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Studies on combining ability for yield and quality attributing traits in okra [*Abelmoschus esculentus* (L.) Moench.]

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Abstract
The present investigation was taken up at three different locations named HRS Lam, KVK Venkataramannagudem and KVK Vonipenta, Andhra Pradesh, India during 2018-2019, to study the combining ability of six different lines of okra. They were mated diallel fashion excluding reciprocals and their fifteen crosses were evaluated along with six parents and one commercial check in Randomized block design (RBD) for yield and quality attributing traits. The pooled analysis for combining ability over three locations revealed significant differences among treatments for all the characters studied. The effects due to parents were significant for all the traits studied except for fruit girth, fruit length and fruit weight. The differences among the hybrids were observed to be significant for all the characters studied except fruit girth and test weight. The differences among the parents vs. hybrids were recorded to be significant for all the characters except for number of fruits per plant and fibre content. The lines HRB-9-2 and VRO-3 recorded significant positive *gca* effects and were found to be promising general combiners for yield attributing traits. In respect of *sca* effects, none of the 15 hybrids was found to be superior for all the traits under investigation whereas, only one cross *i.e.*, 440-10-1 x HRB-9-2 recorded significant positive *sca* effects for fruit yield per plant in okra. The knowledge of combining ability helps in identifying good combiners for hybridization.

Keywords: Okra, Randomized block design, combinig ability, Fruit yield per plant

Introduction
Okra [*Abelomoschus esculentus* (L.) Moench.] commonly known as lady's finger belongs to the family Malvaceae. Tender okra fruits are used as vegetable in countries like India, Brazil, West Africa and is also available in dehydrated and canned forms. The sun-dried (Africa, India), frozen and sterilized (USA) fruits are other important market products. Okra fruit contains 90% water, 3% dietary fibre, 7% carbohydrates, 2% protein, good quantities of minerals, vitamin C and A and moderate contents of thiamin, folate and magnesium (Chopra *et al.*, 1956) [3]. The roots and stems of okra are used for cleaning the cane juice. Mature fruits and stems containing crude fibre are used in the paper industry (Chauhan, 1972) [2].
The combining ability is an important genetic tool which provides a guideline for assessment of the relative breeding potential of the parents or identifying the best combiners, which may be hybridized either to exploit heterosis or to accumulate fixable genes. In order to identify potential crosses for further exploitation, it is important to have prior information about heterosis and nicking ability of the parents involved, since it helps in the identification of superior parents with good general combining ability and crosses with high and desirable specific combining ability effects (Singh *et al.*, 1991) [13].

Materials and Methods
The experimental material consisted of six parental lines *viz.*, VRO-3, VRO-6, 440-10-1, TCR-1674, JPM-20-16-39 and HRB-9-2 and these were crossed in diallel fashion excluding reciprocals during *Kharif*, 2018. The resultant 15 F_1 hybrids along with six parents and one commercial check were evaluated in randomized block design with three replications with spacing of 60 x 30 cm during *Rabi*, 2018. Observations were recorded on five randomly selected plants from each plot for growth and yield characters *viz.*, number of fruits per plant, fruit length (cm), fruit girth (cm), fruit weight (gm), ridges per fruit, number of seeds per fruit, test weight of seeds (g/100g), fruit yield per plant (g), fruit yield per hectare (t), fibre content

(g/100g), ascorbic acid content (mg/100g) and shelf life (d).

Results and Discussion

The analysis of variance revealed significant differences among treatments for all the yield traits indicating the presence of appreciable genetic diversity among the parents and cross combinations. This indicates the existence of wide variability in the material studied and there is a good scope for identifying promising parents and hybrid combinations, and improving the yield through its components. These results are in conformity with the findings of Singh *et al*. (2012) [12], Reddy *et al*. (2013) [10], Harne *et al*. (2015) [5], Arti verma and Soniasood (2015) [1], Tiwari *et al*. (2016) [14] and Shwetha *et al*. (2018) [11] in okra. The estimates of *gca* and *sca* variances, their ratios and gene action are presented in table 1. General combining ability is genetically associated with additive gene action while specific combining ability is due to dominance and epistasis. In the present investigation, the magnitude of *sca* variance greater than that of *gca* variance suggests the predominance of the non additive gene action for majority of the traits. However, for internodal length, number of fruits per plant and number of seeds per fruit, the greater magnitude of *gca* variance than that of *sca* variance suggests the predominance of additive gene action.

