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Research Notes

Combining ability through diallel analysis in okra (*Abelmoschus esculentus* (L.) moench)

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Abstract
Combining ability analysis was carried out for fruit yield and its components in okra in a 12 x 12 diallel cross (excluding reciprocals). Both general a combining ability (GCA) and specific combining ability (SCA) variances were highly significant for all the characters indicating the importance of both additive and non additive gene actions. However, preponderance of additive gene action was recorded for the traits *viz*., primary branches per plant, ridges/fruit and fruit diameter, preponderance of non additive gene action was recorded for plant height, nodes on main stem, days to first flowering, number of fruits per plant, fruit length, fruit weight and fruit yield per plant. The parents Sat-dhari, Ratna - 78, VRO 5 and Varsha Uphar were found to be the best general combiners and close correspondence between *per se* performance of parents and their *gca* effects were observed. The cross combinations *viz*., Sat-dhari x Ratna–78, VRO 5 x Sagun, Ratna-78 x Punjab 8, Ankur–40 x Pankaj Dwarf, Sat-dhari x Varsha Uphar, Arka Anamika x Punjab-5 showed significant *sca* effects in desirable direction for fruit yield per plant and associated characters and were expected to produce transgressive segregants. Exploitation of hybrid vigour from these crosses through heterosis breeding method is advocated.

Key words: Combining ability, gene action, diallel, fruit yield, okra

Breeding method for the improvement of a crop depends primarily on the nature and magnitude of gene actions involved in the expression of quantitative and qualitative traits. Combining ability analysis helps in the identification of parents with high general combining ability (GCA) effects and cross combinations with high specific combining ability (SCA) effects. Additive and non additive gene actions in the parents estimated through combining ability analysis may be useful in determining the possibility for commercial exploitation of heterosis and isolation of purelines among the progenies of the heterotic F_1. The present study was conducted to obtain the information on combining ability of 12 varieties of bhendi (*Abelmoschus esculentus* L.) for fruit yield and its components.

Twelve okra varieties *viz.,* Parbhani kranti, Sat-dhari, Arka Anamika, Ankur 40, Pankaj Dwarf, Varsha Uphar, Nandini, Indam 9821, Ratna 78, Punjab 8, VRO 5 and Sagun were selected on the basis of their diversity for various quantitative characters and crossed in diallel mating design without reciprocals. The experimental material consisting of 12 parents and their 66 hybrids were raised at the District Seed Farm (AB Block), Bidhan Chandra Krishi Viswavidayalaya, Kalyani, Nadia in 2004 in randomized block design with three replications. Each replication comprised of three row plots of 3 m length and 2 m width. A spacing of 60 x 40 cm was followed. N, P, K (100:50:50 kg/ ha) in the form of Urea, Single super phosphate, and Muriate of potash was applied. Half the dose of N and full dose of P and K were applied as basal while remaining half dose of N was applied as top dressing at 35-40 DAS. Observations were recorded on five randomly selected plants from each replication and their mean values were used for statistical analysis. The observations were recorded on ten quantitative traits *viz*., plant height (cm), primary branches per plant, number of nodes on main stem per plant, days to first flowering, number of fruits per plant, number of ridges per fruit, fruit length (cm), fruit diameter (cm), fruit weight (g) and fruit yield per plant (g). The diallel analysis was carried out according to the statistical genetic model described by Griffing (1956) as Method 2 and Model 1 and assuming a fixed effects statistical model (Model 1). The statistical analysis was carried out with INDOSTAT program.

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The F1 means were used for the variance analysis according to Becker (1975).

Analysis of variance for combining ability revealed that both GCA and SCA variances were significant for all the characters which indicated the importance of both additive and non additive gene action in the inheritance of these characters. The ratio of GCA/SCA indicated the preponderance of additive gene action for primary branches per plant, number of ridges per fruit and fruit diameter. Similar results were reported by Senthil kumar (2005). However, preponderance of non additive gene action was recorded for plant height, number of nodes on main stem, days to first flowering, number of fruits per plant, fruit length, fruit weight and fruit yield per plant. These results were also supported by the reports of Sabesan (2007) for plant height, days to first flowering, number of fruits per plant and fruit length and Saravanan (2005) for number of nodes on main stem, fruit length, fruit weight and fruit yield per plant. The estimates of *gca* effects revealed wide differences among the parents.

