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Heterosis study in Okra [*Abelmoschus esculentus* (L.) Moench] genotypes for pod yield attributes

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Abstract: A study was conducted at Vegetable Research Farm, Department of Horticulture, Institute of Agriculture Sciences, Banaras Hindu University, Varanasi during Spring-Summer and Rainy season of 2012 and 2013 using 12 diverse parental lines of okra and their 66 F_1 hybrids (through diallel cross-excluding reciprocals) with the objective to measure the extent of heterosis over better parent and standard commercial check varieties for the purpose of judging the extent up to which heterosis can be exploited in commercial okra breeding. The extent of heterosis for five best crosses over better parent and check (48.32 % to 82.42 % and 7.13 % to 35.66 %, respectively) for yield per hectare suggested the great scope of realizing higher yield in okra through heterosis breeding. Other economic traits also recorded moderate to high level of heterosis over the better parents. The cross combination IC - 282280×EC – 329380showed high heterosis over better parent and standard check for pod yield (82.42 % and 35.66 %), number of pods per plant (62.82 % and 48.54 %) and respectively. This particular cross combination eventually resulted the height magnitude of heterobeltiosis and standard heterosis for the most of the desirable growth parameters as well as yield attributing characters which may be taken for further breeding programme.

Keywords: Diallel cross, Economic traits, Heterobeltiosis, Heterosis, Okra

INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench] known as bhindi or lady's finger is an important annual vegetable crop grown in the tropical and sub-tropical regions of world (Arapitsas, 2008; and Saifullah and Rabbani, 2009). Fairly good amount of proteins, carbohydrates, vitamins (A, B and C) and minerals is found in pod of Okra (Owolarafe, 2004; Gopalan *et al.*, 2007; Arapitsas, 2008 and Dilruba *et al.*, 2009) thus it plays an important role in human diet (Kahlon *et al.*, 2007 and Saifullah and Rabbani, 2009). So many varieties have been developed in okra but significant increase in productivity potential could not be realized possibly because of ceiling in genetic potential of the genotypes. Therefore, there is an urgent need of genetic improvement of crop for yield which can be achieved by exploitation of hybrid vigour (heterosis). In most of developed country like Japan and USA, mainly F_1 hybrid varieties are cultivated on commercial scale instead of open pollinated varieties. Heterosis breeding programme aiming to develop a hybrid variety comprises identification of desirable parents which can produce F_1 hybrid having high level of economic heterosis. The presence of great extent of natural variation for various characters among the varieties of okra suggested a good scope of improvement in the economic traits through heterosis breeding techniques. Keeping in view the above facts, the present study was planned and carried out using 12 parents and their 66 F_1 hybrids (excluding reciprocals) with the objective to measure the extent of heterosis over better parents and standard commercial check varieties for purpose of judging the extent up to which heterosis can be exploited in commercial okra breeding.

MATERIALS AND METHODS

The present experiment conducted at Vegetable Research Farm, Department of Horticulture, Institute of Agriculture Sciences, BHU, Varanasi during Spring -Summer and Rainy season of 2012 and 2013. This place is located in south east part of Varanasi city at 25° 15' North latitude and 83° 03' East longitudes at an elevation of 129.23 m above the mean sea level. The average annual rainfall is about 1110 millimeter (mm). The major portion of precipitation (about 85 to 90 %) is received during July to September. The soil of the experimental site contains 49.75 % sand, 28.73 % silt and 21.52 % clay. The available soil nitrogen, phosphorous and potassium status have been recorded as 0.082, 0.126 and 0.640 %, respectively. The experimental material consisted 12 diverse varieties/lines (thereafter called genotypes) of okra , provided by the Indian Institute of Vegetable Research, Varanasi

Table 1. Genotypes of okra used in the present experiment.

Parents	Name of the genotypes	Sources
P_1	Larm -1	IIVR-Varanasi
P_2	IC -282280	IIVR-Varanasi
P_3	IC – 282337	IIVR-Varanasi
P_4	IC -128891	IIVR-Varanasi
P_5	IC -111527	IIVR-Varanasi
P_6	EC – 329380	IIVR-Varanasi
P_7	IC – 282279	IIVR-Varanasi
P_8	VRO -5	IIVR-Varanasi
P_9	IC – 329422	IIVR-Varanasi
P_{10}	IC – 18537	IIVR-Varanasi
P_{11}	Hisar Unnat	IIVR-Varanasi
P_{12}	IC – 43132	IIVR-Varanasi

