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Exploitation of Heterosis for Plant and Yield Characteristics in Okra (*Abelmoschus esculentus* (L.) Moench)

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ABSTRACT

The present experiment was conducted in bhindi / okra to observe the extent of heterosis for eight characters of plant and fruit yield traits through diallel analysis. The characters consist of plant height (cm), number of primary branches per plant, node at which 1st flower appears, number of nodes on main stem, internodal length, days to 50% flowering, pod yield per plant (g) and pod yield per hectare (q/ha). The experimental material comprised of 66 F_1 hybrids developed from crossing 12 okra genotypes in diallel crossing excluding reciprocals. Out of eight characters studied, plant height, number of branches per plant and number of nodes on main stem are growth determining features. They generally decide the fruit/ pod bearing surface of the okra plant. Therefore, Positive heterosis is desirable for plant height, number of branches per plant, number of nodes on main stem including fruit yield per plant and fruit yield per hectare but negative heterosis is profitable for node at which 1st flower appears, intermodal length and days to 50% flowering. Out of 66 F_1, 50, 32 and 38 hybrids showed significant heterosis positively over mid parent, better parent and standard check respectively for fruit yield per plant and fruit yield per hectare and the highest was reported in hybrids IC-45831 ×IC-43733 subsequently IC-45831 ×Pusa A-4.

Keywords Okra, Plant, Hybrids, Heterosis, Diallel cross.

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INTRODUCTION

Okra / bhindi (*Abelmoschus esculentus* (L.) Moench.), is a member of the family Malvaceae. It is one of the most dominant vegetables grown all round the world, including tropical, sub-tropical and warmer parts of the temperate regions. Okra is mainly grown for its delicious, tender green fruits. Apart from cooking the fruits can be used in various forms like canning, freezing and consumed in several forms in various parts of the country. Okra mucilage is used as a food, non-food and medicinal product. The dry seeds of okra are rich source of protein (20-23%) and oil (18-20%). In sugar cane industries, during the sugar production process, okra stems and roots are used to clean the sugar cane juice. As the crop is adapted to the warm and humid climatic conditions, it has been cultivated commercially in different parts of the country for many years. As the population is growing drastically there is a need to enhance the yield per unit area to accomplish the production from a limited source of land. According to FAOSTAT, okra covered an area of 2.53 million hectares world-wide, with a fruit production of 10.5 million tons in the year 2020 (FAOSTAT 2022). The vital goal of enhancing the productivity in a fast possible way can be achieved through heterosis breeding only, which is attainable in this crop (Kumar *et al.* 2017). In recent decades, hybrid vigour or heterosis is the most key development in plant breeding programs (Kumar *et al.* 2017). Selection of suitable / beneficial parents and estimation of degree of heterosis in the derived crosses forms a crucial step in the production of new F1 hybrids. The extent for employment of heterosis mostly rely on the magnitude and direction of heterosis. Heterosis is exhibited in 3 ways as relative heterosis, heterobeltiosis and standard heterosis, depending on the criteria used to differentiate the performance of a hybrid.

The short life span of the plant, easy emasculation process, very high per cent of pod/fruit set and greater number of seeds per fruit create commercial utilization of hybrid vigour easy in okra. Okra is an often-cross-pollinated crop, 5-9% of cross pollination occurs by insects, which contribute considerable genetic diversity in the crop (Duggi *et al.* 2013). Hence, to attain genetic variability for the improvement of okra, germplasm evaluation should be done at first and later, it is essential to develop the crosses by suitable hybridization method to aware the degree of heterosis in the hybrids for different economic / commercial characters, sequentially, it would help in determining the promising parents and hybrids identification and also the strategies of the breeding programe for more advanced use in breeding programe (Rajawat and Collis 2017).

The phenomenon of heterosis has been a powerful force in the evolution of crop plants and has been exploited extensively in crop production (Mekala *et al.* 2019). Through heterosis breeding, it is often possible to combine desired alleles in regular fashion without waiting for longer term as in case of development of open pollinated cultivars. A number of research findings have described the remarkable heterosis for growth, yield and yield attributing traits (Lyngdoh *et al.* 2013). Hence the present investigation was carried out in okra with an objective of assessing the magnitude/ degree of heterosis for yield and yield parameters.

MATERIALS AND METHODS

The present experiments were carried out at the Vegetable Research Farm of the Horticulture Department, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, in Randomized Block Design with three replications. Experimental material for the present research work was collected from Indian Institute of Vegetable Science (IIVR), Varanasi which comprised of 12 genotypes of *A. esculentus* belonging to different morphological and productive attributes viz., IC- 45831, IC- 282272, IC- 43733, IC- 43750, IC- 45802, Sel – 4, Pusa Mukhmali, Parbhani Kranti, VRO- 3, Sel – 10, Pusa A-4 and SB – 8 and the commercial check used was Arka Anamika. Recommended package of practices was followed to grow the successful crop. Observations were recorded on ten plants in each replication on eight characters viz., plant height (cm), number of primary branches per plant, node at which 1st flower appears, number of nodes on main stem, internodal length, days to 50% flowering, pod yield per plant (g) and pod yield per hectare (q/ha). The nature and magnitude of heterosis was estimated in relation to mid-parental, better parental and standard check values. They were thus, calculated as percentage increase or decrease of F_1s over the mid-parent (MP), better parent (BP) and standard check (SC) using the methods of Turner (1953) and Hayes *et al.* (1956).

