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Studies on combining ability for fruit yield and its related attributes in okra (*Abelmoschus esculents* (L.) Moench)

MA Kharat, DK Zate, DR Bhise and PA Sasane

Abstract
Combining ability effect were estimated for different character in line x tester crossing programme comprising 20 crosses produce by crossing 10 line and 2 testers. The GCA and SCA mean square were significant for all the character under study except length of fruit and internodal length. The ratio of GCA and SCA variance indicated the preponderance of non- additive gene effect for inheritance of all the character. Genotype EC-305675, EC-305672, EC- 305664, EC305741 showed good general combining ability for fruit yield appear to be worthy for exploitation of segregation and varietal development. The estimates of SCA effect revealed that the cross-combination IC-293590 x EC-305672, IC-203590 x EC-305652, Punjab-8 x EC305653were observed most promising for fruit and some related characters.

Keywords: Okra, combining ability, SCA and GCA

1. Introduction
Okra (*Abelmoschus esculentus* L. (Moench), is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. This crop is suitable for cultivation as a garden crop as well as on large commercial farms. It is grown commercially in India, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Burma, Japan, Malaysia, Brazil, Ghana, Ethiopia, Cyprus and the Southern United States.
India is the largest okra producer in the world with 6,176,000 tonnes production per year. India produces alone more than 60% of world's okra. Nigeria comes second with 1,819,018 tonnes yearly production with 512,855 tonnes of production per year, Mali is the third largest producer of okra
In India, Okra is cultivated in an area of 0.51 million hectare with 6.18 million tonnes of produce with an average productivity of 12.04 tonnes per hectare and in Maharashtra it occupies an area of 13.98 thousand hectare with an annual production of 139.40 thousand tonnes and productivity of 9.97 tonnes per hectare (Anonymous., 2018) [1]. The states which are majorly involved in okra production are west Bengal, Gujarat, Orissa, Bihar and Andhra Pradesh. Combining ability support in the evaluation of inbreds in terms of their genetic value, in the selection of suitable parents for hybridization and helps in the identification of superior cross combination, which may be useful for commercial exploitation of heterosis. The knowledge of the relative importance of general combining ability and specific combining ability for yield and its component traits are very useful in selecting parents for production of superior hybrids. Several biometrical methods are used for studying the inheritance pattern of combining ability and heterosis, among which the line x tester technique developed by (Kempthorne., 1957) has been widely used to estimate gca, sca variances and to understand the nature of gene action involved in the expression of various quantitative traits. The combining ability is the important genetic tool for the assessment of relative breeding potential of the parents and identifying the best combiners which may be hybridized to exploit heterosis. 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 pure lines among the progenies of the heterotic F_1.

2. Material and Method
The investigation on combining ability studies in okra was carried out at the Department of horticulture, College of Agriculture, VNMKV, Parbhani Dist. Parbhani, Maharashtra.

The Experimental material comprised 12 parents among which 10 line and 2 testers were collected from NBPGR, New Delhi and their 20 F1s hybrid with 3 standard checks (Mahyco bhindi No- 10, Pusa Sawani, Parbhani Kranti). Each 12-parent cross among each other in line x tester mating design crosses to derive 20 F1 hybrid. The experiment was laid out in randomized block design with two replications. Each treatment or genotype in each replication was represented by one row each according to 20 plants at a spacing row to row spacing of 60 cm and 30 cm from plant to plant. Five plants were randomly selected for each genotype from each replication and evaluated for the quantitative characters of parents and hybrid.

3. Result and Discussion

Selection of parent is an important step for planning an appropriate hybridization programme. The combining ability analysis furnishes is full information of this aspect. The analysis of variance for combining ability (Table 1) revealed that mean square due to line x tester were found highly significant for all the characters under study. The magnitude of σ2SCA variance is greater than σ2GCA variance it indicates that all the character governed by non- additive gene action similar finding were also obtained by Katagi *et al.* (2015) [5].

