (Table 3), negative heterosis is desirable in okra. The heterosis over better parent for this trait varied from -14.79% (AOL-12-59 × VRO-6) to 14.10% (HRB 108-2 × VRO-6); -8.79% (AOL-12-59 × HRB-55) to 7.51% (HRB 108-2 × VRO-6); and -12.77% (HRB 108-2 × GO-2) to 9.42% (EC 169513 × JOL-11-1) in E_1, E_2 and E_3, respectively. Total seven, four and three crosses manifested significant and negative heterobeltiosis in E_1, E_2 and E_3, respectively. Similar results are reported by Rewale *et al.* (2003b) [23], Borgaonkar *et al.* (2005) [3], Tiwari *et al.* (2015) [32], Panchal *et al.* (2021) [16], Chavan *et al.* (2021) [4] and Shinde *et al.* (2023) [28]. The magnitude of standard heterosis for this trait ranged from -15.43% (HRB-55 × GO-2) to 11.11% (JOL-11-1 × HRB-55); -12.79% (EC 169513 × GO-2) to 11.05% (IC 90107 × EC 169513); and -12.77% (HRB 108-2 × GO-2) to 10.11% (EC 169513 × NOL-17-9) in E_1, E_2 and E_3, respectively.

Total seven, three and five crosses manifested significant and desirable standard heterosis in E_1, E_2 and E_3, respectively. These results are in conformity with the findings of Borgaonkar *et al.* (2005) [3], Tiwari *et al.* (2015) [32], Panchal *et al.* (2021) [16], Chavan *et al.* (2021) [4] and Shinde *et al.* (2023) [28].

The positive heterosis for days to last picking is desirable in okra. The heterosis over better parent for days to last picking (Table 4) ranged from -26.14% (EC 169513 × VRO-6) to 28.95% (HRB 108-2 × JOL-11-1); -27.92% (EC 169513 × VRO-6) to 13.17% (IC 90107 × EC 169513); -9.06% (JOL-11-1 × GO-2) to 15.02% (IC 90107 × EC 169513) in E_1, E_2 and E_3, respectively. Total four, two and eleven crosses manifested significant and positive heterosis over better parent in E_1, E_2 and E_3, respectively. Similar results are reported by Rewale *et al.* (2003b) [23], Solanky *et al.* (2013) [30], Tiwari *et al.* (2015) [32], Verma and Sood (2015) [34], Satish *et al.* (2017) [25] and Panchal *et al.* (2021) [16]. The magnitude of standard heterosis for this trait ranged from -14.00% (IC 90107 × HRB-55) to 26.29% (IC 90107 × VRO-6) in E_1; -14.24% (EC 169513 × VRO-6) to 28.14% (IC 90107 × EC 169513) in E_2 and -5.78% (EC 169513 × VRO-6) to 19.11% (IC 90107 × EC 169513) in E_3. Total nine, nine and fourteen crosses manifested significant and desirable standard heterosis in E_1, E_2 and E_3, respectively. These results are in conformity with the findings of Rewale *et al.* (2003b) [23], Solanky *et al.* (2013) [30], Tiwari *et al.* (2015) [32], Verma and Sood (2015) [34], Satish *et al.* (2017) [25] and Panchal *et al.* (2021) [16].

The positive heterosis is desired with respect to number of pickings to get high yield in okra. The heterobeltiosis for number of pickings (Table 5) varied from -20.00% (AOL-12-59 × GO-2) to 4.24% (HRB-55 × VRO-6) in E_1; -28.21% (NOL-17-9 × JOL-11-1 and NOL-17-9 × VRO-6) to -2.92% (IC 90107 × VRO-6) in E_2 and -27.27% (EC 169513 × VRO-6) to 13.64% (IC 90107 × EC 169513) in E_3. Only two crosses manifested significant and positive heterobeltiosis in E_3, while none of the crosses in E_1 and E_2 were found significant and positive for number of pickings. Similar results are reported by Solanky *et al.* (2013) [30] and Patel and Patel (2016) [19]. The spectrum of standard heterosis for number of pickings varied from -18.37% (EC 169513 × VRO-6) to 6.12% (HRB 108-2 × JOL-11-1) in E_1; -10.12% (EC 169513 × GO-2) to 9.68% (IC 90107 × EC 169513 and IC 90107 × GO-2) in E_2 and -23.00% (NOL-17-9 × JOL-11-1) to 30.00% (IC 90107 × JOL-11-1) in E_3. Only two crosses manifested significant and positive standard heterosis in E_3, while none of the crosses in E_1 and E_2 were found significant and positive standard heterosis for number of pickings. Similar results are reported by Patel and Patel (2016) [19].