Parent Sat-dhari ranked first as good general combiner for fruit yield per plant, fruit weight, number of ridges per fruit, number of fruits per plant, number of primary branches per plant, fruit length and fruit diameter, but was poor combiner for plant height and average combiner for number of nodes per plant and days to first flowering (Table 1). Parent Ratna 78 ranked second as good general combiner for fruit yield per plant, number of fruits per plant, fruit length, fruit weight and number of nodes per plant except number of primary branches per plant and number of ridges per fruit. It is clear that almost all combinations involving Sat-dhari, Ratna 78, VRO 5 and Varsha Uphar as one of the parent recorded high mean and significant heterosis for fruit yield per plant and other yield components. Analysis of mean performance of parents and their *gca* effects revealed that *per se* performance of the parents is a reflection of their *gca* effects in most of the crosses. Arora (1993), Senthil kumar (2005) and Saravanan (2005) and Adeniji and Kehinde (2007) made similar reports in bhendi. The behavior of parents as good indication of the performance of their hybrids was reported by Gilbert (1958).

High *sca* effects results mostly from the dominance and interaction effects existed between the hybridizing parents. In the present study, significant sca effects were exhibited by 17 crosses for fruit yield per plant. The top performing hybrids are Sat-dhari x Ratna 78, VRO 5 x Sagun, Ratna 78 x Punjab 8, Varsha Uphar x Ratna 78, Arka Anamika x Punjab 78, Nandini x Punjab 8 and Ankur 40 x Pankaj Dwarf. The best specific combining hybrid sat-dhari x Ratna 78 and Varsha Uphar x Ratna 78 involved high x high combining parents, indicating additive x additive type of interactions. Sabesan (2000) and Mehta *et al*. (2007) also reported about interaction between positive and positive alleles in crosses involving high x high combiners which can be fixed in subsequent generations if no repulsion phase linkages are involved.

The hybrid namely, Ratna 78 x Punjab 8 and VRO 5 x Sagun involved high x low combiners suggesting additive x dominance interactions. Sabesan (2000) also reported about the possibility of interaction between positive alleles from good combiner and negative alleles from poor combiner in high x low combiner crosses and suggested for exploitation of heterosis in F_1 generation as their high yield potential would be unfixable in succeeding generations. Three hybrids *viz*., Nandini x Punjab 8, Ankur 40 x Pankaj Dwarf and Arka Anamika x Punjab 8 involved low x low combining parents indicating overdominance and epistatic interactions. This may be due to genetic diversity in the form of heterozygous loci as reported by Pathak *et al* (1984) in castor.

A comparison between *sca* effects of heterotic hybrids showing > 20% heterosis revealed that almost all the heterotic hybrids recorded positive significant *sca* effects (Table 2). Analysis of mean performance of hybrids and their *sca* effects revealed that *per se* performance of the hybrids is a reflection of their *sca* effects in most of the cases. The results indicated that selection of hybrids should be based on *per se* performance coupled with *sca* effects. From this study it was noted that both additive and non additive gene actions were important in controlling various characters. The best combiners Sat-dhari, Ratna 78, VRO 5, Varsha Uphar could be utilized in future breeding programmes. The crosses Sat-dhari x Ratna 78, VRO 5 x Sagun, Ratna 78 x Punjab 8, Ankur 40 x Pankaj Dwarf, Sat-dhari x Varsha Uphar, Arka Anamika x Nandini and Arka Anamika x Punjab 8 could be used for exploitation of heterosis for fruit yield and its component traits.