(Table 1) and 66 F_1 hybrids derived by crossing these 12 genotypes in all possible combinations in diallel fashion (excluding reciprocals) by hand emasculation and pollination during earlier spring-summer, 2012. The experiment was laid out in a Randomized Block Design (RBD) with three replications during rainy season of 2013.Each genotype was sown in 12 rows of 3 meter length accommodating 10 plants in each row. The observations were taken from randomly selected five competitive plants of parents and their crosses in each replication. The analysis of variance was used for testing as to whether there exists a significant difference between the genotypes and their hybrids. It was carried out following the statistical procedure of RBD analysis (Panse and Sukhatme, 1989) for each of the genotypes and their derived hybrids. Heterosis was calculated over superior parent (heterobeltiosis)and standard variety i.e. checks (economic heterosis), following the method described by Kempthorne (1957). The test of significance of heterosis was accomplished by the Student's 't' test (Student, 1908a).

RESULTS AND DISCUSSION

The extent of heterobeltiosis and standard heterosis were expressed as percent increase or decrease in hybrid performance in comparison to better parent and standard check varieties, respectively. The mean performance of the genotypes (F_1s) and per cent of heterosis (over better parents and standard check) are presented in Table 2.

The heterotic performance over better-parents towards earliness (days to first flowering) was maximum in crosses $P_2 \times P_{10}$ (-20.83 %).Out of 41 cross-combinations, five best combination showed significant heterobeltiosis for days to 50 % flowering viz., $P_3 \times P_{12}$ (-17.31 %), $P_2 \times P_{10}$ (-16.67 %), $P_4 \times P_{10}$ (-16.67 %), $P_2 \times P_9$ (-13.21 %) and $P_1 \times P_9$ (-13.2 %). The estimates of heterosis for plant height in hybrids varied from -31.83 % ($P_3 \times P_9$) to 50.75 % ($P_1 \times P_4$) over better parents. The manifestation of heterosis in desirable direction for internodal length over the better parents was recorded in 20 cross-combinations. However, extent of heterobeltiosis ranged from -37.16 % ($P_3 \times P_8$) to 68.75 % ($P_1 \times P_2$). The heterotic increase in the number of pods per plant over their better parent was recorded in 32 hybrids and the increase varied from 0.59 % ($P_4 \times P_6$) to 62.82 % ($P_2 \times P_6$). The highest numbers of seeds per pod 54.84 were recorded in P_8 and lowest 41.27 in pods of P_5, while, among hybrids it was recorded from 46.27 as in $P_3 \times P_6$ to 58.96 in $P_9 \times P_{10}$.The five best parents which had high mean pod yield were P_8 (106.26 q ha^{-1}), P_3 (101.23 q ha^{-1}), P_{11} (93.34 q ha-^{1}), P_4 (79.75 q ha^{-1}) and P_6 (79.02 q ha^{-1}) whereas among hybrids, five best cross combinations were $P_2 \times P_6$ (144.16 q ha^{-1}), $P_4 \times P_7$ (118.16 q ha^{-1}), $P_1 \times P_{12}$ (117.78 q ha^{-1}), $P_5 \times P_{12}$ (115.19 q ha^{-1}) and $P_1 \times P_3$ (113.05 q ha^{-1}).

A close observation of table 2 revealed that nine cross combinations showed significant standard heterosis for days to first flowering with highest in $P_2 \times P_{10}$ (-15.56 %), followed by $P_5 \times P_6$ (-9.89 %) and $P_3 \times P_{12}$ (-9.76 %) whereas, seventeen cross combinations showed significant relative heterosis for earliness with best three combination were $P_2 \times P_{10}$ (-14.56 %), $P_2 \times P_9$

Table 2. Heterosis (%) over better parent (BP) and the commercial check (CC) for Days to first flowering Days to 50 % flowering Node at which first flower appear Plant height (cm) Number of branches per plant in okra.

