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Heterosis for yield and its components in okra [*Abelmoschus esculentus* (L.) Moench]

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ABSTRACT : The present investigation was carried out to study heterosis for various horticultural traits of okra in late *Kharif*- 2013 and summer, 2014 by involving five diverse parents in a diallel mating including reciprocals. The analysis of variance reflected considerable variability for yield and other component traits. VRO-6 was excellent over other parents in *per se* performance for majority of traits under investigation except average fruit weight, fruit stalk length and ascorbic acid. The cross-combination VRO-6 x GJO-3 was the only F_1 exhibiting significant heterobeltiosis as well as standard heterosis for yield per plant. Whereas hybrids AA x AOL-12-52, AA x GJO-3 and VRO-6 x AA also displayed significant heterosis over better parent for this character. The cross-combination VRO-6 x GJO-3 also recorded significant and desirable heterotic gain over standard check for other traits like first flowering node, days to first flowering, number of branches per plant and average fruit weight.

KEY WORDS : Heterosis, Okra, *Per se* performance, Diallel, Horticultural traits

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Okra or *Bhindi* or lady's finger [*Abelmoschus esculentus* (L.) Moench] is an extensively cultivated and highly remunerative vegetable crop in tropical, subtropical and warm areas of temperate zones across the globe. Though, India is the largest producer of okra in world with an annual production of 63.46 lakh tonnes from an area of 5.33 lakh hectares with a productivity of 11.91 tonnes per hectare, but there is still a huge scope for improving productivity of this crop (Anonymous, 2014). Exploitation of heterosis in okra has been recognized as a practical tool in providing the breeders a mean of improving yield and other important traits. Nevertheless, the choice of parents is a matter of great concern to the plant breeder and is largely dependent on the ability of genotypes entering into hybridization to yield desirable recombinants (Hallauer and Mirada, 1981). The primary objective of heterosis breeding is to achieve a quantum jump in yield and quality aspects of crop plants and several observations of earlier workers *viz.*, Panda and Singh (1998); Singh and Sood (1999), Dhankhar and Dhankhar (2001); Sood and Sharma (2001) and Khatik *et al.* (2012) in okra on hybrid vigour for yield and related traits substantiated the scope for commercial utilization. Therefore, the present investigation was planned to identify potential hybrid (s) for South- Gujarat conditions.

RESEARCH METHODS

The experimental material comprised of five genetically diverse genotypes of okra, namely Parbhani Kranti (PK), Arka Anamika (AA), AOL-12-52, VRO-6 and GJO-3. Five parents and their 20 F_1s including reciprocals along with standard check (SC) No.64 (A popular F_1 among farmers) were planted in a Randomized Block Design with three replications at the experimental farm of Vegetable Research Scheme, Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat (India) during late *Kharif*-2013 and summer, 2014. Each cross/parent was raised in single row of 3 m length with inter and intra row spacing of 60 and 30 cm, respectively. The guard rows were provided surrounding the experiment to avoid border effects. The observations were recorded on five randomly taken plants from each genotype in each replication for various horticultural traits *viz*., first flowering node, days to first flowering, days to 50 per cent flowering, days to first picking, internodal length, days to last picking, number of fruits per plant, number of branches per plant, plant height, stem diameter, yield per plant, fruit length, fruit diameter, average fruit weight and ascorbic acid. The data were subjected to full diallel analysis suggested by Griffing (1956). The magnitude of heterosis in different F_1s as the performance over better parent (BP) in percentage was calculated and presented as per Singh *et al.* (1996).

RESEARCH FINDINGS AND DISCUSSION

Analysis of variance with respect to fifteen characters in parents and hybrids revealed that the mean sum of squares due to parents and hybrids were highly significant for all the characters except for days to 50 per cent flowering, days to first picking, days to last picking, stem diameter, fruit length, fruit diameter and average fruit weight in parents (Table 1).The mean squares due to F_1s (direct crosses) also exhibited significant differences for most of the traits except days to last picking, fruit length and fruit diameter. Whereas reciprocals displayed significant values for nine traits namely first flowering node, days to first flowering, days to 50 per cent flowering, internodal length, number of fruits per plant, number of branches per plant, plant height, yield per plant and ascorbic acid. This indicates the existence of high genetic variations in parents and hybrids for all the characters studied, hence may further be useful in heterosis breeding.

