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Combining Ability Studies for Growth, Yield and its Related Traits in Okra [*Abelmoschus esculentus* (L.) Moench]

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ABSTRACT: An experiment was conducted on okra crop with ten genotypes and their 45 F_1's obtained from diallel excluding reciprocal during 2020. The experiment was sown in randomized block design with three replications at vegetable research farm, BUAT, Banda to estimate the combining ability of various economically importance traits for genetic improvement and their effects in the population. Both general combining ability (GCA) and specific combining ability (SCA) variances were highly significant for most of the characters indicating the importance of both additive and non-additive gene actions. The parents P_6, P_7 and P_2 were identified as good GCA for node at first flower appear, fruit diameter, 50% flowering, seed weight/fruit, 100- seed weight, seed yield and fruit length. The parent P_{10} was found good GCA for fruit weight and plant height (cm) and the parent P_8 was identified as good general combiner for fruit yield/plant and fruit yield q/ha^{-1}. The crosses were identified as good SCA effects P_5 x P_6 for days to first flowering, P_1 × P_{10} for node at first flower appear, P_5 × P_7 for days to edible fruit maturity showed significant positive effect for more than one traits recommended their value in speed up of breeding programme. The best parents and their matings are used for breeding to improve the yield component.

Keywords: ANOVA, Combining ability, Diallel, GCA, SCA.

INTRODUCTION

Okra (*Abelmoschus esculentus* L. (Moench) is an economically important vegetable crop grown in the tropical and sub-tropical parts of the world. which have chromosome number 2n=2x=130 (Patil *et al.,* 2015). It is native of Tropical Africa (Yawalkar, 1980 and Benchasri, 2012). The immature green seed pods are the edible part of this plant which are consumed as cooked vegetable, mostly fresh but sometimes sun-dried (Liu *et al.,* 2021). Okra is gaining importance with regard to its nutritional, medicinal and industrial value. Apart from nutritional and health importance, okra plays an important role in income generation and subsistence among rural farmers in developing countries like India. Okra is commercially grown in the Indian states of Andhra Pradesh, Gujarat, Maharashtra, Karnataka and Tamil Nadu (Raikar *et al.,* 2020). It represents 13% of the total fresh vegetable exports and having potential to earn foreign currency. Commercial exploitation of hybrid vigour in okra is simple due to its ease emasculation; high fruit set rate and huge amount of seeds per fruit (Varmu *et al.,* 2011). Being an often cross-pollinated crop, out crossing to an extent of 5 to 9% by insects is reported which renders considerable genetic diversity (Duggi *et al.,* 2013). Hence, the first step in okra improvement should involved evaluation of the germplasm for genetic variability. As a second step, it is required to generate crosses employing a suitable mating design to know the extent of heterosis for various economic traits and inheritance pattern of desired characters, which in turn, would help in deciding the breeding strategies as well as identifying potential parents and crosses for further use in breeding programme (Singh and Singh 2012). Combining ability helps to assess the genetic value, selection of suitable parents for hybridization and identification of good hybrid cross combinations that can be utilized for commercial exploitation of heterosis (Das *et al.,* 2020).

The prominent position of okra among Indian vegetables can be due to its easy cultivation, dependable and regular yield, wider adaptability and year round cultivation. In spite of its importance, no major breakthrough has been made in this crop and the farmers are still growing their own local varieties or open pollinated varieties. Hence, there is a need for restructuring this vegetable crop for increasing the productivity. Therefore, the present investigation was undertaken to obtain the information on combining ability and mode of gene action in okra genotypes for yield and quality parameters.

MATERIAL AND METHODS

The present investigation on combining ability studies in okra was carried out at the Vegetable Research Farm, Department of Vegetable Science, Banda University of Agriculture and Technology, Banda, Uttar Pradesh during *rabi* season by providing good agronomic practices to keep the crop in good condition. The material for experimentation comprised of 10 distinct genotypes [Arka Anamika (P_1), Kashi Pragati (P_2), Hisar Naveen (P_3), Hisar Unnat (P_4), Punjab-8 (P_5), Pusa A-4 (P_6), Varsha Uphar (P_7), Akola Bahar (P_8), Phule Vimukta (P_9) and Punjab Suhavani (P_{10})] collected from different research Institutes & SAU_s and maintained in department of vegetable science. These 10 lines were crossed in all the possible combination in diallel technique, excluding reciprocals crosses to derive all possible 45 F_1 hybrids and seeds were collected under study purpose. The parents were also maintained through selfing. All the 45 F_1s seeds along with 10 parents were sown in randomized block design (RBD) with three replications during *kharif* season. Each treatment or a genotype in each replication was represented by one row each accommodating 10 plants at a row to row spacing of 60cm and 30cm from plant to plant. The observations were recorded on randomly selected five plants in each replication of F_1s and their parents. The selected plants were tagged and properly labeled before flowering for taking observations, *viz.* Days to first flowering, Days to 50% flowering, Plant height (cm), Number of branches per plant, Node at which first flower Appear, Internodal length (cm), Number of nodes per plant, Number of fruits per plant, Fruit yield per plant (g), Fruit yield (q ha^{-1}), Fruit length (cm), Fruit diameter (cm), Fruit weight (g), Days to edible fruit maturity, Number of seeds per fruit, Seed weight per fruit, 100-Seed weight and Seed yield per plant. The combining ability analysis was carried out by the procedure suggested by Griffing (1956a&b) and Robinson (1996) was taken up for the material under study.

