

Original Research Article

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Combining Ability Analysis for Fruit Yield and Its Attributing Traits in Okra [*Abelmoschus esculentus* (L.) Moench]

K.N. Gavint*, K.V. Vadodariya and B.B. Bilwal

Main cotton Research Station (MCRS), Navsari Agricultural University, Navsari,
Gujarat, India

*Corresponding author

ABSTRACT

The present study is aimed to estimate general combining ability of the parents and specific combining ability of hybrids for fruit yield and its attributing traits in okra. Combining ability analysis revealed that the mean squares due to general and specific combining ability were important for inheritance of various traits. However, the magnitude of GCA variance were higher than SCA variance for most of the characters except number of internodes per plant, fruit weight, total sugar and total phenol indicating pre ponderance of additive type gene action for inheritance of these traits. This was further supported by high magnitude of $\sigma^2_{gca} / \sigma^2_{sca}$ ratios. The general combining ability effects revealed that among females, JOL-11-12, AOL-03-1, Arka-Anamika and KS-404 were good general combiners for fruit yield per plant and most of their yield attributing traits, whereas among males GAO-5 was good general combiner for fruit yield per plant and its yield attributing characters. In the present study none of the cross combination was the best specific combinations for all the characters. However, eleven crosses appeared positive specific cross combinations for fruit yield per plant. Among these the hybrids viz., JF-55 x VRO-6, JF-108-02 x VRO-6 and JOL-11-12 x GAO-5 were found to be the best specific cross combinations and the use of heterosis breeding approach in these hybrids will be more rewarding. On the other hand, the hybrids JOL-13-07 x VRO-6, Arka-Anamika x VRO-6, JOL-11-12 x VRO-6 and JF-55 x GO-2 show low sca effect and involved poor combiners. These combinations may be useful for isolating the desired transgressive segregants.

Keywords

Okra [*Abelmoschus esculentus* (L.) Moench], Line x Tester, Combining ability, gca, sca effect and component traits

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Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] is known by many names in different parts of the world. It is called lady's finger in England, gumbo in United States of America, guinogombo in Spain, guiberio in Portugal and bhindi in India, being native of tropical and sub-tropical Africa. It belongs to Malvaceae family. It is one of the priced vegetables

grown throughout the country as *summer* and *kharif* crop in all type of soil particularly in the state of Uttar Pradesh, Madhya Pradesh, Karnataka, Maharashtra and Gujarat. It is important vegetable crop of Gujarat state. Okra is essentially a native of Africa but wild types have also been found in India. Okra is an allopolyploid, with $2n = 73$ to 130 chromosome numbers and genome size ranged from 3897 Mbp to 17321 Mbp. It is an often

cross pollinated crop and occurrence of out crossing is an extent of 4 to 19 % with the maximum of 42.2 % with the insect assisted pollination (Kumar, 2006).

In any crop improvement programme, the proper choice of parents based on their combining ability is a pre requisite. Sprague and Tatum (1942) proposed concept of General Combining Ability (GCA) and Specific Combining Ability (SCA) for the first time in relation to single crosses of corn. GCA is defined as the average performance of the progeny of an individual when it is mated to a number of other individuals and the SCA, a term refers to the deviation in performance of a cross from what would be expected on the basis of general combining abilities of the parents. The knowledge of combining ability helps in identifying best combiners, which may be hybridized either to exploit heterosis or to accumulate fixable genes through selection, combining ability of plant provides valuable information on genetic potential of the genotypes under any study. The combining ability is most helpful in determining the appropriate parents of a cross.

The knowledge of nature of gene action governing the expression of various traits could be helpful in predicting the effectiveness of selection. The efficient partitioning of genetic variance into its components *viz.*, additive, dominance and epistasis will help in formulating an effective and sound breeding programme. The cases where cost of hybrid seed is prohibitive, the use of additive gene effects of parents could be used to retain the vigour in subsequent generations.