VRO-6 excelled all other parents in *per se* performance for most of the traits under investigation except average fruit weight, ascorbic acid, whereas parents AOL-12-52 showed higher values for fruit

Table 1 : Analysis of variance for various horticultural traits in okra

Source of variation	d. f.	First flowering node	Days to first flowering	Days to 50 % flowering	Days to first picking	Internodal length (cm)	Days to last picking	Number of fruits per plant	Number of branches per plant	Plant height (cm)	Stem diameter (cm)	Yield per plant (g)	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	Ascorbic acid (mg)
Replication	2	0.50	30.09	3.69	61.69	0.23	19.25	1.45	0.003	33.21	0.01	63.90	1.33	0.0001	0.63	11.19
Treatments	24	1.99**	63.03**	59.96**	66.00*	1.54**	51.27	77.16**	1.32**	169.42**	0.10*	10643.02**	0.86	0.03	2.22	32.57**
Parents	4	1.30**	46.43*	35.17	45.23	1.01**	42.57	52.14**	0.82**	131.03*	0.10	6738.66**	0.60	0.04	0.63	42.78**
Hybrids	19	2.16**	66.73**	61.87**	70.88*	1.68**	50.96	79.94**	1.34**	185.13**	0.11*	10929.09**	0.88	0.03	2.66*	32.12**
Parent Vs. Hybrids	1	1.43*	58.96	122.88*	56.33	0.89*	91.85	124.42**	2.82**	24.57	0.03	20825.00**	1.58	0.02	0.42	0.37
F_1s	9	2.02**	79.29**	64.33**	82.16*	1.03**	52.73	69.75**	1.43**	210.30**	0.19**	12440.84**	0.77	0.03	3.67**	47.33**
Reciprocals	9	2.42**	58.16**	61.66**	64.80	2.47**	44.73	99.00**	1.35**	177.83**	0.04	10596.11**	1.04	0.03	1.93	18.68**
F_1 Vs. Reciprocals	1	1.04*	30.82	41.67	24.07	0.50	91.27	0.0004	0.47**	24.27	0.00	320.17	0.41	0.00	0.06	16.26
Error	48	0.20	15.40	18.85	32.32	0.15	71.31	4.10	0.03	48.94	0.05	571.53	1.36	0.03	1.28	5.42

* and ** indicate significance of values at P =0.05 and 0.01, respectively

Table 2 : *Per se* performance of parents and F_1 hybrids of okra for various horticultural traits