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Table 1. Estimates of gca effects of twelve parents for different characters in okra

Name of Parents	Plant height (cm)	No. of Primary branches /plant	No. of nodes on main stem	Days to 1st flowering	No. of fruits/ plant	No. of ridges/ fruit	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (gm)	Fruit Yield / plant (gm)
1) Parbhani Kranti (P_1)	4.42**	-0.43**	-2.15**	-0.59	-0.72**	-0.16**	-0.03	0.00	0.08	-9.70**
	(69.88)	(1.63)	(23.17)	(43.53)	(15.23)	(5.18)	(12.15)	(1.48)	(12.26)	(188.72)
2) Sat-dhari (P_2)	-3.54**	0.60**	0.17	-0.31	0.56**	1.48**	0.31**	0.08**	1.15**	27.42**
	(71.29)	(2.87)	(27.94)	(43.33)	(16.48)	(6.69)	(11.41)	(1.59)	(13.35)	(221.36)
3) Arka Anamika (P_3)	4.83**	-0.25**	-0.61	1.16**	-0.06	-0.15**	0.12	-0.01	-0.20*	-3.84
	(78.6)	(1.67)	(26.94)	(45.80)	(15.5)	(5.00)	(119.96)	(1.49)	(11.99)	(195.65)
4) Ankur-40 (P_4)	3.18**	-0.24**	0.62	-0.50	-0.23	-0.15**	-0.04	-0.01	-0.30**	-8.66**
	(79.76)	(1.77)	(26.85)	(44.40)	(15.63)	(5.03)	(12.27)	(1.48)	(11.81)	(190.68)
5) Pankaj Dwarf (P_5)	-8.36**	0.58**	0.55	1.70**	-0.42**	-0.12**	-1.34**	-0.08**	-1.36**	-30.76**
	(61.97)	(2.93)	(32.8)	(46.57)	(15.07)	(5.00)	(10.43)	(1.39)	(9.96)	(154.58)
6) Varsha Upahar (P_6)	-1.79	0.04	-1.12**	-0.32	0.18	-0.15**	0.56**	0.00	0.54**	10.11**
	(69.18)	(1.80)	(28.54)	(43.40)	(15.62)	(5.00)	(12.32)	(1.48)	(12.47)	(200.90)
7) Nandini (P_7)	2.19*	-0.14*	0.66*	0.55	-0.35*	-0.16**	-0.14	0.00	-0.42**	-10.99**
	(93.99)	(1.73)	(27.56)	(43.27)	(14.78)	(5.06)	(114.41)	(1.51)	(11.86)	(182.17)
8) Indam-9821 (P_8)	-4.18**	0.45**	-0.80*	-0.18	0.16	-0.14**	0.52**	-0.01	0.35**	8.66**
	(69.32)	(2.40)	(27.35)	(44.34)	(15.93)	(5.00)	(12.24)	(1.51)	(11.98)	(198.11)
9) Ratna – 78 (P_9)	1.59	-0.14*	1.13**	-0.34	0.83**	-0.13**	0.29**	0.01	0.54**	21.68**
	(72.21)	(1.80)	(26.21)	(45.10)	(16.27)	(5.12)	(11.77)	(1.48)	(12.80)	(218.19)
10) Punjab-8 (P_{10})	2.51**	-0.09	0.23	-0.32	-0.22	-0.14**	-0.16	-0.02**	-0.26**	-5.99**
	(81.78)	(1.93)	(30.81)	(43.87)	(14.95)	(5.05)	(11.24)	(1.41)	(11.09)	(175.35)
11) VRO-5 (P_{11})	-2.13*	-0.01	0.09	-0.38	0.81**	-0.07**	0.54**	0.05**	0.55**	20.00**
	(70.78)	(1.8)	(26.50)	(44.20)	(17.26)	(5.02)	(13.26)	(1.59)	(13.26)	(235.51)
12) Sagun (P_{12})	1.28	-0.06	1.21**	-0.46	-0.54**	-0.11**	-0.63**	-0.02**	-0.68**	-17.93**
	(78.79)	(1.93)	(30.82)	(43.67)	(15.94)	(5.00)	(11.68)	(1.50)	(11.91)	(189.91)
S.E.(gi) ±	0.9668	0.0563	0.3248	0.3072	0.1493	0.0159	0.0891	0.0058	0.0977	2.2412
S.E. (mean)	3.778	0.219	1.269	1.200	0.583	0.060	0.348	0.018	0.381	8.759

*,** Significant at 5% and 1% level Figures in parenthesis are mean values.