Materials and Methods

Eight parental lines *viz.*, Arka- Anamika, KS-404, AOL-03-1, JF-108-02, JF-55, JOL-13-07, JOL-11-12, JOL-09-07 and testers *viz.*, GO-2, GJO-3, GAO-5 and VRO-6 were crossed in

using line x tester mating design resultant thirty two cross combination alongwith one standard check (GJOH-3) were evaluated in randomized block design with three replication during *khari*f2016 at college farm, NAU, Navsari. In experiment, Each plot consisted of fifteen plants in a row at 60 cm x 30 cm inter and intra row spacing all the recommended package of practices were adopted for raising a successful and healthy crop. Observations were recorded on five plants for the characters *viz.*, days to 50% flowering, plant height (cm), number of internodes per plant, fruit length (cm), Fruit girth(cm), fruit weight (g), number of fruits per plant, fruit yield per plant (g), fruit dry weight (mg/100g), total sugar (%), total phenol (%). Replication means of different characters were used for statistical analysis.

Results and Discussion

Combining ability variance

The analysis revealed significance of both general (gca) and specific (sca) combining ability variance for the traits under study which indicated that both the variances were important in inheritance of the characters (Table 1).

However, variance due to gca were higher in magnitude than gca variance for days to 50% flowering, plant height, fruit length, fruit girth, fruit weight, number of fruits per plant, fruit yield per plant and fruit dry weight where preponderance of additive type of gene action which will respond to selection while, for remaining characters manifested of variance were lower than that of sca variance indicating the predominance of non-additive gene action suggested that improvement through recurrent selection breeding approaches. The presence of non-additive genetic variance is the primary justification for initiating the hybrid breeding programme. Almost akin results have been

reported by Khatik *et al.*, (2012), Adiger *et al.*, (2013), and Paul (2013).

Combining ability effects

Based on estimates of general combining ability effects for various characters (Table 2). It was observed that none of the parents was found to be good general combiner for all the traits. However, an overall appraisal of general combining ability effects revealed that among females JOL-11-12, AOL-03-1, Arka-Anamika and KS-404 were good general combiners for fruit yield per plant and most of their yield attributing characters, whereas among males, GAO-5 was good general combiner for fruit yield and its yield attributing traits. As in present investigation, parent *viz.*, JOL-11-12 and AOL-03-1 exhibited high *per se* performance coupled with significant *gca* effect for majority of the characters. It was also observed that the *per se* performance of different characters in general agreed with the *gca* effects. However, this cannot be taken as a rule because parents or genotypes with high *per se* performance need not always be good general combiners.

It was further observed (Table 2) that parents possessing good general combining ability for fruit yield per plant also possessed high general combining ability for one or more of its yield components. It appeared that *per se* performance as such may give an indication of the general combining ability of the parents involved in crosses. This suggested that while selecting the parents for hybridization programme *per se* performance of the parents should be given due consideration. General combining ability was also reported by Bhalekar *et al.*, (2014), Jethava *et al.*, (2014), Katagi *et al.*, (2015) and Patel (2016).

The estimates of *sca* effects (Table 3) revealed that none of the hybrid was found consistently superior for all the traits. Out of thirty two

hybrids, eleven crosses appeared positive specific cross combinations for fruit yield per plant. Among these the hybrids *viz.*, JF-55 x VRO-6, JF-108-02 x VRO-6 and JOL-11-12 x GAO-5 were found to be the best specific cross combinations and the use of heterosis breeding approaches in these hybrids will be more rewarding.

A perusal of *sca* effects revealed that out of thirty two crosses two crosses for days to 50% flowering, seven crosses for plant height, three crosses for number of internodes per plant, one crosses for fruit length, two crosses for fruit girth, eleven crosses for fruit dry weight, thirteen for total sugar and sixteen for total phenol expressed significant and positive *sca* effects. The highest significant *sca* effects in desired direction for component characters was exhibited by different hybrids *viz.*, KS-404 x VRO-6 (-4.78), JOL-11-12 x GO-2 (-3.57) for days to 50% flowering; JOL-13-07 x GJO-3 (10.56), JF-55 x GJO-3 (9.81) and JOL-11-12 x GAO-5 (6.44) for plant height; AOL-03-1 x GO-2 (2.61), JOL-09-07 x GAO-5 (1.36) and Arka-Anamika x GAO-5 (1.30) for number of internodes per plant; JF-55 x GAO-5 (1.64) for fruit length; JF-108-02 x GAO-5 (0.30) and JF-55 x GAO-5 (0.23) for fruit girth. None of the cross combinations found significant and positive *sca* effect for number of fruits per plant, fruit yield per plant and fruit dry weight.

