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Research Article

Genetic studies on fruit yield and yield attributes of okra (*Abelmoschus esculentus* L. Moench)

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Abstract

Eight genotypes of okra were crossed in half diallel fashion to study the combining ability of the parents and gene action in respect of fruit yield and 12 other component characters. The magnitude of GCA variance was higher than respective SCA variance indicating predominance of additive gene action for expression of all the characters. The components of variance for both GCA and SCA were recorded to be higher for fruit yield per plant and plant height. Considering the genetic variance, it was higher due to SCA than that of GCA for all the characters except for flowering characters thus suggesting significant role of non additive gene action in the expression of former characters. The genotype IC-332453 and Parbhani Kranti were the best general combiners. The crosses that exhibited higher SCA effects and *per se* performance for fruit yield per plant were IC-33107 X IC-433665, IC-342075 X IC-332453, IC-43736 X Parbhani Kranti, IC-433672 X IC-332453 and IC-3307 X IC-4376. In these crosses atleast one of the parents is a good general combiner. Therefore, complementary type of gene effect might have played important role in expression of the character.

Key words: Okra, diallel, gene action, general combining ability.

Introduction:

Okra (*Abelmoschus esculentus* L. Moench), also called bhindi or lady's finger, is primarily a warm season, annual vegetable crop grown mainly for its tender green fruits. The realisable yield potential in this crop as revealed by available literature is much more than what has been achieved so far in India. Development of high yielding varieties depends mainly on the presence of genetic diversity in the respective crop. Studies on combining ability and heterosis breeding might be potential alternative for achieving quantum jump in production and productivity of okra. Further, the knowledge of combining ability is useful to assess the breeding value of parents and at the same time elucidate the nature and magnitude of gene actions involved. The present study was, therefore, undertaken to select parents with high general combining ability and crosses with desirable specific combining ability effect for tailoring effective breeding programme as well as rapid selection in advance segregating generations.

Material and Methods

Eight genotypes of okra *viz.*, IC-342075, IC-43736, IC-433645, Parbhani Kranti, IC-433672, IC-332453, IC-3307 and IC-8991 were collected from NBPGR, Regional Station Akola, Maharashtra. Crosses were made among these eight parents in a diallel fashion without reciprocal during year 2010 at the Experimental Farm, C Block; B.C.K.V. Kalyani, Nadia (W.B.). The 28 F_1s along with their eight parents were evaluated in a randomised block design with three replications in the year 2011 during June to September. Each genotype was raised in three rows of 3m length at spacing of 60 cm between rows and 40 cm between plants. Recommended package of practices were adopted during the cropping period to obtain a good harvest. Observations were recorded from five randomly selected competitive plants from the middle row of each genotype in each replication for 13 characters viz, days to first flowering, days to 50% flowering, number of fruits/plant, fruit length (cm), number of ridges/ fruit, fruit diameter (cm), weight/ fruit (g), plant height (cm), number of primary branches/plant, number of nodes on main stem, number of fruiting nodes, inter nodal distance and fruit yield/ plant (g). Mean value of the data obtained from the above five plants was used for statistical analysis. Data were analysed as per Method-2 and Model-1 of Griffing (1956). The statistical analysis was carried out by using INDOSTAT software.

Results and Discussion

The mean squares due to all the sources of variation were found to be significant for all the characters (Table 1) except for fruit diameter among the parents and for fruit length, number of ridges/fruit, fruit diameter and inter node length among parents *vs* hybrids. The significant mean sum of squares among parents and among the hybrids revealed the presence of genetic variability among them and that due to parents *vs* hybrids indicated the presence of substantial differences between the crosses and parents.

