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Combining ability analysis of genotype through half-diallel method in okra (*Abelmoschus esculentus* (L.) Moench) over different environments

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Abstract

A study was conducted to evaluate combining ability of nine genetically divergent parental strains of okra by half-diallel analysis with respect to fruit yield and its contributing traits. The combining ability analysis revealed significant mean sum of squares due to both, general combining ability (GCA) and specific combining ability (SCA) for fruit yield and its components. The ratio of GCA: SCA indicated predominance of non-additive gene action for all the characters. The parents HRB-108-2, EC 169513 and GO-2 were good general combiners for yield and most of the yield contributing characters. Among the crosses HRB 108-2 x AOL-15-29, HRB 108-2 x HRB-55 and NOL-17-9 x JOL- 11-1 showed significant and high sca effects for fruit yield per plant and most of the yield contributing characters.

Keywords: Abelmoschus esculentus, contributing characters, combining ability

Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] is one of the most important vegetable crops of India. In crop improvement programme, the success rests upon isolation of valuable gene combinations on determination in the form of lines with high combining ability. The lines which produce good progenies on crossing are of immense value to the plant breeders. The knowledge of gene action and combining ability helps in identifying the best combiners which may be hybridized either to exploit heterosis or to accumulate gene through selection and in understanding the quantitative characters to choose the proper selection method to be followed in breeding programmes. The present investigation was undertaken to study the combining ability effects and variance using 9 x 9 diallel set.

Materials and Methods

The experimental material for the study comprised of forty-five entries including nine parents (IC 90107, HRB 108-2, EC 169513, AOL-12-59, NOL-17-9, JOL-11-1, HRB-55, GO-2 and VRO-6) and their 36 F1s derived by crossing in all possible combinations excluding reciprocals and one standard check GJOH-2. The trial was laid out in a randomized block design with three replications over three seasons *viz.*, *Early* Kharif 2020-21 (E1), Kharif 2020-21(E2) and *Late* Kharif 2020-21(E3) at Junagadh Agricultural University, Junagadh, (Gujarat). Each entry was sown in a single row plot of 2.2 m length keeping row-to- row and plant-to-plant distance of 60 cm, and 30 cm, respectively. The recommended package of practices and necessary plant protection measures were followed to raise a healthy crop of okra. Five competitive plants excluding border plants were randomly selected for recording the observations on different characters like days to first flowering, days to first picking plant height (cm), no. of branches per plant, no. of nodes per plant, internodal length (cm), no. of fruits per plant, fruit length (cm), fruit girth (cm), ten fruit weight (g), days to last picking, no. of pickings and fruit yield per plant (g). The combining ability analysis was done by following Model 1, Method 2 of Griffing (1956) [2].

Results and Discussion

In pooled analysis over the environments (Singh, 1976, method II, model I), mean squares due to environments, GCA and SCA were significant for all the characters revealed varied environments, differences among parents for GCA and differences among crosses for SCA.

Similarly, mean squares due to GCA ×E were highly significant for all the character except days to first flowering, days to first picking and internodal length while that due to SCA×E were significant for all the characters thereby, indicating sensitivity of both kinds of genetic variance to the environmental fluctuation. SCA variance was higher than their respective GCA variance for all the characters indicated that non-additive type of gene action played major role in the expression of yield and all yield attributing traits. Likewise, SCA×E interaction component was higher than their respective GCA ×E interaction component for all the characters. From the present results, it was evident that the large portion of non-additive gene action was responsible in the expression of all the characters under study. Similar results have been reported Solankey and Singh (2010) [17], Rai *et al.* (2011) [15], Raghuvanshi *et al.* (2011) [14], Youssef (2011) [19], Prakash *et al.* (2012) [13], Reddy *et al.* (2013) [16], Kumar *et al.* (2015) [5], More *et al.* (2015) [7], Patil *et al.* (2016) [10], Paul *et al.* (2017) [11], Eswaran and Anbanandan (2018) [1], Hadiya *et al.* (2018) [3], Padadalli *et al.* (2019) [9], Pithiya *et al.* (2020) [12], Suganthi *et al.* (2020) [18], Kumar *et al.* (2021) [4] and Mudhulvan and Senthilkumar (2021) [8]. Therefore, heterosis breeding may be adopted to exploit non-additive gene action and for obtaining high yield in okra at commercial scale. Reciprocal recurrent selection may also be adopted for population improvement in the present material.