These results are in accordance with those obtained by [17], [18] and [19]. The best three hybrids for fruit yield per plant *viz.*, JOL-11-12 x GAO-5 (good x good), Arka-Anamika x GAO-5 (good x good) and AOL-03-1 x GAO-5 (good x good) had positive *sca* effects. High yielding hybrids also possessed high *sca* effects, high heterosis as well as high *per se* performance for most of its yield contributing characters. This appeared appropriate as yield being a complex character depends on a number of its component traits.

Table.1 Analysis of variance (mean squares) for experimental design for various characters in okra

Source of Variations	DF	Days to 50% flowering	Plant height (cm)	Number of internodes per plant	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)
Replication	2	14.16	12.35	0.74	1.24	0.02	0.00
Hybrids	31	44.13**	473.10**	4.08**	4.46**	0.14**	2.76**
Females	7	99.61**	1406.85**	5.71	8.63**	0.17	6.35**
Males	3	112.95**	808.35**	2.63	9.85*	0.45**	10.80**
Female x Male	21	15.81**	113.96**	3.74**	2.30**	0.08*	0.42**
Error	62	4.64	12.48	1.17	1.02	0.04	0.01
\square^2 F		7.83**	116.35**	0.39	0.61**	0.01	0.19**
\square^2 M		4.47**	33.24**	0.07	0.36*	0.02**	0.28**
\square^2 gca		5.59**	60.94**	0.17	0.44**	0.02**	0.25**
\square^2 sca		3.39**	34.42**	0.89**	0.35*	0.01**	-1.20
\square^2 gca/ \square^2 sca		1.65	1.77	0.19	1.27	1.07	-0.20

* and ** = Significant at 5% and 1% levels of probability, respectively

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Source of Variations	DF	Number of fruits per plant	Fruit yield per plant (g)	Fruit dry weight (mg/100mg)	Total sugar (%)	Total phenol (%)
Replication	2	4.87	1075.68	0.01	0.11	0.35
Hybrids	31	35.30**	5433.04**	3.64**	37.82**	37.62**
Females	7	122.50**	19385.70**	10.20**	56.80	54.91
Males	3	51.92**	7527.45**	9.58**	55.92	43.66
Female x Male	21	3.87	482.95	0.60**	28.91**	30.99**
Error	62	3.60	466.86	0.01	0.13	0.11
\square^2 F		9.85**	1574.80**	0.85**	4.72	4.57
\square^2 M		1.99**	293.31**	0.40**	2.32	1.82
\square^2 gca		4.60**	720.47**	0.55**	3.12**	2.73*
\square^2 sca		-0.12	-1.71	0.19**	9.59**	10.30**
\square^2 gca/ \square^2 sca		-36.95	-422.03	2.84	0.33	0.27

* and ** = Significant at 5% and 1% levels of probability, respectively.

Table.2 Estimation of general combining ability effects of parents for various characters in okra