With regards to fruit yield per plant (Table 6), positive directed heterosis is useful, where heterobeltiosis ranged from -33.46% (IC 90107 × HRB-55) to 66.25% (HRB 108-2 × AOL-12-59); -26.48% (IC 90107 × HRB-55) to 72.29% (EC

169513 × GO-2); -49.83% (EC 169513 × AOL-12-59) to 71.93% (HRB 108-2 × AOL-12-59) in E_1, E_2 and E_3, respectively. Total of four, thirteen and five crosses in E_1, E_2 and E_3 respectively reported significant and positive heterobeltiosis. Similar results are reported by Naphade *et al.* (2002) [14] Singh and Singh (2003) [27], Rewale *et al.* (2003b) [23], Borgaonkar *et al.* (2005) [3], Vermani and Vidyasagar (2006) [35], Nichal *et al.* (2006) [15], Mannivannan *et al.* (2007) [12], Dabhi *et al.* (2010) [6], Patel *et al.* (2010) [21], Shashank and Singh (2011) [26], Kacchadia *et al.* (2011b) [8], Solanky *et al.* (2013) [30], Patel *et al.* (2015) [20], Tiwari *et al.* (2015) [32], Bhatt *et al.* (2016) [2], Patel and Patel (2016) [19], Satish *et al.* (2017) [25], Kumar and Chowdhury (2019) [11], Kerure *et al.* (2019) [10], Suganthi *et al.* (2019) [31], Abinaya *et al.* (2020) [1], Patel *et al.* (2020) [18], Ranjani *et al.* (2020) [22], Rynjah *et al.* (2020) [24], Panchal *et al.* (2021) [16], Karadi and Hanchinamani (2021) [9], Chavan *et al.* (2021) [4], Mundhe *et al.* (2022) [13] and Shinde *et al.* (2023) [28].

The standard heterosis for fruit yield per plant (Table 6) varied from -26.48% (IC 90107 × HRB-55) to 72.29% (EC 169513 × GO-2); -32.81% (IC 90107 × VRO-6) to 68.40% (HRB 108-2 × AOL-12-59); -45.64% (HRB 108-2 × VRO-6) to 58.76% (HRB 108-2 × AOL-12-59) in E_1, E_2 and E_3, respectively for fruit yield per plant. Total of thirteen, six and five crosses in E_1, E_2 and E_3, respectively reported significant and positive standard heterosis for this trait. These results are in conformity with the findings of Mannivannan *et al.* (2007) [12], Dabhi *et al.* (2010) [6], Patel *et al.* (2010) [21], Shashank and Singh (2011) [26], Kacchadia *et al.* (2011b) [8], Solanky *et al.* (2013) [30], Tiwari *et al.* (2015) [32], Verma and Sood (2015) [34], Bhatt *et al.* (2016) [2], Patel and Patel (2016) [19], Satish *et al.* (2017) [25], Kumar and Chowdhury (2019) [11], Kerure *et al.* (2019) [10], Suganthi *et al.* (2019) [31], Patel *et al.* (2020) [18], Rynjah *et al.* (2020) [24], Panchal *et al.* (2021) [16], Karadi and Hanchinamani (2021) [9], Chavan *et al.* (2021) [4] and Shinde *et al.* (2023) [28].

Table 1: Analysis of variance (mean squares) of individual environment for different characters in okra

S. N.	Characters	Env.	Replications [2]	Genotypes [44]	Parents (P) [8]	Hybrids (F_1) [35]	P *vs* F_1 [1]	Error [88]
1	Days to first flowering	E_1	0.42	41.49**	13.83*	48.54**	16.02	5.78
		E_2	3.21	12.83	3.98	15.19**	1.16	6.98
		E_3	14.62	23.59**	11.26	25.69**	48.60*	8.00
2	Days to first picking	E_1	3.47	37.48**	13.70	43.68**	10.70**	7.53
		E_2	11.92	12.87**	4.98	14.96*	2.82	8.98
		E_3	28.50	23.51**	11.83	25.40**	51.03*	12.38
3	Days to last picking	E_1	13.21	427.62**	470.51**	429.57**	16.36	36.71
		E_2	7.92	201.75**	160.65**	209.67**	253.52**	27.75
		E_3	15.61	64.16**	67.37**	64.08**	41.67	16.24
4	Number of pickings	E_1	2.02	3.04**	1.98	3.32**	1.78	1.16
		E_2	2.10	1.94**	2.34**	1.09	28.47**	0.75
		E_3	0.56	1.94**	1.01**	1.73**	16.71**	0.26
5	Fruit yield per plant (g)	E_1	1201.18	7313.78**	4242.85**	8000.41**	7849.22**	883.10
		E_2	326.21	4843.20**	4835.00**	4974.75**	304.49	447.67
		E_3	22.66	4426.66**	5509.36**	4305.12**	18.91**	292.67

*,** Significant at 5% and 1%, respectively

Table 2: Estimation of heterobeltiosis (H) and standard heterosis (SH) for days to first flowering in okra

