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Study on combining ability for fruit yield and its related attributes in okra (*Abelmoschus esculentus* (L.) Moench)

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Abstract
Combining ability effects were estimated for different traits in a line x tester crossing programme comprising 32 crosses produced by crossing 8 lines and 4 testers. The GCA and SCA mean squares were significant for all the traits under study except number of nodes per plant. The ratio of GCA and SCA variances indicated the preponderance of non-additive gene effect for inheritance of all the traits. Genotypes JOL-09-05, JOL-09-07, Pusa Swani and AOL-09-02 showed good general combining ability for fruit yield appear to be worthy for exploitation of segregation and varietal development. The estimates of SCA effects revealed that the cross combinations JOL-0-05 x AOL-09.02, JOL-09-07 x JOL-2K-19 and JF-55 x AOL-08-05 were observed most promising for fruit yield and some related traits.

Keywords: Okra, combining ability, SCA and GCA

Introduction
Okra (*Abelmoschus esculentus* (L.) Moesch) is a fast growing annual which has captured a prominent position among the vegetables and is commonly known as bhindi or lady's finger in India. India is the larger producer of okra in the world with annual production of 63.46 lakh tones from an area of 5.32 lakh hectare with a productivity of 11.9 tonnes per hectare (ANON., 2016) [1]. Okra is specially valued for its tender, delicious green fruits which are cooked, canned and consumed in various forms in different part of the country. Combining ability analysis helps in evaluation of inbreds in terms of their genetic value and the selection of suitable parents for hybridization and helps in the identification of superior cross combination, which ultimately helps in deciding about exploitation of heterosis using the specific cross combination. Clear cut knowledge of type of gene action and magnitude and composition of genetic variance is of fundamental importance to a plant breeder. Line x tester analysis is a useful tool for preliminary evaluation of genetic stock for use as a population with favourable fixable and genes for effective yield improvement.

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 45cm distance between row and 30 cm within row, The observation were recorded for fruit yield and its contributing traits, *viz.*, days to 50% flowering, days to first picking, plant height (cm), No. of branches per plant, No. of nodes per plant, inter nodal length, No. of fruit per plant, fruit length (cm), fruit girth (cm) and fruit yield. Data was analyzed to work out the combining ability of the parents as well as crosses (krmptnrone, 1957) [2].

Results and Discussion
Selection of parents is an important step for planning an appropriate hybridization programme. The combining ability analysis furnishes is full information of this aspect. Knowledge of the relative importance of additive and non-additive gene action is essential to a plant breeder. The performance, GCA and SCA effects determine the potentiality of parents/crosses or mobilizing

them in an efficient breeding programme. The analysis of variance for combining ability (Table1) revealed that mean squares due to lines x testers were found highly significant for all the traits under study. Whereas, variances due to lines and testers were found also significant all the traits. The magnitude of $\hat{\sigma}^2_{SCA}$ was higher than $\hat{\sigma}^2_{GCA}$ for all the traits indicated preponderance of non-additive gene action in the expression of yield and yield attributing traits. Similar findings were also obtained by Katagi *et al.* (2015) [3] for fruit yield per plant, days 50% flowering, days to first picking number of branches per plant, number of fruits per plant, fruit girth and fruit length, Das *et al*. (2013) [4] for plant height and inter nodal length.

From the present results, it was evident that the non-additive gene action had greater role in the expression of all the traits under study, hence, merely selection will result in no or slow genetic improvement. Successful breeding methods are those that accumulate the genes to form superior gene constellations interacting in a favorable manner. The importance of non-additive gene action for all yield components in the present study indicated that heterosis breeding is the best possible option for improving these traits in okra.