RESULTS AND DISCUSSION

Obtaining a highest yield is the prior objective or intention in majority of the breeding experiments, and originating improved varieties is major concern in vegetable breeding. The most successful achievement

Table 1. Heterosis for eight plant and yield characters of okra.

F1	Plant height			No. of branches per plant			Node at which 1st flower appears			No. of nodes on main stem		
	MP	BrP	BP	MP	BrP	BP	MP	BrP	BP	MP	BrP	BP
1×2 IC-45831 ×IC-282272	5.86	-4.81	5.5	101.79**	75.78**	82.93**	-5.06	-7.41*	-7.41*	22**	11.67	26.42**
1 ×3 IC-45831 ×IC-43733	3.11	-2.09	-3.65	78.26**	51.85**	66.67**	-18.64**	-25**	-11.11**	26.83**	23.42**	22.64**
1 ×4 IC-45831 ×IC-43750	6.73	-2.45	4.26	109.30**	87.50**	82.93**	-10.56**	-11.11**	-11.11**	24.78**	12.67*	31.45**
1 ×5 IC-45831 ×IC-45802	18.57**	12.24**	11.20**	103.33**	68.28**	98.37**	-16.09**	-21.51**	-9.88**	45.63**	38.79**	44.03**
1 ×6 IC-45831 ×Sel-4	4.96	-0.49	-1.74	137.68**	119.64**	100.00**	-13.21**	-14.81**	-14.81**	32.9**	28.93**	28.93**
1 ×7 IC-45831 ×PM	-1.58	-12.32**	-0.75	128.84**	105.00**	100.00**	-3.11	-3.7	-3.7	15.81**	3.7	23.27**
1 ×8 IC-45831 ×PK	14.29**	1.94	15.07**	137.07**	120.91**	97.56**	-19.3**	-23.33**	-14.81**	36.16**	24.31**	41.51**
1 ×9 IC-45831 ×VRO-3	8.19*	-4.52	10.45**	131.88**	114.29**	95.12**	-20.69**	-25.81**	-14.81**	32.94**	19.89**	40.25**
1 ×10 IC-45831 ×Sel-10	20.08**	13.17**	13.17**	111.93**	87.80**	87.80**	-14.81**	-14.81**	-14.81**	41.33**	37.11**	37.11**
1 ×11 IC-45831 ×Pusa A-4	12.69**	0.25	13.84**	126.79**	107.89**	92.68**	-17.24**	-22.58**	-11.11**	35.96**	24.44**	40.88**
1 ×12 IC-45831 ×SB-8	33.31**	25.84**	25.41**	114.68**	90.24**	90.24**	-8.77**	-13.33**	-3.7	48.17**	41.21**	46.54**
2 ×3 IC-282272 ×IC-43733	11.23**	5.00	16.37**	65.78**	61.48**	77.24**	-16.76**	-25**	-11.11**	33.14**	25**	41.51**
2 ×4 IC-282272 ×IC-43750	4.49	2.64	13.75**	75.81**	70.31**	77.24**	-8.28**	-10**	-11.11**	25.85**	23.99**	44.65**
2 ×5 IC-282272 ×IC-45802	16.40**	10.23**	22.16**	57.51**	48.28**	74.80**	-8.24**	-16.13**	-3.7	37.39**	31.67**	49.06**
2 ×6 IC-282272 ×Sel-4	12.14**	6.03	17.50**	98.33**	85.94**	93.50**	0.65	0	-3.7	38.05**	30**	47.17**
2 ×7 IC-282272 ×PM	3.00	1.92	15.36**	89.52**	83.59**	91.06**	-15.92**	-17.5**	-18.52**	17.62**	14.81*	36.48**
2 ×8 IC-282272 ×PK	-6.74*	-7.58*	4.32	75.63**	63.28**	69.92**	-20.96**	-26.67**	-18.52**	16.9**	16.57*	32.7**
2 ×9 IC-282272 ×VRO-3	-2.65	-4.70	10.25**	72.50**	61.72**	68.29**	-18.82**	-25.81**	-14.81**	21.86**	19.89**	40.25**
2 ×10 IC-282272 ×Sel-10	-0.23	-5.10	5.17	83.27**	79.69**	86.99**	-8.86**	-11.11**	-11.11**	23.3**	16.11*	31.45**

Table 1. Continued.