Hybrids	Days to first flowering		Days to 50% flowering		Node at which first flower appear		Plant height (cm)		Number of branches per plant	
	BP	CC	BP	CC	BP	CC	B P	CC	BP	CC
$P_1 \times P_2$	2.38	-0.76	-6.49*	-2.04	9.41	-13.89	40.87**	24.56**	136.36**	67.47*
$P_1 \times P_3$	2.38	-0.76	-7.69**	-2.04	-5.26	0.00	7.58	43.70**	60.71	44.93
$P_1 \times P_4$	10.26**	-0.76	11.63**	-2.04	22.35	-3.70	50.75**	43.70**	126.92**	90.02**
$P_1 \times P_5$	-4.44	-0.76	-6.96*	0.00	-1.42	28.70**	-12.31*	1.64	74.19*	73.91*
$P_1 \times P_6$	0.00	6.16	20.00**	10.20**	2.83	0.93	-15.45**	7.19	59.09	12.72
$P_1 \times P_7$	15.38**	3.85	2.68	4.08	31.25**	36.11**	0.42	10.58	10.00	6.28
$P_1 \times P_8$	-0.77	-0.76	-2.04	-2.04	0.93	0.93	-2.84	-2.84	-3.23	-3.38
$P_1 \times P_9$	-1.52	0.01	-13.21**	-6.12*	-26.67**	-18.52	-15.83**	9.77	-40.91	-58.13
$P_1 \times P_{10}$	-12.50**	-3.07	-11.11**	-2.04	-12.28	-7.41	-22.19**	7.25	86.36*	32.05
$P_1 \times P_{11}$	0.79	-2.30	6.67*	-2.04	33.68**	17.59	16.82**	35.95**	27.78	48.15
$P_1 \times P_{12}$	-7.50*	-14.61**	-4.55	-14.29**	9.62	5.56	5.36	34.56**	33.33	15.94
$P_2 \times P_3$	-2.38	-5.38	-7.69**	-2.04	0.00	5.56	-14.01**	14.85*	14.29	3.06
$P_2 \times P_4$	-0.79	-3.84	-14.29**	-10.20**	81.16**	15.74	29.57**	23.51**	119.23**	83.57**
$P_2 \times P_5$	-4.44	-0.76	-8.86**	-2.04	-5.67	23.15*	5.85	22.69**	119.35**	119.00**

Contd……...