Parents	Days to 50% flowering	Plant height (cm)	Number of Internodes Plant	Fruit Length (cm)	Fruit girth (cm)	Fruit weight (g)
Lines						
JOL-09-07	-1.84**	-5.26**	-0.60*	-0.60	-0.01	-0.84
JOL-11-12	-0.59	7.67**	0.97**	-0.88**	-0.03	0.35
JOL-13-07	-0.18	-5.51**	2.28	1.153**	-0.05	-0.34
JF-55	3.41**	-11.16**	0.21	0.88**	0.26**	-0.88
JF-108-02	4.99**	-16.21**	0.33	0.69*	0.01	-0.50
AOL-03-1	0.16	9.03**	-0.91**	0.27	-0.15*	0.53
KS-404	-3.26**	9.17**	-0.83**	-0.55	-0.002	0.75
Arka-Anamika	-2.68**	12.27**	0.55	-0.97**	-0.08	0.94
SE(gj)	0.68	0.94	0.30	0.32	0.06	0.58
SE (gi-gj)	0.97	1.34	0.42	0.46	0.08	0.82
Testers						
GO-2	0.41	1.24	-0.18	0.65**	0.03	-0.06
GJO-3	1.49**	-3.08**	-0.2	0.043	0.14**	-0.15
GAO-5	-3.18**	7.57**	0.494*	-0.88**	-0.19**	0.91*
VRO-6	1.28*	-5.73**	-0.117	0.18	0.02	-0.70
SE(gj)	0.48	0.66	0.21	0.23	0.04	0.41
SE (gi-gj)	0.68	0.94	0.30	0.32	0.06	0.58

* Significant at 5 % level, ** Significant at 1 %

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Parents	Number of fruits/Plant	Fruit yield/plant (g)	Fruit dry weight (mg/100mg)	Total sugar (%)	Total phenol (%)
Lines					
JOL-09-07	0.52	4.21	0.45**	-0.97**	0.06
JOL-11-12	3.11**	39.67**	0.77**	3.40**	2.07**
JOL-13-07	-1.54*	-19.95**	-0.35**	-3.43**	3.61**
JF-55	-5.10**	-63.25**	-1.56**	1.14**	-0.04
JF-108-02	-3.99**	-49.99**	-1.13**	-0.08	0.10
AOL-03-1	3.10**	36.61**	0.22**	0.63**	-1.13**
KS-404	1.81**	19.62**	0.85**	1.52**	-1.19**
Arka-Anamika	2.08**	33.08**	0.75**	-2.21**	-3.47**
SE(gj)	0.59	6.38	0.04	0.11	0.09
SE (gi-gj)	0.84	9.02	0.06	0.15	0.12
Testers					
GO-2	-0.23	-4.12	0.01	0.56**	1.98**
GJO-3	-0.48	-7.47	-0.30**	1.30**	-0.46**
GAO-5	2.08**	25.81**	0.87**	0.34**	-1.06**
VRO-6	-1.37**	-14.22**	-0.60**	-2.20**	-0.44**
SE(gj)	0.42	12.76	0.03	0.07	0.06
SE (gi-gj)	0.60	9.38	0.04	0.11	0.09

* Significant at 5 % level, ** Significant at 1 %

Table.3 Estimates specific combining ability (sca) effects of hybrids for fruit yield and its component traits in okra