F1	Plant height			No. of branches per plant			Node at which 1st flower appears			No. of nodes on main stem		
	MP	BrP	BP	MP	BrP	BP	MP	BrP	BP	MP	BrP	BP
2 ×11 IC-282272 ×Pusa A-4	-16.68**	-17.68**	-6.53	89.26**	78.91**	86.18**	-11.76**	-19.35**	-7.41*	2.78	2.78	16.35*
2 ×12 IC-282272 ×SB-8	-2.15	-7.08*	2.98	83.27**	79.69**	86.99**	-10.18**	-16.67**	-7.41*	21.74**	16.67*	32.08**
3 ×4 IC-43733 ×IC-43750	-0.53	-4.47	2.10	68.63**	59.26**	74.80**	-18.18**	-25**	-11.11**	17.03**	8.36	26.42**
3 ×5 IC-43733 ×IC-45802	4.63	4.28	3.31	58.57**	53.10**	80.49**	-23.81**	-25**	-11.11**	26.93**	24.24**	28.93**
3 ×6 IC-43733 ×Sel-4	21.35**	21.15**	19.62**	74.09**	59.26**	74.80**	-17.24**	-25**	-11.11**	33.75**	33.33**	33.33**
3 ×7 IC-43733 ×PM	3.47	-3.29	9.47*	78.82**	68.89**	85.37**	-14.77**	-21.88**	-7.41*	21.61**	11.64	32.7**
3 ×8 IC-43733 ×PK	2.53	-4.04	8.31*	77.96**	61.48**	77.24**	-22.58**	-25**	-11.11**	23.89**	16.02*	32.08**
3 ×9 IC-43733 ×VRO-3	-4.44	-11.58**	2.29	60.32**	46.67**	60.98**	-20.63**	-21.88**	-7.41*	22.09**	12.9*	32.08**
3 ×10 IC-43733 ×Sel-10	12.75**	11.85**	11.85**	68.22**	60.74**	76.42**	-11.86**	-18.75**	-3.7	42.59**	42.14**	42.14**
3 ×11 IC-43733 ×Pusa A-4	1.76	-5.03	7.84*	71.89**	58.52**	73.98**	-20.63**	-21.88**	-7.41*	23.08**	15.56*	30.82**
3 ×12 IC-43733 ×SB-8	12.42**	11.71**	11.33**	55.04**	48.15**	62.60**	-16.13**	-18.75**	-3.7	22.6**	20**	24.53**
4 ×5 IC-43750 ×IC-45802	14.51**	10.32**	17.91**	72.08**	57.24**	85.37**	-16.76**	-22.58**	-11.11**	22.68**	15.9*	35.22**
4 ×6 IC-43750 ×Sel-4	2.34	-1.56	5.22	85.34**	79.17**	74.80**	6.33*	5	3.7	17.85**	9.43	27.67**
4 ×7 IC-43750 ×PM	-2.76	-5.46	7.00	80.83**	80.83**	76.42**	-6.25*	-6.25	-7.41*	18.56**	17.46**	39.62**
4 ×8 IC-43750 ×PK	-7.79*	-10.23**	1.32	93.04**	85**	80.49**	-15.29**	-20**	-11.11**	8.05	6.74	24.53**
4 ×9 IC-43750 ×VRO-3	-9.11**	-12.57**	1.14	84.48**	78.33**	73.98**	-14.45**	-20.43**	-8.64**	16.29**	16.13*	35.85**
4 ×10 IC-43750 ×Sel-10	8.22*	4.73	11.94**	95.06**	92.68**	92.68**	0.62	0	0	24.82**	15.9*	35.22**
4 ×11 IC-43750 ×Pusa A-4	-4.05	-6.87*	5.75	86.32**	81.67**	77.24**	-6.36*	-12.9**	0	19.84**	18.06**	37.74**
4 ×12 IC-43750 ×SB-8	19.51**	15.47**	23.42**	67.08**	65.04**	65.04**	-11.76**	-16.67**	-7.41*	32.38**	25.07**	45.91**
5 ×6 IC-45802 ×Sel-4	16.90**	16.71**	15.62**	75.1**	55.17**	82.93**	-22.81**	-29.03**	-18.52**	35.8**	33.33**	38.36**

Table 1. Continued.