Genotypes	First flowering node	Days to first flowering	Days to 50 % flowering	Days to first picking	Internodal length (cm)	Days to last picking	Number of fruits per plant	Number of branches per plant	Plant height (cm)	Stem diameter (cm)	Yield per plant (g)	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	Ascorbic acid (mg)
Parents															
AA	4.05	45.33	47.67	53.67	4.99	95.33	14.72	1.84	89.09	2.33	173.87	10.63	1.54	11.83	13.91
PK	4.05	45.67	48.00	54.33	5.07	95.00	11.64	0.84	80.07	2.23	144.37	10.73	1.63	12.42	19.65
AOL-12-52	4.11	43.67	46.67	52.00	3.92	97.00	17.03	1.12	75.99	2.06	199.43	10.89	1.78	11.73	18.17
VRO 6	2.72	36.00	39.67	44.67	3.86	104.00	23.01	1.86	92.12	2.46	270.35	11.73	1.78	11.77	12.66
GJO-3	4.43	43.33	46.33	52.33	4.24	95.67	16.98	0.81	82.19	2.04	216.18	11.23	1.54	12.75	21.52
Mean	3.872	42.8	45.67	51.40	4.41	97.4	16.68	1.29	83.89	2.22	200.84	11.04	1.65	12.10	17.18
Direct crosses															
AA x PK	3.91	42.67	44.00	51.33	5.46	95.00	12.75	1.01	80.93	2.46	162.35	10.43	1.49	12.74	15.16
AA x AOL-12-52	4.11	46.67	47.67	54.67	4.04	104.67	20.73	1.25	92.87	2.38	306.35	10.73	1.73	14.80	16.41
AA x VRO-6	3.77	42.33	44.67	50.67	3.79	102.67	23.07	1.89	94.75	2.59	275.75	10.11	1.60	11.97	12.66
AA x GJO-3	2.68	35.67	37.33	44.00	3.54	104.00	27.49	1.65	100.31	2.21	310.31	10.43	1.68	11.31	21.40
PK x AOL-12-52	4.56	46.33	47.00	54.67	4.11	94.67	14.89	0.87	81.06	2.21	176.92	10.73	1.76	12.16	13.29
PK x VRO-6	4.45	45.67	48.33	55.00	4.19	102.00	16.67	1.92	89.08	2.46	204.13	10.73	1.67	12.26	15.16
PK x GJO-3	4.63	46.00	47.67	55.00	4.26	101.67	18.06	2.01	88.65	2.53	199.45	11.63	1.68	11.06	20.70
AOL-12-52xVRO-6	2.72	36.00	39.33	44.67	3.86	103.33	21.72	2.74	79.08	2.17	257.37	10.29	1.68	11.61	15.16
AOL-12-52 x GJO-3	3.30	39.00	41.33	47.67	4.04	98.33	17.25	2.87	74.92	1.96	204.11	11.03	1.85	11.85	24.52
VRO-6 x GJO-3	2.46	32.67	35.67	41.00	3.24	107.67	26.25	2.47	77.92	1.83	351.36	11.53	1.86	13.40	13.91
Reciprocals															
PK x AA	4.48	46.67	49.33	55.67	4.92	94.00	13.47	0.94	81.66	2.34	169.59	10.13	1.60	12.60	13.91
AOL-12-52 x AA	3.22	37.00	38.33	45.67	3.99	100.33	19.89	1.93	84.78	2.29	220.11	11.53	1.86	11.17	18.28
AOL-12-52 x PK	4.79	43.33	45.67	51.67	4.32	98.33	13.40	1.81	78.26	2.23	180.74	10.03	1.70	13.49	18.40
VRO-6 x AA	3.01	40.00	41.67	48.67	3.17	105.00	28.12	2.85	83.12	2.29	332.99	10.27	1.68	11.88	16.40
VRO-6 x PK	2.72	36.00	37.67	44.67	3.67	101.33	24.16	1.51	84.52	2.04	274.50	10.13	1.57	11.38	22.64
VRO-6xAOL-12-52	2.16	32.33	34.67	39.67	3.01	102.67	27.84	2.67	71.90	2.17	325.08	10.03	1.63	11.70	18.38
GJO-3 x AA	2.83	37.67	39.00	47.67	5.64	95.67	16.45	0.91	98.05	2.42	212.76	10.43	1.87	12.95	14.53
GJO-3 x PK	4.61	45.33	46.67	54.00	5.55	95.00	14.36	1.04	94.72	2.25	180.36	11.33	1.68	12.58	18.28
GJO-3 x AOL-12-52	3.11	41.00	42.67	49.67	4.32	95.00	17.39	1.46	80.59	2.34	228.24	11.23	1.74	13.14	19.66
GJO-3 x VRO-6	3.03	39.33	40.67	48.67	3.77	102.00	23.89	1.79	89.26	2.40	277.56	10.87	1.58	11.64	18.28
Mean	3.53	40.58	42.47	49.24	4.14	100.17	19.89	1.78	85.32	2.28	242.50	10.68	1.70	12.28	17.36
SC (No.64)	4.43	41	42.33	49.67	3.64	107.00	25.76	1.86	92.06	2.29	296.64	10.53	1.79	11.54	16.04

