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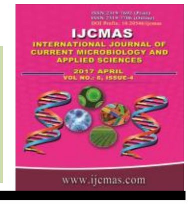

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Genetic Architecture, Combining Ability and Gene Action Study in Okra [*Abelmoschus esculentus* (L.) Moench]

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A B S T R A C T

A study was conducted in okra to estimate the magnitude of gene action involved and to identify the good combiner for fruit yield and other yield attributing characters. 55 okra hybrids derived by crossing of 11parents in diallel mating design excluding reciprocals were studied to assess the combining ability and gene action. The general and specific combining ability variances were significant for all the traits except sca mean square for fruit weight. The σ^2gca and σ^2sca ratio indicated that both additive and non-additive gene action was predominant for the inheritance of different traits. The estimates of general combining ability effects suggested that parents HRB-55 (21.195**), AOL-09-17 (30.008**), AOL-09-2 (10.679**) and JOL-09-7 (1.288**) were good general combiners for fruit yield per plant and its related attributes. The analysis of variance for specific combining ability indicates sufficient variation was there among cross combinations for yield and related traits. The estimates of specific combining ability effects indicated that cross combinations JOL-55-3 x HRB-55 (56.786**), JOL-09-8 x JOL-09-7 (46.346**) and JOL-09-8 x AOL-09-17 (46.110**) were most significant for fruit yield per plant and related traits. Present investigation indicates sufficient scope of exploitation of heterosis using the parents and crosses.

Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] is a versatile vegetable crop from malvaceae family and is comprising of valuable nutrients. Okra is the important vegetable crop of India and is grown successfully during both summer and rainy seasons for its green tender fruits. Nutritionally it is low in saturated fat, cholesterol and sodium and high in dietary fiber, vitamin A, vitamin C, vitamin K, Thiamin, vitamin B_6, Folate, Calcium, Magnesium, Phosphorus, Potassium, Manganese, Protein, Riboflavin, Niacin, Iron, Zinc and Copper. Bhendi has a vast potential as one of the foreign exchange earner and accounts for about 60% of the export of fresh vegetables. This vegetable is grown in different parts of the country and has high demand. Short duration, photo insensitive nature, high seed setting capacity make the crop ideal for genetical study for crop improvement. A further increase in okra productivity needs intensive research and breeders need to examine whether productivity is enhanced mainly by genes favored by heterozygosity or homozygosity. Combining ability analysis provides clues to the usefulness of individuals to be employed as the parents in the hybridization programme as well as simultaneously to screen the hybrids. Besides, it also ascertains the magnitude and nature of quantitative genetic variation which could be of great use to plant breeders for deciding efficient and effective breeding programme. Study of gene action involved is very crucial for choosing of best parents and crosses for okra yield improvement and has been reported by many researchers viz; Reddy *et al.,* (2012), Adiger *et al*., (2013). Hence the present investigation was done to assess the combining ability of parents and crosses to identify the best suitable parents and cross combinations which can be utilized for exploitation of heterosis in okra.

Materials and Methods

The present study consists of 11 different okra genotypes viz., AOL-09-13, JOL-55-3, AOL-08-5, JOL-1, JOL-09-8, JOL-09-12, HRB-55, JOL-08-16, AOL-09-17, AOL-09-2, JOL-09-7. The genotypes were crossed in diallel fashion excluding reciprocals to produce 55 hybrids in late *kharif* 2011. These 55 F_1 hybrids evaluated along with their 11 parents and check GOH-2 in Randomized Block Design in three replications during late *kharif* 2012 at university farm, Department of Botany, Navsari Agricultural University, Navsari. Each plot consisted of a single row of 10 plants. Inter and intra row spacing was kept 60 and 30 cm, respectively. Agronomic practices followed as per the standard recommendation and sufficient protection measures were taken to raise a healthy crop stand. The different 11 quantitative characters like Days to First Flowering, No. of Primary Branches per Plant, Plant Height, Internodal Length, Fruit Length, Fruit Diameter, No. of Ridges on Fruit, Fruit Weight, No. of Fruits per Plant and Fruit Yield per Plant has been recorded. The various observations were recorded on five competitive plants in each plot leaving border ones. Combining ability analysis was done by employing method-ii, model-i (fixed effect) of Griffing (1956) and difference between the gca and sca effects were also calculated as per Griffing (1956).

