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Heterosis studies in okra (*Abelmoschus esculentus* (L.) Moench)

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Abstract
A set of 45 genotypes including 8 females, 4 males, their 32 resultant hybrids and one commercial check variety (GJOH-3) were sown during *khrif* 2016 at the Instructional Farm, Junagadh Agricultural University, Junagadh to study the magnitude of heterosis using line x tester analysis for ten characters. Significant differences were observed among the parents and hybrids indicating considerable genetic variation among these genotypes. Significant standard heterosis and high per se performance with regards to fruit yield per plant were recorded by the crosses *viz*., JOL-11-12 x AOL-03-02, KS -404 x JOL--2K-19, Pusa Sawani x AOL-03-01 and Pusa Sawani x AOL-08-05.

Keywords: Okra, standard heterosis and line x tester

Introduction
Okra **(***Abelmoschus esculentus* (L.) Moench) has captured a prominent position among vegetables and commonly known as bhendi or lady's finger in India, being native of tropical Africa. It is the choicest fruit vegetable grown extensively in the tropical, subtropical and warm area of the world like India, Africa, Turkey and other neighboring countries. Major area of cultivation in India are Utter Pradesh, Bihar, Orissa, West Bengal, Andhra Pradesh, Gujarat, Karnataka and Assam. Okra is polyploid, belong to the family *Malvaceae* with 2n =8x=72 or 144 chromosome and a self-pollinated crop, occurrence of out crossing to an extent of 4-19 % with maximum of 42.2 % is noticed with the insect assisted pollination (Kumar, 2006) [1].
Major problems of Okra are lack of location specific varieties, tolerant or resistant to disease, pest and abiotic stress. An important challenge would be to develop a variety / hybrid which response well to resources and resistant to yellow vein mosaic virus. To exploit the heterosis of potential yield components, knowledge of genetic architecture of fruit yield and its attributes is important in crop improvement. Hybrid vigour provides the means to an increase in the crop yield, disease and insect resistance and to combining ability characters, it is one of the important objectives in the plant breeding. There is very less total area under F_1 hybrids. Yield is mere universal breeding objective. The magnitude of heterosis provide a basis for genetic diversity and guide to choice of desirable parents for developing superior F_1 hybrids. A clear understanding for heterosis of the traits under consideration will help in deciding the appropriate breeding methods to improve the genetic makeup as well as productivity. Therefore, present investigation was carried out to estimate the magnitude of heterosis of fruit yield and its contributing characters in okra. Several reports on heterosis and fruit yield and its attributes have enhanced the scope for commercial utilization of heterosis in okra. The present investigation was undertaken to work out for further exploitation of heterosis for fruit yield in okra.

Materials and Methods
The experimental materials consisted 8 female parents (lines) and 4 male parents (testers). These parental lines were selected on the bases of *per se* performance, adoption and geographical diversity and crossed in the line x tester design for producing 32 hybrids. All the 32 F_1s and their parents and one check variety were grown in randomized block design with three replication at the Instructional Farm, Junagadh Agricultural University, Junagadh during *Kharif* 2016, The seeds were grown in single row of 3.6 m length keeping 45 cm distance between row and 30 cm within row. Data were recorded on quantitative characters *viz.*, days to 50% flowering, days to first picking, plant height (cm), number of branches per plant,

number of nodes per plant, inter nodal length, number of fruit per plant, fruit length (cm), fruit girth (cm) and fruit yield.

Results and discussion

The exploitation of heterosis in crop plant is regarded as one of the major breakthrough in the field of plant breeding. The application of heterosis is considered to an outstanding application of principles of genetics to agriculture. The scope of exploitation of hybrid vigour depends on direction and magnitude of heterosis and type of gene action involved.

The knowledge of heterosis with inbreeding depression would help in elimination of poor crosses in early stages. The magnitude of heterosis varied from cross to cross for all the characters studied, of these, the character of economic importance for okra is fruit yield and the heteotic response obtained for this character is of greater importance for the purpose of practical plant breeding.