RESULTS AND DISCUSSIONS

General Combining Ability (GCA). During experimentation, variance due to general combining ability (GCA) and specific combining ability (SCA) are presented in (Table 1). It is evident from the table that mean squares due to GCA were highly significant for all the characters except days to edible fruit maturity and fruit diameter (cm). Were SCA had also highly significant for all the eighteen characters studied. The estimation of GCA effects of the parents for all the eighteen characters are presented in (Table 1).

Table 1: Analysis of variance (mean squares) for combining ability in methods-II model-I of diallel analysis in okra.

Source of variation	Degree of freedom	Days to First Flowering	Days to 50% Flowering	Node at first flower appear	Days to Edible Fruit Maturity	Number of Node Per Plant	Internodal length (cm)	Number of branches/ plant	Plant height (cm) at harvesting	No. of fruit per plant
GCA	9	5.930 **	5.205 ***	0.573 ***	3.691	5.338 ***	1.208 ***	0.312 ***	257.562 ***	10.255 ***
SCA	45	4.407 ***	3.719 ***	0.502 ***	7.360 *	7.026 ***	0.445 ***	0.146 ***	235.007 ***	12.006 ***
Error	108	2.053	1.109	0.077	4.221	1.477	0.103	0.028	9.031	1.986

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Source of variation	Degree of freedom	Fruit Weight (g)	Fruit Length (cm)	Fruit diameter (cm)	No. of Seeds per fruit	Seed Weight Per Fruit	100-Seed Weight	Seed Yield Per Plant (g)	Fruit yield per plant (g)	Fruit yield quintal per hectare
GCA	9	8.498 ***	0.760 **	0.011	23.342 ***	0.421 ***	0.603 ***	81.242 ***	3684.924 ***	1137.299 ***
SCA	45	17.520 ***	0.592 **	0.022 ***	24.470 ***	0.320 ***	0.733 ***	69.841 ***	1651.759 ***	509.792 ***
Error	108	1.241	0.286	0.006	4.108	0.063	0.084	21.584	120.959	37.332

* - Significant at 5 per cent probability level, ** - Significant at 1 per cent probability level

For days to first flowering, number of seed per fruit and other maturity traits general combiners with negative values are desirable. The general combiners with negative value are usually desirable for the character days taken to first flowering. Out of ten parental lines, one parent namely P_7 (-0.817) showed significant and negative GCA estimates and they were classified as good general combiners (Table 2). Out of ten parental lines, one lines *viz.,* P_6 (-0.828) showed significant and negative GCA effect in desirable direction for days to 50 % flowering (Table 2). During study, node at which first flower appears, general combiners with negative values are usually desirable. Out of ten parental lines two expressed the negative significant GCA effects.

The most desirable parental lines was P_2 (-0.177) and P_{10} (-0.153) both are valuable because this showed highly negative significant GCA effects (Table 2). Earliness for days to edible fruit maturity is most important character in okra. None of the parents showed significant GCA effects in desirable direction (Table 2). Two parental lines *viz.,* P_7 (1.230) and P_5 (0.733) showed positive significant GCA effect for number of node per plant. However, 2 lines were poor general combiners in which P_1 exhibited significant GCA effects with a higher value (-0.932) followed by P_4 (-0.677) (Table 2).

Table 2: Estimates of GCA effects of parents for Days to First Flowering, Days to 50% Flowering, Node at first flower appear, Days to Edible Fruit Maturity, Number of Node Per Plant, Internodal length (cm), Number of branches/ plant, Plant height (cm) at harvesting and No. of fruit per plant characters in Okra.

Parents	Days to First Flowering	Days to 50% Flowering	Node at first flower appear	Days to Edible Fruit Maturity	Number of Node Per Plant	Internodal length (cm)	Number of branches/ plant	Plant height (cm) at harvesting	No. of fruit per plant
P_1	1.100 **	0.589 *	-0.145	0.220	-0.932 **	-0.434 ***	0.092 *	-4.738 ***	-1.593 ***
P_2	0.850 *	0.617 *	-0.177 *	0.665	0.103	-0.524 ***	-0.181 ***	-7.392 ***	0.444
P_3	-0.456	-0.522	0.123	-0.224	-0.321	0.345 ***	0.220 ***	2.004 *	0.155
P_4	-0.678	-0.494	-0.117	-0.837	-0.677 *	-0.138	0.021	1.184	-1.053 **
P_5	0.739	0.839 **	-0.071	0.247	0.733 *	-0.152	-0.107 *	4.534 ***	-0.568
P_6	-0.150	-0.828 **	0.171 *	-1.048	-0.578	0.150	0.070	1.973 *	0.188
P_7	-0.817 *	-0.494	0.527 ***	0.253	1.230 ***	0.135	-0.289 ***	-3.039 ***	1.614 ***
P_8	0.183	-0.050	-0.085	-0.046	0.419	0.283 **	0.010	-4.859 ***	0.881 *
P_9	-0.761	-0.522	-0.074	0.349	-0.028	-0.063	-0.041	5.148 ***	0.170
P_{10}	-0.011	0.867 **	-0.153 *	0.421	0.050	0.397 ***	0.205 ***	5.183 ***	-0.239
S.E. (gi)	0.888	0.652	0.171	1.273	0.753	0.199	0.103	1.862	0.873
S.E. (gi-gj)	1.275	0.937	0.246	1.828	1.082	0.286	0.149	2.675	1.254

* - Significant at 5 per cent probability level ; ** - Significant at 1 per cent probability level