Table 3 : Estimates of heterosis over better parent and standard check for various horticultural traits in okra

Crosses	First flowering node		Days to first flowering		Days to 50% flowering		Days to first picking		Internodal length (cm)		Days to last picking		Number of fruits per plant		Number of branches per plant	
	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC
AA x PK	-3.46	16.04	-6.57	4.07	-8.33	3.94	-5.52	3.36	7.62	50.00**	-0.35	-11.21	-13.32	-50.47**	-45.03**	-45.62**
AA x AOL-12-52	0.00	21.98*	2.94	13.82	0.00	12.6	1.86	10.07	-19.04**	10.99	7.90	-2.18	21.73*	-19.53**	-32.01**	-32.74**
AA x VRO-6	-6.92	11.88	-6.62	3.25	-6.29	5.51	-5.59	2.01	-24.11**	4.03	-1.28	-4.05	0.30	-10.41	1.61	1.61
AA x GJO-3	-39.31**	-20.2	-21.32**	-13.01	-21.68**	-11.81	-18.01*	-11.41	-29.06**	-2.75	8.71	-2.8	61.97**	6.76	-10.31	-11.27
PK x AA	10.63	32.97**	2.19	13.82	2.78	16.54	2.45	12.08	-3.02	35.16**	-1.40	-12.15	-8.49	-47.72**	-48.82**	-49.37**
PK x AOL-12-52	10.96	35.35**	1.46	13.01	-2.08	11.02	0.61	10.07	-18.99**	12.91	-2.41	-11.53	-12.55	-42.19**	-22.26	-53.13**
PK x VRO-6	9.88	32.08**	0.00	11.38	0.69	14.17	1.23	10.74	-17.41**	15.11	-1.92	-4.67	-27.56**	-35.29**	3.22	3.22
PK x GJO-3	4.74	37.72**	0.73	12.2	-0.69	12.6	1.23	10.74	-16.10*	16.94	6.27	-4.98	6.36	-29.90**	138.74**	8.05
AOL-12-52 x AA	-21.67*	-4.46	-18.38*	-9.76	-19.58*	-9.45	-14.91	-8.05	-20.11**	9.52	3.44	-6.23	16.80	-22.79**	4.34	3.22
AOL-12-52 x PK	16.56	42.18**	-5.11	5.69	-4.86	7.87	-4.91	4.03	-14.85*	18.68*	1.37	-8.1	-21.28*	-47.96**	61.13**	-2.86
AOL-12-52xVRO-6	-33.85**	-19.31	-17.56*	-12.2	-15.71*	-7.09	-14.10	-10.07	-1.53	6.04	-0.64	-3.43	-5.56	-15.65*	47.23**	47.23**
AOL-12-52xGJO-3	-25.53**	-2.08	-10.69	-4.88	-11.43	-2.36	-8.92	-4.03	-4.71	11.08	1.37	-8.1	1.29	-33.04**	155.19**	53.85**
VRO-6 x AA	-25.70**	-10.69	-11.76	-2.44	-12.59	-1.57	-9.32	-2.01	-36.47**	-12.91	0.96	-1.87	22.21**	9.16	53.13**	53.13**
VRO-6 x PK	-32.87**	-19.31	-21.17**	-12.2	-21.53**	-11.02	-17.79*	-10.07	-27.66**	0.82	-2.56	-5.3	5.00	-6.21	-18.78*	-18.78*
VRO-6xAOL-12-52	-47.32**	-35.74**	-25.95**	-21.14**	-25.71**	-18.11*	-23.72*	-20.13*	-23.21**	-17.31	-1.28	-4.05	20.99**	8.08	43.47**	43.47**
VRO-6 x GJO-3	-44.50**	-27.03*	-24.62**	-20.33*	-23.02**	-15.75	-21.66*	-17.45	-23.64**	-10.99	3.53	0.62	14.13	1.94	32.74**	32.74**
GJO-3 x AA	-36.14**	-16.04	-16.91*	-8.13	-18.18*	-7.87	-11.18	-4.03	13.03*	54.95**	0.00	-10.59	-3.06	-36.11**	-50.45**	-50.98**
GJO-3 x PK	4.07	36.83**	-0.73	10.57	-2.78	10.24	-0.61	8.72	9.40	52.47**	-0.70	-11.21	-15.43	-44.26**	23.72	-44.01**
GJO-3xAOL-12-52	-29.82**	-7.72	-6.11	0.00	-8.57	0.79	-5.10	0.00	1.89	18.77*	-2.06	-11.21	2.11	-32.50**	30.27*	-21.47**
GJO-3 x VRO-6	-31.48**	-9.9	-9.23	-4.07	-12.23	-3.94	-7.01	-2.01	-11.15	3.57	-1.92	-4.67	3.82	-7.26	-3.76	-3.76