F1	Plant height			No. of branches per plant			Node at which 1st flower appears			No. of nodes on main stem		
	MP	BrP	BP	MP	BrP	BP	MP	BrP	BP	MP	BrP	BP
5 ×7 IC-45802 ×PM	2.97	-3.45	9.28*	50.19**	37.24**	61.79**	-5.2*	-11.83**	1.23	18.64**	11.11	32.08**
5 ×8 IC-45802 ×PK	11.94**	5.09	18.62**	90.59**	67.59**	97.56**	-24.59**	-25.81**	-14.81**	26.59**	20.99**	37.74**
5 ×9 IC-45802 ×VRO-3	2.57	-4.79	10.14**	55.64**	37.93**	62.6**	-19.35**	-19.35**	-7.41*	30.48**	23.12**	44.03**
5 ×10 IC-45802 ×Sel-10	15.26**	14.72**	14.72**	58.96**	46.9**	73.17**	-6.9**	-12.9**	0	39.51**	36.97**	42.14**
5 ×11 IC-45802 ×Pusa A-4	8.01*	1.12	14.83**	66.02**	48.28**	74.8**	-12.9**	-12.9**	0	32.75**	27.22**	44.03**
5 ×12 IC-45802 ×SB-8	9.53**	9.21*	8.84*	54.48**	42.76**	68.29**	-18.03**	-19.35**	-7.41*	40**	40**	45.28**
6 ×7 Sel-4 ×PM	4.93	-1.77	11.19**	81.03**	75**	70.73**	2.53	1.25	0	25.86**	15.87*	37.74**
6 ×8 Sel-4 ×PK	-5.53	-11.45**	-0.05	92.79**	91.07**	73.98**	-3.57	-10**	0	25.29**	17.68**	33.96**
6 ×9 Sel-4 ×VRO-3	-3.58	-10.64**	3.38	80.36**	80.36**	64.23**	-1.75	-9.68**	3.7	25.8**	16.67**	36.48**
6 ×10 Sel-4 ×Sel-10	-1.11	-1.73	-1.73	68.51**	60.98**	60.98**	1.89	0	0	35.85**	35.85**	35.85**
6 ×11 Sel-4 ×Pusa A-4	0.41	-6.13	6.58	80.53**	78.95**	65.85**	-8.77**	-16.13**	-3.7	32.74**	25**	41.51**
6 ×12 Sel-4 ×SB-8	0.69	0.23	-0.11	71.06**	63.41**	63.41**	-7.14**	-13.33**	-3.7	35.8**	33.33**	38.36**
7 ×8 PM ×PK	-3.64	-3.77	8.92*	60.87**	54.17**	50.41**	-11.76**	-16.67**	-7.41*	25.95**	23.28**	46.54**
7 ×9 PM × VRO-3	-10.48**	-11.45**	2.44	60.34**	55**	51.22**	-16.76**	-22.58**	-11.11**	14.4**	13.49*	34.91**
7 ×10 PM × Sel-10	4.63	-1.46	11.53**	55.56**	53.66**	53.66**	-15.53**	-16.05**	-16.05**	27.59**	17.46**	39.62**
7 ×11 PM × Pusa A-4	-1.75	-1.91	11.38**	69.23**	65**	60.98**	-13.29**	-19.35**	-7.41*	21.95**	19.05**	41.51**
7 ×12 PM × SB-8	-9.51**	-14.92**	-3.70	80.25**	78.05**	78.05**	-14.12**	-18.89**	-9.88**	13.56*	6.35	26.42**
8 ×9 PK × VRO-3	-12.75**	-13.81**	-0.30	102.7**	100.89**	82.93**	-14.75**	-16.13**	-3.7	11.17*	9.68	28.3**
8 ×10 PK × Sel-10	-10.21**	-15.33**	-4.43	87.98**	78.05**	78.05**	-15.79**	-20**	-11.11**	25.88**	18.23**	34.59**
8 ×11 PK × Pusa A-4	-13.85**	-14.10**	-2.46	74.11**	71.05**	58.54**	-21.31**	-22.58**	-11.11**	14.68**	14.36*	30.19**
8 ×12 PK × SB-8	1.26	-4.66	7.61	97.42**	86.99**	86.99**	-13.33**	-13.33**	-3.7	30.06**	24.31**	41.51**

Table 1. Continued.

	Plant height			No. of branches per plant			Node at which 1st flower appears			No. of nodes on main stem		
F1	MP	BrP	BP	MP	BrP	BP	MP	BrP	BP	MP	BrP	BP
9 ×10 VRO-3 × Sel-10	0.99	-5.85	8.91*	68.51**	60.98**	60.98**	-10.34**	-16.13**	-3.7	33.33**	23.66**	44.65**
9 ×11 VRO-3 × Pusa A-4	-9.33**	-10.16**	3.92	76.99**	75.44**	62.6**	-25.81**	-25.81**	-14.81**	9.29	7.53	25.79**
9 ×12 VRO-3 × SB-8	5.80	-1.53	13.91**	65.96**	58.54**	58.54**	-22.4**	-23.66**	-12.35**	21.37**	14.52*	33.96**
10 ×11 Sel-10 × Pusa A-4	-0.67	-6.59	6.06	54.43**	48.78**	48.78**	-16.09**	-21.51**	-9.88**	25.07**	17.78**	33.33**
10 ×12 Sel-10 × SB-8	12.73**	12.54**	12.54**	59.35**	59.35**	59.35**	-12.28**	-16.67**	-7.41*	33.95**	31.52**	36.48**
11 ×12 Pusa A-4 × SB-8	-2.30	-8.28*	4.15	79.75**	73.17**	73.17**	-15.85**	-17.2**	-4.94	13.04*	8.33	22.64**
Comparison of F1 with	SED	CD 95%	CD 99%	SED	CD 95%	CD 99%	SED	CD 95%	CD 99%	SED	CD 95%	CD 99%
Mid parent	2.365	4.723	6.168	0.195	0.389	0.508	0.145	0.289	0.377	0.673	1.344	1.755
Better parent	2.731	5.454	7.122	0.225	0.45	0.587	0.167	0.334	0.436	0.777	1.551	2.026
Best parent/ Checks	2.731	5.454	7.122	0.225	0.45	0.587	0.167	0.334	0.436	0.777	1.551	2.026