For Internodal length, estimates of negative GCA effects values are considered desirable. Two potential lines P_2 (-0.524) and P_1 (-0.434) expressed this trends and were classified as the good general combiners (Table 2). Three parental line *viz.,* P_3 (0.220) followed by P_{10} (0.205) and P_1 (0.092) were best general combiner as they showed significant GCA effect in desirable direction for this trait. On the other hand, parent P_7 (-0.289), P_2 (-0.181) and P_5 (-0.107) exhibited significant and negative GCA effect was considered as poor general combiner for this trait. Rest of the parents were considered as average as average combiners due to non-significant GCA effects. In order to merit, five parents lines were found to be positively significant GCA effects, in which P_{10} (5.183) followed by P_9 (5.148) and P_5 (4.534) were identified as good combiners for plant height which is desirable in okra. On the other hand, four parents were found to be negatively significant GCA effects, in which P_2 (-7.392) followed by P_8 (-4.859) and P_1 (-4.738) were proved to be poor general combiners since they exhibited significant and negative GCA effects. The rests of the parents were average combiner for this trait as they showed non-significant GCA effects. A critical examination of (Table 2) reveled that only two parents *viz.,* P_7 (1.614) and P_8 (0.881) exhibited significant and positive GCA effect and hence, it was depicted as good general combiner for this trait. On the other hand, two parent *viz.,* P_1 (-1.593) and P_4 (-1.053) exhibited significant and negative GCA effects and were considered as poor general combiner due to non-significant GCA effects. Significant and positive GCA effects for 10-fruits weight were observed in three parents *viz.,* P_{10} (0.900) followed by P_8 (0.704) and P_2 (0.630). Thus, they were registered as good general combiners for fruit weight (gm). On other hand, three parents *viz.,* P_1 (-1.752) followed by P_3 (-0.937) and P_9 (-0.643) exhibited significant and negative GCA effects, hence they were proved as poor general combiner for this trait. The rest of the parents were average combiner for this trait as they showed non-significant GCA effects. Estimates of GCA effects revealed that one parent *viz.,* P_7 (0.559) was considered as good combiner for fruit length as it had exerted significant and positive GCA effect, on other hand, one parents *viz.,* P_2 (-0.353) exhibited significant and negative GCA effects. While rest of the parents were average combiner for this trait as they showed non-significant GCA effects. A critical examination of Table 3 revealed that only one parent i.e. P_2 (0.062) showed good combiners as they had significant effect in desirable direction for fruit diameter. On the other hand no any parents exhibited significant and negative GCA effects and were considered as poor general combiners for this trait. Rests of the parents were considered as negative combiners due to non- significant GCA effects. In order of merit, P_4 (-1.803) followed by P_1 (-1.701), P_3 (-1.322) and P_9 (-1.106) exhibited significant and negative GCA effects which is desirable in okra hence, expressed as good combiners for number of seeds per fruit. On the other hand, parent P_{10} (2.259) and P_5 (1.162) was proved to be poor general combiner since it exhibited significant and positive GCA effect for this trait, while rest of the parents were average combiner for this traits as they showed non-significant GCA effects. In seed weight per fruit, two parental lines *viz.,* P_6 (0.340) and P_1 (0.251) shows valuable positive significant GCA effects and found to be good combiners for this trait. On the other hand, three parents *viz.,* P_4 (-0.253), P_7 (-0.179) and P_8 (-0.139) exhibited significant and negative GCA effects and were considered as poor general combiners for this trait. The rests of the parents were considered as average combiners due to non-significant GCA effects. In 100-seed weight only three parents *viz.,* P_6 (0.459) followed by P_3 (0.194) and P_7 (0.163) were considered as good combiners for 100-Seed weight as they had exerted significant positive GCA effects. On other hand, parent P_2 (-0.289), P_4 (-0.226) and P_1 (-0.166) exhibited significant and negative GCA effects suggested that poor general combiners for this trait (Table 3). The rests of the parents were considered as average combiners due to non-significant GCA effects. In seed yield per plant, only one parent line *i.e.* P_6 (4.056) were found for positive significant GCA effects, this is desirable for okra. On the other hand, two parents *viz.,* P_8 (-3.862) and P_{10} (-3.291) exhibited significant and negative GCA effects and were poor general combiner for this trait. The rests of the parents were considered as average combiners due to non- significant GCA effects. For fruit yield per plant two parents P_8 (30.719) and P_3 (29.156) showed significant positive GCA effects whereas, five parental lines were poor general combiner, with negative GCA effects (Table 3).

Table 3: Estimates of GCA effects of parents for Fruit Weight in (g), Fruit Length (cm), Fruit diameter (cm), No. of Seed per fruit, Seed Weight Per Fruit, 100- Seed Weight, Seed Yield Per Plant (g), Fruit yield per plant (g), Fruit yield quintal per hectare character in okra.

Parents	Fruit Weight in (g)	Fruit Length (cm)	Fruit diameter (cm)	No. of Seed per fruit	Seed Weight Per Fruit	100- Seed Weight	Seed Yield Per Plant (g)	Fruit yield per plant (g)	Fruit yield quintal per hectare
P_1	-1.752 ***	-0.192	-0.017	-1.701 **	0.251 ***	-0.166 *	2.393	-10.112 **	-5.618 **
P_2	0.630 *	-0.353 *	0.062 **	0.834	0.001	-0.289 ***	0.878	5.670	3.150
P_3	-0.937 **	0.207	-0.027	-1.322 *	0.086	0.194 *	1.644	29.156 ***	16.198 ***
P_4	0.332	-0.043	0.005	-1.803 **	-0.253 ***	-0.226 **	-1.566	-10.657 ***	-5.921 ***
P_5	0.248	-0.130	-0.007	1.162 *	-0.115	-0.043	1.950	-17.528 ***	-9.737 ***
P_6	0.219	-0.076	0.032	0.109	0.340 ***	0.459 ***	4.056 **	-0.745	-0.414
P_7	0.298	0.559 ***	-0.031	0.746	-0.179 *	0.163 *	-0.448	-7.297 *	-4.054 *
P_8	0.704 *	-0.011	-0.020	0.822	-0.139 *	-0.116	-3.862 **	30.719 ***	17.066 ***
P_9	-0.643 *	0.137	0.025	-1.106 *	0.029	0.011	-1.754	-0.209	-0.116
P_{10}	0.900 **	-0.098	-0.022	2.259 ***	-0.021	0.012	-3.291 *	-18.998 ***	-10.554 ***
S.E. (gi)	0.690	0.332	0.048	1.256	0.156	0.180	2.878	6.813	3.785
S.E. (gi-gj)	0.992	0.476	0.069	1.804	0.224	0.259	4.135	9.788	5.438