Results and Discussion

The mean squares due to gca and sca for different traits are presented in table 1. Analysis of variance for combining ability portrayed that gca variance were highly significant for all the characters, while sca variance were highly significant for all the characters except for fruit weight (Table 1). The significance of both gca and sca variance for most of the characters indicated that both additive as well as non-additive types of gene actions were involved in the inheritance of traits. Significance of both the variances also has been reported by Srivastava *et al.,* (2008), Balakrishnan *et al.,* (2009), Patel *et al.,* (2010), Mistry and Vashi (2011), Reddy *et al.,* (2012), Adiger *et al*., (2013) Akhtar *et al.,* (2010).

The character wise estimates of general combining ability effects for each parent are presented in table 2 and indicates that the merit of the parents differs significantly for different characters. The parents AOL-09-13, JOL-55-5, AOL-08-5, JOL-08-16 and JOL-09-7 showed significant negative gca effect for days to initiation of flowering which is desirable and contribute for earliness in crosses followed by average combiners JOL-1, JOL-09-8 and AOL-09-2.

Table.1 Mean square due to general and specific combining ability for different characters in okra

Sources of variation	d.f.	Days to initiation of flowering	No. of primary branches per plant	Plant height (cm)	Inter nodal length (cm)	Fruit length (cm)	Fruit diameter (cm)	No. of ridges on fruit	Fruit weight (g)	No. of fruits per plant	Fruit yield per plant (g)
gca	10	23.288**	1.575**	445.611**	1.403**	1.785**	0.016**	0.178**	0.953**	20.645**	3332.513**
sca	55	1.949**	0.113**	33.553**	0.203**	0.503**	0.003**	0.026**	0.111	4.115**	962.423**
error	130	0.333	0.047	26.711	0.042	0.150	0.000	0.001	0.109	0.659	230.169
σ^2 gca		1.766	0.117	32.223	0.105	0.126	0.001	0.014	0.065	1.538	238.642
σ^2 sca		1.616	0.065	6.842	0.161	0.353	0.003	0.025	0.002	3.456	732.253
σ^2 gca/ σ^2 sca		1.093	1.797	4.709	0.650	0.356	0.410	0.544	41.545	0.445	0.326

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

Table.2 General combining ability effects of parents for various traits in okra

Parents	Days to initiation of flowering	No. of primary branches per plant	Plant height(cm)	Internodal length(cm)	Fruit length (cm)	Fruit diameter (cm)	No. of ridges on fruit	Fruit weight(g)	No. of fruits per plant	Fruit Yield per plant (g)
AOL-09-13	-2.462**	-0.203**	-10.075**	-0.665**	-0.405**	-0.009	-0.029**	-0.311**	-1.324**	-26.394**
JOL-55-3	-0.935**	0.000	3.386*	0.217**	0.207*	-0.037**	-0.087**	-0.096	0.336	-13.307**
AOL-08-5	-0.663**	-0.340**	1.642	-0.457**	-0.254*	-0.048**	-0.005	-0.170	-0.018	-11.304**
JOL-1	-0.036	-0.003	1.169	-0.206**	-0.492**	0.002	-0.159**	-0.067	-0.370	-4.226
JOL-09-8	0.101	0.356**	3.369*	0.222**	-0.139	-0.003	-0.026**	0.283**	-0.529*	-0.630
JOL-09-12	0.554**	-0.368**	-6.513**	0.266**	-0.086	-0.021**	-0.087**	-0.221*	-1.101**	1.428
HRB-55	2.521**	0.514**	5.575**	0.338**	0.347**	0.063**	0.114**	0.212*	1.974**	21.195**
JOL-08-16	-0.494**	-0.267**	-6.787**	0.143**	-0.073	-0.024**	0.065**	-0.231**	-0.648**	-8.737*
AOL-09-17	1.868**	0.421**	8.512**	-0.175**	0.835**	0.055**	0.275**	0.605**	2.630**	30.008**
AOL-09-2	-0.108	-0.425**	-3.481*	0.125*	0.096	0.007	-0.033**	-0.022	-1.070**	10.679**
JOL-09-7	-0.346**	0.315**	3.204*	0.194**	-0.037	0.014**	-0.027**	0.020	0.120	1.288**