In case of standard heterosis, many crosses manifested significant shift in desired direction *viz*., for days 50% flowering 13 crosses, days to first picking and number of branches per plant seven crosses, plant height eight crosses, fruit girth two crosses, inter nodal length four crosses, number of fruits per plant five crosses, and fruit yield per plant six crosses.

The parents showed significant difference for all the characters studied, which indicated the sufficient variability among the parents. The variance due to females were significant for all the traits indicating the existence of enormous amount of genetic variability among the female parents. Similarly, the male parents showed significant difference for all the characters revealing the presence of sufficient genetic variability among them.

The hybrid showed highly significant difference for all the characters. Parents' vs crosses showed highly significant difference for number of branches per plant, number of nodes per plant and fruit girth and rest of characters were non-significant (Table 1).

Earliness is an important trait in vegetable like Okra. Earliness is required in such crops for realizing the potential economic yield in as less time as possible, which is important consideration for vegetable grower. With regards days to 50% flowering, thirteen crosses showed significant negative standard heterosis in desired direction. The earliest crosses GO-2 x AOL-03-01showed negative of the extent of -21.65% for this character. Similar results have been observed by Paul (2013) [2] and Reddy *et al*. (2013a) [3] for days to 50% flowering (Table 2).

In case of, days to first picking seven crosses observed to be significant and desirable heterosis for days first picking over standard check, out of them GO-2 x AOL-03-01 was earliest to standard heterosis for days to first picking. Heterosis for earliness was earlier reported by Pawar *et al.* (1999a) [4] and Pathak and Prabhat (2014) [5].

Plant height at fully matured stages is one of the important ideotype in okra for higher yield. For plant height cross showing higher negative value may be used for developing dwarf varieties. The results for plant height testified that eight crosses highlighted highly significant over standard check in desired direction. The hybrid KS-404 x JOL-2K-19 (21.21%) demonstrated highest standard heterosis. The present findings are in close association with reported by Badiger *et al.* (2014) [6] and Katagi *et al*. (2015) [7].

The branches are important growth parameter contributing to productivity. For number of branches per plant seven crosses gave significant result for standard heterosis. The cross showing highest percentage of standard heterosis was KS-404 x JOL-2K-19 and Pusa Sawani x AOL-03-01 (29.14%). Badiger *et al.* (2014) [6] and Katagi *et al*. (2015) [7] also reported similar results in okra.

The standard heterosis for fruit girth were ranged from -9.47% (JOL-09-07 x AOL-08-05) to 8.28% (JOL-09-05 x AOL -03-01) and (KS-404 x AOL -03-01). Though, thicker fruits are not preferred by consumer, nevertheless fruit girth directly contributes toward higher yield and hence their positive value increases total yield. The present finding is in agreement with the findings of Kumar and Sreeparvathy (2010) [8] and Paul (2013) [2].

In case intermodal length, only one cross JF-55 x AOL-08-05 (-11.05%) tracked most eminent negative economic heterosis. The results are in agreement with previous findings of Himani Patel *et al*. (2015) [9] and Kumar *et al*. (2015) [10]. As okra bears pod at each node, shorter distance between the node, will ultimately lead to higher production. Joshi *et al*. (1958) [11] have stressed the importance of shorter internodes for increase yield in okra.

Number of fruits per plant, fruit length, fruit weight and fruit diameter are very closely related productivity parameters for number of fruits per plant, 5 crosses generated desirable significant standard heterosis. The cross picturing highest percentage of heterosis over standard check was KS-404 x AOL-08-05 and Pusa Sawani x AOL-03-01 (16.73%).Number fruits per plant is the most contributing traits to yield especially in hybrids. These results are harmony with earlier findings of Himani Patel *et al*. (2015) [9] and Kumar *et al*. (2015) [10] for number of fruits per plant.

Fruit yield is the ultimate and most important trait. In present study fair amount of standard heterosis was observed for fruit yield per plant. Six crosses depicted significant positive standard heterosis for this character. The best performing cross for this trait was JOL-11-12 x AOL-03-01 (30.95%) followed by KS404 x JOL-2K-19 (27.63%) and Pusa Sawani (19.65%). Similar observations were reported by Himani Patel *et al*. (2015) [9] and Kumar *et al*. (2015) [10] for fruits yield per plant.