The estimate of gca effect (Table 1) revealed that the female parent EC-305675 (1.33) depicted maximum positive gca effect for the days to 50% flowering. female line EC-305612 (0.48) expressed Maximum positive significant gca for node at which first flower appeared. The female parent EC-305672 (2.24) depicted maximum positive gca effect for the number of fruits per plant, The female parent EC-305689 (0.61) depicted maximum positive gca effect for the number of fruits per plant. The female line EC-305612 (0.67) expressed maximum positive gca effect for length of fruit. Maximum positive gca effects were shown by female line, EC-305653(0.14) among tester IC-293590 (0.02) displayed maximum positive gca effect for diameter of fruit. The female parent EC-305652, EC-305675 and EC-305714(0.35) and among tester Punjab-8 (0.05) showed highest significant gca effect for number of ridges per fruit which might due to its high per se performance.

The female parent EC-305613 (0.61) showed highest significant gca effect for number of nodes per plant which might due to its high per se performance. The female line EC-305653 (5.22) and tester punjab8 (1.42) showed highest significant gca effect for height of plant. The parent EC-305653(0.21) depicted maximum positive gca effect for the number of branches per plant. The parent EC-305613(-0.49) depicted maximum negative gca effect for internodal length. The female line EC-305653 (4.54) showed highest significant gca effect for number of seed per fruit. The line EC-305672 (0.94) depicted maximum positive gca effect for the weight of 100 seed. The female line EC-305975 (41.02) expressed maximum positive gca effect. The female line EC-305672 (-1.22%) expressed minimum negative gca effect with respect to the pod borer infestation percentage. The female line EC-305653 (-0.63%) expressed minimum negative gca effect expressed minimum negative gca effect. With respect incidence of yellow vein mosaic virus. The estimation of specific combining effect indicated in (Table 2) The maximum positive sca effects were registered by the hybrids IC-293590 x EC-305741(2.72%) for days required to 50% flowering Similar results reported by Sapavadiya *et al*. (2019) [6]. As regard to days required for first fruit of harvest, the cross IC-293590 x EC- 305675 (-3.22) exhibited highly negative significant sca effect These results are in agreement with reported by Bhatt *et al*. (2015) [3], Wakode *et al*. (2016) [7]. The cross-combination Punjab-8 x EC-305664 (-0.28) expressed significant negative sca effect for number of nodes at first flowering which might be due to high per se performance of parent These results are in agreement with the finding reported by Wakode *et al*. (2016) [7]. Highest significant positive sca effect for the number of fruits per plant As regard to weight of fruit cross combination of IC-293590 x EC-305652(0.97) found highly positive significant sca effect which attributed to dominance variance play important role for improving this trait. These results are in agreement with reported by Bhatt *et al*. (2015) [3]. As regard with the diameter of fruit, cross IC-293590 x EC-305652(0.15) showed maximum positive sca effect which might due to significant gca effect of parent. Thus, it was observed that, non-additive variance is important for this trait. Similarly, results were obtained by Sapavadiya *et al*. (2019) [6]. As regard with the number of ridges per fruit, cross Punjab-8 x EC- 305714 showed maximum positive sca effect which might due to significant gca effect of parent. Thus, it was observed that, non-additive variance is important for this trait. Highest significant positive sca effect for the number of nodes per plant cross combination of Punjab-8 x EC-305653 These results are in agreement with reported by Bhatt *et al*. (2015) [3]. As regard with the plant height, cross Punjba-8 x EC-305653 showed maximum positive sca effect. Similarly, results were obtained by Sapavadiya *et al.* (2019) [6]. For the character of number of branches per plant, the cross IC-293590 x EC- 305653 had significant positive sca effect which is attributed due to the better gca effect of one of its parents Similarly results reported by Wakode *et al*. (2016) [7]. For the character of number of seed per fruit, the cross IC-293590 x EC- 305741 had significant positive sca effect similarly results reported by Kumar *et al*. (2021) [8]. For the character of weight of seed, the cross Punjab-8 x EC- 305689 had significant positive sca effect which is attributed due to the better gca effect of one of its parents. Similarly, results are in confirmation with the earlier findings of Adiger *et al*. (2013) [2]. With respect to fruit yield per plant, the cross IC-293590 x EC-305653 exhibited highly positive significant sca effect These results were in conformity to those reported by Wakode *et al*. (2016) [7]. With respect to pod borer infestation percentage, the cross IC-293590 x EC- 305672 exhibited minimum positive significant sca effect. With respect to the incidence of yellow vein mosaic virus, the cross IC-293590 x EC- 305613 exhibited minimum negative significant sca effect. These results were in conformity to those reported by K jagan *et al*. (2013) [4].