The components of variances were presented in Table 2. The ratio of σ^2A/ σ^2D was high for all the aforementioned characters except fruit diameter, fruit weight, number of primary branches per plant and inter node length indicating the predominance of additive gene action in these characters. Pal and Sabesan (2009) reported preponderance of non additive gene action for the same characters. Heritability in broad sense was high for all the characters except for fruit diameter while the same in narrow sense was moderate for days to first flowering, number of fruits per plant and number of fruiting nodes and low for all the remaining characters indicating the extent of breeding value. The estimates of predictability ratios following Baker (1978) showed that seven characters out of thirteen such as days to first flowering, days to 50% flowering, number of fruiting nodes, number of ridges per fruit, plant height, number of fruit per plant and fruit yield per plant had the values more than 0.50. It may, therefore, be expected that the characters with moderate narrow sense heritability and higher predictability ratio will have the potentiality to transmit it to the next generation. Ramalingam *et al.* (1997) and Solankey *et al.* (2010) indicated the preponderance of non-additive gene action for all the characters they studied. The characters like days to first flowering, number of fruits per plant and number of fruiting nodes revealed to be controlled predominantly by additive gene action and therefore pedigree transgressive breeding would be useful whereas days to 50% flowering, number of ridges per fruit, plant height and number of nodes on main stem indicated to be controlled both by additive and by non additive gene action and therefore transgressive breeding and heterosis breeding might be a better option for them. The remaining characters were controlled mainly by non additive gene action indicating heterosis breeding may be employed to improve them. Moreover, in case of the characters controlled predominantly by the non additive gene action breeding methodology such as biparental mating, recurrent selection and diallel selective mating (Jensen, 1970) may be resorted to, than conventional pedigree or backcross techniques which would leave the unfixable components of genetic variances unexploited for yield and its components. However, characters predominantly controlled by additive gene action are amenable to conventional breeding methods.

The *gca* effects (Table 3) revealed that among the eight parents used for diallel crossing IC-3307, IC-433665, IC-332453 and Parbhani Kranti were significantly positive general combiners for number of fruits per plant, fruit length, plant height, number of nodes on main stem, number fruiting nodes and fruit yield per plant. Considering earliness however, the parents, *viz.*, IC-342075, IC-8991and IC-332453 were desirable. Such inter genotypic difference with respect to *gca* effects has earlier been reported by Balkrishanan *et al.* (2009) and Yograj *et al.* (1995). The above results thus indicated that IC-332453 was the best general combiner since it exhibited significantly desirable *gca* effect for eleven characters studied. Parbhani Kranti appeared to be a good general combiner for nine characters. Among the other parents IC-3307, IC-342075 and IC-433665 appeared to be good general combiner for seven characters each. High *gca* effects involve mostly additive effect or additive × additive interaction effect and represent fixable proportion of the genetic variation (Sprague, 1942).

The results with respect to best general combiners along with their *per se* performances and a list of superior crosses presented in the Table 4. It reveals that the superior crosses involved parents with high × high, high × medium, high × low, medium × medium, medium × low and, low × low type of general combiners. According to Malhotra (1983) high *sca* effect arising due to involvement of one good general combiner might be due to complementary type of gene effect. Further, high *sca* effect involving medium x medium, medium x high or high x high general combiners may be exploited further using pedigree method of breeding for the development of pure lines. The desirable *sca* effects resulting from good x good general combiner are expected to possess additive x additive type of gene action and are fixable. Desirable *sca* effects involving parents either good *gca* effects and poor *sca* effects might have resulted due to additive genetic system present in good combiner and the epistatic effect present in the crosses acted in a complementary fashion to maximize desirable plant attributes (Singh *et al.*, 1983). Among the 39 superior cross combinations presented in the Table 4, nine combinations had both the parents with high *gca* effects, five had high x medium combinations, six had medium x low, twelve combinations had high x low and four combinations had low x low combinations and three combinations had medium x medium combiners. It may, therefore, be stated that desirable *sca* effect of any cross combination need not necessarily depend on the level of *gca* effects of the parents involved. According to Dubey (1975) the desirable performance of combination with parents having high × low *gca* effects may be ascribed to the interaction between dominant allele from good combiner and recessive alleles from poor combiners. Moreover, a high × low cross can result in strong transgressive segregants for the desired characters due to segregation of genes with strong potentials and their specific buffers (Langham, 1961). According to Singh *et al*. (1983) crosses involving one parent with significant *gca* effect and the other with poor *gca* effect would throw up transgressive segregants giving rise to new population, if the additive genetic system present in the good combiner and the epistatic effect present in the crosses act in a complementary fashion to maximize desirable plant attributes which could be exploited for further breeding purposes. In the present experiment, such combinations were IC-433672 X Parbhani Kranti for days to first flowering, IC-3307 X IC-433672, IC-342075 X IC-433665 and IC-342075 X IC-332453 for number of fruits per plant, IC-43736 X Parbhani Kranti, IC-43736 X IC-433665 and IC-3307 X IC-43736 for fruit length, IC-433672 X IC-332453 and IC-433672 X Parbhani Kranti for fruit diameter, IC-3307 X IC-43736 for fruit weight, IC-3307 X IC-433672 for plant height, IC-3307 X IC-433672 for number of nodes on main stem, IC-3307 X IC-4336752, IC-342075 X IC-332453 for number of fruiting nodes, IC-342075 X IC-8991 and IC-3307 X IC-8991 for inter node length and IC-43736 X Parbhani Kranti, IC-433672 X IC-332453 and IC-3307 X IC-43736 for fruit yield per plant. The similar results have been reported by Singh *et al.* (2009). When the crosses exhibiting desirable significant *sca* effects, involving one good and one poor or both poor combiners as parent that would indicate the importance of genetic divergence of parents involved in the crosses and balanced gene complexes associated with low degree of inbreeding depression. Similar opinion has been made by Kumar *et al.* (2006).