Sr . No.	Crosses/ Hybrid	Days to 50% flowerin g	Plant height (cm)	No. of internodes/ Plant	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Number of fruits/ plant
1	JOL-09-07 x GO-2	1.34	1.26	-1.40*	0.89	-0.21	0.26	-0.18
2	JOL-09-07 x GJO-3	-0.07	-0.42	-0.07	-0.48	0.03	0.26	-0.58
3	JOL-09-07 x GAO-5	-2.41	0.34	1.36*	-0.09	-0.03	-0.48	-0.41
4	JOL-09-07 x VRO-6	1.36	-1.77	0.11	-0.32	0.21	-0.04	1.17
5	JOL-11-12 x GO-2	-3.57*	-1.21	-0.79	0.40	0.15	-0.49	-0.44
6	JOL-11-12 x GJO-3	-0.99	-7.69**	0.72	-0.06	-0.07	0.11	0.60
7	JOL-11-12 x GAO-5	1.34	6.44**	0.93	-0.67	-0.03	0.82	1.20
8	JOL-11-12 x VRO-6	3.22*	2.46	-0.86	0.34	-0.05	-0.45	-1.36
9	JOL-13-07 x GO-2	0.34	-3.62	-0.64	-0.87	-0.03	0.16	1.09
10	JOL-13-07 x GJO-3	-0.41	10.56**	-0.07	0.10	0.08	0.11	0.64
11	JOL-13-07 x GAO-5	1.26	-13.12**	0.55	0.86	-0.10	-0.14	0.10
12	JOL-13-07 x VRO-6	-1.20	6.18**	0.17	-0.08	0.05	-0.13	-1.83
13	JF-55 x GO-2	-0.91	-2.11	-0.17	0.77	-0.05	-0.13	-1.02
14	JF-55 x GJO-3	2.01	9.81**	0.37	-1.06	-0.15	-0.09	-0.72
15	JF-55 x GAO-5	0.68	-6.20**	-0.23	1.64*	0.23*	0.38	-0.46
16	JF-55 x VRO-6	-1.78	-1.51	0.02	-1.35*	-0.03	-0.16	2.19
17	JF-108-02 x GO-2	-1.49	2.21	0.98	-0.20	-0.16	-0.11	-0.87
18	JF-108-02 x GJO-3	-1.58	-6.34**	-0.07	1.04	0.00	-0.03	-0.59
19	JF-108-02 x GAO-5	0.09	2.25	-1.70**	-0.43	0.30**	-0.37	-0.24
20	JF-108-02 x VRO-6	2.97*	1.88	0.79	-0.40	-0.14	0.51	1.69
21	AOL-03-1 x GO-2	-1.32	0.17	2.61**	-0.40	0.08	-0.01	0.56
22	AOL-03-1 x GJO-3	-0.41	2.65	-0.90	0.67	-0.11	0.32	-0.23
23	AOL-03-1 x GAO-5	1.26	3.91*	-1.93**	-1.26	0.07	-0.47	-0.19
24	AOL-03-1 x VRO-6	0.47	-6.73**	0.22	0.97	-0.04	0.16	-0.14
25	KS-404 x GO-2	4.09**	4.23*	0.19	0.39	0.04	0.19	-0.24
26	KS-404 x GJO-3	1.01	-6.65**	0.35	-0.41	0.16	-0.18	0.70
27	KS-404 x GAO-5	-0.32	1.96	-0.28	-0.14	-0.29*	0.03	-0.50
28	KS-404 x VRO-6	-4.78**	0.46	-0.27	0.16	0.09	-0.05	0.04
29	Arka-Anamika x GO-2	1.51	-0.93	-0.78	-0.98	0.17	0.12	1.09
30	Arka-Anamika x GJO-3	0.42	-1.93	-0.35	0.19	0.07	-0.51	0.18
31	Arka-Anamika x GAO-5	-1.91	3.83*	1.30*	0.10	-0.15	0.22	0.49
32	Arka-Anamika x VRO-6	-0.03	-0.97	-0.17	0.69	-0.09	0.16	-1.77
	S.E(S _{ij})±	1.37	1.89	0.59	0.64	0.11	1.16	1.19
	S.E(S _{ij} - S _{kl}) ±	1.94	2.67	0.84	0.91	0.16	1.64	1.68
	S.E(S _{ij} - S _{ik}) ±	2.90	4.01	1.26	1.37	0.23	2.46	2.52