* - Significant at 5 per cent probability level ; ** - Significant at 1 per cent probability level

Parents P_8 the best general combiner for fruit yield per plant was also found as the best general combiner for fruit yield per plant. Estimates of GCA effects reveled that two parents *viz.,* P_8 (17.066) and P_3 (16.198) were considered as good general combiners for fruit yield q/ha^{-1} as they had exerted significant and positive GCA effects which is considered as desirable traits in okra. On the other hand, parent P_{10} (-10.554) followed by P_5 (-9.737) and P_4 (-5.921) exhibited significant and negative GCA effect suggested that poor general combiner for this trait. Remaining parents were considered as average combiners due to non-significant GCA effects. Similar result were found by Similar correspondence between these parameters was observed by Gill and Kumar (1988) in water melon, Musmade and Kale (1986) in cucumber, Jindal and ghai (2005); Rai *et al.* (2011); Singh *et al.* (2012); Vachhani *et al.* (2012); Nimbalkar (2017); Ivin *et al.* (2022) in okra.

Specific Combining Ability (SCA). The estimates of SCA effects (S_{ij}) of 45 F_1s crosses and their standard errors of different comparisons were studied for eighteen metric traits and the results have been presented in (Table 4). The SCA effects in negative directions was considered desirable for maturity traits *viz.,* days to first flowering, days to 50 per cent flowering and days to edible fruit maturity. Out of 45 F_1 hybrids, three showed significant and negative SCA effects in desirable direction for days to first flowering. The highest, significant and negative SCA effect was observed in cross $P_5 \times P_6$ (-4.328) followed by $P_2 \times P_{10}$ (-3.578) and $P_4 \times P_7$ (-3.578). Five crosses had found significant and positive SCA effects for late flowering (Table 4). Estimates of specific combining ability for earliness in respect of days to 50 % flowering were significantly negative and desirable in five hybrids. The crosses $P_5 \times P_7$ (-3.854) followed by $P_2 \times P_{10}$ (-3.659) and $P_3 \times P_5$ (-2.826) were found as the best three specific combiners (Table 4). Eight crosses had found significant and positive SCA effects for late flowering. The significant negative SCA effects for earliness for node at which first flower appear were observed in 9 hybrids. The best three promising crosses in order of performance for earliness were $P_1 \times P_{10}$ (-1.014) exhibits maximum negative SCA effects followed by $P_1 \times P_5$ (-0.983) and $P_1 \times P_4$ (-0.911) were identified as good specific combiner for this trait (Table 4). On the other hand, 13 crosses showed positively significant which is not desirable for this trait (Table 4). The magnitude of SCA effects in hybrids varied from -4.337 ($P_5 \times P_7$) to 9.671 ($P_7 \times P_9$). Out of 45 crosses, one cross combinations showed significant and negative SCA effects for days to edible fruit maturity. The highest SCA effect was exhibited by the cross $P_5 \times P_7$ (-4.337) (Table 4). The spectrum of variation for SCA effects in hybrids was from -5.786 ($P_5 \times P_6$) to 3.461 ($P_3 \times P_{10}$) (Table 4).

Table 4: Estimates of SCA effects of F_1 hybrids for Days to First Flowering, Days to 50% Flowering, Node at first flower appear, Days to Edible Fruit Maturity, Number of Node Per Plant, Internodal length (cm), Number of branches/ plant, Plant height (cm) at harvesting and No. of fruit per plant characters in Okra.