The *sca* effect is an important index to determine the usefulness of a particular cross combination for exploitation of heterosis (Peng and Virmani, 1990). Among the crosses which exhibited high *sca* effects and *per se* performance for fruit yield per plant were IC-33107 X IC-433665, IC-342075 X IC-332453, IC-43736 X Parbhani Kranti, IC-433672 X IC-332453 and IC-3307 X IC-4376. One of the parents in all the above crosses appeared to be a good general combiner. Therefore, complementary type of gene effect might have played important role in expression of the character. The above potential crosses can be further tested with a view to boost the fruit yield. The present investigation advocates that hybrid breeding can be used efficiently to improve okra production.

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Table 1. Analysis of variance for yield and its attributing characters

Source of variation	Mean sum of square													
	df	**Days to 1st flowering**	**Days to 50% flowering**	**No. of fruits / plant**	**Fruit length (cm)**	**No. of ridges / fruit**	**Fruit diameter (mm)**	**Fruit weight (g)**	**Plant height (cm)**	**No. of primary branches / plant**	**No. of nodes on main stem / plant**	**No. of fruiting nodes**	**Inter node length (cm)**	**Fruit yield / plant (g)**
Replication	2	1.15	2.53	8.86	0.22	0.00	5.68	2.24	3.02	0.10	0.80	4.2	0.02	121.04
Genotype	35	9.33***	9.03***	34.08***	8.55***	0.31***	2.85***	8.14***	210.21***	0.43***	41.47***	27.85***	0.32***	11135***
Parents(P)	7	12.04***	8.76***	30.12***	7.37***	0.51***	1.97	8.45***	150.27***	0.65***	22.66***	24.01***	0.17***	6408***
F_1(Hybrid)	27	7.48***	7.05***	34.82***	9.16***	0.27***	3.18***	6.27***	231.97***	0.37***	47.32***	29.08***	0.37***	10836***
P vs. F_1	1	40.35***	64.38***	41.77***	0.29	0.00	0.07	56.37***	42.03**	0.64***	14.92***	21.50***	0.04	52317***
GCA	7	11.23***	9.02***	46.21***	6.99***	0.30***	1.54***	2.23***	216.01***	0.21***	38.01***	38.02***	0.20***	10516***
SCA	28	1.08**	1.51***	2.65***	1.81***	0.06***	0.80***	2.52***	33.58***	0.13***	7.77***	2.10***	0.08***	2011***
Error	70	1.32	1.34	0.73	0.61	0.00	1.16	0.26	4.42	0.06	0.97	0.74	0.01	48.52
Total	107	3.94	3.88	11.79	3.20	0.11	1.80	2.88	71.71	0.18	14.22	9.67	0.11	3676

*, **, *** Significant at 5%, 1% and 0.1% levels of probability respectively.