	Intermodal length			**Days to 50% flowering**			**Fruit yield per plant**			**Fruit yield per ha**		
F1	**MP**	**BrP**	**BP**	**MP**	**BrP**	**BP**	**MP**	**BrP**	**BP**	**MP**	**BrP**	**BP**
1×2 IC-45831 ×IC-282272	-12.69**	-14.44**	-16.62**	-3.91*	-5*	-3.98	45.22**	39.83**	3.83	45.22**	39.82**	3.83
1 ×3 IC-45831 ×IC-43733	-19.8**	-22.93**	-21.8**	-3.63*	-5.61**	-4.59*	59.01**	56.1**	11.36*	59**	56.1**	11.36*
1 ×4 IC-45831 ×IC-43750	-14.15**	-15.36**	-20.82**	-6.36**	-6.36**	-5.36**	41.53**	29.99**	6.75	41.53**	30**	6.75
1 ×5 IC-45831 ×IC-45802	-18.46**	-19.05**	-23.17**	-4.85**	-4.85*	-3.83	46.71**	22.79**	25.24**	46.71**	22.79**	25.23**
1 ×6 IC-45831 ×Sel-4	-20.8**	-22.69**	-24.05**	-5.23**	-6.49**	-2.91	12.61*	-0.69	-10.63*	12.61*	-0.69	-10.63*
1 ×7 IC-45831 ×PM	-14.95**	-15.48**	-19.94**	-7.59**	-8.35**	-5.82**	12.85**	-8.27	0.77	12.85**	-8.26	0.77
1 ×8 IC-45831 ×PK	-15.83**	-17.96**	-19.16**	-6.8**	-7.08**	-5.51**	9.18*	-19.24**	15.77**	9.18*	-19.24**	15.77**
1 ×9 IC-45831 ×VRO-3	-18.45**	-20.4**	-21.8**	-3.81*	-4.24*	-3.22	21.4**	-3.04	11.57*	21.4**	-3.04	11.57*
1 ×10 IC-45831 ×Sel-10	-14.95**	-17.69**	-17.69**	-0.69	-1.21	-0.15	12.69**	-4.92	-4.92	12.69**	-4.92	-4.92
1 ×11 IC-45831 ×Pusa A-4	-16.77**	-19.45**	-19.45**	-4.39*	-4.53*	-3.22	50.03**	34.56**	16.53**	50.03**	34.56**	16.53**
1 ×12 IC-45831 ×SB-8	-9.54*	-9.77*	-15.15**	-0.83	-0.91	0.31	47.45**	30.58**	16.38**	47.45**	30.58**	16.38**

Table 1. Continued.

F1	Intermodal length MP	BrP	BP	Days to 50% flowering MP	BrP	BP	Fruit yield per plant MP	BrP	BP	Fruit yield per ha MP	BrP	BP
2 ×3 IC-282272 ×IC-43733	-17.74**	-19.36**	-18.18**	-3.76*	-4.65*	-5.82**	49.71**	46.77**	8.98	49.71**	46.77**	8.98
2 ×4 IC-282272 ×IC-43750	-17.18**	-19.96**	-21.99**	-6.05**	-7.12**	-6.13**	40.47**	33.75**	9.83*	40.48**	33.75**	9.83*
2 ×5 IC-282272 ×IC-45802	-15.45**	-16.55**	-18.67**	-3.3	-4.39*	-3.37	26.76**	9.53*	11.71*	26.76**	9.53*	11.71*
2 ×6 IC-282272 ×Sel-4	-19.08**	-19.4**	-20.82**	-7.94**	-10.18**	-6.74**	43.98**	31.4**	18.24**	43.98**	31.4**	18.24**
2 ×7 IC-282272 ×PM	-12.61**	-13.84**	-16.03**	-4.1*	-5.96**	-3.37	16.02**	-2.77	6.8	16.02**	-2.77	6.8
2 ×8 IC-282272 ×PK	-20.4**	-20.83**	-21.99**	-3.74*	-5.12**	-3.52	-8.52*	-30.57**	-0.47	-8.52*	-30.57**	-0.47
2 ×9 IC-282272 ×VRO-3	-20.28**	-20.6**	-21.99**	-6.08**	-6.73**	-6.58**	19.7**	-1.53	13.31**	19.7**	-1.53	13.31**
2 ×10 IC-282272 ×Sel-10	-19.6**	-20.63**	-20.63**	-1.54	-2.14	-2.14	13.16**	-1.4	-1.4	13.16**	-1.4	-1.4
2 ×11 IC-282272 ×Pusa A-4	-18.81**	-19.84**	-19.84**	-6.5**	-7.7**	-6.43**	26.97**	17.92**	2.12	26.97**	17.92**	2.12
2 ×12 IC-282272 ×SB-8	-19.04**	-20.46**	-22.48**	-3.68*	-4.84*	-3.68	40.72**	28.97**	14.96**	40.71**	28.97**	14.95**
3 ×4 IC-43733 ×IC-43750	-16.67**	-21**	-19.84**	-5.03**	-6.97**	-5.97**	35.62**	26.72**	4.06	35.62**	26.72**	4.06
3 ×5 IC-43733 ×IC-45802	-18.67**	-21.29**	-20.14**	-4.25*	-6.21**	-5.21**	39.91**	18.89**	21.26**	39.91**	18.89**	21.26**
3 ×6 IC-43733 ×Sel-4	-10.62**	-12.04**	-10.75**	-5.57**	-8.7**	-5.21**	29.11**	15.73**	4.14	29.11**	15.73**	4.14
3 ×7 IC-43733 ×PM	-16.29**	-19.08**	-17.89**	-6.29**	-8.94**	-6.43**	17.19**	-3.35	6.17	17.19**	-3.35	6.17
3 ×8 IC-43733 ×PK	-18.48**	-19.65**	-18.48**	-5.01**	-7.23**	-5.67**	3.41	-22.57**	11*	3.41	-22.57**	11*
3 ×9 IC-43733 ×VRO-3	-22.96**	-24.18**	-23.07**	-2.87	-4.43*	-4.29*	5.85	-14.27**	-1.35	5.85	-14.27**	-1.35
3 ×10 IC-43733 ×Sel-10	-22.37**	-22.93**	-21.8**	-0.31	-1.84	-1.84	25.99**	7.94	7.94	25.99**	7.94	7.94
3 ×11 IC-43733 ×Pusa A-4	-18.78**	-19.36**	-18.18**	-2.7	-4.83*	-3.52	28.28**	16.98**	1.31	28.29**	16.98**	1.31
3 ×12 IC-43733 ×SB-8	-8.9*	-12.24**	-10.95**	-3.55*	-5.6**	-4.44*	35.25**	21.76**	8.52	35.25**	21.76**	8.52
4 ×5 IC-43750 ×IC-45802	-6.58	-8.55*	-13.2**	-7.12**	-7.12**	-6.13**	20.97**	9.18*	11.36*	20.97**	9.18*	11.36*
4 ×6 IC-43750 ×Sel-4	-13.39**	-16.62**	-18.08**	-4.33*	-5.6**	-1.99	32.65**	26.85**	14.15**	32.65**	26.85**	14.15**
4 ×7 IC-43750 ×PM	-18.48**	-20.12**	-24.34**	-5.33**	-6.11**	-3.52	13**	-1.26	8.46	13**	-1.26	8.46