The estimates of gca effect (Table 3) revealed that none of the parents was found good general combiner simultaneously for all the characters studied. Four parents *viz*., JOL-09-02, JOL-09-07, Pusa Swani and AOL-09-07 were observed to good general combiner for fruit yield per plant. In addition to fruit yield per plant, parent AOL-09-07 was also observed to good general combiner for traits like days to 50% flowering, days to first picking, plant height, number of braches per plant, number of nodes per plant and number of fruits per plant. While, parent JOL-09-07 was also observed to be general combiner for traits like plant height, number of branches per plant and number of nodes per plant. Thus, these four parents were observed to be good general combiner for fruit yield along with most of the other yield contributing traits. Thus, four parents could be considered in future breeding programme to generate more number of desirable segregants for fruit yield and its component traits. Rest of all the parents except JF-55, GO-2 and AOL-08-05 were average combiner for fruit yield per plant. The parent JOL-11-12 was good general combiner for days to 50% flowering, days to first picking and fruit girth. While, parent KS-404 found good general combiner for days to 50% flowering and fruit girth. The parent AOL-08-05 found good general combiner fruit girth and fruit length. While, parent JOL-2K-19 was observed to be general combiner for days to 50% flowering fruit length and inter nodal length. These parents may be utilized in the components breeding programme. On other hand, parents JOL13-07 and AOL 03-01 were observed to be average or poor combiner for most of the traits.

The estimate of specific combining effect (Table 3) indicate that none of the hybrids was found to be superior for all the traits under investigation. However, seven crosses registered significant and positive sca effect for fruit yield per plant. Of these, top three were JOL-0-05 x AOL-09.02, JOL-09-07 x JOL-2K-19 and JF-55 x AOL-08-05. All the top three crosses which exhibited high sca effect for fruit yield involved at least one good general combiner. Such type of results were also obtained by Kulkarni *et al. (*1991) [5], Shinde *et al*. (1995) [6], Pal and Houssain (2000) [7], Rajendra *et al*. (2005) [8] and Dabhi *et al*. (2010) [9]. These hybrids could be exploited through heterosis breeding and may also give transgressive segregants in subsequent generations and, therefore, it would be worthwhile to use them for improvement in fruit yield *per se*.

The result on *per se* gca and sca effects (Table 4) revealed that the crosses with high sca effects for fruit yield involved good x good, good x average, average x average and good x poor general combiners. This indicated the role of additive and non-additive gene actions in the genetic control of these traits. The presence of additive gene action would enhance the chances for making improvement through simple selection. For exploitation of dominance and epistatic effects, it appears worthwhile to intermate the selected progenies in early segregating generations, which would result in accumulation of favourale genes for the characters. Hence, biparental mating of few cycles of recurrent selection followed by pedigree selection may give fruitful results.

Table 1: Analysis of variance for combining ability for 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)		Internodal length (cm)		Numbers of fruits per plant		Fruit yield per plant (g)	
Crosses	31	27.004	**	25.571	**	214.051	**	0.731	**	7.876	**	0.227	**	1.062	**	0.392	**	9.452	**	4737.321	**
Lines	7	29.837	**	22.368	**	193.340	**	0.977	**	10.675	**	0.369	**	0.908	**	0.237	**	10.372	**	6199.355	**
Testers	3	48.387	**	39.847	**	580.449	**+	1.216	**	14.278	**	0.274	**	2.684	**	0.723	**	15.670	**	6230.959	**
Lines x Testers	21	23.005	**	24.599	**	168.612	**	0.580	**	6.029	**	0.173	**	0.882	**	0.397	**	8.257	**	4036.600	**
Error	62	2.150		4.694		29.865		0.047		2.325		0.030		0.173		0.055		1.956		241.482	
Estimates of genetic component of variance																					
$\hat{\sigma}^2_l$		0.5694		@		2.0606		0.0331		0.3872		0.0163		0.0022		@		0.1762		180.2296	
$\hat{\sigma}^2_t$		1.0576		0.6353		17.1599	*	0.0265		0.3437		0.0042		0.0751		0.0136		0.3089		91.4316	
$\hat{\sigma}^2_{GCA}$		0.8948	*	0.3616		12.1268	**	0.0287	**	0.3582	**	0.0082	**	0.0508	**	0.0046		0.2647	*	121.0310	*
$\hat{\sigma}^2_{lt}$ ($\hat{\sigma}^2_{SCA}$)		6.9514	**	6.6348	**	46.2490	**	0.1776	**	1.2346	**	0.0480	**	0.2362	**	0.1137	**	2.1003	**	1265.0395	**
$\hat{\sigma}^2_{GCA}$ / $\hat{\sigma}^2_{SCA}$		0.129		0.055		0.262		0.162		0.290		0.171		0.215		0.040		0.126		0.096	