Across the environments (Table 2), the parent AOL-12-59 were found good general combiner for days to first flowering and days to first picking. In case of plant height parents HRB 108-2, EC 169513 and AOL-12-59 and for number of branches per plant parents HRB 108-2, AOL-12-59, GO-2 and VRO-6 were found good general combiner. For the trait number of nodes per plant parents HRB 108-2, EC 169513, AOL-12-59 and GO-2 found good general combiner. For the trait internodal length parent HRB 108-2 observed with good general combiner. The parents HRB 108-2, EC 169513 and GO- 2 recorded with good general combiner for number of fruits per plant. In case of fruit length, the parents EC 169513 and AOL-12-59 were observed good general combiner. The parents IC 90107, HRB 108-2 and GO-2 found good general combiner for fruit girth. For the ten fruit weight parents EC 169513 and GO-2 were found good general combiner. The parents IC 90107, EC 169513, JOL-11-1, GO-2 and VRO-6 were found good general combiner for days to last picking. In case of number of pickings, the parents IC 90107 and HRB 108-2 found good general combiner. The parents HRB 108-2, EC 169513 and GO-2 were found good general combiner for fruit yield per plant.

The parent HRB 108-2 was good general combiner for fruit yield per plant other than, it was also found good general combiner for characters like plant height, number of branches per plant, number of nodes per plant, internodal length, number of fruits per plant, fruit girth and number of pickings. The EC 169513 also found good general combiner for plant height, number of nodes per plant, number of fruits per plant, fruit length, ten fruit weight and days to last picking other than fruit yield per plant. The parent GO-2 recorded good general combiner for number of branches per plant, number of nodes per plant, number of fruits per plant, fruit girth, ten fruit weight and days to last picking other than fruit yield per plant.

It was concluded that combining ability of parents also varied according to environment conditions and parent that found good general combiner in one environment may not be necessarily in another environment. The parents were good general combiner for fruit yield per plant were also showed good general combining ability for at least one component traits. Similar finding were recorded by Solankey and Singh (2010) [17], Rai *et al.* (2011) [15], Raghuvanshi *et al.* (2011) [14], Youssef (2011) [19], Prakash *et al.* (2012) [13], Reddy *et al.* (2013) [16], Kumar *et al.* (2015) [5], More *et al.* (2015) [7], Patil *et al.* (2016) [10], Paul *et al.* (2017) [11], Eswaran and Anbanandan (2018) [1], Hadiya *et al.* (2018) [3], Padadalli *et al.* (2019) [9], Pithiya *et al.* (2020) [12], Suganthi *et al.* (2020) [18], Kumar *et al.* (2021) [4] and Mudhalvan and Senthilkumar (2021) [8].