Crosses	Days to First Flowering	Days to 50% flowering	Node at First Flower appear	Days to Edible Fruit Maturity	Number of Node Per Plant	Internodal Length (cm)	Number of Branches Per Plant	Plant Height (cm) at harvesting	Number of Fruit Per Plant
P_1 x P_2	-1.023	-0.048	0.073	-3.805	0.182	0.193	-0.144	-1.955	0.505
P_1 x P_3	-2.384	-0.909	0.213	-1.225	0.420	-0.625 *	-0.142	-10.431 ***	-0.999
P_1 x P_4	0.505	1.063	-0.911 ***	1.548	-2.635 *	-0.056	-0.633 ***	2.866	-2.788 *
P_1 x P_5	-0.578	-0.604	-0.983 ***	0.333	0.848	0.622 *	0.222	-10.893 ***	-2.920 *
P_1 x P_6	1.977	2.063 *	-0.368	2.372	1.339	0.940 **	-0.111	21.947 ***	-0.895
P_1 x P_7	3.977 **	2.396 *	-0.625 *	1.544	-0.185	-0.608 *	-0.406 *	-5.254	0.189
P_1 x P_8	0.977	1.285	0.708 **	1.787	-3.087 **	-0.364	0.702 ***	4.535	2.892 *
P_1 x P_9	-2.078	-1.909	0.267	-2.405	-1.391	-1.224 ***	-0.570 ***	-7.018 *	3.390 *
P_1 x P_{10}	0.505	-0.631	-1.014 ***	0.783	2.861 *	-0.424	0.457 **	18.140 ***	-5.652 ***
P_2 x P_3	3.199 *	2.396 *	-0.178	2.552	-5.052 ***	-0.342	-0.282	15.680 ***	-6.665 ***
P_2 x P_4	3.422 *	2.369 *	0.691 **	6.245 **	1.301	-0.443	0.330 *	-16.283 ***	1.692
P_2 x P_5	0.338	0.702	-0.731 **	1.551	1.894	-1.575 ***	-0.321 *	-14.666 ***	5.227 ***
P_2 x P_6	0.227	0.702	0.227	1.373	3.288 **	-0.624 *	0.379 *	17.374 ***	-1.192
P_2 x P_7	1.894	1.035	-0.353	0.191	2.074	0.522	0.624 ***	5.144	3.639 **
P_2 x P_8	0.227	-0.076	-0.323	1.234	-0.256	0.933 **	-0.391 *	32.350 ***	-1.842
P_2 x P_9	-1.162	-1.270	0.819 **	-2.001	1.558	0.792 *	0.013	-21.221 ***	-2.464
P_2 x P_{10}	-3.578 **	-3.659 ***	-0.636 *	-3.140	-0.870	0.016	0.074	-8.882 **	1.042
P_3 x P_4	-1.606	-1.492	-0.619 *	-1.585	2.258 *	-0.234	0.506 **	-30.123 ***	1.902
P_3 x P_5	-1.356	-2.826 **	-0.317	-2.916	2.591 *	0.304	-0.079	20.551 ***	-1.594
P_3 x P_6	-0.801	-0.159	-0.546 *	-0.244	-3.804 **	0.221	-0.036	15.328 ***	1.987
P_3 x P_7	1.533	1.174	0.314	0.168	-0.159	-0.317	-0.341 *	-17.753 ***	-4.345 **
P_3 x P_8	1.533	2.730 **	0.930 ***	2.977	-4.268 ***	-0.159	0.404 *	-12.493 ***	4.474 **
P_3 x P_9	-0.523	-0.798	0.816 **	-1.731	2.159	0.617 *	0.479 **	13.183 ***	3.629 **
P_3 x P_{10}	0.061	2.146 *	-0.076	2.373	3.461 **	0.621 *	-0.191	-7.755 **	2.344
P_4 x P_5	-0.134	0.480	0.556 *	-0.957	-2.280 *	0.026	0.227	16.315 ***	0.877
P_4 x P_6	-0.912	-0.520	-0.119	-2.068	-0.565	0.381	-0.574 ***	-9.542 **	-1.635
P_4 x P_7	-3.578 **	-0.854	0.717 **	-1.963	2.190	-0.291	0.018	14.858 ***	5.176 ***
P_4 x P_8	-0.912	-0.965	0.610 *	-0.733	1.461	0.597 *	-0.053	4.597	1.892
P_4 x P_9	3.366 *	2.508 *	-0.814 **	2.802	-2.592 *	0.547	0.631 ***	14.153 ***	0.573
P_4 x P_{10}	-0.051	0.452	1.187 ***	-0.464	0.273	-0.590	0.085	12.432 ***	-2.361
P_5 x P_6	-4.328 **	-2.187 *	-0.485	-2.195	-5.786 ***	0.772 *	0.452 **	14.959 ***	5.417 ***
P_5 x P_7	-0.995	-3.854 ***	-0.415	-4.377 *	0.753	1.310 ***	-0.120	-18.368 ***	2.277
P_5 x P_8	0.672	1.369	0.018	1.999	-2.529 *	-0.418	0.352 *	-9.219 **	-5.247 ***
P_5 x P_9	2.283	0.841	0.714 **	-0.223	-0.439	-0.922 **	-0.434 **	-4.083	1.568
P_5 x P_{10}	-0.134	-0.215	-0.311	-0.825	1.973	-0.586	-0.343 *	-20.225 ***	-2.357
P_6 x P_7	1.561	1.813	0.277	0.835	2.231	-0.449	0.526 **	-7.688 **	-4.182 **
P_6 x P_8	2.894 *	2.035 *	-0.271	0.955	3.302 **	-0.507	-0.662 ***	-1.132	5.794 ***
P_6 x P_9	-0.828	-1.159	-0.365	-1.467	-1.531	-0.174	0.165	-1.053	-4.141 **
P_6x P_{10}	2.422	1.785	0.604 *	1.804	-4.086 ***	0.349	0.046	-21.264 ***	3.505 **
P_7 x P_8	0.227	0.369	-0.254	-1.141	1.694	0.415	-0.003	-8.093 **	-1.932
P_7 x P_9	0.172	0.174	0.445	9.671 ***	-5.139 ***	-0.996 **	-0.296	-10.643 ***	1.136
P_7x P_{10}	0.755	0.119	0.447	-0.235	-4.394 ***	0.321	0.228	18.875 ***	2.565
P_8 x P_9	0.838	-0.270	-0.076	0.774	2.575 *	-1.001 **	-0.314 *	-9.674 **	-3.411 *
P_8x P_{10}	2.422	1.674	0.683 *	0.518	0.977	0.252	-0.504 **	-17.936 ***	3.065 *
P_9x P_{10}	-1.634	-2.520 *	0.875 **	-2.097	0.714	0.725 *	0.334 *	4.384	4.786 ***
Sij<>0 at 5%	2.660	1.955	0.514	3.814	2.256	0.596	0.310	5.579	2.616
Sij <> 0 at 99%	3.553	2.612	0.686	5.095	3.014	0.796	0.414	7.453	3.494
Sij—Sik at 95%	3.910	2.874	0.755	5.606	3.317	0.876	0.456	8.201	3.845
Sij--Sik at 99%	5.223	3.839	1.009	7.489	4.430	1.171	0.609	10.955	5.137

*, ** - Significant at 5 per cent and 1 per cent probability level, respectively.