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

Table.3 Classification of parents with respect to General Combining Ability of parents for various traits in okra

Parents	Days to initiation of flowering	No. of primary branches per plant	Plant height (cm)	Internodal length(cm)	Fruit length(cm)	Fruit diameter(cm)	No. of ridges on fruit	Fruit weight (g)	No. of fruits per plant	Fruit Yield per plant(g)
AOL-09-13	G	P	P	P	P	A	G	P	P	P
JOL-55-3	G	A	G	G	G	P	G	A	A	P
AOL-08-5	G	P	A	P	P	P	A	A	A	P
JOL-1	A	A	A	P	P	A	G	A	A	A
JOL-09-8	A	G	G	G	A	A	G	G	P	A
JOL-09-12	P	P	P	G	A	P	G	P	P	A
HRB-55	P	G	G	G	G	G	P	G	G	G
JOL-08-16	G	P	P	G	A	P	P	P	P	P
AOL-09-17	P	G	G	P	G	G	P	G	G	G
AOL-09-2	A	P	P	G	A	A	G	A	P	G
JOL-09-7	G	G	G	G	A	G	G	A	A	G

A= Average combiner, G= Good combiner, P= Poor combiner

Table.4 SCA of top 10 hybrids for yield and attributing characters

S.No	Hybrids	Days to first flowering	No. of primary branches per plant	Plant height (cm)	Internodal length(cm)	Fruit length (cm)	Fruit diameter (cm)	No. of ridges on fruit	Fruit weight (g)	No. of fruits per plant	Fruit Yield per plant(g)
1	JOL-55-3 X HRB-55	0.423	0.154	14.538**	-0.311	1.661	0.062**	0.455**	0.199**	1.325	56.786**
2	JOL-09-8 X JOL-09-7	0.427	-0.332	-12.117*	0.061	-0.392	-0.042**	-0.038	-0.407	-0.819	46.346**
3	JOL-09-8 X AOL-09-17	1.039**	-0.009	13.888**	-0.003	1.890**	0.064**	0.306**	0.108	0.926	46.110**
4	AOL-09-2 X JOL-09-7	-0.208	0.685**	-1.937	0.758**	0.036	-0.002	0.012	0.098	0.341	39.073**
5	AOL-09-17 X JOL-09-7	2.487**	-0.021	12.777**	-0.009	1.634	0.030*	0.284**	0.681*	5.141**	39.008**
6	AOL-08-5 X AOL-09-2	0.006	-0.391*	5.541	-0.124	0.320	0.016*	-0.003	-0.269	-1.058	36.819**
7	AOL-08-5 X AOL-09-17	0.130	0.677**	-2.645	-0.257	-0.049	0.072**	0.079**	0.294	1.138	36.970**
8	HRB-55 X JOL-08-16	-0.655	0.168	-11.582*	0.497**	0.091	0.016*	-0.140**	0.165	7.227**	35.175*
9	JOL-09-12 X AOL-09-2	-1.417**	-0.219	-1.928	0.286	0.055	0.046**	0.159**	0.439	0.185	35.123*
10	HRB-55 X AOL-09-17	0.936	-0.070	13.962**	-0.052	1.627	0.054**	0.286**	0.842**	0.243	34.138*

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

Table.5 Top three of the parents and F1s for per se performance, Combining Ability and Heterosis estimates