Table 1: The analysis of variance for combining ability revealed that mean square due to line x tester were found highly significant for all the characters under study.

SN	Genotypes	Days to 50% Flowering	No days to 1st Harvest	No. of node at 1st flowering	Number of Fruits / Plant	Fruit Weight (g)	Fruit Length (cm)	Fruit Diameter (cm)	No of Ridges / fruit	No of Nodes / plant
	Lines									
1	EC305613	-0.68 ns	-0.32 ns	-0.55 **	-0.03 ns	-0.24 ns	-0.18 ns	-0.09**	-0.15**	0.61 **
2	EC305652	-0.68 ns	0.17 ns	-0.39 **	-1.03 **	-1.01**	-0.17ns	-0.04ns	0.35 **	-0.44**
3	EC305689	0.32 ns	0.93 ns	-0.10 ns	0.54 *	0.61 *	-0.27ns	-0.01ns	-0.15**	0.24 *
4	EC305672	0.32 ns	0.17 ns	-0.04 ns	2.24 **	0.01ns	0.08ns	-0.06**	-0.15**	-0.18ns
5	EC305675	1.33 *	0.68 ns	-0.10 ns	-4.41 **	0.36ns	-1.10**	-0.06**	0.35 **	-0.51**
6	EC305664	-0.43 ns	-0.08 ns	0.28 **	1.57 **	0.34ns	0.40 *	-0.01ns	-0.15**	0.04 ns
7	EC305653	-0.43 ns	-1.33 ns	0.10 ns	-0.13 ns	0.59 *	0.20ns	0.14 **	-0.15**	0.51 **
8	EC305612	0.32 ns	0.17 ns	0.48 **	-0.09 ns	-0.11ns	0.67**	0.04 ns	-0.15**	0.04 ns
9	EC305741	-0.68 ns	-0.57 ns	0.21 **	1.97 **	-0.24ns	0.10ns	0.04 ns	-0.15**	-0.26 *
10	EC305714	0.57 ns	0.17 ns	0.10 ns	-0.61 *	-0.31ns	0.28ns	0.06 **	0.35 **	-0.06ns
	Testers									
11	Punjab-8	0.03 ns	0.03 ns	0.03 ns	-0.59 **	-0.53**	-0.03ns	-0.02 *	0.05 **	0.06 ns
12	IC-293590	-0.03 ns	-0.03 ns	-0.03 ns	0.59 **	0.53**	0.03ns	0.02 *	-0.05**	-0.06ns
	SE± (Lines)	0.72	1.05	0.08	0.36	0.31	0.26	0.03	0.00	0.15
	CD @ 5% (Lines)	1.51	2.20	0.18	0.76	0.64	0.55	0.06	0.00	0.31
	CD @ 1% (Lines)	2.05	3.02	0.25	1.04	0.88	0.75	0.08	0.00	0.42
	SE± (Testers)	0.32	0.47	0.04	0.16	0.14	0.12	0.01	0.00	0.07
	CD @ 5% (Testers)	0.67	0.99	0.08	0.34	0.29	0.24	0.03	0.00	0.14
	CD @ 1% (Testers)	0.92	1.35	0.10	0.46	0.39	0.33	0.04	0.00	0.19