Cont....

Crosses	Plant height (cm)		Stem diameter (cm)		Yield per plant (g)		Fruit length (cm)		Fruit diameter (cm)		Average fruit weight (g)		Ascorbic acid (mg)	
	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC	BP	SC
AA x PK	-9.16	-12.09	5.57	7.57	-6.63	-45.27 **	-2.80	-0.95	-8.57	-16.73*	2.66	10.49	-22.85 *	-5.49
AA x AOL-12-52	4.24	0.88	1.86	3.78	53.61 **	3.28	-1.47	1.90	-2.80	-3.35	25.11 **	28.26 **	-9.69	2.31
AA x VRO-6	2.85	2.93	5.15	12.95	2.00	-7.04	-13.86	-4.05	-9.93	-10.59	1.18	3.73	-8.99	-21.08
AA x GJO-3	12.59	8.97	-5.29	-3.49	43.55 **	4.61	-7.12	-0.95	8.66	-6.69	-11.30	-1.99	-0.56	33.42 **
PK x AA	-8.34	-11.3	0.00	1.89	-2.47	-42.83 **	-5.59	-3.80	-2.04	-10.78	1.53	9.27	-29.22**	-13.28
PK x AOL-12-52	1.24	-11.94	-0.90	-3.64	-11.29	-40.36 **	-1.47	1.90	-1.68	-2.23	-2.09	5.37	-32.37**	-17.15
PK x VRO-6	-3.30	-3.23	0.00	7.42	-24.50**	-31.19 **	-8.52	1.90	-6.18	-6.88	-1.21	6.33	-22.85 *	-5.49
PK x GJO-3	7.87	-3.7	13.47	10.33	-7.74	-32.76 **	3.56	10.44	3.06	-6.13	-13.26	-4.16	-3.81	29.06 *
AOL-12-52 x AA	-4.84	-7.9	-1.86	0.00	10.37	-25.80 **	5.88	9.49	4.30	3.72	-5.58	-3.21	0.61	13.97
AOL-12-52 x PK	-2.27	-14.99 *	0.15	-2.62	-9.37	-39.07 **	-7.89	-4.75	-4.67	-5.2	8.62	16.90 *	-6.36	14.72
AOL-12-52 x VRO-6	-14.15 *	-14.09 *	-11.92	-5.39	-4.80	-13.24 *	-12.33	-2.34	-5.61	-6.13	-1.33	0.64	-16.57	-5.49
AOL-12-52 x GJO-3	-8.84	-18.61 **	-5.02	-14.56	-5.58	-31.19 **	-1.78	4.75	3.74	3.16	-7.06	2.69	13.94	52.88 **
VRO-6 x AA	-9.77	-9.71	-6.78	0.15	23.17 **	12.26	-12.50	-2.53	-5.62	-6.32	0.42	2.95	17.91	2.24
VRO-6 x PK	-8.25	-8.18	-17.07 *	-10.92	1.53	-7.46	-13.64	-3.80	-11.61	-12.27	-8.30	-1.3	15.27	41.22 **
VRO-6 x AOL-12-52	-21.95 **	-21.89 **	-11.92	-5.39	20.24 **	9.59	-14.55	-4.81	-8.60	-9.11	-0.59	1.39	1.16	14.59
VRO-6 x GJO-3	-15.41 *	-15.36 *	-25.75 **	-20.23 *	29.96 **	18.45 **	-1.70	9.49	4.12	3.35	5.18	16.21 *	-35.37**	-13.28
GJO-3 x AA	10.06	6.51	3.86	5.82	-1.58	-28.28 **	-7.12	-0.95	21.21*	4.09	1.57	12.22	-32.44**	-9.35
GJO-3 x PK	15.25 *	2.9	1.20	-1.6	-16.57	-39.20 **	0.89	7.59	2.45	-6.69	-1.33	9.01	-15.06	13.97
GJO-3 x AOL-12-52	-1.94	-12.46	13.43	2.04	5.58	-23.06 **	0.00	6.65	-2.80	-3.35	3.14	13.96	-8.64	22.57
GJO-3 x VRO-6	-3.11	-3.04	-2.57	4.66	2.66	-6.43	-7.33	3.23	-11.61	-12.27	-8.71	0.87	-15.06	13.97