Table 1. Continued.

F1	Intermodal length			Days to 50% flowering			Fruit yield per plant			Fruit yield per ha		
	MP	BrP	BP	MP	BrP	BP	MP	BrP	BP	MP	BrP	BP
4 ×8 IC-43750 ×PK	-14.76**	-18.06**	-19.26**	-5.44**	-5.72**	-4.13*	-0.72	-21.93**	11.92*	-0.72	-21.93**	11.92*
4 ×9 IC-43750 ×VRO-3	-21.86**	-24.78**	-26.1**	-7**	-7.42**	-6.43**	8.01	-7.46	6.49	8.01	-7.46	6.49
4 ×10 IC-43750 ×Sel-10	-13.98**	-17.89**	-17.89**	-6.02**	-6.52**	-5.51**	23.27**	12.25**	12.25**	23.27**	12.25**	12.25**
4 ×11 IC-43750 ×Pusa A-4	-20.23**	-23.85**	-23.85**	-6.35**	-6.5**	-5.21**	34.03**	30.56**	13.07**	34.03**	30.56**	13.07**
4 ×12 IC-43750 ×SB-8	-9.2*	-10.71*	-16.03**	-2.65	-2.72	-1.53	35.07**	29.76**	15.65**	35.07**	29.76**	15.65**
5 ×6 IC-45802 ×Sel-4	-13.77**	-15.22**	-16.72**	-7.92**	-9.14**	-5.67**	28.98**	21.38**	23.8**	28.97**	21.38**	23.8**
5 ×7 IC-45802 ×PM	-13.2**	-13.29**	-17.69**	-7.74**	-8.49**	-5.97**	15.11**	10.99*	21.92**	15.11**	10.99*	21.92**
5 ×8 IC-45802 ×PK	-11.57**	-13.19**	-14.47**	-3.78*	-4.07*	-2.45	8.39*	-7.24*	32.97**	8.39*	-7.24*	32.97**
5 ×9 IC-45802 ×VRO-3	-21.36**	-22.69**	-24.05**	-6.09**	-6.52**	-5.51**	21.33**	14.43**	31.68**	21.33**	14.43**	31.68**
5 ×10 IC-45802 ×Sel-10	-17.65**	-19.75**	-19.75**	-3.12	-3.64	-2.6	20.26**	19.09**	21.46**	20.26**	19.09**	21.46**
5 ×11 IC-45802 ×Pusa A-4	-18.76**	-20.82**	-20.82**	-6.35**	-6.5**	-5.21**	47.45**	36.33**	39.05**	47.46**	36.33**	39.04**
5 ×12 IC-45802 ×SB-8	-21.37**	-21.73**	-25.71**	-6.13**	-6.2**	-5.05*	47.19**	37.91**	40.66**	47.19**	37.91**	40.66**
6 ×7 Sel-4 ×PM	-17.02**	-18.51**	-19.94**	-8.82**	-9.29**	-5.82**	14.25**	3.92	14.16**	14.25**	3.92	14.16**
6 ×8 Sel-4 ×PK	-24.79**	-24.9**	-26**	-7.9**	-8.85**	-5.36**	-6.37	-23.8**	9.24	-6.37	-23.8**	9.24
6 ×9 Sel-4 ×VRO-3	-23.58**	-23.58**	-24.93**	-8.71**	-10.32**	-6.89**	2.46	-8.71*	5.05	2.46	-8.71*	5.05
6 ×10 Sel-4 ×Sel-10	-27.61**	-28.25**	-28.25**	-6.99**	-8.7**	-5.21**	12.74**	7.09	7.09	12.74**	7.09	7.09
6 ×11 Sel-4 ×Pusa A-4	-24.46**	-25.12**	-25.12**	-8.21**	-9.29**	-5.82**	22**	19.71**	7.72	22**	19.7**	7.72
6 ×12 Sel-4 ×SB-8	-25.47**	-27.06**	-28.35**	-6.95**	-8.11**	-4.59*	16.56**	16**	4.39	16.56**	16**	4.39
7 ×8 PM ×PK	-23.72**	-25.2**	-26.3**	-7.72**	-8.2**	-5.67**	-12.56**	-22.78**	10.7*	-12.55**	-22.77**	10.7*
7 ×9 PM × VRO-3	-21.99**	-23.38**	-24.73**	-4.91**	-6.11**	-3.52	-2.55	-4.76	9.59*	-2.55	-4.76	9.59*
7 ×10 PM × Sel-10	-18.67**	-20.82**	-20.82**	-7.4**	-8.64**	-6.13**	-3.05	-7.4	1.72	-3.05	-7.4	1.72
7 ×11 PM × Pusa A-4	-19.78**	-21.9**	-21.9**	-5.78**	-6.41**	-3.83	15.25**	3.05	13.2**	15.25**	3.05	13.2**

