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Combining ability studies in okra (*Abelmoschus esculentus* (L.) *moench*) through diallel analysis for yield and yield attributing characters

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Abstract
The present investigation was undertaken to evaluate seven parents and twenty one hybrids through diallel mating system to study general and specific combining ability effects and genetic analysis for various yield and yield related traits. In diallel analysis, the variance of the genotype for all the characters were highly significant indicating high genetic variability among the parents studied. Based on gca effects, the parent VRO-3 was declared as superior parent. Arka Anamika, VRO-4 and VRO-6 were identified as next better parents. Among the hybrids, VRO-4 × Arka Anamika, VRO-3 × VRO-4, VRO-3 × VRO-6 and VRO-3 × Arka Anamika were rated as best hybrids for exploitation of heterosis based on mean performance. The hybrids VRO-4 × Arka Anamika, VRO-3 × VRO-4, VRO-3 × VRO-6 and VRO-3 × Arka Anamika had high positive significant sca for the characters, first flowering node, and first fruiting node, no of branch/plant, Width of fruit, number of fruit/plant, no of seed/seed yield/plant. Incorporating these hybrids into multiple crosses may be a meaningful approach for tangible improvement of these traits. Hybrids were therefore suitable for breeding heterosis to improve fruit yields toward plants and other yield components.

Keywords: Okra, diallel analysis, combining ability, GCA, SCA

Introduction
Okra (*Abelmoschus esculentus* (L.) Moench) 2n = 130 is a common vegetable cultivated in India. Origin of Tropical Africa, it is a prized vegetable of India. Okra is especially valued for its tender delicious fruit and is a rich source of iodine. The fruit has an average nutritive value of 3.21, which is higher than tomato, eggplant and cucurbits. The dehydrated okra is a processed product for preservation and export. Okra pod seeds forms a nutrition ingredient of cattle feed and is a source of vegetable oil. It is a potential export vegetable accounting for 60 percent of fresh vegetable. Its quick growth, short duration and photo insensitivity in nature enable the genetics and breeders to raise two or three crops a year and thus reduce the period for achieving the genetic results. The main states of India where the vegetables are grown commercially in Gujarat, Maharashtra, followed by Andhra Pradesh, Karnataka, Uttar Pradesh and Tamil Nadu etc. The total area in India is 10, 436 mha with production of 1, 87, 474 thousand metric tons and productivity is 17.96 tons per hectare (Anonymous 2019) [2].
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. The present study was carried out to assess the breeding values of the chosen parents, to understand their genetic potential on yield and its component traits and to estimate the combining ability effects.

Materials and Methods
The experimental material for the present investigation was generated by Parents (7) genotype - VRO-3, VRO4, VRO5, VRO6, PusaA4, Arka Anamika, Pusa Sawni, and crosses (21) Progeny VRO-3 X VRO-4, VRO-3 X VRO-5, VRO-3 X VRO-6, VRO-3 X Pusa A 4, VRO-3 X Pusa Sawni, VRO-3 X Arka Anamika, VRO-4 X VRO-5, VRO-3 X VRO-6, VRO-4 X Pusa A4, VRO-4 X Pusa Sawni, VRO-4 X Arka Anamika, VRO-5 X VRO-6, VRO-5 X Pusa A 4, VRO-5 X Pusa Sawni, VRO-5 X Arka Anamika, VRO-6 X Pusa A 4, VRO-6 X Pusa Sawni, VRO-6 X Arka Anamika, Pusa A 4 x Pusa Sawni, Pusa A 4 x Arka Anamika, Pusa Sawni x Arka Anamika. (7) parents and their (21) $F_{1'S}$ were grown at carried out the research farm of

the department of Genetics & Plant Breeding, Ch. Charan Singh University, Meerut (UP) India in Zaid seasons of 2017-18, 2018-19 & 2019-20.