Table 1: Analysis of variance for experimental design in respect to ten characters in okra

Source of variation	d.f.	Days to 50% flowering		Days to first picking		Plant height (cm)		Numbers of branches per plant		Numbers of nodes per plant		Fruit girth (cm)		Fruit length (cm)		Inter nodal length (cm)		Number of fruits per plant		Fruit yield per plant (g)	
Replications	2	3.860		6.194		9.929		0.106		0.835		0.057		0.406		0.061		0.416		124.924	
Parents	11	19.368	**	28.319	**	237.186	**	0.388	**	4.961	**	0.492	**	1.575	**	0.530	**	15.089	**	8455.849	**
Female	7	29.837	**	22.368	**	193.340	**	0.977	**	10.675	**	0.369	**	0.908	**	0.237	**	10.372	**	6199.355	**
Males	3	48.387	**	39.847	**	580.449	**+	1.216	**	14.278	**	0.274	**	2.684	**	0.723	**	15.670	**	6230.959	**
Hybrids	31	27.004	**	25.571	**	214.051	**	0.731	**	7.876	**	0.227	**	1.062	**	0.392	**	9.452	**	4737.322	**
Parent *vs.* Hybrid	1	3.207		5.237		16.582		2.695	**	64.661	**	0.006		2.212	**	0.215	*	2.683		849.197	
Error	86	2.101		4.577		29.968		0.047		2.528		0.034		0.184		0.055		1.875		231.991	

*,** Significant at P=0.01 and P=0.05, respectively

Table 2: Magnitude of heterosis for various characters in Okra

Hybrids	Days to 50% flowering	Days to first picking	Plant height (cm)	Numbers of branches per plant	Numbers of nodes per plant	Fruit girth (cm)	Fruit Length (cm)	Internodal length (cm)	Numbers of fruits per plant	Fruit yield per plant (g)
JOL-09-05 X AOL-03-01	-7.97**	7.65*	3.53	2.94	-2.47	8.28**	-8.97**	5.68	-1.56	4.03
JOL-09-05 X AOL-08-05	1.65	0.81	5.26	-23.53**	-2.88	-4.14	1.43	10.57**	8.95	8.30
JOL-09-05 X AOL-09-02	3.91	4.30	16.50**	-26.47**	-13.58	4.73	-15.19**	3.62	-6.64	-30.13**
JOL-09-05 X JOL-2K-19	1.50	3.36	-2.67	-23.53**	-15.23*	-5.92*	-9.74**	8.51*	-1.17	-0.91
JOL-09-07 X AOL-03-01	-10.08**	9.40*	-10.45	0.00	-5.35	5.50*	-11.09	6.88	-0.78	-30.08**
JOL-09-07 X AOL-08-05	6.02*	7.11	8.64	-14.71	-6.79	-9.47**	-11.75**	5.98	8.56	15.07**
JOL-09-07 X AOL-09-02	-0.45	-1.74	-8.96	11.26	-11.52	-2.37	-9.46**	-7.19*	-3.59	-15.89**
JOL-09-07 X JOL-2K-19	-11.28**	9.40*	-9.27	-35.29**	-11.11	-7.10**	-6.30	3.26	0.78	5.38
JOL-11-12 X AOL-03-01	18.95**	-16.64**	12.49**	23.53**	5.76	4.73	-6.59*	5.13	14.79**	30.95**
JOL-11-12 X AOL-08-05	-1.05	0.54	7.15	-17.65*	-3.70	-1.18	-5.44	1.63	0.39	-3.29
JOL-11-12 X AOL-09-02	10.68**	9.40*	8.17	20.59*	-7.41	1.18	-8.02**	4.77	-5.06	-29.97**
JOL-11-12 X JOL-2K-19	6.02*	8.72*	2.12	-8.82	-6.58	-0.59	1.72	-2.05	1.56	5.02
JOL-13-07 X AOL-03-01	-12.78**	-11.28**	10.92*	23.53**	3.29	6.51*	-4.87	3.26	3.11	8.75
JOL-13-07 X AOL-08-05	3.31	4.83	15.55**	-41.18**	-14.81*	1.18	1.72	-2.54	-6.23	-2.99
JOL-13-07 X AOL-09-02	3.61	8.05*	-12.41*	-23.53**	-16.87*	1.18	-9.17**	-4.11	-12.45	-18.61**
JOL-13-07 X JOL-2K-19	-2.41	0.00	-6.83	-20.59*	-12.35	2.96	-1.43	-5.86	1.17	9.18
JF-55 X AOL-03-01	5.86*	5.50	-0.31	-26.47**	-1.23	-2.37	-10.89**	-5.31	15.18*	15.31**
JF-55 X AOL-08-05	-12.48**	-12.62**	-8.88	-41.18**	-9.47	-5.92*	-14.33**	-11.05**	-4.67	9.39
JF-55 X AOL-09-02	-8.72**	7.38*	-3.38	0.00	-7.41	4.73	-10.89**	1.75	-1.17	-12.05*
JF-55 X JOL-2K-19	4.21	6.44	13.43**	17.65**	-7.41	-7.69**	-6.02*	-3.38	4.67	6.83
GO-2 X AOL-03-01	-21.65**	-20.81**	0.16	-20.59*	-2.06	-4.14	-2.58	8.88*	5.84	-5.32
GO-2 X AOL-08-05	7.67**	9.40*	-4.01	8.82	-7.00	-0.59	2.29	5.80	-1.17	-4.54