Table 2. Estimate of genetic variances for yield and its attributing characters

Sources of variation	Days to 1st flowering	Days to 50% flowering	No. of fruits / plant	Fruit length (cm)	No. of ridges / fruit	Fruit diameter (mm)	Fruit weight (g)	Plant height (cm)	No. of primary branches / plant	No. of nodes on main stem / plant	No. of fruiting nodes	Inter node length (cm)	Fruit yield / plant (g)
σ^2gca	1.08	0.86	4.60	0.68	0.03	0.12	0.24	21.45	0.02	3.77	3.78	0.02	1049.96
σ^2sca	0.64	1.06	2.40	1.61	0.05	0.41	2.67	32.11	0.11	7.45	1.85	0.08	1994.66
σ^2e	0.44	0.45	0.24	0.20	0.00	0.39	0.09	1.47	0.02	0.32	0.25	0.00	16.17
σ^2A	2.16	1.71	9.19	1.36	0.06	0.23	0.49	42.91	0.04	7.54	7.55	0.04	2099.9
σ^2D	0.64	1.06	2.40	1.61	0.05	0.41	2.67	32.11	0.11	7.45	1.85	0.08	1994.7
σ^2 p	3.24	3.22	11.84	3.17	0.11	1.03	3.25	76.49	0.17	15.31	9.65	0.12	4110.74
h^2 % (N.S.)	67.0	53.0	78.0	43.0	52.0	22.0	15.0	56.0	23.0	49.0	78.0	31.0	51.0
h^2 % (B.S.)	86.0	86.0	98.0	94.0	99.0	63.0	97.0	98.0	88.0	98.0	97.0	96.0	100
σ^2A/ σ^2D	3.37	1.61	3.82	0.84	1.20	0.56	0.18	1.33	0.36	1.01	4.08	0.50	1.05
$\frac{\sigma_A^2}{\sigma_A^2+\sigma_D^2}$	0.77	0.61	0.79	0.46	0.54	0.35	0.15	0.57	0.27	0.50	0.80	0.33	0.51

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Table 3. Estimate of general combining ability (GCA) effects of parents for yield and its attributing characters

Sources of variation	Days to 1st flowering	Days to 50% flowering	No. of fruits / plant	Fruit length (cm)	No. of ridges / fruit	Fruit diameter (mm)	Fruit weight (g)	Plant height (cm)	No. of primary branches / plant	No. of nodes on main stem / plant	No. of fruiting nodes	Inter node length (cm)	Fruit yield / plant (g)
IC-3307	0.33	0.20	1.52***	0.53***	-0.08***	-0.20	0.56***	4.40***	0.01	1.68***	1.88***	-0.10***	29.96***
IC-433672	-0.21	-0.20	-1.16***	-0.41**	-0.11***	-0.48*	-0.28**	-5.93***	-0.03	-2.94***	-1.37***	0.27***	-19.68***
IC-43736	0.09	0.27	0.24	-0.89***	-0.11***	-0.43*	-0.35***	-3.80***	-0.04	-1.35***	-0.22	0.04	-2.81*
IC-342075	-0.64**	-0.67**	-0.86***	0.29*	-0.10***	0.32	0.53***	1.20**	0.10*	0.86***	-0.86***	-0.08***	-1.44
IC-433665	2.16***	2.00***	1.94***	0.57***	0.10***	0.16	0.03	3.29***	0.00	1.15***	1.69***	-0.04	23.43***
IC-8991	-1.34***	-1.07***	-4.48***	-1.45***	0.02	-0.28	-0.76***	-6.51***	-0.31***	-2.53***	-3.75***	0.14***	-66.91***
IC-332453	-0.81***	-0.73***	1.14***	0.37**	0.38***	0.48*	-0.29**	3.14***	0.12**	1.53***	1.33***	-0.13***	5.69***
Parbhani Kranti	0.42*	0.20	1.66***	1.00***	-0.10***	0.43*	0.55***	4.22***	0.16***	1.60***	1.31***	-0.09***	31.76***
SE(gi)	0.196	0.197	0.146	0.133	0.011	0.184	0.087	0.359	0.042	0.168	0.146	0.021	1.189

*, **, *** Significant at 5%, 1% and 0.1% levels of probability respectively.

Table 4. Best general combiner and a few specific combiners for different characters