$P_2 \times P_6$	-8.70**	-3.07	-6.49*	-2.04	20.75*	18.52	2.15	29.51**	244.44**	99.68**
$P_2 \times P_7$	2.38	-0.76	-10.39**	-6.12*	5.36	9.26	-4.73	4.91	13.33	9.50
$P_2 \times P_8$	-0.77	-0.76	-6.49*	-2.04	-4.63	-4.63	0.68	0.68	19.35	19.16
$P_2 \times P_9$	-2.27	-0.76	-13.21**	-6.12*	-28.33**	-20.37*	-20.49**	3.68	72.22	-0.16
$P_2 \times P_{10}$	-20.83**	-12.30**	-16.67**	-8.16**	-10.53	-5.56	1.44	39.82**	31.82	-6.60
$P_2 \times P_{11}$	2.38	-0.76	-8.44**	-4.08	1.05	-11.11	11.76	30.06**	8.33	25.60
$P_2 \times P_{12}$	4.76	1.55	-6.49*	-2.04	-25.00*	-27.78**	-18.96**	3.51	-40.74	-48.47
$P_3 \times P_4$	-2.38	-5.38	-9.62**	-4.08	-31.58**	-27.78**	-4.20	27.95**	-53.57	-58.13
$P_3 \times P_5$	2.22	6.16	1.90	9.52**	-17.02*	8.33	-16.20**	11.93	-54.84	-54.91
$P_3 \times P_6$	-4.35	1.55	-7.69**	-2.04	2.63	8.33	2.93	37.49**	35.71	22.38
$P_3 \times P_7$	7.94*	4.62	-1.92	4.08	7.89	13.89	-1.66	31.35**	-3.33	-6.60
$P_3 \times P_8$	2.31	2.32	-5.77*	0.00	-19.30*	-14.81	-19.44**	7.60	-54.84	-54.91
$P_3 \times P_9$	-2.27	-0.76	-7.55**	0.00	-11.67	-1.85	-31.83**	-8.95	-82.14*	-83.90**
$P_3 \times P_{10}$	-5.56	4.62	-5.56*	4.08	31.58**	38.89**	19.56**	64.80**	139.29**	115.78**
$P_3 \times P_{11}$	-4.76	-7.69*	-9.62**	-4.08	0.00	5.56	17.16**	56.49**	13.89	32.05
$P_3 \times P_{12}$	-11.90**	-14.61**	-17.31**	-12.24**	-2.63	2.78	-6.48	24.91**	35.71	22.38
$P_4 \times P_5$	-11.11**	-7.69*	-10.76**	-4.08	-36.88**	-17.59	-16.25**	-2.92	16.13	15.94
$P_4 \times P_6$	-2.17	3.85	11.11**	2.04	21.70*	19.44*	4.75	32.81**	57.69	32.05
$P_4 \times P_7$	10.26**	-0.76	-11.41**	-10.20**	-3.57	0.00	13.33*	24.80**	13.33	9.50
$P_4 \times P_8$	-0.77	-0.76	-2.04	-2.04	-0.93	-0.93	16.08*	16.08*	9.68	9.50
$P_4 \times P_9$	-2.27	-0.76	-8.81**	-1.36	-12.50	-2.78	-15.52**	10.18	-50.00	-58.13
$P_4 \times P_{10}$	-12.50**	-3.07	-16.67**	-8.16**	-2.63	2.78	-1.99	35.09**	-11.54	-25.93
$P_4 \times P_{11}$	-4.76	-7.69*	0.00	-8.16**	-3.16	-14.81	-9.35	5.50	-88.89**	-87.12**
$P_4 \times P_{12}$	-5.00	-12.30**	-6.82*	-16.33**	-4.81	-8.33	-9.89	15.09*	-48.15	-54.91
$P_5 \times P_6$	-10.87**	-5.38	-1.27	6.12*	8.51	41.67**	2.86	30.41**	54.84	54.59
$P_5 \times P_7$	-2.22	1.55	0.00	7.48*	-11.35	15.74	-15.49**	-2.05	19.35	19.16
$P_5 \times P_8$	-4.44	-0.76	-7.59**	-0.68	-1.42	28.70**	8.27	25.50	122.58**	122.22**
$P_5 \times P_9$	-4.44	-0.76	-6.29*	1.36	-2.84	26.85**	-8.88	18.83**	70.97*	70.69*
$P_5 \times P_{10}$	-10.42**	-0.76	-8.02**	1.36	-3.55	25.93**	-8.40	26.26**	112.90**	112.56**
$P_5 \times P_{11}$	-5.93	-2.30	-12.66**	-6.12*	-14.18	12.04	5.63	22.92**	36.11	57.81
$P_5 \times P_{12}$	0.00	3.85	-3.80	3.40	11.35	45.37**	9.89	40.35**	112.90**	112.56**
$P_6 \times P_7$	-12.32**	-6.92*	-1.34	0.00	16.07	20.37*	16.97**	48.30**	83.33**	77.13*
$P_6 \times P_8$	-6.52*	-0.76	6.12*	6.12*	15.74	15.74	-5.35	20.00**	32.26	32.05
$P_6 \times P_9$	-8.70**	-3.07	-7.55**	0.00	-1.67	9.26	4.84	36.73**	138.89**	38.49
$P_6 \times P_{10}$	-10.42**	-0.76	-12.96**	-4.08	23.68**	30.56**	7.76	48.54**	150.00**	77.13*
$P_6 \times P_{11}$	-10.87**	-5.38	0.00	-8.16	31.13**	28.70**	10.33	39.88**	102.78**	135.10**
$P_6 \times P_{12}$	-15.22**	-9.99**	-6.67*	-14.29	24.53*	22.22*	10.62	41.29**	81.48*	57.81
$P_7 \times P_8$	-5.38	-5.38	-9.40**	-8.16	8.04	12.04	2.92	13.33	58.06	57.81
$P_7 \times P_9$	-4.55	-3.07	-7.55**	0.00	-6.67	3.70	-24.39**	-1.40	-36.67	-38.81
$P_7 \times P_{10}$	0.00	10.78**	-0.62	9.52	4.39	10.19	-15.74**	16.14*	-36.67	-38.81
$P_7 \times P_{11}$	0.00	-3.07	-4.03	-2.72	-13.39	-10.19	-12.66*	1.64	-25.00	-13.04
$P_7 \times P_{12}$	5.00	-3.07	-1.34	0.00	-14.29	-11.11	-18.96**	3.51	3.33	-0.16
$P_8 \times P_9$	-2.27	-0.76	-7.55**	0.00	-21.67*	-12.96	-29.60**	-8.19	0.00	-0.16
$P_8 \times P_{10}$	-2.08	8.47*	-2.47	7.48	-14.91	-10.19	-25.16**	3.16	12.90	12.72
$P_8 \times P_{11}$	1.54	1.55	0.00	0.00	-24.07*	-24.07*	-28.24**	-16.49*	-2.78	12.72
$P_8 \times P_{12}$	-3.08	-3.07	-2.04	-2.04	-15.74	-15.74	-22.25**	-0.70	45.16	44.93
$P_9 \times P_{10}$	-12.50**	-3.07	-11.11**	-2.04	-18.33*	-9.26	-17.88**	13.19	90.91*	35.27
$P_9 \times P_{11}$	-2.27	-0.76	-1.26	6.80	-19.17*	-10.19	-20.36**	3.86	-36.11	-25.93
$P_9 \times P_{12}$	-2.27	-0.76	-5.66*	2.04	-10.83	-0.93	-8.07	19.88**	-25.93	-35.59
$P_{10} \times P_{11}$	-2.08	8.47*	-1.85	8.16	-16.67	-12.04	-15.06**	17.08*	33.33	54.59
$P_{10} \times P_{12}$	-14.58**	-5.38	-11.11**	-2.04	-16.67	-12.04	-0.13	37.66**	122.22**	93.24**
$P_{11} \times P_{12}$	0.00	-3.07	2.22	-6.12	-3.85	-7.41	-1.69	25.56**	-38.89	-29.15
S.E.D.	1.497	1.497	1.414	1.414	0.689	.689	3.917	3.917	0.624	0.624
C.D. at 5%	2.990	2.990	2.825	2.825	1.375	1.375	7.822	7.822	1.246	1.246
C.D. at 1%	3.905	3.905	3.689	3.689	1.796	1.796	10.215	10.215	1.627	1.267