S. N	Crosses	H (%) E_1	H (%) E_2	H (%) E_3	SH (%) E_1	SH (%) E_2	SH (%) E_3
1	IC 90107 × HRB 108-2	13.24**	5.88	9.52*	8.45*	7.28	10.18*
2	IC 90107 × EC 169513	13.67**	7.55	4.65	-11.27**	-13.25**	7.78
3	IC 90107 × AOL-12-59	0.72	-4.40	-8.09*	-1.41	0.66	-4.79
4	IC 90107 × NOL-17-9	-5.04	0.63	8.14*	-7.04	5.96	11.38**
5	IC 90107 × JOL-11-1	-9.35*	7.21	5.78	-11.30**	5.30	9.58*
6	IC 90107 × HRB-55	-2.88	-0.63	-6.36	-4.93	4.64	-2.99
7	IC 90107 × GO-2	9.35*	-1.89	8.09*	7.04	3.31	-11.98**
8	IC 90107 × VRO-6	5.04	1.91	-9.47*	2.82	5.96	10.78*
9	HRB 108-2 × EC 169513	11.76**	4.58	4.76	7.04	5.96	5.39
10	HRB 108-2 × AOL-12-59	12.50**	1.31	4.17	7.75	2.65	4.79
11	HRB 108-2 × NOL-17-9	0.74	-1.31	-13.69**	-3.52	2.34	14.37**
12	HRB 108-2 × JOL-11-1	1.47	3.92	5.95	-2.82	5.30	6.59
13	HRB 108-2 × HRB-55	9.56*	1.96	1.79	4.93	3.31	2.40
14	HRB 108-2 × GO-2	11.76**	7.19	14.29**	7.04	8.61*	14.97**
15	HRB 108-2 × VRO-6	16.91**	-8.50*	8.93*	11.97**	-9.93*	9.58*
16	EC 169513 × AOL-12-59	2.08	3.75	6.40	3.52	9.93*	9.58*
17	EC 169513 × NOL-17-9	-4.17	-2.50	9.30*	-2.82	3.31	12.57**
18	EC 169513 × JOL-11-1	-12.50**	4.37	-10.47*	-11.47**	-10.60*	-13.77**
19	EC 169513 × HRB-55	4.17	-1.26	8.14*	5.63	3.97	11.38**
20	EC 169513 × GO-2	1.35	-8.75*	9.30*	1.41	-15.23**	-12.57**
21	EC 169513 × VRO-6	-2.08	-2.55	6.51	-0.70	1.32	7.78
22	AOL-12-59 × NOL-17-9	0.69	-6.79	-5.23	2.82	3.35	-2.40
23	AOL-12-59 × JOL-11-1	-0.66	-1.25	6.32	6.34	4.64	10.78*

24	AOL-12-59 × HRB-55	-12.24**	-8.81*	-9.84*	-9.15*	-3.97	-1.20
25	AOL-12-59 × GO-2	-16.67**	-7.32	1.14	-15.49**	0.66	5.99
26	AOL-12-59 × VRO-6	-18.00**	0.38	11.83**	-13.38**	3.97	-13.17**
27	NOL-17-9 × JOL-11-1	-11.72**	4.37	5.81	-9.86*	-10.60*	-8.98*
28	NOL-17-9 × HRB-55	-6.21	7.55	8.14*	-4.23	13.25**	11.38**
29	NOL-17-9 × GO-2	9.72*	0.62	4.65	11.27**	7.95	7.78
30	NOL-17-9 × VRO-6	-1.38	-3.18	-1.78	0.70	0.66	-0.60
31	JOL-11-1 × HRB-55	9.52*	-3.77	-1.72	13.38**	1.32	2.40
32	JOL-11-1 × GO-2	-2.78	-2.50	-0.57	-1.41	3.31	3.59
33	JOL-11-1 × VRO-6	-2.00	6.37	7.69	3.52	10.60*	8.98*
34	HRB-55 × GO-2	16.67**	-5.66	-2.86	18.31**	-0.66	1.80
35	HRB-55 × VRO-6	-14.29**	0.68	2.37	-11.18**	3.97	3.59
36	GO-2 × VRO-6	9.72*	5.73	4.73	11.27**	9.93*	5.99
	S.Ed±	1.96	2.17	2.34	1.96	2.17	2.34
	Number of significant and positive cross	12	00	10	06	05	13
	Number of significant and negative cross	07	03	05	08	05	05

*,** Significant at 5% and 1%, respectively

Table 3: Estimation of heterobeltiosis (H) and standard heterosis (SH) for days to first picking in okra