The estimates of GCA effects revealed that none of the parents were found good general combiners for all the traits studied (Table-2). Among the parents, two parents *viz.*, HRB-9-2 and VRO-3 were observed to be good general combiners for fruit yield per plant. In addition to yield per plant the parent HRB-9-2 was also observed to be good general combiner for traits like days to last picking, internodal length, fruit girth, fruit length, fruit weight, number of fruits per plant, seeds per fruit while the parent VRO-3 was observed to be good general combiner for traits like days to first flowering, plant height, internodal length, days to 50% flowering and first flowering node. Thus these two parents were observed to be good combiners for fruit yield along with most of the other yield contributing triats.

The estimates of specific combining ability effects indicated that none of the crosses was found to be superior for all the traits under investigation. Among the crosses, only one cross *i.e.*, 440-10-1 x HRB-9-2 recorded significant and positive *sca* effects for fruit yield per plant. The crosses VRO-6 x HRB-9-2, VRo-6 x JPM-20-16-39, VRO-3 x TCR-1674 were the other genotypes which recorded positive *sca* effects for yield and yield attributing characters (Table 3). All the top crosses which exhibited high *sca* effects for fruit yield involved at leaset one good general combiner. Similar findings were earlier reported by Poshiya and Vashi (1995) [8], Pawar *et al.* (1999) [7], Prakash *et al.* (2002) [9], Pal and Sabesan (2009) [6] and Dabhi *et al*. (2010) [4] in okra. The identified hybrids could be exploited through heterosis breeding and it would be worthwhile to use them for improvement in fruit yield.

Table 1: Pooled analysis of variance and gene action of combining ability analysis for yield and quality attributing traits in 6x6 half diallel of okra

Source of variation	Mean sum of squares			$\sigma^2 gca$	$\sigma^2 sca$	*gca/sca*
	GCA	SCA	Error			
Degrees of freedom	**05.00**	**15.00**	**40.00**			
Characters						
Yield parameters						
Number of fruits per plant	7.544 **	0.819	0.731	0.853	0.088	9.693
Fruit length	0.349 **	0.245 **	0.083	0.033	0.162	0.204
Fruit girth	0.023	0.076 **	0.029	-0.001	0.047	-0.021
Fruit weight	1.447	3.803**	0.662	0.098	3.140	0.031
Number of seeds per fruit	101.832 **	16.327 **	4.226	12.200	12.100	1.008
Test weight of seeds	0.244 **	0.078	0.048	0.024	0.030	0.800
Fruit yield per plant	3858.510**	1514.354 *	783.766	384.343	730.588	0.526
Fruit yield per hectare	10.683	3.971	2.450	1.029	1.520	0.677
Quality parameters						
Fibre content (g/100g)	0.543**	0.021	0.042	0.063	-0.021	-3.000
Ascorbic acid content (mg/100g)	25.701**	4.691**	0.400	3.162	4.290	0.737
Shelf life (d)	0.901**	0.156**	0.015	0.110	0.140	0.786

** 1% level of significance, * 5% level of significance

GCA= General combining ability, SCA= Specific combining ability, σ^2gca= Variance due to GCA, σ^2sca= Variance due to SCA

Table 2: Pooled estimates of general combining ability effects for yield and quality attributing traits in 6x6 half diallel of okra

Parent	Yield parameters								Quality parameters		
	NFP	FL	FG	FW	NSF	TWS	FYP	FYH	FC	AAC	SL
VRO-3	-1.241**	-0.153	-0.106	0.088	-3.082**	-0.112	-24.002*	-1.344*	-0.140*	-1.033**	-0.287**
VRO-6	-0.554	-0.107	0.306	-0.378	-2.241**	-0.035	-12.68*	-0.635	0.141*	-1.659**	0.005
440-10-1	-0.340	0.082	0.000	-0.569*	-1.788*	-0.136	-11.903*	-0.59	-0.347**	2.727**	0.532**
TCR-1674	-0.060	-0.226*	0.019	-0.054	-0.058	-0.154*	-0.263	0.047	0.157*	-0.399	0.075
JPM-20-16-39	0.683*	0.052	0.031	0.384	6.765**	0.193**	11.387*	0.575	0.356**	1.696**	-0.427**
HRB-9-2	1.513**	0.351**	0.020	0.528*	0.404	0.244**	37.46**	1.946**	-0.167*	-1.332**	0.101*
SE (gi)	0.276	0.093	0.054	0.262	0.663	0.07	9.035	0.505	0.066	0.204	0.039