Specific combining ability is an important component, which may be utilized for heterosis breeding. None of the cross combination was superior for all the characters. However, on the basis of pooled data as many as 10 cross combinations exhibited significant positive sca effects for fruit yield per plant. The best hybrids on the basis of significant positive sca effects for fruit yield per plant were IC 90107 X EC 169513, IC 90107 X AOL-12-59, HRB 108-2 X AOL-12-59, HRB 108-2 X HRB-55, EC 169513 X GO-2, NOL-17-9 X JOL-11-1, NOL-17-9 X HRB-55, NOL-17-9 X GO-2, HRB-55 X GO-2 and HRB-55 X VRO-6 (Table 3). The highest yielding hybrid HRB 108-2 x AOL-15-29 (216 g) had significant and positive sca effect (105.91) for fruit yield per plant which involves good x average combiner parents. This cross also expressed significant and desirable sca effect for number of branches per plant, number of nodes per plant, internodal length, number of fruits per plant, ten fruit weight, days to last picking and number of pickings. On other hand, in cross combination HRB 108-2 x HRB-55 had significant and positive sca effect for fruit yield per plant which involved good x poor combiner parents, was reflected through plant height, number of branches per plant, number of nodes per plant, internodal length, number of fruits per plant and fruit length. The high sca effects for above components were also accompanied by high heterosis as well as high per se performance. Similarly, the cross combination NOL-17-9 x JOL-11-1 had also significant and positive sca effects for fruit yield per plant involved poor x poor combiner parents. This cross also possessed significant and desirable sca effects for many yield components. Thus, on the basis of these results it is expected that these three crosses may give desirable segregates in subsequent generations and hence, it would be worthwhile to use them for genetic improvement of fruit yield per se. The significant sca effects for fruit yield and different component traits were also recorded by several workers *viz*., Solankey and Singh (2010) [17], Rai *et al.* (2011), Raghuvanshi *et al.* (2011) [14], Youssef (2011) [19], Prakash *et al.* (2012) [13], Reddy *et al.* (2013) [16], Kumar *et al.* (2015) [5], More *et al.* (2015) [7], Patil *et al.* (2016) [10], Paul *et al.* (2017) [11], Eswaran and Anbanandan (2018) [1], Hadiya *et al.* (2018) [3], Padadalli *et al.* (2019) [9], Pithiya *et al.* (2020) [12], Suganthi *et al.* (2020) [18], Kumar *et al.* (2021) [4] and Mudhalvan and Senthilkumar (2021) [8].

The significant and positive correlation was observed between per se performance and GCA effects (Table 4) of parental lines for plant height, number of branches per plant, number of nodes per plant, fruit length, fruit girth, ten fruit weight, number of pickings and fruit yield per plant. The association between per se performance and GCA effects suggested that selection of parents for hybridization programme should be according to per se performance of parents was rewarding.

The correlation between per se performance and sca effects (Table 4) were found positively significant for days to first flowering and number of branches per plant indicated that selection of crosses according to per se performance for these traits may be rewarding.
Among the parents, HRB-108-2, EC 169513 and GO-2 were good general combiners for yield and most of the yield contributing characters. The crosses with high sca effects for fruit yield and its components involved good x good, good x average, good x poor, average x average, average x poor and poor x poor general combiners. This reflected the role of both additive and non-additive gene actions in the genetic control of these characters. The presence of additive gene action would be enhanced the chance for making improvement through simple selection. For exploitation of non- additive effects, it appears worthwhile to interrater the selected progenies in early segregating generations, which would be resulted in the accumulation of favourable genes for the characters. Hence, bi-parental progeny selection may be useful to get some desirable transgressive segregants from such crosses.

Table 1: Analysis of variance for combining ability over the environments for different characters in okra

S. No	Characters	Source						Components of Variance (Model I)				
		GCA [8]	SCA [36]	Env (E) [2]	GCA × E [16]	SCA × E [72]	Pooled error [264]	GCA	SCA	GCA × E	SCA × E	GCA / SCA
1	Days to first flowering	7.34**	11.97**	1469.48**	2.92	8.42**	2.31	0.15	3.22	0.06	6.11	0.05
2	Days to first picking	9.64**	10.89**	1402.46**	2.56	7.96**	3.21	0.20	2.56	-0.06	4.75	0.08
3	Plant height (cm)	461.26**	108.85**	1568.85**	114.47**	63.01**	24.56	13.23	28.10	8.17	38.46	0.47
4	Number of branches per plant	0.22**	0.16**	0.38**	0.04**	0.02**	0.01	0.01	0.05	0.00	0.01	0.12
5	Number of nodes per plant	50.97**	17.62**	233.82**	1.79**	1.25**	0.33	1.53	5.77	0.13	0.92	0.27
6	Internodal length (cm)	0.33**	1.19**	2.36**	0.03	0.09**	0.05	0.01	0.38	-0.01	0.03	0.02
7	Number of fruits per plant	23.23**	6.84**	238.63**	2.32**	3.79**	1.10	0.67	1.92	0.11	2.70	0.35
8	Fruit length (cm)	11.96**	4.33**	83.76**	0.95**	0.51**	0.21	0.36	1.37	0.07	0.30	0.26
9	Fruit girth (cm)	0.08**	0.02**	2.21**	0.03**	0.02**	0.01	0.02	0.01	0.01	0.02	0.52
10	Ten fruit weight (g)	910.52**	724.40**	18920.68**	113.85**	74.35**	25.14	26.83	233.09	8.06	49.21	0.12
11	Days to last picking	180.06**	141.71**	18193.84**	44.72**	40.48**	8.97	5.18	44.25	3.25	31.51	0.12
12	Number of pickings	1.84**	1.03**	927.38**	0.50**	0.58**	0.24	0.05	0.26	0.02	0.34	0.18
13	Fruit yield per plant (g)	9016.07**	3589.47**	16104.43**	485.84**	473.66**	180.38	267.75	1136.36	27.77	293.28	0.24

