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Combining ability studies in okra [*Abelmoschus esculentus* (L.) Moench] for growth and earliness parameters

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Abstract
The present investigation was carried out with the objective to identify good general and specific combiners for growth and earliness characters using eight parental lines of okra and their 28 F_1 hybrids obtained from half diallel mating design. The parent KO1608 was identified as good general combiner for all the growth parameters except internodal length. The parents *viz.,* KO1604 (-0.739) and KO1605 (-0.509) showed significantly negative gca effects for internodal length. The cross KO1603 x KO1606 was identified as good specific combiner for number of leaves (5.361), internodal length (-3.344) and number of nodes on the main stem (5.255). The maximum sca effects was observed in the cross KO1601 x KO1608 (0.532) followed by KO1606 x KO1607 (0.322) for number of branches per plant. The parent KO1602 was identified as good combiner for days to first flowering (-0.713) and days to 50 per cent flowering (-2.013). Significant maximum negative sca effects for days to 50 per cent flowering was observed in the cross KO1601 x KO1602 (-3.994) followed by KO1602 x KO1605 (-3.344) and KO1603 x KO1608 (-3.194).

Keywords: General combining ability, specific combining ability, half diallel, okra

Introduction
Okra [*Abelmoschus esculentus* (L.) Moench] is a fast growing annual which has captured a prominent position among the vegetables and is commonly known as bhendi or lady's finger in India. Okra is specially valued for its tender, delicious green fruits which are cooked, canned and consumed in various forms in different parts of the country. Combining ability analysis helps in the evaluation of inbreds in terms of their genetic value and the selection of suitable parents for hybridization and helps in the identification of superior cross combination, which ultimately helps in deciding about exploitation of heterosis using the specific cross combination. Diallel analysis technique developed by Jinks and Hayman (1953) has been extensively used to estimate GCA and SCA variances and to understand the nature of gene action involved in the expression of various quantitative traits. Hence, an attempt has been made with an objective to assess the information on combining ability of eight genotypes of okra (*Abelmoschus esculentus* L.) for growth and earliness parameters in okra through half diallel mating design.

Materials and methods
The investigation on heterosis and combining ability in okra was carried out at the Department of Vegetable Science, K.R.C. College of Horticulture, Arabhavi, Gokak Taluk, Belagavi district of Karnataka state. The experimental material comprised of 8 parents which were collected from the department itself and their 28 F_1 hybrids along with two commercial checks (Arka Anamika and MHY-10). Each of the 8 parents crossed among each other in half diallel fashion without reciprocal crosses to derive 28 F_1 hybrids. The experiment was laid out in randomized block design with two replications. Each treatment or a genotype in each replication was represented by one row each accommodating 20 plants at a row to row spacing of 60cm and 30cm from plant to plant. Five plants were randomly selected for each genotype from each replication and evaluated for the quantitative characters and the replicated mean values of various characters of parents and hybrids were subjected to half diallel analysis.

Results and discussion
The analysis of variance revealed significant differences among treatments for all the traits indicating the presence of appreciable genetic diversity among the parents and cross combinations (Table 1). Variance due to genotypes (crosses and parents) was highly significant (at p=0.01) for all the growth and earliness parameters, *viz*., plant height, number of

leaves, internodal length, number of branches per plant, number of nodes on the main stem, days to first flowering and days to 50 per cent flowering. Variance due to parents vs crosses was significant for plant height, number of leaves, internodal length and number of nodes on main stem and for other parameters (number of branches per plant, days to first flowering and days to 50 per cent flowering) variance due to parents vs crosses was not significant. General combining ability effects and specific combining ability effects for various traits are presented in Tables 3 and 4.