** Significant at 5 % and * significant at 1 % probability level. BP and CC - Heterosis over better parent and commercial check (Kashi Pragati) respectively.

Table 2. Heterosis (%) over better parent (BP) and the commercial check (CC) for Internodal distance (cm) Number of pods per plant Pod weight (g) Number of seeds per pod Pod yield (q/ ha) in okra.

Hybrids	Internodal distance (cm)		Number of pods per plant		Pod weight (g)		Number of seeds per pod		Pod yield (q/ ha)	
	BP	CC	BP	CC	BP	CC	B P	CC	BP	CC
$P_1 \times P_2$	68.75**	-1.75	7.69	-1.75	28.46**	-7.80	11.94*	-2.07	39.69**	-9.24
$P_1 \times P_3$	-10.81	15.47*	4.47	15.47*	6.92	-7.60	14.43*	-2.68	11.68	6.39
$P_1 \times P_4$	-1.20	7.60	8.88	7.60	12.96	-14.45*	6.60	-7.78	22.85*	-7.80
$P_1 \times P_5$	-34.15**	-12.87	16.41	-12.87	7.76	-16.98*	7.86	-8.27	26.85**	-27.88**
$P_1 \times P_6$	-26.24**	-26.32**	-16.56	-26.32**	1.79	-14.29*	10.20	-1.59	-15.58*	-37.22**
$P_1 \times P_7$	-35.81**	-16.96*	2.16	-16.96*	22.52*	-12.55	-3.25	-5.96	29.94**	-27.50**