* and ** = Significant at 5% and 1% levels of probability, respectively

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Sr. No.	Crosses/ Hybrid	Fruit yield/plant (g)	Fruitdry weight (mg/100mg)	TotalSugar (%)	TotalPhenol (%)
1	JOL-09-07 x GO-2	-0.84	0.03	-0.35	-0.94**
2	JOL-09-07 x GJO-3	-5.38	0.02	0.80**	-1.66**
3	JOL-09-07 x GAO-5	-5.65	-0.16	1.42**	1.73**
4	JOL-09-07 x VRO-6	11.87	0.11	-1.88**	0.87**
5	JOL-11-12 x GO-2	-8.62	0.31**	-3.30**	1.51**
6	JOL-11-12 x GJO-3	4.05	-0.81**	1.11**	-0.60**
7	JOL-11-12 x GAO-5	16.51	0.04	0.47*	-6.04**
8	JOL-11-12 x VRO-6	-11.93	0.46**	1.71**	5.13**
9	JOL-13-07 x GO-2	13.79	0.08	1.63**	0.97**
10	JOL-13-07 x GJO-3	8.74	-0.38**	6.46**	-3.19**
11	JOL-13-07 x GAO-5	-0.19	-0.26**	-1.71**	-2.10**
12	JOL-13-07 x VRO-6	-22.34	0.56**	-6.38**	4.32**
13	JF-55 x GO-2	-10.83	0.19*	3.08**	3.11**
14	JF-55 x GJO-3	-6.92	0.65**	-4.35**	-2.97**
15	JF-55 x GAO-5	-6.36	-0.15	-1.63**	3.65**
16	JF-55 x VRO-6	24.11	-0.70**	2.89**	-3.80**
17	JF-108-02 x GO-2	-9.01	0.01	-1.68**	-0.52**
18	JF-108-02 x GJO-3	-5.34	0.34**	-1.87**	3.16**
19	JF-108-02 x GAO-5	-3.70	-0.30**	0.47*	1.15**
20	JF-108-02 x VRO-6	18.05	-0.05	3.08**	-3.79**
21	AOL-03-1 x GO-2	12.63	-0.72**	1.27**	-0.90**
22	AOL-03-1 x GJO-3	-2.62	0.45**	-2.18**	0.62**
23	AOL-03-1 x GAO-5	-4.62	0.37**	0.52*	-0.81**
24	AOL-03-1 x VRO-6	-5.39	-0.10	0.39	1.09**
25	KS-404 x GO-2	-1.46	-0.23*	1.42**	-0.16
26	KS-404 x GJO-3	10.05	-0.08	2.08**	2.75**
27	KS-404 x GAO-5	-6.83	0.10	-1.19**	0.56**
28	KS-404 x VRO-6	-1.76	0.21*	-2.32**	-3.15**
29	Arka-Anamika x GO-2	4.33	0.32**	-2.08**	-3.08**
30	Arka-Anamika x GJO-3	-2.57	-0.176*	-2.05**	1.89**
31	Arka-Anamika x GAO-5	10.84	0.36**	1.64**	1.86**
32	Arka-Anamika x VRO-6	-12.60	-0.51	2.49**	-0.66**
	S.E(S _{ij})±	12.76	0.09	0.21	0.18
	S.E(S _{ij} - S _{kl}) ±	18.04	0.12	0.30	0.25
	S.E(S _{ij} - S _{ik}) ±	27.06	0.19	0.45	0.37

The perusal of data (Table 2 and 3) revealed that good general combining parents may not necessarily always produce good specific combinations for different traits. In many cases, it was observed that at least one good general combining parents was involved in heterotic hybrid having desirable sca effects. This suggested that information of gca effects of parents should be considered along with sca effects and *per se* performance of hybrid

for predicting the value of any hybrid. In a view of *per se* performance of parents and their gca effects for seed yield per plant and other characters studied among the female parents, JOL-11-12, AOL-03-1, Arka-Anamika and KS-404 were the best general combiner for most of the characters under study, whereas among males GAO-5 was good general combiner for fruit yield per plant and its yield attributing characters. five

best cross combinations viz., JOL-11-12 xGAO-5, Arka-Anamika xGAO-5, AOL-03-1 x GAO-5, AOL-30-1 xGO-2, and KS-404 x GAO-5 had high *per se* performance coupled with high positive sca effect can be exploited for hybrid vigour or to be utilized for the improvement of genotype were identified as the most promising parents and hybrids hence they could be used extensively in breeding programme for improving fruit yield per plant in okra. A combination of poor combiners also gives several crosses with high and significant sca effects across the traits, such crosses could be expected to through up some transgressive segregants in recurrent selection. A progeny selection with pedigree method in such crosses may through up transgressive segregants leading to development of good inbreds.

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