Table 2. *Per se* performance, sca and gca effects of heterotic hybrids

Hybrids	Fruit yield per plant (g)	*sca* effects	Heterosis (%)		*gca* effects	
			MP	BP	Female	Male
Parbhani Kranti x Varsha Uphar	244.23	21.00**	25.37**	21.57**	L	H
Sat-dhari x Arka Anamika	265.16	18.76**	27.17**	35.53**	H	L
Sat-dhari x Varsha Uphar	284.21	23.86**	34.61**	41.47**	H	H
Sat-dhari x Nandini	263.43	24.18**	30.56**	44.61**	H	L
Sat-dhari x Ratna 78	355.23	83.31**	61.63**	62.81**	H	H
Arka Anamika x Nandini	233.14	25.15**	23.41**	27.98**	L	L
Arka Anamika x Indam 9821	248.52	20.87**	26.23**	25.44**	L	H
Arka Anamika x Punjab 8	246.80	33.81**	33.05**	40.75**	L	L
Ankur 40 x Pankaj Dwarf	223.33	39.93**	29.37**	44.48**	L	L
Ankur 40 x Punjab 8	227.65	19.48**	24.39**	29.82**	L	L
Varsha Uphar x Nandini	239.63	17.68*	25.11**	31.54**	H	L
Varsha Uphar x Ratna 78	281.06	26.45**	34.13**	28.82**	H	H
Nandini x Indam 9821	243.71	23.22**	28.18**	23.02**	L	H
Nandini x Punjab 8	237.00	31.16**	32.58**	35.15**	L	L
Ratna 78 x Punjab 8	284.16	45.65**	44.41**	62.05**	H	L
VRO 5 x Sagun	292.22	67.33**	37.38**	53.58**	H	L

Table 3. Hybrid combinations with significantly positive specific combining ability effects

Character	Crosses
Plant height	Arka Anamika x Varsha Uphar, Ankur 40 x Pankaj Dwarf, Arka Anamika x Pankaj Dwarf, Parbhani kranti x Ratna-78, Parbhani kranti x Nandini
Primary branches per plant	Parbhani kranti x Pankaj dwarf, Arka Anamika x Pankaj Dwarf
Number of nodes on main stem	Arka anamika x Punjab-8, Parbhani kranti x Ratna-78, Nandini x Ratna-78, Parbhani kranti x A. Anamika, Nandini x VRO-5
Days to 1st flowering	7-dhari x Ratna-78, Arka Anamika xVRO-5, Varsha Uphar x Ratna-78, Ankur-40 x Varsha Uphar, VRO-5 x Sagun
Number of fruits per plant	7-dhari x Ratna-78, VRO-5 x Sagun, Nandini x Punjab-8, Arka Anamika x Indam-9821, Arka anamika x Punjab-8
Number of ridges per fruit	7-dhari x VRO-5, 7-dhari x Arka Anamika, Pankaj dwarf x Sagun, 7-dhari x Ratna-78, 7-dhari x Indam-9821, 7-dhari x Sagun
Fruit length	7-dhari x Ratna-78, Ratna-78 x Punjab-8, Ankur-40 x Pankaj Dwarf, 7-dhari x Nandini, Arka Anamika x Nandini
Fruit diameter	7-dhari x Ratna-78, Ratna-78 x Punjab-8, Parbhani kranti x A.Anamika, VRO-5 x Sagun, 7-dhari x Varsh Uphar, Arka Anamika x Nandini, 7-dhari x Arka Anamika, Ankur-40 x Pankaj Dwarf
Fruit weight	VRO-5 x Sagun, Ratna-78 x Punjab-8, 7-dhari x Ratna-78, Ankur-40 x Pankaj Dwarf, Parbhani kranti x A.Anamika
Fruit yield per plant	7-dhari x Ratna-78, VRO-5 x Sagun, Ratna-78 x Punjab-8, Ankur-40 x Pankaj Dwarf, Arka anamika x Punjab-8