Table 1. Continued.

F1	Intermodal length			Days to 50% flowering			Fruit yield per plant			Fruit yield per ha		
	MP	BrP	BP	MP	BrP	BP	MP	BrP	BP	MP	BrP	BP
7 ×12 PM × SB-8	-19.63**	-19.92**	-24.14**	-6.76**	-7.45**	-4.9*	4.28	-5.55	3.75	4.28	-5.55	3.74
8 ×9 PK × VRO-3	-21.61**	-21.73**	-22.87**	-5.92**	-6.63**	-5.05*	-12.83**	-21.43**	12.64**	-12.83**	-21.43**	12.64**
8 ×10 PK × Sel-10	-29.1**	-29.62**	-29.62**	-5.54**	-6.33**	-4.75*	-7.48*	-21.47**	12.57**	-7.48*	-21.47**	12.57**
8 ×11 PK × Pusa A-4	-25.16**	-25.71**	-25.71**	-5.43**	-5.57**	-3.98	-2.47	-21.78**	12.13*	-2.47	-21.78**	12.13*
8 ×12 PK × SB-8	-21.73**	-23.51**	-24.63**	-6.57**	-6.78**	-5.21**	-8.44*	-25.75**	6.43	-8.44*	-25.75**	6.44
9 ×10 VRO-3 × Sel-10	-24.65**	-25.32**	-25.32**	-4.97**	-5.05*	-4.9*	5.83	-1.1	13.8**	5.82	-1.11	13.8**
9 ×11 VRO-3 × Pusa A-4	-17.16**	-17.89**	-17.89**	-5.93**	-6.5**	-5.21**	13.15**	-0.84	14.1**	13.15**	-0.85	14.1**
9 ×12 VRO-3 × SB-8	-12.35**	-14.23**	-15.74**	-6.46**	-6.96**	-5.82**	9.62*	-2.74	11.92*	9.62*	-2.74	11.92*
10 ×11 Sel-10 × Pusa A-4	-20.82**	-20.82**	-20.82**	-6.31**	-6.95**	-5.67**	12.65**	5.1	5.1	12.65**	5.1	5.1
10 ×12 Sel-10 × SB-8	-15.67**	-18.18**	-18.18**	-5.94**	-6.51**	-5.36**	18.49**	12.05*	12.05*	18.49**	12.05*	12.05*
11 ×12 Pusa A-4 × SB-8	-13.15**	-15.74**	-15.74**	-4.61**	-4.68*	-3.37	37.09**	35.14**	20.45**	37.09**	35.15**	20.45**
Comparison of F1 with	SED	CD 95%	CD 99%	SED	CD 95%	CD 99%	SED	CD 95%	CD 99%	SED	CD 95%	CD 99%
Mid parent	0.24	0.479	0.625	0.752	1.502	1.961	11.045	22.058	28.806	8.181	16.339	21.338
Better parent	0.277	0.553	0.722	0.868	1.734	2.264	12.753	25.47	33.263	9.447	18.867	24.639
Best parent/ Checks	0.277	0.553	0.722	0.868	1.734	2.264	12.753	25.47	33.263	9.447	18.867	24.639

of vegetable breeders can be the employment of the outcome of heterosis in a correct direction. Vegetable breeders have broadly utilized and exploited heterosis in maximizing the yield of various crops. All commercial okra hybrids are made from crosses of inbred lines. The objective of okra hybridization is to discover and then accurately produce potential hybrids in view of economic characters. The knowledge on selecting potential parents for developing superior hybrid combinations is meagre. Yield is an ultimate economic and complex character. The improvement in such complex characters can be achieved through component approach of breeding. This method, in general, assumes strong associations of yield with a number of other characters leading to yield and simpler inheritance for these component characters. Overall average heterosis, heterobeltiosis and standard heterosis of crosses as a whole were evaluated and presented in Table 1.