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$P_1 \times P_8$	-9.81	-10.53	-10.53	-10.53	-23.65**	-23.63**	-0.61	-0.61	-32.77**	-32.77**
$P_1 \times P_9$	-8.03	-21.05**	-2.17	-21.05**	-11.78	-28.82**	2.74	-4.26	-13.84	-43.72**
$P_1 \times P_{10}$	4.25	11.70	49.22**	11.70	4.60	-25.34**	-7.88	-13.37*	55.66**	-16.80**
$P_1 \times P_{11}$	17.86	14.62	10.73	14.62	-2.45	-16.51*	11.26*	3.27	8.51	-4.68
$P_1 \times P_{12}$	-21.48*	26.32**	40.26**	26.32**	11.48	-12.35	1.92	-9.85	56.67**	10.82
$P_2 \times P_3$	-33.65**	2.92	-6.88	2.92	8.93	-5.86	4.44	-8.63	1.85	-2.97
$P_2 \times P_4$	-1.72	-11.70	-10.65	-11.70	8.57	-17.78*	8.47	-5.11	-2.98	-27.19**
$P_2 \times P_5$	-22.11*	1.75	11.54	1.75	-18.81*	-37.45**	4.03	-9.00	-2.90	-36.91**
$P_2 \times P_6$	-29.65**	48.54**	62.82**	48.54**	8.37	-8.75	5.17	-6.08	82.42**	35.66**
$P_2 \times P_7$	-26.94**	10.53	21.15*	10.53	11.80	-19.75**	4.63	1.69	37.21**	-10.85
$P_2 \times P_8$	-8.70	8.77	8.77	8.77	-25.63**	-25.61**	-4.50	-4.50	-19.39*	-19.39**
$P_2 \times P_9$	-7.86	6.43	16.67*	6.43	-14.03	-30.64**	0.39	-6.45	13.54	-25.84**
$P_2 \times P_{10}$	20.47*	22.22**	33.97**	22.22**	8.94	-21.81**	-3.75	-9.48	47.40**	-4.23
$P_2 \times P_{11}$	21.61*	14.04	10.17	14.04	-6.06	-19.60**	-3.14	-10.09	4.69	-8.04
$P_2 \times P_{12}$	-20.00*	-2.34	7.05	-2.34	-5.04	-25.34**	3.30	-8.63	1.22	-28.41**
$P_3 \times P_4$	1.35	12.28	1.59	12.28	-16.40*	-27.75**	8.29	-6.32	-14.23*	-18.29**
$P_3 \times P_5$	-14.86	-16.96*	-24.87**	-16.96*	-16.63*	-27.95**	18.81**	-10.21	-37.11**	-40.09**
$P_3 \times P_6$	-27.97**	-20.47**	-28.04**	-20.47**	-15.03	-26.56**	-5.58	-15.68**	-38.73**	-41.63**
$P_3 \times P_7$	-26.35**	-1.17	-10.58	-1.17	-19.79*	-30.68**	0.63	-2.19	-28.05**	-31.46**
$P_3 \times P_8$	-37.16**	-19.88**	-27.51**	-19.88**	-16.76*	-16.75*	-3.04	-3.04	-33.48**	-33.48**
$P_3 \times P_9$	-27.03**	-45.03**	-50.26**	-45.03**	-13.06	-24.86**	-0.78	-7.54	-56.85**	-58.90**
$P_3 \times P_{10}$	-15.54*	-11.70	-20.11**	-11.70	-17.20*	-28.44**	-4.65	-10.33*	-34.10**	-37.23**
$P_3 \times P_{11}$	-20.54**	9.94	-0.53	9.94	-16.22	-27.59**	0.65	-6.57	-16.26*	-20.23**
$P_3 \times P_{12}$	-36.49**	18.71*	7.41	18.71*	-15.39	-26.88**	5.91	-6.32	-9.53	-13.82*
$P_4 \times P_5$	-28.62**	-3.51	-2.37	-3.51	-5.09	-26.88**	-1.26	-14.59**	-6.36	-29.73**
$P_4 \times P_6$	-15.89	-0.58	0.59	-0.58	-1.93	-17.42*	10.88	-0.98	8.36	-18.68**
$P_4 \times P_7$	-0.48	25.15**	26.63**	25.15**	18.92*	-9.94	-7.50	-10.09	48.32**	11.31
$P_4 \times P_8$	1.72	1.75	1.75	1.75	-12.37	-12.35	-6.08	-6.08	-10.85	-10.86
$P_4 \times P_9$	-3.42	-15.79*	-14.79	-15.79*	1.82	-17.85*	0.26	-6.57	-7.49	-30.57**
$P_4 \times P_{10}$	-1.57	3.51	4.73	3.51	7.37	-18.69**	-6.72	-12.28*	11.44	-16.37**
$P_4 \times P_{11}$	6.35	-19.30*	-22.03**	-19.30*	-7.63	-20.94**	-9.03	-15.56**	-27.28**	-36.12**
$P_4 \times P_{12}$	-14.07	-21.64**	-20.71**	-21.64**	8.26	-14.89*	0.69	-10.94*	-11.86	-33.85**
$P_5 \times P_6$	-3.55	-7.60	4.64	-7.60	-2.73	-18.09*	2.86	-8.15	0.94	-24.93**
$P_5 \times P_7$	-12.10	-25.15**	-7.91	-25.15**	-25.64**	-42.72**	-19.63**	-21.88**	-24.12*	-56.86**
$P_5 \times P_8$	0.98	8.77	8.77	8.77	-17.32*	-17.30*	-2.67	-2.68	-12.29	-12.29*
$P_5 \times P_9$	-0.81	-4.09	18.84*	-4.09	-13.89	-30.52**	0.00	-6.81	1.88	-33.45**
$P_5 \times P_{10}$	-1.57	4.09	41.27**	4.09	-15.88	-35.19**	-7.75	-13.25*	18.25*	-32.77**
$P_5 \times P_{11}$	1.63	31.58**	27.12**	31.58**	-16.74*	-28.74**	-7.33	-13.98**	4.12	-8.53
$P_5 \times P_{12}$	11.11	27.49**	41.56**	27.49**	8.41	-14.77*	6.04	-6.20	53.25**	8.40
$P_6 \times P_7$	4.26	-0.58	12.58	-0.58	-7.95	-22.49**	0.62	-2.19	3.43	-23.08**
$P_6 \times P_8$	-16.45*	-23.39**	-23.39**	-23.39**	-15.46*	-15.44*	-6.08	-6.08	-35.54**	-35.54**
$P_6 \times P_9$	-9.22	-9.94	1.99	-9.94	11.61	-6.02	5.48	-1.71	13.93	-15.27*
$P_6 \times P_{10}$	-9.93	2.92	16.56	2.92	1.13	-14.85*	5.68	-0.61	18.02*	-12.23*
$P_6 \times P_{11}$	-9.93	25.15**	20.90**	25.15**	-12.81	-25.38**	3.53	-3.89	6.67	-6.29
$P_6 \times P_{12}$	-10.07	22.22**	35.71**	22.22**	-14.25	-27.79**	3.67	-7.42	18.83*	-11.63
$P_7 \times P_8$	-0.81	-10.53	-10.53	-10.53	-18.86**	-18.84**	5.47	5.46	-27.95**	-27.95**
$P_7 \times P_9$	0.00	-2.92	19.42*	-2.92	-14.03	-30.64**	-5.37	-8.03	2.74	-32.89**
$P_7 \times P_{10}$	-5.51	-28.65**	-12.23	-28.65**	-11.36	-38.52**	-16.00**	-18.35**	-21.99*	-56.47**
$P_7 \times P_{11}$	2.42	-30.41**	-32.77**	-30.41**	-13.55	-26.01**	5.38	2.42	-42.34**	-49.35**
$P_7 \times P_{12}$	-5.93	-26.32**	-18.18*	-26.32**	-20.09*	-37.17**	-10.00	-12.52*	-34.43**	-53.62**
$P_8 \times P_9$	8.72	-26.32**	-26.32**	-26.32	-20.05**	-20.03**	-1.46	-1.46	-41.56**	-41.56**
$P_8 \times P_{10}$	-3.15	-4.09	-4.09	-4.09	-31.13**	-31.12**	-14.22**	-14.22**	-34.59**	-34.59**
$P_8 \times P_{11}$	-13.39	-0.58	-3.95	-0.58	-18.54**	-18.53**	-8.75	-8.75	-19.35*	-19.35**
$P_8 \times P_{12}$	-17.04*	1.17	1.17	1.17	5.96	5.98	-3.16	-3.17	7.13	7.13
$P_9 \times P_{10}$	-5.51	-14.62	5.80	-14.62	19.43*	-3.64	13.82*	7.04	25.94**	-17.74**
$P_9 \times P_{11}$	-19.83*	-14.04	-16.95*	-14.04	8.83	-6.85	-4.04	-10.58*	-9.14	-20.19**
$P_9 \times P_{12}$	-7.41	6.43	18.18*	6.43	-3.29	-21.97**	-6.91	-13.25*	16.19*	-17.81**
$P_{10} \times P_{11}$	-14.17	8.77	5.08	8.77	-13.32	-25.81**	-0.13	-6.08	-8.75	-19.84**
$P_{10} \times P_{12}$	0.00	-11.11	-1.30	-11.11	1.66	-20.07**	4.78	-1.46	-0.88	-29.89**
$P_{11} \times P_{12}$	-9.04	15.79*	11.86	15.79*	-9.34	-22.41**	8.51	0.72	2.23	-10.20
S.E.D.	0.376	0.376	0.865	0.865	1.187	1.187	2.867	2.867	6.566	6.566
C.D. at 5%	0.752	0.752	1.727	1.727	2.370	2.370	5.725	5.725	13.114	13.114
C.D. at 1%	0.982	0.982	2.255	2.255	3.095	3.095	7.477	7.477	17.125	17.125