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

Table 2: Estimation of general combining ability effects for ten characters in okra

Parents	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)	
Lines																				
JOL-09-05	2.82	**	2.34	**	2.99		0.45	**	1.31	**	0.37	**	-0.23		0.12		0.47		10.79	**
JOL-09-07	2.00	**	1.83	**	4.57	**	0.18	**	1.33	**	0.08		0.09		0.17	*	0.64		16.44	**
JOL-11-12	-1.60	**	-1.59	*	0.65		-0.39	**	-0.24		-0.18	**	0.20		0.05		-0.09		6.23	
JOL-13-07	-1.23	**	-0.83		0.77		-0.20	**	-0.32		-0.05		-0.01		-0.08		-0.09		-2.52	
JF-55	-0.73		-0.76		-6.81	**	0.06		-1.17	**	0.08		-0.53	**	-0.21	**	-1.85	**	-44.01	**
GO-2	-0.13		-0.33		-2.01		0.11		-0.44		-0.08		-0.05		-0.08		-0.10		-19.01	**
KS-404	-0.88	*	-0.58		-4.05	*	-0.34	**	-0.91	*	-0.14	**	0.23		-0.12		-0.33		2.39	
Pusa Sawani	-0.23		-0.09		3.89	*	0.13	*	0.44		-0.09		0.31	*	0.15	*	1.37	**	29.68	**
S.E. (gi) ±	0.42		0.63		1.58		0.06		0.44		0.05		0.12		0.07		0.40		4.49	
S.E. (gi - gj) ±	0.60		0.88		2.23		0.09		0.62		0.07		0.17		0.09		0.57		6.34	
Testers																				
AOL-03-01	-0.13		-0.26		-1.52		-0.18	**	0.17		-0.04		-0.44	**	-0.10	*	-0.02		-2.52	
AOL-08-05	2.02	**	1.84	**	-3.39	**	-0.06		-0.73	*	-0.13	**	0.19	*	0.01		-0.84	**	-17.99	**
AOL-09-02	-1.25	**	-1.16	*	7.29	**	0.33	**	1.01	**	0.11	**	-0.07		0.24	**	1.09	**	21.18	**
JOL-2K-19	-0.63	*	-0.43		-2.38	*	-0.09	*	-0.45		0.07		0.32	**	-0.15	**	-0.24		-0.67	
S.E. (gj) ±	0.29		0.44		1.12		0.04		0.31		0.04		0.09		0.05		0.29		3.17	
S.E. (gi - gj) ±	0.42		0.63		1.58		0.06		0.44		0.05		0.12		0.07		0.40		4.49	

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

Table 3: Specific combining ability (sca) effects for different characters in okra

Crosses	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)	Numbers of fruits per plant	Fruit yield per plant (g)
JOL-09-05 x AOL-03-01	-0.54	-028	1.42	0.154	-0.20	0.20	0.05	-0.22	-0.71	13.16
JOL-09-05 x AOL-08-05	0.48	-0.39	5.95	0.163	0.86	-0.16	0.77**	0.21	1.17	21.54*
JOL-09-05 x AOL-09-02	0.50	0.68	-7.39*	-0.29*	0.01	0.22*	-0.45	-0.05	0.05	-23.33*
JOL-09-05 x JOL-2K-19	-0.44	0.00	0.01	0.020	-0.65	-0.26	-0.37	0.06	-0.52	-11.37
JOL-09-07 x AOL-03-01	0.93	-0.42	-8.40**	-0.10	-0.64	0.27**	-0.10	0.11	-0.80	-65.57**
JOL-09-07 x AOL-08-05	1.10	1.74	10.87**	0.18	0.25	-0.23*	-0.34	0.22	0.90	42.11**
JOL-09-07 x AOL-09-02	-2.75**	-3.33**	1.06	0.40	0.35	0.05	0.31	-0.38**	0.30	15.41
JOL-09-07 x JOL-2K-19	2.56**	2.00	-3.54	-0.48	0.04	-0.09	0.12	0.04	-0.40	8.04
JOL-11-12 x AOL-03-01	2.16	1.80	0.47	0.12	0.23	-0.07	-0.17	0.00	1.57	65.55**-
11-12 x AOL-08-05	-2.88	-2.91**	-1.00	-0.20	-0.18	-0.01	-0.19	-0.02	-0.80	19.64*
JOL-11-12 x AOL-09-02	1.33	0.83	5.00	0.28	0.09	0.00	-0.11	0.28*	-0.20	-35.93**
JOL-11-12 x JOL-2K-19	-0.61	0.28	-4.47	-0.20	-0.15	0.02	0.47	-0.26	-0.57	-9.98
JOL-13-07 x AOL-03-01	1.34	0.52	10.55**	0.58	1.00	-0.02	-0.10	0.16	0.69-	15.49
JOL-13-07 x AOL-08-05	0.97	0.61	-8.85**	-0.29	-0.81	0.01	0.51	0.01	-0.82	-15.03
JOL-13-07 x AOL-09-02	0.12	1.54	1.05	-0.27	-0.27	-0.10	-0.38	0.05	-0.35	-4.46
JOL-13-07 x JOL-2K-19	-2.43**	-2.67*	-0.65	-0.01	0.08	0.11	-0.03	-0.21	0.48	3.40
JF-55 x AOL-03-01	-3.28**	-3.32*	-4.23	-0.63**	-0.35	-0.20*	0.03	-0.19	-2.36**	-27.03