S. N	Crosses	H (%)			SH (%)		
		E_1	E_2	E_3	E_1	E_2	E_3
1	IC 90107 × HRB 108-2	12.18**	5.20	7.45	8.02	5.81	7.45
2	IC 90107 × EC 169513	11.39**	6.70	4.19	8.64*	11.05*	5.85
3	IC 90107 × AOL-12-59	0.63	-5.03	-7.25	-1.85	-1.16	-4.79
4	IC 90107 × NOL-17-9	1.27	-0.56	7.29	-1.23	3.49	9.57*
5	IC 90107 × JOL-11-1	-5.70	1.12	4.66	-8.02	5.23	7.45
6	IC 90107 × HRB-55	1.27	-1.12	-6.22	-1.23	2.91	-3.72
7	IC 90107 × GO-2	8.23	-1.12	8.33	5.56	2.91	-10.64*
8	IC 90107 × VRO-6	5.06	-0.56	8.51	2.47	3.49	8.51
9	HRB 108-2 × EC 169513	12.18**	5.20	4.26	8.02	5.81	4.26
10	HRB 108-2 × AOL-12-59	9.62*	1.16	3.72	5.56	1.74	3.72
11	HRB 108-2 × NOL-17-9	1.28	-1.16	-12.23**	-2.47	-0.58	-12.23**
12	HRB 108-2 × JOL-11-1	3.85	4.62	5.32	2.43	5.23	5.32
13	HRB 108-2 × HRB-55	8.33	4.05	1.60	4.32	4.65	1.60
14	HRB 108-2 × GO-2	10.90*	6.94	-12.77**	6.79	7.56	-12.77**
15	HRB 108-2 × VRO-6	14.10**	7.51	7.45	9.88*	8.14	7.45
16	EC 169513 × AOL-12-59	0.60	4.42	5.76	3.09	9.88*	7.45
17	EC 169513 × NOL-17-9	-4.82	2.76	8.38*	-2.47	8.14	10.11*
18	EC 169513 × JOL-11-1	-10.84**	3.87	9.42*	-8.64*	9.30*	-11.17*
19	EC 169513 × HRB-55	2.41	-1.66	7.33	4.94	3.49	9.04*
20	EC 169513 × GO-2	1.84	7.18	7.85	2.47	-12.79**	9.57*
21	EC 169513 × VRO-6	-2.41	-2.78	6.91	0.69	1.74	6.91
22	AOL-12-59 × NOL-17-9	-0.60	-7.61*	-4.69	2.47	-1.16	-2.66
23	AOL-12-59 × JOL-11-1	-0.58	-0.55	4.62	4.94	4.65	8.51
24	AOL-12-59 × HRB-55	-11.45**	-8.79**	-7.96	-9.26*	-3.49	-1.60
25	AOL-12-59 × GO-2	-14.11**	-5.41*	1.56	-13.58**	1.74	3.72
26	AOL-12-59 × VRO-6	-14.79**	-1.67	-11.17*	-11.11**	2.91	-11.18*
27	NOL-17-9 × JOL-11-1	-11.38**	3.31	5.21	-8.64*	8.72*	7.45
28	NOL-17-9 × HRB-55	-6.63	2.20	7.29	-4.32	8.14	9.57*
29	NOL-17-9 × GO-2	7.98	-0.54	4.17	8.64*	6.40	6.38
30	NOL-17-9 × VRO-6	-2.40	-3.33	-1.06	0.62	1.16	-1.06
31	JOL-11-1 × HRB-55	8.43*	-4.42	-3.08	11.11**	0.58	0.53
32	JOL-11-1 × GO-2	-2.45	3.31	1.04	-1.85	-8.72*	3.19
33	JOL-11-1 × VRO-6	-1.78	3.89	7.98	2.47	-8.76*	7.98
34	HRB-55 × GO-2	-14.72**	-6.04*	-1.04	-15.43**	-0.58	1.06
35	HRB-55 × VRO-6	-12.65**	-1.11	2.13	-10.49*	3.49	2.13
36	GO-2 × VRO-6	8.59*	3.89	4.26	9.26*	8.72*	4.26
	S.Ed±	2.24	2.47	2.88	2.24	2.47	2.88
	Number of significant and positive cross	08	00	02	05	05	05
	Number of significant and negative cross	07	04	03	07	03	05

*,** Significant at 5% and 1%, respectively

Table 4: Estimation of heterobeltiosis (H) and standard heterosis (SH) for days to last picking in okra