SN	Genotypes	Plant Height (cm)	No of Branches/plant	Inter nodal Length (cm)	No of Seeds / Fruit	100 Seed wt (g)	Yield/Plant (g)	Pod Borer Infestation (%)	Incidence Of YVMV
	Lines								
1	EC305613	0.59 ns	-0.09 *	-0.49 *	1.19 ns	0.56 **	-1.27 ns	-0.85 *	1.77 **
2	EC305652	1.67 ns	-0.17 **	0.16 ns	-5.41 **	-0.04 ns	24.12 **	1.78 **	1.39 **
3	EC305689	-3.46 **	-0.14 **	-0.39 *	4.29 **	0.51 **	14.60 **	-2.87 **	-0.26 ns
4	EC305672	-3.66 **	-0.09 *	-0.09 ns	-2.56 *	0.94 **	22.68 **	-1.22 **	-1.01 **
5	EC305675	-5.66 **	0.11 **	0.01 ns	-1.06 ns	-0.46 **	41.02 **	-0.27 ns	1.37 **
6	EC305664	0.49 ns	-0.12 **	0.11 ns	-2.31 *	-0.34 **	21.63 **	0.30 ns	-2.13 **
7	EC305653	5.22 **	0.21 **	-0.02 ns	4.54 **	-0.01 ns	7.85 **	-0.67 ns	-0.63 **
8	EC305612	2.89 *	0.14 **	0.21 ns	-3.01 **	-0.46 **	-3.52 *	-1.37 **	-0.81 **
9	EC305741	1.09 ns	0.11 **	0.36 ns	4.39 **	0.31 **	14.78 **	4.11 **	-0.68 **
10	EC305714	0.84 ns	0.03 ns	0.14 ns	-0.06 ns	-1.01 **	11.60 **	1.06 *	0.99 **
	Testers								
11	Punjab-8	1.42 **	0.02 ns	0.02 ns	-0.06 ns	0.05 ns	13.65 **	0.15 ns	0.13 ns
12	IC-293590	-1.42 **	-0.02 ns	-0.02 ns	0.06 ns	-0.05 ns	13.65 **	-0.15 ns	-0.13 ns
	SE± (Lines)	1.43	0.05	0.26	1.49	0.13	1.86	0.53	0.21
	CD @ 5% (Lines)	2.99	0.10	0.55	3.11	0.27	3.89	1.11	0.44
	CD @ 1% (Lines)	4.10	0.14	0.75	4.26	0.37	5.33	1.52	0.60
	SE± (Testers)	0.64	0.02	0.12	0.67	0.06	0.83	0.24	0.09
	CD @ 5% (Testers)	1.34	0.05	0.24	1.39	0.12	1.74	0.50	0.20
	CD @ 1% (Testers)	1.84	0.06	0.33	1.90	0.17	2.38	0.68	0.27

*, ** denotes significance at 5% and 1% respectively.

Table 2: The estimation of specific combining effect indicated in the maximum positive sca effects

SN	Genotypes	Days to 50% Flowering	No days to 1st Harvest	No. of node at 1st flowering	Number of Fruits / Plant	Fruit Weight (g)	Fruit Length (cm)	Fruit Diameter (cm)	No of Ridges / fruit	No of Nodes / plant
1	IC293590 X EC305714	-0.27 ns	0.72 ns	-0.03 ns	-0.91 *	-0.97 **	0.08 ns	-0.15 **	-0.05 **	-0.01 ns
2	IC293590 X EC305652	0.28 ns	-0.73 ns	0.03 ns	0.91 *	0.97 **	-0.08 ns	0.15 **	0.05 **	0.01 ns
3	IC293590 X EC305689	-1.27 ns	-1.77 ns	0.32 **	0.09 ns	0.00 ns	0.18 ns	0.05 ns	0.45 **	0.19 ns
4	IC293590 X EC305612	1.27 ns	1.77 ns	-0.32 **	-0.09 ns	-0.00 ns	-0.18 ns	-0.05 ns	-0.45 **	-0.19 ns
5	IC293590 X EC305672	-1.27 ns	-1.02 ns	-0.08 ns	2.41 **	0.08 ns	-0.12 ns	0.02 ns	-0.05 **	-0.34 *
6	IC293590 X EC305653	1.27 ns	1.02 ns	0.08 ns	-2.41 **	-0.08 ns	0.12 ns	-0.02 ns	0.05 **	0.34 *
7	IC293590 X EC305613	-1.27 ns	-1.77 ns	0.12 ns	0.82 *	0.58 ns	-0.37 ns	0.07 *	-0.05 **	0.09 ns
8	IC293590 X EC305664	1.27 ns	1.77 ns	-0.12 ns	-0.82 *	-0.58 ns	0.37 ns	-0.07 *	0.05 **	-0.09 ns
9	IC293590 X EC305741	2.72 **	3.22 **	0.02 ns	-0.04 ns	0.83 *	0.01 ns	0.07 *	0.45 **	0.07 ns
10	IC293590 X EC305675	-2.73 **	-3.22 **	-0.02 ns	0.03 ns	-0.83 *	-0.01 ns	-0.07 *	-0.45 **	-0.07 ns
11	Punjab 8 x EC305675	-1.02 ns	-1.02 ns	0.04 ns	0.09 ns	0.70 *	0.30 ns	-0.03 ns	-0.05 **	0.22 ns
12	Punjab 8 x EC305652	1.02 ns	1.02 ns	-0.04 ns	-0.09 ns	-0.70 *	-0.30 ns	0.03 ns	0.05 **	-0.22 ns