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

Table 2: Estimates of general combining ability effects of parents for various characters in okra (pooled data)

Parents	Days to first flowering	Days to first picking	Plant height	No. of branches per plant	No. of nodes per plant	Internodal length	No. of fruits per plant	Fruit length	Fruit girth	Ten fruit weight	Days to last pickings	Number of pickings	Fruit yield per plant
IC 90107	-0.24	-0.32	-2.33*	-0.15**	-0.85**	-0.15**	-0.66**	-0.12	0.04**	0.48	2.21**	0.33**	-6.93*
	A	A	P	P	P	P	P	A	G	A	G	G	P
HRB 108-2	0.18	0.22	3.54**	0.11**	2.13**	0.17**	0.89**	-0.27**	0.08**	1.08	-0.75	0.33**	18.34**
	A	A	G	G	G	G	G	P	G	A	A	G	G
EC 169513	0.71*	0.84*	3.91**	-0.06**	1.29**	0.04	1.18**	1.10**	0.01	10.30**	1.16*	0.06	27.14**
	P	P	G	P	G	A	G	G	A	G	G	A	G
AOL-12-59	-0.61*	-0.79*	4.56**	0.05**	0.58**	-0.01	-0.25	0.80**	-0.08**	0.99	-1.96**	-0.16	-1.89
	G	G	G	G	G	A	A	G	P	A	P	A	A
NOL-17-9	-0.24	-0.17	-0.02	-0.02	-0.24*	0.02	-0.33	-0.07	-0.06**	-9.13**	-2.29**	-0.11	-18.45**
	A	A	A	A	P	A	A	A	P	P	P	A	P
JOL-11-1	0.06	0.19	-5.06**	0.01	-1.29**	-0.01	-0.04	-0.23	0.01	-1.43	1.61*	0.10	-5.82*
	A	A	P	A	P	A	A	A	A	A	G	A	P
HRB-55	-0.51	-0.54	-0.35	-0.06**	-0.05	-0.14**	-0.45*	0.04	-0.01	-3.50**	-4.09**	-0.42**	-6.25*
	A	A	A	P	A	P	P	A	A	P	P	P	P
GO-2	0.71*	0.69*	1.27	0.03*	0.25*	0.03	0.97**	-0.41**	0.03*	3.24*	1.86**	-0.06	14.67**
	P	P	A	G	G	A	G	P	G	G	G	A	G
VRO-6	-0.05	-0.13	-5.52**	0.09**	-1.82**	0.06	-1.30**	-0.86**	-0.01	-2.02	2.24**	-0.07	-20.80**
	A	A	P	G	P	A	P	P	A	A	G	A	P
SE.(gi) ±	0.25	0.29	0.81	0.01	0.09	0.04	0.17	0.08	0.01	0.82	0.49	0.08	2.20
SE. (gi-gj) ±	0.37	0.44	1.22	0.02	0.14	0.06	0.26	0.11	0.02	1.23	0.74	0.12	3.30

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

Table 3: Estimates of specific combining ability effects for various characters in okra (pooled data