S. N	Crosses	H (%)			SH (%)		
		E_1	E_2	E_3	E_1	E_2	E_3
1	IC 90107 × HRB 108-2	0.56	1.27	9.01*	3.43	8.14	12.89**
2	IC 90107 × EC 169513	16.67**	13.17**	15.02**	20.00**	28.14**	19.11**
3	IC 90107 × AOL-12-59	-7.22	-3.17	1.72	-0.86	3.39	5.33
4	IC 90107 × NOL-17-9	10.00*	10.79**	2.22	13.14**	18.31**	2.22
5	IC 90107 × JOL-11-1	1.67	-2.14	14.59**	4.57	8.47	18.67**
6	IC 90107 × HRB-55	-16.39**	-13.65**	-4.8	-14.00**	-7.80	-3.11
7	IC 90107 × GO-2	-13.35**	-12.78**	-4.29	2.00	4.07	-0.89
8	IC 90107 × VRO-6	6.00	0.28	8.58*	26.29**	19.32**	12.44**
9	HRB 108-2 × EC 169513	-0.56	-2.99	2.43	0.57	9.83*	12.44**
10	HRB 108-2 × AOL-12-59	-15.51**	-9.58*	-6.88	-9.71*	-4.07	2.22
11	HRB 108-2 × NOL-17-9	16.31**	-0.98	6.22	8.00	2.71	6.22
12	HRB 108-2 × JOL-11-1	28.95**	5.50	-6.07	26.00**	16.95**	3.11
13	HRB 108-2 × HRB-55	-8.55*	-7.67	9.17*	-11.43**	-6.10	11.11*
14	HRB 108-2 × GO-2	-10.19**	-8.81*	-2.83	5.71	8.81*	6.67
15	HRB 108-2 × VRO-6	-10.31**	-11.11**	11.16**	6.86	5.76	15.11**
16	EC 169513 × AOL-12-59	4.81	-10.48**	-0.39	12.00**	1.36	12.44**
17	EC 169513 × NOL-17-9	-8.76*	-10.18**	11.56**	-7.71	1.69	11.56**
18	EC 169513 × JOL-11-1	6.78	-7.78*	-7.69*	8.00	4.41	6.67
19	EC 169513 × HRB-55	7.91	0.01	6.11	9.14*	13.22**	8.00
20	EC 169513 × GO-2	-14.56**	-16.48**	-4.72	0.57	-0.34	7.56
21	EC 169513 × VRO-6	-26.14**	-27.92**	-9.01*	-12.00**	-14.24**	-5.78
22	AOL-12-59 × NOL-17-9	-2.41	-6.71	2.22	4.29	-1.02	2.22
23	AOL-12-59 × JOL-11-1	-12.83**	-11.62**	-5.51	-6.86	-2.03	6.67
24	AOL-12-59 × HRB-55	-11.5**	-4.15	-4.80	-5.43	1.69	-3.11
25	AOL-12-59 × GO-2	-10.44**	-2.27	-5.51	5.43	16.61**	6.67
26	AOL-12-59 × VRO-6	-22.54**	-15.10**	1.72	-7.71	1.02	5.33
27	NOL-17-9 × JOL-11-1	1.46	-6.42	9.33*	-0.86	3.73	9.33*
28	NOL-17-9 × HRB-55	-10.62*	-9.15*	9.78*	-13.43**	-5.76	9.78*
29	NOL-17-9 × GO-2	-9.47**	-11.65**	4.44	6.57	5.42	4.44
30	NOL-17-9 × VRO-6	-3.6	-9.12*	-2.22	14.86**	8.14	-2.22
31	JOL-11-1 × HRB-55	2.05	-7.65	7.42	-0.29	2.37	9.33*
32	JOL-11-1 × GO-2	-6.31	-2.84	-9.06*	10.29*	15.93**	2.67
33	JOL-11-1 × VRO-6	-12.71**	-11.40**	9.44*	4.00	5.42	13.33**
34	HRB-55 × GO-2	-15.53**	-16.19**	-4.37	-0.57	0.54	-2.67
35	HRB-55 × VRO-6	-2.64	-8.83*	9.17*	16.00**	8.47	11.11*
36	GO-2 × VRO-6	-16.75**	-9.97**	-1.29	-2.00	7.12	2.22
	S.Ed±	4.91	4.28	3.27	4.91	4.28	3.27
	Number of significant and positive cross	04	02	11	09	09	14
	Number of significant and negative cross	17	19	03	05	01	00

*,** Significant at 5% and 1%, respectively

Table 5: Estimation of heterobeltiosis (H) and standard heterosis (SH) for number of pickings in okra

S. N	Crosses	H (%)			SH (%)		
		E_1	E_2	E_3	E_1	E_2	E_3
1	IC 90107 × HRB 108-2	-10.00	-8.33	-9.09	-8.16	6.45	2.33
2	IC 90107 × EC 169513	1.24	-5.56	13.64*	-2.04	9.68	25.00**
3	IC 90107 × AOL-12-59	-12.00*	-8.82	2.33	-10.20	-3.23	-11.00
4	IC 90107 × NOL-17-9	-8.33	-15.38**	10.53	-10.20	6.45	5.00
5	IC 90107 × JOL-11-1	2.08	-8.33	13.04*	1.04	6.45	30.00**
6	IC 90107 × HRB-55	-8.33	-8.82	-10.00	-10.20	-5.56	-10.00
7	IC 90107 × GO-2	-2.08	-8.82	-15.00*	-4.08	9.68	-15.00*
8	IC 90107 × VRO-6	6.25	-2.94	-13.04*	4.08	6.45	-3.55
9	HRB 108-2 × EC 169513	-10.00	-8.33	-4.55	-8.16	6.45	5.00
10	HRB 108-2 × AOL-12-59	2.00	-8.33	-11.00	4.08	6.45	2.34
11	HRB 108-2 × NOL-17-9	3.54	-23.08**	-10.00	2.04	-3.23	-5.00
12	HRB 108-2 × JOL-11-1	4.00	-8.33	-18.18**	6.12	6.45	-10.00
13	HRB 108-2 × HRB-55	-16.00**	-13.89*	3.55	-14.29**	-9.68	-11.00
14	HRB 108-2 × GO-2	-8.00	-8.33	-5.00	-6.12	6.45	10.53
15	HRB 108-2 × VRO-6	-6.00	-16.67**	-4.55	-4.08	-3.23	5.00
16	EC 169513 × AOL-12-59	4.00	-22.22**	-15.00*	6.12	-9.68	-15.00*
17	EC 169513 × NOL-17-9	2.08	-20.51**	-15.79*	4.35	-9.25	-20.00**
18	EC 169513 × JOL-11-1	4.17	-19.44**	-13.64*	2.04	-6.45	-5.00
19	EC 169513 × HRB-55	-8.33	-16.67**	-15.00*	-10.20	-3.23	-15.00*