Out of 45 crosses, eight are showed significant and positive SCA effects for number of node per plant. The highest, significant and positive SCA effect was observed in cross $P_3 \times P_{10}$ (3.461) followed by $P_6 \times P_8$ (3.302) and $P_2 \times P_6$ (3.288) which is desirable good specific combiners for this trait. Out of 45 crosses, eight crosses exhibits significant and negative SCA effects for less Internodal length which is desirable trait. The highest, significant and negative SCA effect was observed in cross $P_2 \times P_5$ (-1.575) followed by $P_1 \times P_9$ (-1.224) and $P_8 \times P_9$ (-1.001) (Table 4). Ten crosses had found significant and positive SCA effects for more Internodal length. The significant variation of specific combining ability effects in hybrids ranged from -0.663 ($P_1 \times P_4$) to 0.702 ($P_1 \times P_8$) (Table 4). Out of 45 crosses, thirteen hybrids showed significant and positive SCA effects, therefore, they were considered as good specific combinations for more number of branches per plant. While twelve crosses noted as poor specific cross combinations as they noted significant and negative SCA effects. The magnitude of SCA effects in hybrids varied from -30.123 ($P_3 \times P_4$) to 32.350 ($P_2 \times P_8$) (Table

4). Out of 45 crosses, fourteen hybrids exhibited significant and positive SCA effects for this trait. The crosses $P_2 \times P_8$ (32.350) rank first trailed by $P_1 \times P_6$ (21.947) and $P_3 \times P_5$ (20.551) (Table 4) for this trait. Among the 45 crosses producing significant SCA effects, twelve crosses were in desired direction.

Table 5: Estimates of SCA effects of F_1 hybrids for Fruit Weight in (g), Fruit Length (cm), Fruit diameter (cm), No. of Seed per fruit, Seed Weight Per Fruit, 100- Seed Weight, Seed Yield Per Plant (g), Fruit yield per plant (g), Fruit yield quintal per hectare character in okra.