Characters	Best general combiners						Best specific combiners	SCA effects	*Per se* performance of crosses	GCA status of parents
	Genotype	Parent GCA effect	*Per se* performance	Genotype	Parent GCA effect	*Per se* performance				
Days to first flowering (Earliness)	IC-332453	-0.81***	34.3	IC-342075	-0.64**	34.3	IC-433672X Parbhani Kranti	-1.45**	33.00	L X H
							IC-43736 X IC-8991	-1.32*	31.7	M X L
							IC-3307 X IC-342075	-1.25*	32.7	M X L
Days to 50% flowering (Earliness)	IC-331067	-1.07***	36.00	IC-332453	-0.73***	37.7	IC-433672 X IC-43736	-1.62**	35.3	L X M
							IC-3307 X IC-433665	-1.42*	37.7	M X H
							IC-43736 X IC-8991	-1.42*	34.7	M X L
Number of fruits / plants	IC-433665	1.94***	22.5	Parbhani Kranti	1.66***	22.6	IC-3307 X IC-433672	2.18***	22.4	H X L
							IC-43736 X Parbhani Kranti	1.95***	23.7	M X H
							IC-342075 X IC-433665	1.62***	22.6	L X H
Fruit length (cm)	Parbhani Kranti	1.00***	11.0	IC-433665	0.57***	10.3	IC-3307 X Parbhani Kranti	2.04***	14.1	H X H
							IC-43736 X Parbhani Kranti	1.68***	12.3	L X H
							IC-43736 X IC-433665	1.34***	11.5	L X H
No. of ridges / fruit	IC-332453	0.38***	6.2	IC-433665	0.10***	5.00	IC-433665 X IC-8991	0.74***	6.00	H X M
							IC-433665 X IC-332453	0.58***	6.20	H X H
							IC-433672 X IC-43736	0.09***	5.00	L X L
Fruit diameter (mm)	IC-332453	0.48*	12.9	Parbhani Kranti	0.43*	12.6	IC-433672 X IC-332453	1.79**	14.4	L X H
							IC-3307 X IC-43736	1.62**	11.4	M X L
							IC-43736 X IC-342075	1.12*	13.6	L X M

*, **, *** Significant at 5%, 1%and 0.1% levels of probability, respectively; H = High gca effect, M = Medium gca effect and L = Low gca effect

Table 4. Contd..

Characters	Best general combiners						Best specific combiners	SCA effects	*Per se* performance of crosses	GCA status of parents
	Parent			Parent						
	Genotype	GCA effect	*Per se* performance	Genotype	GCA effect	*Per se* performance				
Fruit weight (g)	IC-3307	0.56***	11.9	Parbhani Kranti	0.55***	12.4	IC-3307 X IC-433665	3.03***	15.8	H X M
							IC-8991 X 332453	2.32***	13.5	L X L
							IC-433672 X IC-332453	2.30***	13.9	L X L
Plant height (cm)	IC-3307	4.40***	90.9	Parbhani Kranti	4.22***	91.3	IC-433665 X Parbhani Kranti	7.42***	104.8	H X H
							IC-3307 X IC-342075	7.17***	102.6	H X H
							IC-3307 X IC-433672	6.89***	95.2	H X L
No. of primary branches / plant	Parbhani Kranti	0.16***	2.3	IC-332453	0.12**	2.6	IC-332453 X Parbhani Kranti	0.54***	3.2	H X H
							IC-3307 X IC-433665	0.50***	2.9	M X M
							IC-3307 X IC-43736	0.48***	2.9	M X M
No. of nodes on main stem /plant	IC-3307	1.68***	23.4	Parbhani Kranti	1.60**	24.5	IC-3307 X IC-433665	4.48***	30.4	H X H
							IC-342075 X IC-332453	2.86***	28.3	H X H
							IC-433672 X IC-8991	2.84***	20.5	L X L
No. of fruiting nodes	IC-3307	1.88***	19.2	IC-433665	1.69***	20.5	IC-433665 X Parbhani Kranti	2.44***	23.2	H X H
							IC-3307 X IC-433672	2.03***	20.3	H X L
							IC-342075 X IC-332453	2.03***	20.3	L X H
Inter node length (cm)	IC-433672	0.27***	4.5	IC-8991	0.14***	4.0	IC-43736 X IC-433665	0.59***	4.5	M X M
							IC-342075 X IC-8991	0.54***	4.5	L X H
							IC-433672 X IC-332453	0.49***	4.6	H X L
Fruit Yield/ Plant (g)	Parbhani Kranti	31.76***	280.7	IC-3307	29.96***	235.7	IC-3307 X IC-433665	84.9***	382.3	H X H
							IC-342075 X IC-332453	57.7***	306.0	M X H
							IC-43736 X Parbhani Kranti	56.4***	329.3	L X H

*, **, *** Significant at 5%, 1%and 0.1% levels of probability, respectively; H = High gca effect, M = Medium gca effect and L = Low gca effect