20	EC 169513 × GO-2	-2.08	-13.89*	-5.00	-4.08	-10.12	-5.00
21	EC 169513 × VRO-6	-16.67**	-22.22**	-27.27**	-18.37**	-9.68	-20.00**
22	AOL-12-59 × NOL-17-9	-10.00	-25.64**	-15.79*	-8.16	-6.45	-20.00**
23	AOL-12-59 × JOL-11-1	-4.00	-13.89*	-15.00*	-2.04	1.36	-15.00*
24	AOL-12-59 × HRB-55	-16.00**	-5.88	-15.00*	-14.29**	3.23	-15.00*
25	AOL-12-59 × GO-2	-20.00**	-2.94	-20.00**	-18.37**	6.45	-21.00**
26	AOL-12-59 × VRO-6	-12.00*	-11.76	-20.00**	-10.20	-3.23	-20.00**
27	NOL-17-9 × JOL-11-1	-4.35	-28.21**	-15.79*	-10.20	-9.68	-23.00**
28	NOL-17-9 × HRB-55	-6.52	-25.64**	-10.00	-12.24*	-6.45	-5.00
29	NOL-17-9 × GO-2	2.08	-17.95**	-5.26	3.05	3.23	-10.00
30	NOL-17-9 × VRO-6	3.24	-28.21**	5.26	-2.04	-9.68	-12.00
31	JOL-11-1 × HRB-55	1.25	-13.89*	-5.00	-10.20	3.23	-5.00
32	JOL-11-1 × GO-2	-6.25	-8.33	-5.04	-8.16	6.45	-7.00
33	JOL-11-1 × VRO-6	-4.17	-16.67**	-17.39**	-6.12	-3.23	-5.00
34	HRB-55 × GO-2	3.12	-3.12	-10.00	-5.04	-3.12	-10.00
35	HRB-55 × VRO-6	4.24	-15.15*	-12.34	-6.46	-9.68	-5.00
36	GO-2 × VRO-6	2.26	-4.24	-10.00	-3.04	3.23	-10.00
	S.Ed±	0.89	0.70	0.42	0.89	0.70	0.42
	Number of significant and positive cross	00	00	02	00	00	02
	Number of significant and negative cross	06	18	14	05	00	11

*,** Significant at 5% and 1%, respectively

Table 6: Estimation of heterobeltiosis (H) and standard heterosis (SH) for fruit yield per plant in okra

S. N	Crosses	H (%)			SH (%)		
		E_1	E_2	E_3	E_1	E_2	E_3
1	IC 90107 × HRB 108-2	16.19	23.96*	-23.39*	23.96*	-19.31*	-29.26**
2	IC 90107 × EC 169513	17.33*	55.98**	-0.71	55.98**	16.39	26.06**
3	IC 90107 × AOL-12-59	15.52	23.24*	7.83	23.24*	10.77	-1.51
4	IC 90107 × NOL-17-9	-11.11	-5.16	2.17	-5.16	-12.32	-6.67
5	IC 90107 × JOL-11-1	-17.27	-11.74	-27.68**	-11.74	-12.17	-27.00**
6	IC 90107 × HRB-55	-33.46**	-26.48*	-27.67**	-26.48*	-30.35**	-33.93**
7	IC 90107 × GO-2	2.51	14.41	-34.97**	14.41	-2.19	-15.32
8	IC 90107 × VRO-6	-24.23*	-18.96	-21.46*	-18.96	-32.81**	-28.25**
9	HRB 108-2 × EC 169513	6.08	41.02**	-5.77	41.02**	22.47*	19.64*
10	HRB 108-2 × AOL-12-59	66.25**	65.98**	71.93**	65.98**	68.40**	58.76**
11	HRB 108-2 × NOL-17-9	14.13	9.89	-32.04**	9.89	-11.03	-37.25**
12	HRB 108-2 × JOL-11-1	11.73	18.31	-0.35	18.31	9.46	0.60
13	HRB 108-2 × HRB-55	18.46	30.88**	67.36**	30.88**	40.93**	54.54**
14	HRB 108-2 × GO-2	2.39	14.28	-8.98	14.28	18.66*	18.51*
15	HRB 108-2 × VRO-6	-15.29	-9.40	-41.13**	-9.40	-26.01**	-45.64**
16	EC 169513 × AOL-12-59	-15.58*	12.23	-49.83**	12.23	2.45	-36.30**
17	EC 169513 × NOL-17-9	-26.70**	-2.55	-25.42**	-2.55	-1.36	-5.30
18	EC 169513 × JOL-11-1	-9.32	20.55*	-40.33**	20.55*	8.14	-24.24**
19	EC 169513 × HRB-55	-18.12*	8.85	-37.20**	8.85	0.79	-20.27*
20	EC 169513 × GO-2	29.6**	72.29**	-17.93*	72.29**	23.46**	6.86
21	EC 169513 × VRO-6	-0.84	31.82**	-46.68**	31.82**	5.11	-32.30**
22	AOL-12-59 × NOL-17-9	0.60	0.43	-20.37	0.43	-15.95	-39.94**
23	AOL-12-59 × JOL-11-1	-4.23	1.41	-23.42*	1.41	-3.89	-22.70*
24	AOL-12-59 × HRB-55	-2.53	7.70	27.99*	7.70	-6.19	-3.47
25	AOL-12-59 × GO-2	-17.12	-7.50	-45.18**	-7.50	-23.37**	-28.62**
26	AOL-12-59 × VRO-6	-14.58	-8.65	2.99	-8.65	-17.59	-22.33*
27	NOL-17-9 × JOL-11-1	21.75*	28.92**	-7.52	28.92**	18.92*	-6.64
28	NOL-17-9 × HRB-55	-9.50	5.36	69.72**	4.98	-3.74	-0.45
29	NOL-17-9 × GO-2	9.26	21.94*	-13.18	21.94*	11.32	13.04
30	NOL-17-9 × VRO-6	-14.09	-8.12	0.84	-8.12	-5.91	-26.31**
31	JOL-11-1 × HRB-55	-18.66*	-10.13	-38.24**	-10.13	-20.40*	-37.65**
32	JOL-11-1 × GO-2	-6.95	3.85	-32.47**	3.85	-17.59	-12.07
33	JOL-11-1 × VRO-6	-8.56	-2.21	-16.59	-2.21	-17.78*	-15.80
34	HRB-55 × GO-2	15.51	28.92**	-13.61	28.92**	6.89	12.48
35	HRB-55 × VRO-6	14.03	26.00*	3.76	26.00*	-23.49**	-24.17**
36	GO-2 × VRO-6	4.74	12.02	16.48**	12.02	-22.20*	-14.87
	S.Ed±	24.08	17.42	14.09	24.08	17.42	14.09
	Number of significant and positive cross	04	13	05	13	06	05
	Number of significant and negative cross	06	01	17	01	09	17