Genotypes	DFF	DFP	PH	NBP	NNP	IL	NFP	FL	FG	TFW	DLP	NP	FYP
IC 90107 × HRB 108-2	2.14*	1.96**	9.70**	-0.05	4.90**	-1.08**	-2.25**	0.72**	0.11**	5.10	0.87	-0.61*	-22.60**
IC 90107 × EC 169513	2.61**	2.11**	-3.55	-0.15**	-0.61*	-0.50**	0.93	-0.01	0.09*	22.19**	13.51**	0.67**	44.32**
IC 90107 × AOL-12-59	-2.52**	-2.70**	-1.96	-0.28**	-1.03**	0.10	-0.27	-0.79**	0.06	11.63**	-3.03	-0.46	30.60**
IC 90107 × NOL-17-9	0.12	0.68	-0.60	0.05	1.94**	0.30*	0.79	0.49*	-0.03	-7.85**	6.86**	-0.17	7.89
IC 90107 × JOL-11-1	-1.30	-1.01	-8.98**	0.16**	-1.28**	0.91**	0.61	-0.33	-0.05	-18.89**	0.51	0.74**	-20.04**
IC 90107 × HRB-55	-2.17*	-1.84	2.05	0.24**	0.75*	0.06	0.50	-0.38	-0.20**	-22.45**	-11.79**	-0.41	-46.15**

IC 90107 × GO-2	1.06	1.15	-4.04	0.13**	-3.23**	0.75**	-1.32*	0.13	0.04	8.30**	-7.07**	-0.56*	-8.11
IC 90107 × VRO-6	1.37	1.08	-1.84	-0.09*	-2.45**	-0.19	-0.15	-0.30	0.09*	-15.29**	10.33**	0.46	-24.53**
HRB 108-2 × EC 169513	-0.14	0.13	-3.80	0.40**	2.68**	-1.08**	1.12*	0.24	-0.07	-5.48*	1.25	-0.22	8.23
HRB 108-2 × AOL-12-59	0.61	0.44	1.09	0.24**	2.64**	-0.44**	2.43**	-0.32	-0.02	37.80**	-6.74**	0.55*	105.91**
HRB 108-2 × NOL-17-9	-0.19	-0.30	-1.53	-0.48**	-1.93**	0.82**	-1.21*	-1.06**	-0.02	-6.57*	3.71*	-0.06	-20.60**
HRB 108-2 × JOL-11-1	-0.94	-0.54	0.21	-0.13**	-1.99**	0.99**	-1.50**	-0.53*	0.03	17.43**	10.70**	0.18	5.71
HRB 108-2 × HRB-55	-0.27	0.07	4.55*	0.18**	3.08**	0.35**	3.44**	1.37**	0.05	4.74	-3.72*	-0.41	63.53**
HRB 108-2 × GO-2	2.08*	2.17*	-2.95	0.54**	1.92**	0.39**	-0.10	-1.25**	-0.11**	-5.96*	0.78	-0.22	-2.82
HRB 108-2 × VRO-6	2.84**	2.55*	-2.98	-0.17**	-0.92**	-0.08	-1.99**	0.06	0.09*	-12.17**	1.96	-0.21	-46.95**
EC 169513 × AOL-12-59	1.53	1.70	0.75	0.01	-2.21**	-0.48**	-0.43	0.02	-0.15**	-17.67**	4.13*	0.04	-35.01**
EC 169513 × NOL-17-9	-0.39	0.30	3.36	0.44**	2.45**	-0.12	-0.30	2.63**	0.12**	0.96	-3.32*	-0.12	-16.43*
EC 169513 × JOL-11-1	-0.58	-0.73	3.99	-0.32**	0.50	1.12**	-1.42*	2.73**	-0.09*	-3.86	-1.44	-0.10	-14.88*
EC 169513 × HRB-55	1.10	0.89	1.89	-0.28**	-0.13	0.17	0.74	-0.42	0.05	-8.99**	7.93**	-0.36	-26.13**
EC 169513 × GO-2	1.33	1.10	-3.68	-0.22**	-2.46**	0.50**	-1.96**	0.15	0.02	29.52**	-5.91**	-0.06	29.99**
EC 169513 × VRO-6	-1.47	-1.19	-14.72**	0.06	-4.22**	-0.08	-3.17**	-1.46**	0.03	22.09**	-19.06**	-1.50**	2.67
AOL-12-59 × NOL-17-9	-1.52	-1.62	3.61	0.04	-1.28**	0.52**	-0.74	1.11**	-0.07	-12.14**	1.25	-0.58*	-12.16
AOL-12-59 × JOL-11-1	1.96*	1.91	4.02	0.03	1.30**	0.57**	0.22	0.30	0.06	-5.65*	-6.20**	-0.11	-7.49
AOL-12-59 × HRB-55	-3.59**	-3.58**	4.24*	0.00	2.52**	0.17	0.16	1.58**	0.01	4.32	-1.17**	-0.15	6.07
AOL-12-59 × GO-2	-3.69**	-3.48**	-6.00*	-0.12**	-1.45**	0.13	-0.41	1.30**	0.08	-22.24**	4.43**	-0.74	-50.38**
AOL-12-59 × VRO-6	-0.71	-0.44	-9.65**	-0.13**	-0.66*	-1.01**	0.60	-0.69**	0.10*	-11.61**	-6.50	-0.62*	-8.85
NOL-17-9 × JOL-11-1	-0.30	-0.60	2.95	0.06	0.32	-0.74**	1.85**	-0.76**	-0.01	8.74**	-0.98	-1.05**	53.03**
NOL-17-9 × HRB-55	2.05*	1.23	-6.69*	-0.01	-4.55**	-0.12	0.82	-1.29**	0.08	12.85**	-3.17	-0.20	19.86*
NOL-17-9 × GO-2	1.73*	1.34	-4.10*	-0.25**	0.08	0.55**	0.39	-0.37	0.04	10.15**	0.99	0.32	32.34**
NOL-17-9 × VRO-6	-1.96*	-1.85	-1.89	0.07	1.45	0.36**	0.55	-0.81**	-0.09*	7.67**	3.06	0.00	13.62
JOL-11-1 × HRB-55	0.86	0.33	-1.82	0.10	0.48	-0.54**	-1.27*	-0.64*	0.11**	-2.57	0.59	-0.07	-30.22**
JOL-11-1 × GO-2	-2.13*	-1.13	3.12	0.01	-0.37	-0.49**	-1.04	-1.25**	0.07	-7.88**	1.53	-0.10	-25.59**
JOL-11-1 × VRO-6	1.62*	1.47	-7.31**	-0.07	-1.14**	-0.36**	-0.42	-1.83**	-0.10*	0.09	-2.06	-0.31	3.22
HRB-55 × GO-2	0.54	0.49	1.89	0.12**	-1.91**	-0.20	-0.37	0.12	-0.08	13.10**	-3.55*	0.41	22.34**
HRB-55 × VRO-6	-2.26**	-2.36*	-2.27	-0.11**	1.04**	0.67**	0.07	1.82**	0.04	-5.05	8.75**	0.31	17.32*
GO-2 × VRO-6	1.53	1.41	9.11**	0.36**	3.07**	-0.60**	1.98**	0.04	-0.06	-18.72**	-6.87**	0.17	-8.74
SE (Sij)	0.80	0.95	2.62	0.04	0.30	0.12	0.55	0.24	0.04	2.65	1.58	0.26	7.09