Table 2: Continued

Hybrids	Days to 50% flowering	Days to first picking	Plant height (cm) P	Numbers of branches per plant	Numbers of nodes per plant	Fruit girth (cm)	Fruit length (cm)	Internodal length (cm)	Numbers of fruits per plant	Fruit yield per plant (g)
GO-2 X AOL-09-02	-11.73**	-11.4**1	3.77	20.59**	-13.17	1.18	4.30	-6.04	-6.61	-9.44
GO-2 X JOL-2K-19	-17.17**	-16.11**	-6.99	-32.35**	-11.93	-3.35	0.29	8.15*	1.95	-13.54*
KS-404 X AOL-03-01	0.00	1.07	8.25	20.59**	4.12	8.28**	-5.73	17.57**	10.89	0.82
KS-404 X AOL-08-05	-6.77*	-4.16	8.01	8.82	.82	2.96	-9.46**	13.41**	16.73**	0.52
KS-404 AOL-09-02	-3.01	-2.01	6.13	-17.65*	-3.70	-7.10**	-12.61**	7.97*	-7.00	-21.65**
KS-404 X JOL-2K-19	1.35	3.36	21.21**	29.41**	11.93	4.73	-6.02*	11.17**	15.56**	27.63**
Pusa Sawani X AOL-03-01	-14.89**	-13.42**	15.87**	29.41**	13.17	2.96	-1.15	3.50	16.73**	19.65**
Pusa Sawani X AOL-08-05	-0.15	1.61	10.92**	-23.53**	3.70	-1.18	-2.58	-1.69	7.00	16.37**
Pusa Sawani X AOL-09-02	5.71*	6.71	-13.59	-11.76	-9.47	-5.33	-6.30*	3.02	0.39	-1.95
Pusa Sawani X JOL-2K-19	-0.45	-0.54	-6.91	-20.59*	-11.93	-1.18	-1.43	7.31*	3.50	15.15**

*,** Significant at P=0.01 and P=0.05, respectively

Conclusion

It is clear from the above discussion that hybrid was found to be the most promising for fruit yield and other desirable traits. It is also clear that the high degree of non-additive gene action for all the component traits observed in the present study favours breeding methodology such as biparental mating, recurrent selection and diallel selective mating (Jensen, 1970) [12]. may be resorted to, than conventional pedigree or back cross techniques which would leave the unfixable components of genetic variances unexploited for yield and its components. So, it can be identified as potential hybrid combination for commercial exploitation in other climate against this hybrid check.

The disparities in interaction between the present study and previous reports might be due to difference in parental materials used and the environment under which the trial was conducted because estimates of gene effects change with environment and genotype (Das *et al*.2013).

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