Crosses	Fruit Weight (g)	Fruit Length (cm)	Fruit diameter (cm)	Number of Seed per Fruit	Seed Weight per Fruit (g)	100-Seed Weight	Seed Yield Per Plant (g)	Fruit Yield Per Plant (g)	Fruit Yield quintal per hectare
$P_1 \times P_2$	0.989	0.651	-0.117	0.174	-0.123	0.210	5.143	26.675 *	14.819 *
$P_1 \times P_3$	1.053	-0.723	0.186 *	0.663	-0.778 **	-0.760 **	-5.656	11.345	6.303
$P_1 \times P_4$	2.221 *	0.360	0.097	3.715	0.364	0.376	1.748	-26.702 *	-14.834 *
$P_1 \times P_5$	-1.942	0.564	0.083	2.053	0.516 *	0.730 **	4.435	-14.885	-8.269
$P_1 \times P_6$	-3.887 ***	0.046	-0.013	-0.494	0.188	0.285	3.095	-19.028	-10.571
$P_1 \times P_7$	1.395	-0.382	-0.071	-3.428	-0.317	-0.793 **	-2.134	-49.519 ***	-27.510 ***
$P_1 \times P_8$	-0.688	-0.208	0.006	-2.023	0.300	0.813 **	4.263	33.725 **	18.736 **
$P_1 \times P_9$	-0.890	0.313	-0.179 *	-10.219 ***	0.098	0.603 *	-3.341	25.270 *	14.039 *
$P_1 \times P_{10}$	-1.121	-0.018	0.030	-3.140	-0.401	-0.582 *	-9.828 *	-39.895 ***	-22.164 ***
$P_2 \times P_3$	-5.939 ***	-0.462	0.107	-9.788 ***	-0.031	0.167	-6.328	35.877 ***	19.931 ***
$P_2 \times P_4$	-3.371 **	0.048	-0.025	2.093	-1.019 ***	-1.497 ***	-24.964 ***	1.194	0.663
$P_2 \times P_5$	2.609 *	-1.031 *	0.201 **	3.291	-0.204	-0.077	1.046	-63.486 ***	-35.270 ***
$P_2 \times P_6$	6.638 ***	-0.086	-0.072	-2.512	0.025	0.518	1.183	-22.026 *	-12.236 *
$P_2 \times P_7$	-5.684 ***	-0.173	-0.023	2.454	1.283 ***	1.801 ***	-2.913	-42.400 ***	-23.555 ***
$P_2 \times P_8$	2.733 *	-0.030	0.150 *	-6.878 ***	-0.290	-0.793 **	7.584	56.530 ***	31.405 ***
$P_2 \times P_9$	7.077 ***	0.648	0.069	7.673 ***	0.265	1.046 ***	6.997	20.539 *	11.410 *
$P_2 \times P_{10}$	-2.093 *	1.097 *	-0.058	1.288	-0.991 ***	-1.482 ***	-0.943	1.524	0.847
$P_3 \times P_4$	-4.670 ***	-0.732	-0.219 **	3.635	-0.250	0.000	3.887	23.061 *	12.811 *
$P_3 \times P_5$	2.923 **	0.488	-0.173 *	-4.873 *	0.514 *	0.797 **	6.621	31.844 **	17.691 **
$P_3 \times P_6$	2.462 *	-0.193	-0.023	-1.566	0.627 **	1.249 ***	-4.982	-53.392 ***	-29.662 ***
$P_3 \times P_7$	8.094 ***	1.153 *	-0.093	-1.867	0.172	-0.069	6.578	15.484	8.602
$P_3 \times P_8$	-2.216 *	0.316	0.053	0.294	0.642 **	0.687 *	-2.344	-75.919 ***	-42.177 ***
$P_3 \times P_9$	1.038	0.481	0.021	8.105 ***	-0.586 *	-0.350	-1.379	-22.941 *	-12.745 *
$P_3 \times P_{10}$	-1.425	-0.783	0.274 ***	4.497 *	0.137	0.698 *	3.728	14.914	8.286
$P_4 \times P_5$	1.428	0.611	0.005	-1.182	0.310	0.307	10.084 *	-39.839 ***	-22.133 ***
$P_4 \times P_6$	6.473 ***	1.817 ***	-0.078	-2.805	0.192	0.705 *	8.844 *	56.651 ***	31.473 ***
$P_4 \times P_7$	-0.582	-0.084	0.141	-8.939 ***	-0.069	-0.032	10.625 *	-19.960	-11.089
$P_4 \times P_8$	-3.848 ***	0.126	-0.129	2.615	-0.955 ***	-0.587 *	-14.341 **	-53.313 ***	-29.618 ***
$P_4 \times P_9$	2.469 *	0.918	0.093	-0.963	-0.354	-0.360	5.231	-33.051 **	-18.361 **
$P_4 \times P_{10}$	2.446 *	0.433	-0.124	-1.131	0.623 *	1.095 ***	11.778 **	-4.496	-2.498
$P_5 \times P_6$	-6.327 ***	0.664	-0.166 *	-3.320	-0.940 ***	-0.542 *	-4.188	-59.148 ***	-32.860 ***
$P_5 \times P_7$	8.918 ***	0.103	-0.216 **	3.129	-0.541 *	-0.719 *	3.453	-17.549	-9.750
$P_5 \times P_8$	-0.708	0.627	0.103	4.077 *	-0.718 **	-1.317 ***	-13.133 **	53.988 ***	29.993 ***
$P_5 \times P_9$	2.430 *	0.085	0.098	-10.479 ***	-0.133	0.913 **	-6.031	10.503	5.835
$P_5 \times P_{10}$	0.459	0.740	-0.069	3.020	-0.459	0.295	-3.824	16.638	9.243
$P_6 \times P_7$	1.897	0.262	0.054	-0.041	-0.089	-0.557 *	3.012	55.878 ***	31.043 ***
$P_6 \times P_8$	-1.283	-0.734	-0.183 *	-3.093	0.158	0.572 *	7.500	27.715 **	15.397 **
$P_6 \times P_9$	-1.398	-0.103	0.035	6.048 **	0.340	0.725 **	-1.725	-44.937 ***	-24.965 ***
$P_6 \times P_{10}$	1.945	-0.587	0.052	5.064 **	0.827 ***	0.910 **	6.892	-23.312 *	-12.951 *
$P_7 \times P_8$	-0.541	0.858	-0.057	5.659 **	0.703 **	0.771 **	-5.359	5.844	3.246
$P_7 \times P_9$	-6.260 ***	-0.144	-0.299 ***	-8.193 ***	-0.289	-0.292	-14.687 **	-44.718 ***	-24.843 ***
$P_7 \times P_{10}$	3.903 ***	0.532	-0.009	3.623	-0.551 *	-0.287	5.326	8.081	4.489
$P_8 \times P_9$	2.603 *	0.820	0.128	-2.005	-0.111	-0.713 *	9.104 *	-15.364	-8.536
$P_8 \times P_{10}$	6.170 ***	0.349	-0.229 **	-2.380	0.289	0.665 *	0.364	-67.959 ***	-37.755 ***
$P_9 \times P_{10}$	2.814 **	-0.700	-0.198 **	-3.881 *	-0.249	0.362	-16.634 ***	-5.277	-2.932
Sij <> 0 at 95%	2.068	0.994	0.144	3.763	0.468	0.540	8.625	20.417	11.343
Sij <> 0 at 99%	2.763	1.327	0.192	5.027	0.625	0.721	11.522	27.275	15.153
Sij--Sik at 95%	3.040	1.460	0.211	5.531	0.687	0.793	12.678	30.012	16.673
Sij--Sik at 99%	4.061	1.951	0.282	7.389	0.918	1.060	16.936	40.093	22.273

*, ** - Significant at 5 per cent and 1 per cent probability level, respectively.

The cross $P_6 \times P_8$ (5.794) ranked first followed by $P_5 \times P_6$ (5.417) and P_2 x P_5 (5.227) (Table 4). While nine hybrids depicted as the poor specific cross combinations for this trait. The magnitude of SCA effects for fruit weight in hybrids varied from -6.327 ($P_5 \times P_6$) to 8.918 ($P_5 \times P_7$) (Table 5). Out of 45 crosses, Seventeen hybrids exhibited significant and desirable (positive) SCA effects for this trait. The cross $P_5 \times P_7$