** 1% level of significance, * 5% level of significance

NFP = Number of fruits per plant, FL = Fruit length, FG = Fruit girth, FW = Fruit weight, NSP = Number of seeds per fruit, TWS = Test weight of seeds, FYP = Fruit yield per plant, FYH = Fruit yield per hectare, FC = Fibre content, AAC = Ascorbic acid content, SL = Shelf life

Table 3: Pooled estimates of specific combining ability effects for yield and quality attributing traits in 6x6 half diallel of okra

Cross	Yield parameters								Quality parameters		
	NFP	FL	FG	FW	NSF	TWS	FYP	FYH	FC	AAC	SL
VRO-3 x VRO-6	-0.319	-0.028	0.019	0.26	1.856	0.321	-4.621	-0.146	-0.094	-0.453	-0.125
VRO-3 x 440-10-1	0.023	-0.197	-0.092	0.127	-0.884	0.292	-0.341	0.089	0.093	1.425*	-0.429*
VRO-3 x TCR-1674	0.697	0.097	-0.054	0.859	3.097*	0.083	33.262*	1.965*	0.099	1.567*	0.138
VRO-3 x JPM-20-16-39	-0.803	0.616*	0.464**	2.567**	-3.526*	-0.29	20.052	0.857	-0.044	0.305	0.080
VRO-3 x HRB-9-2	0.374	0.284	0.288	1.000	2.769	-0.082	18.386	0.563	-0.027	-0.680	0.222
VRO-6 x 440-10-1	0.340	-0.239	-0.204	0.094	-5.394**	-0.497*	-2.991	0.236	-0.007	-0.792	0.500*
VRO-6 x TCR-1674	0.123	0.295	0.200	-0.518	3.033	0.22	16.846	0.973	-0.011	-1.040	-0.153
VRO-6 x JPM-20-16-39	0.514	0.244	0.315	1.831*	6.790**	0.053	36.283*	1.675*	0.029	-1.748*	0.238*
VRO-6 x HRB-9-2	0.020	0.442	0.222	2.387**	0.618	0.079	37.883*	1.84*	-0.167	5.000*	0.374**
440-10-1 x TCR-1674	-0.401	0.269	-0.191	0.703	0.093	0.334	2.963	0.201	-0.284	3.071*	0.650**
440-10-1 x JPM-20-16-39	-0.570	0.128	-0.033	0.502	-0.774	0.201	-6.598	-0.707	-0.223	2.926**	-0.512*
440-10-1 x HRB-9-2	2.003*	0.783**	0.211	2.444**	3.008*	0.23	81.476**	4.265**	-0.020	-0.722	0.513**
TCR-1674 x JPM-20-16-39	0.463	0.359	0.072	1.13	-0.016	0.018	14.906	0.826	0.073	-1.512*	0.062
TCR-1674 x HRB-9-2	0.080	-0.296	0.039	0.736	2.275	0.201	11.91	0.405	0.016	-0.860	-0.250*
JPM-20-16-39 x HRB-9-2	-1.890*	0.286	0.004	-1.019	4.452*	-0.079	-46.741*	-2.233	0.217	-1.525	-0.308*
Seij	0.758	0.255	0.149	0.721	1.822	0.193	24.815	1.387	0.181	0.561	0.108

** 1% level of significance, * 5% level of significance

NFP= Number of fruits per plant, FL= Fruit length, FG= Fruit girth, FW= Fruit weight, NSP= Number of seeds per fruit, TWS= Test weight of seeds, FYP= Fruit yield per plant, FYH= Fruit yield per hectare, FC= Fibre content, AAC= Ascorbic acid content, SL= Shelf life

Conclusion

The study reveals that combining ability helps in identifying good combiners and cross combinations for hybridization and to exploit heterosis. Among six parents studied HRB-9-2 and VRO-3 are identified as good general combiners which made significant contribution towards fruit yield traits. Among the 15 crosses the best performed one cross can be used for further breeding programmes.

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