(DFF-Days to First Flowering, DFP-Days to First Picking, PH- Plant Height, NBP-Number of Branch Plant, NNP-Number of Nods per plant, IL-Internodal length, NFP-Number of Fruits per Plant, FL-Fruit Length, FG-Fruit Girth, TFW- Ten Fruit Weight, DLP- Days to Last Picking, NP-Number of Pickings, FYP-Fruit Yield per Plant)

Table 4: Correlation coefficient between per se performance and GCA effect of parents and sca effect of crosses on pooled basis in okra

S. No	Characters	***Per se* performance and GCA effect**	***Per se* performance and sca effect**
1.	Days to first flowering	0.156	-0.440**
2.	Days to first picking	0.144	-0.440**
3.	Plant height (cm)	0.489**	0.232
4.	Number of branches per plant	0.343*	-0.332*
5.	Number of nodes per plant	0.660**	-0.256
6.	Internodal length (cm)	-0.173	0.042
7.	Number of fruits per plant	0.130	-0.057
8.	Fruit length (cm)	0.671**	-0.035
9.	Fruit girth (cm)	0.752**	0.156
10.	Ten fruit weight (g)	0.648**	-0.289*
11.	Days to last picking	-0.240	0.038
12.	Number of pickings	0.454**	0.156
13.	Fruit yield per plant (g)	0.645**	-0.180

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