From the consequence of the heterosis studies, it is proved that none of the 66 F_1 hybrids made from diallel crossing (without reciprocals) of 12 genotypes of okra expressed harmony in degree and direction of heterosis over three bases for all the eight characters examined. Few crosses exhibited positive heterosis whereas others expressed negative heterosis (Table 1). The main reason for this was varying degree of genetic diversity between the parents of distinct cross combinations for the constituent characteristics. In the current experiment, the assessment of average heterosis, heterobeltiosis and standard heterosis among crosses were found to be highly wavering in direction and magnitude for all the characters under evaluation (Sidapara *et al.* 2021). Negative heterosis also observed in few crosses for the characters under study. This may be due to the blend of the unfavorable / adverse genes of the parents. In the current study, plant height, number of branches per plant and number of nodes on main stem are major growth attributing parameters. They determine majorly the fruit / pod bearing surface of the okra plant. The cultivars with more plant height, higher number nodes on main stem, shorter internodal lengths and a greater number of primary branches per plant are essential for producing more numbers of pods per plant to achieve higher pod yield per plant. Hence, positive heterosis is advantageous for plant height, number of branches per plant, number of nodes on main stem, fruit yield per plant and fruit yield per hectare but negative heterosis is beneficial for node at which 1st flower appears, intermodal length and days to 50% flowering.

In the productivity point of view, plant height is a paramount character. The hybrid IC-45831 × SB-8 exhibited greatest heterosis over mid, better and economic parent (MPH= 33.31, BPH= 25.84 and SPH= 25.41). The positive heterosis for plant height was also reported in earlier findings (Prakash *et al.* 2019). The number of branches per plant is also one of the contributing parameters to productivity. On comparing the overall performance of the hybrids, the crosses IC-45831 × Sel-4 (MPH= 137.68, BPH= 119.64 and SPH= 100) and IC-45831 × VRO-3 (MPH= 131.88, BPH= 114.29 and SPH= 95.12) better in terms of mid, better and standard heterosis. Similar results reported by earlier findings (Keerthana *et al.* 2021, Prakash and Pitchaimuthu 2018) . Similarly, number of nodes per plant is an important productivity contributing character. Out of 66 crosses, majority of the hybrids expressed positive significant heterosis. Highest observed in IC-45831 ×SB-8 (MPH= 48.17, BPH= 41.21 and SPH= 46.54) (Prakash *et al.* 2019).

Negative heterosis is desirable for the character node at which first flower appears. The hybrids IC-45802 × Sel-4 (MPH= -22.81, BPH= -29.03 and SPH= -18.52) and IC-282272 × Parbhani Kranti (MPH= -20.96, BPH= -26.67 and SPH= -18.52) are better on account of heterosis. Fruit production being occurs at each node in okra, shorter gap between the nodes, will eventually lead to more production. The desirable negative heterosis for this character observed in Parbhani Kranti × Sel-10 (MPH= -29.1, BPH= -29.62 and SPH= -29.62) and Sel-4 ×Sel-10 (MPH= -27.61, BPH= -28.25 and SPH= -28.25) (Shwetha *et al.* 2021 and Prakash *et al.* 2019). Early crop yield is one of the important characters in okra. Earliness is a favorable trait which helps the grower to get an economic yield by extending the product early to the market. In the current research, days to 50% flowering and node at which 1st flower appears are recorded to study earliness of genotypes. The number of hybrids expressing negative heterosis for this earliness related trait was more. Further, the extent of negative heterosis is in general greater than the extent of positive heterosis. Out of 66 cross combinations, 57 crosses over mid parent, 60 crosses over better parent and 43 crosses over standard parent expressed significant negative heterosis i.e., in desired direction. Out of them the most desirable hybrid for this trait during the investigation was Sel-4 × VRO-3 (MPH= -8.71, BPH= -10.32 and SPH= -6.89). Negative heterosis to for earliness days to 50 % flowering was observed in earlier findings (Prakash *et al.* 2019 and Sawadogo *et al.* 2014).

The ultimate and most important characters are fruit yield per plant and fruit yield per hectare. Out of 66 hybrids, 50, 32 and 38 hybrids showed significant positive heterosis over mid parent, better parent and standard check respectively. Out of which highest was reported in IC-45831 ×IC-43733 (MPH= 59.01, BPH= 56.1 and SPH= 11.36) followed by IC-45831 ×Pusa A-4 (MPH= 50.03, BPH= 34.56 and SPH= 16.53). Positive heterosis for fruit yield was also disclosed in other findings (Sawadogo *et al.* 2014 and Prakash *et al.* 2019).

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