** Significant at 5 % and * significant at 1 % probability level. BP and CC - Heterosis over better parent and commercial check (Kashi Pragati) respectively.

(-11.82 %), and $P_3 \times P_{12}$ (-10.42 %). Among 66 F_1 hybrids, 16 combinations manifested significant standard heterosis over check 1 (VRO-5) while six combinations exhibited significant standard heterosisfor day 50 % flowering with maximum in $P_4 \times P_{12}$ (-8.89 %) followed by $P_1 \times P_{12}$ (-6.67 %) and $P_6 \times P_{12}$ (-6.67 %). Perusal of heterosis data manifested four cross combinations in desired direction with maximum in $P_8 \times P_{11}$ (-19.21 %) followed by $P_8 \times P_9$ (-17.54 %), and $P_3 \times P_8$ (17.12 %). Eleven cross combinations for node at which first flower appear showed significant negative heterobeltiosis with best three were $P_4 \times P_5$ (-36.88 %) followed by $P_3 \times P_4$ (-31.58 %) and $P_2 \times P_9$ (-28.33 %) and four hybrids showed significant standard heterosis over check 1with maximum in $P_2 \times P_{12}$ (-27.78 %), $P_3 \times P_4$ (-27.78 %) followed by $P_8 \times P_4$ (-24.07 %) and $P_2 \times P_9$ (-0.37 %). Out of 66, 22 cross combination showed significant mid parental heterosis with best three combination *viz.*$P_1 \times P_4$ (56.41 %), $P_1 \times P_2$ (49.16 %) and $P_2 \times P_4$ (42.03 %) for plant height while all combination showed significant standard heterosis over check 1. Out of 66, 27 cross combination showed significant average heterosis for number of branches with best three were $P_2 \times P_6$ (254.29 %), $P_2 \times P_5$ (183.33 %), $P_6 \times P_{10}$ (175 %) while three best significant heterobeltiosis recorded in cross combination $P_2 \times P_6$ (244.44 %), $P_6 \times P_{10}$ (150 %) and $P_3 \times P_{10}$ (139.29 %).