The mean sum of squares due to SCA and GCA were found highly significant for all the parameters. Ratio of general combining ability variance (GCA) to specific combining ability variance (SCA) is an indication of predominance of additive or non-additive genetic variance. GCA to SCA ratio (Table 2) was very low for the traits plant height (Akotkar *et al*., 2014, Kumar and Reddy, 2016, Kumari *et al.*, 2020 and Patel *et al.*, 2021) [1, 5, 6, 10] and number of nodes on the main stem (Patel *et al.*, 2021, Kumari *et al.*, 2020, Wakode *et al.*, 2016 and Solankey *et al.*, 2012) [10, 6, 14, 12] indicating preponderance of non-additive gene action and hence these traits can be improved through recurrent selection for specific combining ability or heterosis breeding. Non-additive component of genetic variance was higher than additive component for days to 50 per cent flowering (Patel *et al.*, 2021, Vekariya *et al.*, 2020 and Laxman *et al*., 2013) [10, 13, 7], number of leaves (Jonah *et al.*, 2015 and Lyngdoh *et al*., 2013) [4, 8], days to first flowering (Wakode *et al.*, 2016 and Bhatt *et al*., 2015) [14, 2] and internodal length (Patel *et al.*, 2021, Javiya *et al.*, 2020, Kumari *et al.*, 2020, Paul *et al.*, 2017, Kumar and Reddy, 2016 and Medagam *et al*., 2012) [10, 3, 6, 11, 5, 9]. Hence, these characters can be improved through recurrent selection schemes. Non-additive component of genetic variance was slightly higher than additive components for number of branches per plant (Patel *et al.*, 2021, Javiya *et al.*, 2020 and Jonah *et al.*, 2015) [10, 3, 4]. Hence, direct selection or recurrent selection schemes can be employed for improvement of this trait. There is great scope for heterosis breeding to exploit the non-additive genetic variance.

For plant height, two parents *viz.*, KO1608 (4.46) and KO1606 (1.66) exhibited significantly positive gca effects. Among 28 crosses, nine crosses showed significant positive sca effects and the maximum sca effects was observed in the cross KO1601 x KO1603 (15.106) followed by KO1604 x KO1608 (11.586).

Three parents showed significantly positive gca effects for number of leaves and the maximum gca effects was observed in the parent KO1608 (2.093) followed by KO1606 (0.455). Among 28 crosses, eight crosses showed significant positive sca effects and the maximum sca effects was observed in the cross KO1603 x KO1606 (5.361) followed by KO1605 x KO1606 (3.401).

The parents and crosses with negative gca and sca effects are desirable for internodal length respectively. Among eight parents, two parents *viz.*, KO1604 (-0.739) and KO1605 (-0.509) showed significantly negative gca effects. Among 28 crosses, four crosses showed significant negative sca effects. The maximum negative sca effects was observed in the cross KO1603 x KO1606 (-3.344) followed by KO1601 x KO1604 (-2.270).

For number of branches per plant, two parents *viz.*, KO1608 (0.22) and KO1602 (0.16) showed significantly positive gca effects. Among 28 crosses, only two crosses exhibited significant positive sca effects. The maximum sca effects was observed in the cross KO1601 x KO1608 (0.532) followed by KO1606 x KO1607 (0.322).

For number of nodes on the main stem, three parents exhibited significantly positive gca effects. The parent KO1604 (0.691) showed maximum positive and significant gca effects followed by KO1608 (0.652) and KO1605 (0.365). Among crosses, six crosses showed significant positive sca effects. The maximum sca effects was observed in the cross KO1603 x 1606 (5.255) followed by KO1601 x KO1604 (3.094).

The parents and crosses with negative combining ability effects (gca and sca) are desirable for earliness parameters (days to first flowering and days to 50% flowering). The maximum negative and significant gca effects was observed in the parent KO1602 (-0.713) followed by KO1608 (-0.563) for days to first flowering. Among 28 crosses, four crosses exhibited significant negative sca effects and the maximum negative sca effects was observed in the cross KO1603 x KO1607 (-2.706) followed by KO1604 x KO1607 (-1.756).

The maximum negative and significant gca effects was observed in the parent KO1602 (-2.013) followed by KO1608 (-1.313) for days to 50% flowering. Among crosses, three crosses exhibited significant negative sca effects and the maximum negative sca effects was observed in the cross KO1601 x KO1602 (-3.994) followed by KO1602 x KO1605 (-3.344) and KO1603 x KO1608 (-3.194).