13	Punjab 8 x EC305672	1.48 ns	1.23 ns	0.02 ns	-1.81 **	-0.05 ns	-0.10 ns	-0.08 *	-0.05 **	-0.61 **
14	Punjab 8 x EC305653	-1.48 ns	-1.22 ns	-0.02 ns	1.81 **	0.05 ns	0.10 ns	0.08 *	0.05 **	0.61 **
15	Punjab 8 x EC305689	-0.27 ns	-0.28 ns	-0.05 ns	-0.86 *	-0.50 ns	-0.17 ns	0.02 ns	-0.05 **	0.27 ns
16	Punjab 8 x EC305612	0.28 ns	0.28 ns	0.05 ns	0.86 *	0.50 ns	0.17 ns	-0.02 ns	0.05 **	-0.27 ns
17	Punjab 8 x EC305664	0.73 ns	0.47 ns	-0.28 **	0.09 ns	-0.17 ns	0.06 ns	0.02 ns	-0.05 **	-0.14 ns
18	Punjab 8 x EC305613	-0.72 ns	-0.48 ns	0.28 **	-0.09 ns	0.17 ns	-0.06 ns	-0.02 ns	0.05 **	0.14 ns
19	Punjab 8 x EC305741	0.48 ns	0.23 ns	-0.08 ns	0.11 ns	-0.50 ns	0.13 ns	-0.00 ns	-0.55 **	0.26 ns
20	Punjab 8 x EC305714	-0.47 ns	-0.22 ns	0.08 ns	-0.11 ns	0.50 ns	-0.13 ns	0.00 ns	0.55 **	-0.26 ns
	SE± (sca)	1.01	1.49	0.12	0.51	0.43	0.37	0.04	0.00	0.21
	CD @ 5% (sca)	2.12	3.12	0.26	1.07	0.91	0.77	0.09	0.00	0.43
	CD @ 1% (sca)	2.90	4.27	0.36	1.46	1.24	1.06	0.12	0.00	0.59