*,** Significant at 5% and 1%, respectively

Conclusion

The present investigation revealed that the cross combinations *viz*., HRB 108-2 x AOL-12-59, HRB 108-2 x HRB-55, EC 169513 x GO-2, IC 90107 x EC 169513 and HRB 108-2 x EC 169513 were identified as stable with desirable heterosis for fruit yield and other earliness related traits in one or another environment in okra.

References

1. Abinaya S, Saravanan KR, Thangavel P, Madhubala R, Pushpanathan KR. Studies on heterosis and combining ability analysis in okra (*Abelmoschus esculentus* (L.) Moench.). Plant Archives. 2020;20(1):1340-1342.
2. Bhatt JP, Patel NA, Acharya RR, Kathiria KB. Heterosis for fruit yield and its components in okra (*Abelmoschus esculentus* (L.) Moench). Int. J Agric. Sci. 2016;8(18):1332-1335.
3. Borgaonkar SB, Vaddoria MA, Dhaduk HL, Poshiya VK. Heterosis in okra (*Abelmoschus esculentus* (L.) Moench). Agric. Science Digest. 2005;25(4):251-253.
4. Chavan SS, Jagtap VS, Dhakne VR, Veer DR, Sargar PR. Heterosis studies in okra [*Abelmoschus esculentus* (L) Moench]. The Pharma Innovation J. 2021;10(10):749-753.
5. Chopra N, Nayar SL, Chopra IC. Glossary of Indian Medicinal Plants. CSIR, New Delhi, 1956, 32.
6. Dabhi KH, Vachhani JH, Poshiya VK, Jivani LL, Vekariya DH, Shekhati HG. Heterosis for fruit yield and its components over environments in okra [*Abelmoschus esculentus* (L.) Moench]. Inter. J Agri. Sci. 2010;5(2):572-576.
7. Hayes HK, Immer FR, Smith DC. Methods of plant breeding. Mc graw Hill Book Co. Inc., New York; c1955. p. 439.
8. Kachhadia VH, Vachhani JH, Jivani LL, Madaria RB, Dangaria CJ. Combining ability for fruit yield and its components over environments in okra (*Abelmoschus esculentus* (L.) Moench). Res. on Crops. 2011b;12(2):561-567.
9. Karadi SM, Hanchinamani CN. Estimation of heterosis in okra (*Abelmoschus esculentus* (L.) Moench) for fruit yield and its components through line× tester mating design. Bangladesh J Botany. 2021;50(3):531-540.
10. Kerure P, Pitchaimuthu M, Srinivasa V, Venugopalan R. Heterosis for yield and its components in okra (*Abelmoschus esculentus* (L.) Moench). Int. J Curr. Microbiol. App. Sci. 2019;8(1):353-367.
11. Kumar S, Chowdhury S. Exploitation of heterosis for yield and yield attributes in okra [*Abelmoschus esculentus* (L.) Moench]. Inter. J Chemical Studies. 2019;7(4):853- 857.
12. Manivannan MI, Rajangam J, Aruna P. Heterosis for yield and yield governing traits in okra. Asian J Horticulture. 2007;2(2):96-103.
13. Mundhe SS, Pole SP, Khandebharad PR, Patil AR. Heterosis studies for yield and yield component traits in okra (*Abelmoschus esculentus* (L.) Moench). The Pharma Innovation J. 2022;11(12):837-842.
14. Naphade PV. Line x tester analysis in okra (*Abelmoschus esculentus* (L.) Moench). Annals of Agriculture Research. 2002;23(2):233-237.
15. Nichal SS, Mehta N, Saxena RR. Study of heterosis through diallel crosses of okra [*Abelmoschus esculentus* (L.) Moench]. Plant Archives. 2006;6(1):109-113.
16. Panchal KN, Bhalekar MN, Kshirsagar DB, Joshi VR, Kute NS. Heterosis for fruit yield and its components traits in okra (*Abelmoschus esculentus* (L.) Moench). The Pharma Inno. J. 2021;10(8):1192-1200.
17. Panse VG, Sukhtme PV. Statistical methods for agricultural workers. Indian Council of Agricultural Research, New Delhi; c1985. p. 435.