Extent of average heterosis for internodal distance were ranged from -33.57 % to 70.53 % out of which, 11 hybrids showed significant negative mid parental heterosis $P_3 \times P_{12}$ (-33.57 %) followed by $P_1 \times P_5$ (-27.64 %), $P_4 \times P_5$ (-26.71 %) while, $P_3 \times P_9$ (-45.03 %), $P_7 \times P_{11}$ (-30.41 %) and $P_7 \times P_{10}$ (-28.65 %) showed significant standard heterosis over check 1. For no of pods per plant, 15 hybrids showed significant heterobeltiosis with three best were $P_2 \times P_6$ (62.82 %), $P_1 \times P_{10}$ (49.22 %) and $P_5 \times P_{12}$ (41.56 %) whereas 11 cross combinations with maximum value, $P_2 \times P_6$ (48.54 %) followed by $P_5 \times P_{11}$(31.58 %) and $P_5 \times P_{12}$ (27.49 %), standard heterosis over check 1 and $P_2 \times P_9$ (43.50 %), $P_5 \times P_{11}$ (27.12 %) and $P_5 \times P_{12}$ (23.16 %) over standard check 2 (Hissar Unnat) for same trait. For pod yield, 24 hybrids manifested significant average heterosis with best three cross combinations were$P_2 \times P_{10}$ (102.08 %), $P_1 \times P_{10}$ (99.85 %) and $P_2 \times P_6$ (94.72 %) where as $P_2 \times P_6$ (82.42 %), $P_{10} \times P_{12}$ (56.66 %), $P_1 \times P_{10}$ (56.66 %) and $P_5 \times P_{12}$ (53.25 %) recorded significant heterobeltiosis, five combinations namely$P_2 \times P_6$ (54.44 %), $P_4 \times P_7$ (26.72 %), $P_1 \times P_{12}$ (26.16 %), $P_5 \times P_{12}$ (23.41 %), $P_8 \times P_{12}$ (21.96 %) and $P_1 \times P_3$ (21.12 %) showed significant standard heterosis over check 2.

The best common crosses based on *per se* performance as well as heterosis over better parent and standard check, the crosses found promising were $P_1 \times P_4$, $P_1 \times P_5$, $P_3 \times P_{12}$ and $P_9 \times P_{11}$ for plant height; $P_2 \times P_6$, $P_5 \times P_{12}$, $P_1 \times P_{12}$ and $P_4 \times P_7$ for number of pods per plant and pod yield per hectare; $P_2 \times P_6$, $P_4 \times P_7$, $P_5 \times P_{12}$, $P_1 \times P_3$ and $P_1 \times P_{12}$. The present results were in conformity to those of the earlier workers of okra like Singh *et al.* (2001), Sood and Kalia (2001) More and Patil (2003)and Lyngdoh *et al.*(2013) Patel and Patel (2016).

The extent of heterosis for five best crosses over better parent and standard check (48.32 % to 82.42 % and 7.13 % to 35.66 %, respectively) for yield per hectare suggested the great scope of realizing higher yield in okra through heterosis breeding. Other economic traits also recorded moderate to high level of heterosis over the better parents.

Conclusion

The hybrid P_2 (IC -282280) × P_6 (EC – 329380) was found to be the most promising for pod yield and other desirable traits. This cross also showed high heterosis over better parent and standard check for pod yield (82.42 %, and 35.66 %) and number of pods per plant (62.82 % and 48.54 %) respectively. It is also clear that the high degree of non additive gene action for all the component traits observed in the present study favours hybrid breeding methodology So, it can be identified as the potential okra hybrid combination for commercial exploitation.

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