SN	Genotypes	Plant Height (cm)	No of Branches / plant	Inter nodal Length (cm)	No of Seeds / Fruit	100 Seed wt (g)	Yield/Plant (g)	Pod Borer Infestation (%)	Incidence of YVMV
1	IC293590 X EC305714	-2.17 ns	0.03 ns	-0.27 ns	-6.04 **	-0.22 ns	-25.60 **	-0.87 ns	0.37 ns
2	IC293590 X EC305652	2.17 ns	-0.03 ns	0.27 ns	6.04 **	0.22 ns	25.60 **	0.87 ns	-0.37 ns
3	IC293590 X EC305689	7.25 **	0.06 ns	0.19 ns	-1.34 ns	-0.52 **	-0.25 ns	-1.00 ns	-0.16 ns
4	IC293590 X EC305612	-7.25 **	-0.06 ns	-0.19 ns	1.34 ns	0.52 **	0.25 ns	1.00 ns	0.16 ns
5	IC293590 X EC305672	0.88 ns	-0.21 **	0.38 ns	-1.44 ns	0.03 ns	27.42 **	-1.20 *	2.34 **
6	IC293590 X EC305653	-0.88 ns	0.21 **	-0.38 ns	1.44 ns	-0.03 ns	-27.42 **	1.20 *	-2.34 **
7	IC293590 X EC305613	-1.42 ns	-0.06 ns	-0.21 ns	3.61 *	0.40 **	18.05 **	-0.60 ns	-0.56 *
8	IC293590 X EC305664	1.42 ns	0.06 ns	0.21 ns	-3.61 *	-0.40 **	-18.05 **	0.60 ns	0.56 *
9	IC293590 X EC305741	1.08 ns	-0.02 ns	0.19 ns	9.01 **	0.85 **	8.15 **	1.70 **	-1.08 **
10	IC293590 X EC305675	-1.08 ns	0.01 ns	-0.19 ns	-9.01 **	-0.85 **	-8.15 **	-1.70 **	1.08 **
11	Punjab 8 x EC305675	4.73 **	0.11 *	0.28 ns	-4.34 **	-0.02 ns	15.60 **	1.07 ns	-0.58 *
12	Punjab 8 x EC305652	-4.73 **	-0.11 *	-0.28 ns	4.34 **	0.02 ns	-15.60 **	-1.07 ns	0.58 *
13	Punjab 8 x EC305672	-11.30 **	0.04 ns	-0.44 ns	-4.19 *	-0.65 **	-19.23 **	1.05 ns	-1.08 **
14	Punjab 8 x EC305653	11.30 **	-0.04 ns	0.44 ns	4.19 *	0.65 **	19.23 **	-1.05 ns	1.08 **
15	Punjab 8 x EC305689	1.53 ns	0.01 ns	-0.02 ns	-4.14 *	0.90 **	-13.85 **	-1.80 **	2.19 **
16	Punjab 8 x EC305612	-1.53 ns	-0.01 ns	0.02 ns	4.14 *	-0.90 **	13.85 **	1.80 **	-2.19 **
17	Punjab 8 x EC305664	-3.67 *	0.09 ns	-0.16 ns	1.46 ns	-0.27 *	-4.65 *	-0.08 ns	-0.58 *
18	Punjab 8 x EC305613	3.67 *	-0.09 ns	0.16 ns	-1.46 ns	0.27 *	4.65 *	0.08 ns	0.58 *
19	Punjab 8 x EC305741	3.08 *	-0.04 ns	0.06 ns	7.41 **	-0.50 **	-5.63 **	1.73 **	-0.86 **
20	Punjab 8 x EC305714	-3.08 *	0.04 ns	-0.06 ns	-7.41 **	0.50 **	5.63 **	-1.73 **	0.86 **
	SE± (sca)	2.03	0.07	0.37	2.10	0.18	2.63	0.75	0.30
	CD @ 5% (sca)	4.24	0.14	0.77	4.40	0.39	5.50	1.57	0.62
	CD @ 1% (sca)	5.80	0.20	1.05	6.02	0.53	7.53	2.15	0.85

Conclusion

1. The parents EC-305675, EC-305672, EC-305664, EC305741, were found to be good general combiners for growth and yield contributing characters. While, the parent EC- 305675 (2.9%) has recorded minimum pod borer infestation while, the parent EC-305664 (4.4%) have recorded minimum incidence of yellow vein mosaic virus. The overall performance of parents EC-305741, EC-305652, EC-305689, Punjab-8 were found promising. Hence, they may be used in further breeding programme for improvement in okra.
2. The hybrid derivatives or crosses like combinations IC-293590 x EC-305653, IC-293590 x EC-305741, Punjab-8 x EC-305613, IC-293590 x EC-305652, Punjba-8 x EC305653 Punjab-8 x EC-305714 were found promising hybrid for the growth characters like plant height, number of branches, number of nodes per plant, node at which first flower appeared days required to 50% flowering, days required for first fruit of harvest and yield contributing characters like number of fruit per plant, length of fruit, weight of fruit, diameter of fruit, number of seed per fruit, weight of 100 seed, fruit yield per plant. They have also exhibited higher additive variance. Hence, they may be exploited for development of hybrid in okra.

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