* and ** indicate significance of values at P =0.05 and 0.01, respectively

diameter and GJO-3 for average fruit weight and ascorbic acid (Table 2). While, VRO-6 x AOL-12-52 exceeded all other cross-combinations in various traits like first flowering node, days to first flowering, days to 50 per cent flowering, days to first picking, internodal length and plant height. In addition, the crosses VRO-6 x GJO-3, VRO-6 x AA, AOL-12-52 x GJO-3, AA x VRO-6, VRO-6 x GJO-3, PK x GJO-3, GJO-3 x AA, AA x AOL-12-52, AOL-12-52 x GJO-3 and GJO-3 x PK had highest mean performance for days to last picking, number of fruits per plant, number of branches per plant, stem diameter, yield per plant, fruit length, fruit diameter, average fruit weight and ascorbic acid, respectively. These results are in agreement with the findings of early workers Mehta *et al.* (2007); Hazem *et al.* (2013); Paul (2013); Reddy *et al.* (2013); Rai *et al.* (2012) and Patel (2014) who also observed higher mean values for parents and hybrids in their respective studies.

It is evident from Table 3 that no single cross could manifest significantly desirable heterosis for all the traits. However, out of 20 cross-combinations AA x AOL-12-52, AA x GJO-3, VRO-6 x GJO-3, VRO-6 x AA displayed significant heterobeltiosis for fruit yield per plant. Whereas, VRO-6 x GJO-3 was the only F_1 exhibiting significant heterosis over standard check for this trait. Manifestation of heterosis in yield by VRO-6 x GJO-3 was also commonly observed for first flowering node, days to first flowering, number of branches per plant except days to 50 per cent flowering and days to first picking for heterobeltiosis and average fruit weight for standard heterosis. The cross VRO-6 x AOL-12-52 expressed desirable heterosis over standard check for maximum number of traits *viz.*, first flowering node, days to first flowering, days to 50 per cent flowering, days to first picking, number of branches per plant and plant height. Whereas VRO-6 x GJO-3 exhibited heterobeltiosis for five important traits namely first flowering node, days to first flowering, days to 50 per cent flowering, days to first picking and yield per plant. VRO-6 x AA, AA x GJO-3, GJO-3 x PK, GJO-3 x AA and AA x AOL-12-52 were the top ranking combinations which displayed significant heterosis over better parent for internodal length, number of fruits per plant, plant height, fruit diameter and average fruit weight, respectively. While cross VRO-6 x AOL-12-52 showed significantly highest standard heterosis for days to 50 per cent flowering and days to first picking. The presence of heterosis for yield in okra has also been reported by Pawar *et al.* (1999); Yadav *et al.* (2002); Rewale *et al.* (2003); Kumar and Pathania (2007); Paul (2013) and Patel (2014).

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