Table 4: Specific combining ability (sca) effects for different characters in okra

Crosses	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)	Numbers of fruits per plant	Fruit yield per plant (g)
JF-55 x AOL-08-05	3.48**	3.51	-8.43**	-0.35	-0.55	-0.06	-0.53*	-0.34*	0.47	-14.62
JF-55 x AOL-09-02	0.83	0.24	1.36	0.20	0.64	0.42**	0.25	0.49**	1.67*	27.42**
JF-55 x JOL-2K-19	-1.04	-0.43	11.30**	0.79	0.27	-0.16	0.26	0.05	1.16	14.24
GO-2 x AOL-03-01	0.74	1.08	-2.15	-0.55**	-0.13	-0.36	-0.36	0.11	0.53-	-0.98
GO-2 x AOL-08-05	-1.63	-1.29	-2.61	0.33*	0.19	0.18	0.05	0.11	0.57	-1.07
GO-2 x AOL-09-02	-0.82	-0.96	9.11**	0.61	0.05	0.16	0.67**	-0.42**	0.04	35.53**
GO-2 x JOL-2K-19	1.71*	1.17	-4.35	-0.40**	-0.10	0.01	-0.36	0.20	0.00	-33.48**
KS-404 x AOL-03-01	-1.48	-1.33	-6.03	-0.08	-1.05	0.18	0.38	0.13	-0.15	-10.45
KS-404 x AOL-08-05	-0.65	-0.64	-3.16	0.26*	-0.46	0.16	-0.21	0.07	0.95	-13.17
KS-404 x AOL-09-02	0.03	-0.24	0.36	-0.72**	-0.32	-0.53**	-0.19	-0.11	-1.59**	-18.53
KS-404 x JOL-2K-19	2.09*	2.21	8.83**	0.54**	1.83	0.26*	0.02	-0.09	0.78	42.16**
Pusa Sawani x AOL-03-01	1.98*	1.95	8.35*	0.50**	1.13	0.00	0.27	-0.12	1.22	9.84
Pusa Sawani x AOL-08-05	-0.87	-0.63	7.22*	-0.09	0.72	0.11	-0.05	-0.24	-0.35	-0.11
Pusa Sawani x AOL-09-02	0.75	1.24	-8.45**	-0.20	-0.54	-0.24*	-0.11	0.14	0.05	3.891
Pusa Sawani x JOL-2K-19	-1.86	-2.57	-7.12*	-0.21	-1.32	0.11	-0.10	0.22	-0.92	-13.62
S.E.(sij) ±	0.85	1.25	3.15	0.13	0.85	0.09	0.24	0.14	0.77	09.30

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

Conclusion
From the present finding, it concluded that sufficient variability was present in the material studied for yield and its components. The non-additive gene action was observed in the inheritance of fruit yield and other associated traits except fruit length. This suggested that heterosis breeding would be more suitable for improvement of these traits in okra.

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