Characters	*Per se* performance		Combining ability effects	
	parents	F_1S	GCA	SCA
Days to initiation of flowering	AOL-09-13 AOL-08-5 JOL-09-7	AOL-09-13 X JOL-55-3 AOL-09-13 X AOL-09-2 AOL-09-13 X AOL-08-5	AOL-09-13 JOL-55-3 AOL-08-5	JOL-55-3 X AOL-09-17 JOL-09-12 X AOL-09-17 JOL-09-8 X JOL-09-12.
No. of primary branches per plant	JOL-09-8 HRB-55 JOL-09-7	HRB-55 X AOL-09-17 AOL-08-5 X AOL-09-17 JOL-55-3 X HRB-55	HRB-55 AOL-09-17 JOL-09-8	JOL-09-8 X JOL-09-12 AOL-09-2 X JOL-09-7 AOL-08-5 X AOL-09-17
Plant height	HRB-55 JOL-09-8 AOL-09-17	HRB-55 X AOL-09-17 JOL-09-8 X AOL-09-17 AOL-09-17 X JOL-09-7	AOL-09-17 HRB-55 JOL-09-8	JOL-55-3 X HRB-55 JOL-09-8 X AOL-09-17 HRB-55 X AOL-09-17
Internodal length	JOL-08-16 HRB-55 JOL-09-8	HRB-55 X AOL-09-2 AOL-09-2 X JOL-09-7 AOL-09-17 X AOL-09-2	HRB-55 JOL-09-12 JOL-09-8	AOL-09-17 X AOL-09-2 JOL-09-12 X AOL-09-17 JOL-55-3 X AOL-08-5
Fruit length	AOL-09-17 AOL-09-2 JOL-08-16	HRB-55 X AOL-09-17 JOL-09-8 X AOL-09-17 AOL-09-17 X JOL-09-7	AOL-09-17 HRB-55 JOL-55-3	JOL-55-3 X JOL-1 JOL-09-8 X AOL-09-17 JOL-09-12 X HRB-55
Fruit diameter	HRB-55 JOL-09-7 AOL-09-17	HRB-55 X AOL-09-17 JOL-09-8 X AOL-09-17 AOL-09-17 X JOL-09-	HRB-55 AOL-09-17 JOL-09-7	JOL-55-3 X JOL-08-16 AOL-08-5 X JOL-08-16 JOL-09-12 X AOL-09-17
No. of ridges on fruit	JOL-55-3 JOL-1 JOL-09-12	JOL-1 X JOL-09-12 JOL-1 X JOL-09-8 JOL- 55-3 X JOL-09-8	JOL-1 JOL-55-3 JOL-09-12	JOL-08-16 X AOL-09-17 AOL-09-13 X AOL-09-17 JOL-55-3 X AOL-09-17
Fruit weight	AOL-09-17 JOL-09-8 HRB-55	HRB-55 X AOL-09-17 AOL-09-17 X JOL-09- JOL-09-8 X AOL-09-17	AOL-09-17 JOL-09-8 HRB-55	JOL-55-3 X HRB-55 HRB-55 X AOL-09-17 AOL-09-17 X JOL-09-7
No. of fruits per plant	HRB-55 AOL-09-17 JOL-09-7	HRB-55 X AOL-09-17 JOL-09-8 X AOL-09-17 AOL-09-17 X JOL-09-7	AOL-09-17 HRB-55 JOL-55-3	HRB-55 X JOL-08-16 JOL-09-8 X JOL-08-16 AOL-09-17 X JOL-09-7
Fruit yield per plant	HRB-55 AOL-09-17 AOL-08-5	HRB-55 X AOL-09-17 JOL-09-8 X AOL-09-17 AOL-09-17 X JOL-09-7	AOL-09-17 HRB-55 AOL-09-2	JOL-55-3 X HRB-55, JOL-09-8 X JOL-09-7, JOL-09-8 X AOL-09-17

The parents JOL-09-8, HRB-55 and AOL-09-17 and JOL-09-7 showed significant positive gca effect for No. of Primary Branches and Plant Height and are good combiners for these traits.