Comprehensive assessment of parents by considering gca effects of seven characters studied has resulted into identification of parents *viz.*, KO1608 and KO1605 as good combiners and parents *viz.*, KO1603 and KO1607 were identified as poor combiners for most of the characters studied. The crosses KO1603 x 1606, KO1601 x KO1604 and KO1602 x KO1607 were identified as good specific combiners for number of nodes on the main stem and internodal length which indirectly depicts increased yield per plant.

Studies on combining ability variance revealed that the plant height, number of leaves, internodal length, number of nodes on the main stem, days to first flowering and days to 50 per cent flowering are predominantly controlled by non-additive gene action and hence heterosis breeding and recurrent selection can be employed for improvement. Non additive component of genetic variance was slightly higher than additive component for number of branches per plant and this character can be improved through direct selection or recurrent selection schemes.

Table 1: Analysis of variance (mean sum of squares) of diallel analysis for growth and earliness parameters in okra

Sl. No.	Character	Replications	Genotypes	Parents	Crosses	Parents vs Crosses	Error
	Degrees of freedom	**1**	**35**	**7**	**27**	**1**	**35**
a.	**Growth parameters**						
1.	Plant height	43.56	157.27**	41.54*	192.19**	24.58NS	13.47
2.	Number of leaves	31.98	13.42**	14.29**	13.56**	3.43**	0.937
3.	Internodal length	0.78	3.65**	2.54*	3.94**	3.61*	0.82
4.	Number of branches per plant	0.06	0.18**	0.17*	0.19**	0.11NS	0.06
5.	Number of nodes on main stem	8.20	6.44**	3.36**	7.38**	2.59**	0.589

b.	Earliness parameters						
6.	Days to first flowering	1.68	3.55**	3.13*	3.77**	0.36NS	1.08
7.	Days to 50 per cent flowering	0.12	12.63**	8.71*	13.87**	6.67NS	2.95

Table 2: Variance due to general and specific combining ability for growth and earliness parameters in okra

Sl. No.	Character	Mean sum of square			σ^2_g	σ^2_s	$\sigma^2_g: \sigma^2_s$
		GCA	SCA	Error			
1.	Plant height	60.933**	83.060**	6.736	5.419	76.324	0.071
2.	Number of leaves	24.121**	10.737**	0.937	2.318	9.800	0.237
3.	Internodal length	2.079**	1.759**	2.079**	0.166	1.347	0.124
4.	Number of branches per plant	0.242**	0.055*	0.242**	0.021	0.026	0.796
5.	Number of nodes on main stem	4.690**	6.877**	4.690**	0.410	6.287	0.065
6.	Days to first flowering	2.241**	1.657**	2.241**	0.170	1.116	0.152
7.	Days to 50 per cent flowering	12.169**	4.853**	12.169**	1.069	3.376	0.317

Table 3: General combining ability effects of parents for growth parameters in okra

Sl. No.	Parents	Plant height	Number of leaves	Internodal length	No. of branches per plant	No. of nodes on the main stem	Days to first flowering	Days to 50 per cent flowering
1.	KO1601	0.380	-1.073**	0.706**	0.070	-0.410*	0.338	-0.063
2.	KO1602	-4.000**	0.415*	0.039	0.160*	-0.402*	-0.713**	-2.013**
3.	KO1603	0.570	-0.398	0.211	-0.080	-0.252	0.388	0.438
4.	KO1604	-1.290	-0.030	-0.739**	-0.130*	0.691**	0.438	1.188**
5.	KO1605	-1.270	-1.538**	-0.509*	-0.240**	0.365*	0.088	0.788*
6.	KO1606	1.660*	0.455*	0.321	0.070	-0.288	0.388	0.638
7.	KO1607	-0.510	0.079	0.033	-0.070	-0.360**	-0.363	0.338
8.	KO1608	4.460**	2.093**	-0.062	0.220**	0.652**	-0.563*	-1.313**
SEm±		0.767	0.202	0.190	0.049	0.161	0.217	0.359
CD at 5 %		1.815	0.412	0.449	0.117	0.329	0.514	0.850
CD at 1 %		2.686	0.552	0.665	0.174	0.441	0.761	1.258