(8.918) rank first trailed by $P_2 \times P_9$ (7.077) and P_2 x P_6 (6.638) (Table 5) for this trait. The spectrum of variation for SCA effects in hybrids was ranged from -1.031 ($P_2 \times P_5$) to 1.817 ($P_4 \times P_6$) (Table 5). Out of 45 crosses, three crosses showed significant and positive SCA effects for fruit length. The maximum fruit length was observed in cross $P_4 \times P_6$ (1.817) followed by $P_3 \times P_7$ (1.153) and $P_2 \times P_{10}$ (1.097) (Table 5) which is positively significant and considered for good specific combiners for fruit length. The ranged of SCA effects in hybrids varied from -0.299 ($P_7 \times P_9$) to 0.274 ($P_3 \times P_{10}$) (Table 5). Out of 45 crosses, Four hybrids cross combinations showed significant and positive SCA effects for high fruit diameter with highest SCA effects in $P_3 \times P_{10}$ (0.274) followed by $P_2 \times P_5$ (0.201) and $P_1 \times P_3$ (0.186) (Table 4.7). On the other hand, $P_7 \times P_9$ (-0.299), $P_8 \times P_{10}$ (-0.229), $P_3 \times P_4$ (-0.219) and $P_5 \times P_7$ (-0.216) occupied the poor specific cross combinations for fruit diameter. In case of crosses only seven were showed positive significant SCA effects. The most promising three crosses were $P_3 \times P_9$ (8.105) followed by $P_2 \times P_9$ (7.673) and $P_6 \times P_9$ (6.048) (Table 5) displayed highest positive significant SCA effects. Whereas $P_5 \times P_9$ (-10.479) followed by $P_1 \times P_9$ (-10.219) and $P_2 \times P_3$ (-9.788) (Table 5) expressed high negative significant SCA effects. The combined result showed that $P_3 \times P_9$ (8.105) and $P_2 \times P_9$ (7.673) were the good specific combinations. Among 45 crosses, only eight were expressed valuable positive significant SCA effects. The most promising three cross were $P_2 \times P_7$ (1.283), $P_6 \times P_{10}$ (0.827) and $P_7 \times P_8$ (0.703) (Table 5) showed positively significant effects. Whereas $P_2 \times P_4$ (-1.019) showed highest negative significant SCA effect followed by $P_2 \times P_{10}$ (-0.991) and $P_4 \times P_8$ (-0.995) (Table 5). While the cross considering the Estimates of SCA effects and *per se* performance of the crosses P_2 x P_7 Was good cross combinations for this trait. In respect of crosses seventeen were expressed positive significant SCA effects. The most promising three crosses were $P_2 \times P_7$ (1.801) showed positive significant SCA effects followed by $P_3 \times P_6$ (1.249) and $P_4 \times P_{10}$ (1.095) (Table 5). While the crosses $P_2 \times P_4$ (-1.497), $P_2 \times P_{10}$ (-1.482) and $P_5 \times P_5$ (-1.317) showed negative significant SCA effects. Considering the estimates of SCA effects and *per se* performance of the crosses $P_2 \times P_7$ and $P_3 \times P_6$ were good cross combination for this trait. Among 45 cross combinations, the SCA effects revealed that only five crosses displayed positive significant effects. Best three cross combinations, P_4 x P_{10} (11.778), $P_4 \times P_7$ (10.625) and $P_4 \times P_5$ (10.084) (Table 5) were most promising specific combiners. Highest negative SCA estimates were observed in cross $P_2 \times P_4$ (-24.964), $P_9 \times P_{10}$ (-16.634) and $P_7 \times P_9$ (-14.687) (Table 5). Considering the estimates of SCA effects and *per se* Performance of the crosses, $P_4 \times P_{10}$ was best combiners for this trait. Twelve cross combinations showed significant and positive SCA effect for higher fruit yield per plant with highest SCA effects in $P_4 \times P_6$ (56.651) followed by $P_2 \times P_8$ (56.530), $P_6 \times P_7$ (55.878) and $P_5 \times P_8$ (53.988) (Table 5). While seventeen cross combinations showed significant and negative SCA effects for fruit yield per plant. Out of 45 F_1 hybrids, twelve displayed positive significant SCA effects. Crosses $P_4 \times P_6$ (31.473) followed by $P_2 \times P_8$ (31.405), $P_6 \times P_7$ (31.043) and $P_5 \times P_8$ (29.993) were the most promising combinations for fruit yield per plant (Table 5). On the other hand, seventeen crosses showed negative estimates of SCA effect with significant values. The seventeen highest negative estimates of SCA effects was observed in cross $P_3 \times P_8$ (-42.177). Similar results have also been reported by Shwetha *et al.* (2018); Tiwari *et al.* (2016); Nagesh *et al.* (2014).

CONCLUSION

It was concluded that highly significant variances were observed for both general and specific combining ability for all the eighteen characters studied. Highly significant GCA and SCA variances revealed that both additive and non additive gene actions were important in the expression of all the traits under studied. Considering higher number of fruits and fruit yield per plant along with earliness parents P_8, P_2, P_6 and P_7 was found as good general combiner. The three best F_1 hybrids showing significant and desirable SCA effects for fruit yield per plant in order of merit were P_4 v P_6, $P_2 \times P_8$ and $P_6 \times P_7$. It was noted that the best F_1 hybrids which expressed higher *per se* performance for a particular trait also exhibited desirable significant SCA effect for that trait but this trend was not always true *i.e.* the best specific cross might or might not have the parent with high *per se* performance. It is suggested that breeding techniques that can accumulate detectable genetic effects while maintaining substantial heterozygosity to take advantage of dominant gene effects have proven to be most beneficial for improving the population studied.

FUTURE SCOPE

Through this experiment it is suggested that parent P_8 may use to be future breeding programme due to its high GCA effects in desirable direction. Crosses $P_4 \times P_6$ and $P_2 \times P_8$ are holds good prospect to provide the commercial hybrid for earliness and yield attributing traits which may be used as a hybrid after their stability test. They are not only high yielder but also possessed attractive fruit colour and length as per present market demand.

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