Parents JOL-09-8, HRB-55, JOL-55-3, JOL-9-12and JOL-9-7 are observed as good general combiners for intermodal length and Fruit Length and rest of the parents are either average or poor combiner for these traits. Significant and positive gca effect was observed for parent JOL-09-8, HRB-55 and AOL-09-17 and was considered as good general combiner for Fruit Weight. Parents HRB-55, AOL-9-2, JOL-9-7 and AOL-9-13, JOL-55-3, JOL-1, JOL-9-7 found to be good combiners for Fruit Diameter and No. of Ridges respectively.

For No. of Fruits per Plant, only HRB-55 and AOL-09-17 manifested positive significant gca effect and hence considered as good general combiner. On the opposite AOL-09-13, JOL-09-8, JOL-09-12, JOL-08-16 and AOL-09-2 depicted as poor combiner for this trait. Rests of the parents are average combiners. Four parents *viz.,* HRB-55, AOL-09-17, AOL-09-2 and JOL-09-7 recorded significant gca effects in desired direction for Fruit Yield per Plant. While, parents AOL-09-13, JOL-55-3, AOL-08-5 and JOL-08-16 had significant negative gca effect and hence observed to be poor general combiner. Whereas, the parents JOL-1, JOL-09-8 and JOL-09-12 are the average combiners for fruit yield.

The general combining ability effects of parents (Table 3) indicated that none of the parents was found good general combiner for all the characters investigated. Four parents *viz.,* HRB-55, AOL-09-17, AOL-09-2 and JOL-09-7 were observed to be good general combiners for fruit yield per plant. Moreover, the parent HRB-55 was observed as good general combiner for maximum of the characters except Days to Initiation of Flowering and No. of Ridges on Fruit. Whereas, parent AOL-09-17 was good combiner for No. of primary branches per plant, Plant Height, Fruit Length, Fruit Diameter, Fruit Weight, No. of Fruits per Plant. The parent JOL-09-7 found to be either good or average combiner for all the characters. Rest of all the parents JOL-1, JOL-09-8 and JOL-09-12 were average combiners for Fruit Yield per Plant and the rest are poor combiners for Fruit Yield per Plant. The parents which manifested high gca effect for yield also found to be superior for the particular trait in their *per se performance.*

Specific combining ability effects (Table 4) found to be both positively and negatively significant for yield and component characters for different cross combinations. The top 10 hybrids which portrayed high specific combining ability for yield and components are JOL-55-3 X HRB-55(56.786**), JOL-09-8 X JOL-09-7(46.346**), JOL-09-8 X AOL-09-17(46.110**), AOL-09-2 X JOL-09-7(39.073**), AOL-09-17 X JOL-09-7(39.008**), AOL-08-5 X AOL-09-2(36.819**), AOL-08-5 X AOL-09-17(36.970**), HRB-55 X JOL-08-16(35.175*), JOL-09-12 X AOL-09-2(35.123*) and HRB-55 X AOL-09-17(34.138*) respectively. Hence three top yielding hybrid HRB-55 x AOL-09-17 (Good x Good) possessed first position for economic heterosis for yield followed by JOL-09-8 x AOL-09-17 (Average x Good) and AOL-09-17 x JOL-09-7 (Good x Good) respectively (Table 5). These three top yielding crosses exhibited high sca effects as well as *per se* performance having at least one or both parents as good general combiner for green fruit yield, it is expected that such type of cross combinations would yield desirable transgressive segregants in later generations. In the present study, top three crosses which exhibited high sca effects for fruit yield involved at least one good general combiner. High specific combining ability of crosses for high yield and yield attributes are also obtained by Reddy *et al.,* (2012), Adiger *et al*., (2013), Lyngdou *et al.,* (20013), singh *et al.,* (2013), Nagesh *et al.,* (20014) Pal and Sabesan (2009) and Dabhi *et al.,* (2010) in okra.

From the present study it can be concluded that HRB-55, AOL-09-17, AOL-09-2 and JOL-09-7 can be used further as parent material in hybridization programme to get high yielding transgressive segregants for exploitation of hybrid vigor. Among the hybrids HRB-55 x AOL-09-17, JOL-09-8 x AOL-09-17 and AOL-09-17 x JOL-09-7 could be exploited fully in future okra breeding programme by adopting appropriate breeding technique in order to evolve high yielding varieties.

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