* and ** indicates significance of value at p= 0.05 and p=0.01, respectively

Table 4: Specific combining ability effects of crosses for growth parameters in okra

Sl. No.	Crosses	Plant height	Number of leaves	Internodal length	Number of branches per plant	Number of nodes on main stem	Days to first flowering	Days to 50% flowering
1	KO1601 x KO1602	5.776*	1.686*	0.852	0.092	-0.513	-0.806	-3.994**
2	KO1601 x KO1603	15.106**	-0.551	0.531	-0.268	0.127	-0.406	0.556
3	KO1601 x KO1604	-3.834	2.811**	-2.270**	0.082	3.094**	1.544*	2.806*
4	KO1601 x KO1605	-1.754	-0.191	-0.410	-0.108	-0.680	-1.106	-0.294
5	KO1601 x KO1606	-3.484	-2.004**	0.871	-0.118	-1.367**	1.094	2.356*
6	KO1601 x KO1607	7.986**	0.632	-0.142	-0.178	-0.135	0.344	0.656
7	KO1601 x KO1608	-12.984**	-0.632	0.054	0.532**	-1.357**	1.044	-0.194
8	KO1602 x KO1603	2.186	-3.519**	0.697	-0.358*	-1.241*	0.644	2.506*
9	KO1602 x KO1604	8.246**	-1.177	0.796	-0.208	-0.324	0.094	0.256
10	KO1602 x KO1605	-6.074*	-1.359*	1.236*	0.202	-1.068*	-1.556*	-3.344**
11	KO1602 x KO1606	-16.504**	-2.252**	1.087	0.092	-1.865**	2.144**	1.806
12	KO1602 x KO1607	-4.234	1.294*	-2.156**	-0.068	2.637**	-0.606	-0.894
13	KO1602 x KO1608	0.096	-1.040	0.570	-0.158	-1.345*	-1.406*	-0.244
14	KO1603 x KO1604	-1.324	-1.144	-0.875	-0.068	0.976	-0.506	0.806
15	KO1603 x KO1605	10.656**	0.524	1.355*	-0.158	-0.808	0.844	1.206
16	KO1603 x KO1606	-4.674	5.341**	-3.344**	0.232	5.255**	0.044	0.856
17	KO1603 x KO1607	-18.004**	-2.963**	1.473*	-0.128	-2.603**	-2.706**	-1.844
18	KO1603 x KO1608	-0.574	-2.037**	1.709**	-0.018	-1.485**	-0.006	-3.194**
19	KO1604 x KO1605	-17.584**	-2.534**	0.214	-0.208	-2.461**	0.794	3.456**
20	KO1604 x KO1606	10.086**	-1.027	1.875**	-0.318*	-1.538**	-1.006	-0.894
21	KO1604 x KO1607	-4.444	-1.311*	-0.698	0.022	1.374**	-1.756*	-2.094
22	KO1604 x KO1608	11.586**	3.365**	0.428	0.132	0.212	1.944**	2.556*
23	KO1605 x KO1606	6.766**	3.401**	-1.325*	0.092	2.238**	0.344	-0.494
24	KO1605 x KO1607	-2.764	-1.063	0.632	0.032	-1.160*	-0.906	-2.194
25	KO1605 x KO1608	-1.034	1.453*	-1.132	-0.058	1.988**	0.294	2.956*
26	KO1606 x KO1607	2.406	1.204	0.493	0.322*	-0.637	0.294	0.456
27	KO1606 x KO1608	10.736**	-2.740**	1.189	-0.268	-0.909	-1.006	-0.394
28	KO1607 x KO1608	-1.094	2.566**	-0.364	0.272	0.753	1.244	1.406
SEm±		2.353	0.621	0.583	0.153	0.492	0.666	1.102
CD at 5 %		4.828	1.262	1.195	0.313	1.008	1.367	2.261
CD at 1 %		6.521	1.693	1.614	0.423	1.353	1.846	3.053

*and** indicate significance of values at p= 0.05 and p= 0.01, respectively.

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