18. Patel AA, Patel AI, Parekh VB, Patel RK, Mali SC, Vekariya RD. Estimation of standard heterosis over environments for fruit yield and its attributes in okra [*Abelmoschus esculentus* (L.) Moench]. Inter. J Chemical Studies. 2020;8(6):2542-2547.
19. Patel BG, Patel AI. Heterosis studies in okra (*Abelmoschus esculentus* (L.) Moench). Annals Agric. and Environ. Sci. 2016;1(1):15-20.
20. Patel H, Bhanderi DR, Patel AI, Tank RV, Kumar A. Magnitude of heterosis for pod yield and its contributing characters in okra (*Abelmoschus esculentus* (L.) Moench). The Bio scan. 2015;10(2):939-942.
21. Patel KD, Barad AV, Savaliya JJ, Butani AM. Generation mean analysis for fruit yield and its attributing traits in okra (*Abelmoschus esculentus* (L) Moench), Asian J. Hort. 2010;5(2):256- 259.
22. Ranjani PS, Rajan REB, Kumar CPS, Joshi JL, Muralidharan A. Estimation of standard heterosis in bhendi (*Abelmoschus esculentus* (L.) Moench). Plant Archives. 2020;20(1):2070-2072.
23. Rewale VS, Bendale VW, Bhave SG, Madav RR, Jadhav BB. Heterosis for yield and yield components in okra. J. Maharashtra Agricultural Universities. 2003b;28(3):247-249.
24. Rynjah S, Arumugam T, Mohankumar S, Kamala Kannan A. Exploitation of heterosis for yield and yield related traits in okra (*Abelmoschus esculentus* (L.) Moench). Inter. J Chemical Studies. 2020;8(4):886-893.
25. Satish K, Bhatt K, Suresh K, Prajapati DB, Agalodiya AV. Heterosis study in okra [*Abelmoschus esculentus* (L.) Moench]. Multilogic in Sci. 2017;7(24):85-89.
26. Shashank SS, Singh AK. Manifestation of heterosis in relation to seasonal variation in okra (*Abelmoschus esculentus* (L.) Moench). Vegetable Sci. 2011;38:107-110.
27. Singh B, Singh SP. Combining ability studies in okra (*Abelmoschus esculentus* (L.) Moench). Pl. Archives. 2003;3(1):133-136.
28. Shinde SL, Zate DK, Rathod AH, Cheke SA. Heterosis studies by using L x T design for yield and yield contributing traits in okra (*Abelmoschus esculentus* (L.) Moench). The Pharma Inno. J. 2023;12(1):228-237.
29. Shull LH. What is Heterosis? Genetica. 1908;33:430-446.
30. Solankey SS, Singh AK, Singh RK. Genetic expression of heterosis for yield and quality traits during different growing seasons in okra. Indian J Agril. Sci. 2013;83(8):815-819.
31. Suganthi S, Sathiskumar P, Kamaraj A, Shanmugapriya R. Exploitation of heterosis through diallel analysis in bhendi (*Abelmoschus esculentus* (L.) Moench). J. Pharmacognosy and Phytochemistry. 2019;2:598-601.
32. Tiwari JN, Sanjeev K, Ahlawat TR, Akhilesh K, Nishtha P. Heterosis for yield and its components in okra [*Abelmoschus esculentus* (L.) Moench]. Asian J Hort.

2015;10(2):201-206.

33. Turner JH. A study of heterosis in upland cotton-I: yield of hybrid compared with varieties. II. Combining ability and inbreeding effects. Agronomy Journal. 43:487- 489.
34. Verma A, Sood S. Gene action studies on yield and quality traits in okra (*Abelmoschus esculentus* (L.) Moench). African J Agric. Res. 2015;10(43):4006-4009.
35. Vermani A, Vidya Sagar. Implications of mean performance, heterosis and specific combining ability effects on performance of okra crosses. Crop Research. 2006;31(2):288-290.
36. Vijayaraghavan C, Warrier VA. Evaluation of high yielding hybrids in bhendi (*Hibischus esculentus*) Proceedings of 33rd Indian Science Congress, 1946, 33(33).