The experimental material consisting of (7) parents- VRO-3, VRO4, VRO5, VRO6, PusaA4, Arka Anamika, Pusa Sawni, using all cultural practices recommended for successful cultivation of okra crop were followed. Hybridization among parental lines was carried out by hand emasculation and pollination than produce F_1 hybrid seeds. All F_1's were allowed to self-pollination to produce F_2 seeds. The experimental material was planted in half diallel mating design which allowed making 21 crosses. These experimental materials were performed in Randomized Complete Block Design (RBD) with three replications in the years 2017-18, 2018-19 & 2019-20.Each genotype was sown in three replications with three lines with four-meter distance. The experimental field was maintains line to line 70 cm and plant to plant 30 cm distance.

Observations recorded

The data were recorded for 13 contributing characters *viz.* 50% days to flowering. First Flowering node, First fruiting node, Inter nodal length (cm), Fruit Length (cm), Fruit width (cm), Fruit Weight (g), no. of Fruit/Plant, no. of seed/fruit, no. of branches/plant, Seed Yield/plant (g), Plant height (cm), Harvest duration.

Statistical methods

In this investigation half diallel mating design was followed and the mean values of the treatments for all the characters were subjected to analysis of variance (ANOVA). General and specific combining variance and their effects will be calculated using Griffings (1956) [6] method second, model first, Components of variance analysis will be done by the procedure given by Hayman (1960) [7], Degree of heterosis in F_1 cross will be estimated over the better parents and inbreeding depression in F_2 will be worked out over the F_1 hybrids, Heritability will be estimated according to the method enunciated Crumpacker and Allard (1962) [4] and genetic advance by the method of Robinson *et al.* (1949) [11]. Genotype and phenotype correlation coefficient will be worked out among all the characters to be studied according by Robinson (1951) [10].

Results and Discussions

Analysis of variance for combining ability and their effects

Parental choice is a must for any crop improvement program. Steps in providing outstanding individual hybrids. During recent decades, breeding in autogamous crops, the methodology mainly depends on the selection of parent for hybridization on the basis of performance followed by single plant selection in segregating populations. Combining ability is an effective tool to identify the appropriate parents and crosses for their use in effective crop improvement program. (Sprague and Tatum, 1942) [14]. The combining ability plays a potential role together with performance of parents, hybrids and heterotic response in selecting potential parents, which can help breeders in producing promising hybrids for systematic breeding program. It is also helpful to identify the nature of gene action and genetic variations in the population, which is essential to workout appropriate breeding strategy. Evaluation of parents for combining ability also permits an indication of relative magnitude of additive or non-additive variance for characters under study. General combining ability (GCA) largely involves additive genetic effects, while specific combining ability (SCA) effects contain non-additive type of gene action.

Analysis of variance for combining ability

The analysis of variance for combining ability was carried out for all the 13 characters under study. The results presented in Table-1indicated that mean sum of square due to parent was highly significant for all the characters indicating genetic diversity among the parent (GCA), thus highest contribution by these characters towards combining ability. The variances due to hybrids (SCA) were also highly significant for all the characters. The σ2GCA/σ2SCA ratio was less than the unity which indicated predominance of non-additive effect for the traits, like first flowering node, first fruiting node, 50% flowering, harvest duration days, plant height, no of fruit per plant, no of seed per fruit. The details of combining ability analysis of seven parents and their twenty one crosses are being furnished as under.

Combining ability effects

The combining ability analysis provides information about the gene action involved in the expression of different characters and thus helps in deciding the breeding procedure to be followed for the genetic improvement of traits. The general combining ability effect is proportional to the additive effects and breeding value. The GCA effects indicated that most of the parents were good general combiners for all the characters, suggesting that specific parents will have to be used for genetic improvement depending on the character under consideration. In general, all characters were controlled by non-additive (SCA) effects. Hence, dominance or epistatic nature of gene action needs to be exploited for heterosis with carefully choosing the parents. The estimates general combining ability (GCA) effects of parents and specific combining ability Table- 4 (b), (SCA) effects of hybrids for thirteen characters.

First flowering node

Mostly all the parents and their hybrids for days to first flowering node traits is significant but highest negative GCA effect was noticed in 'VRO-5' (-1.19) followed by VRO-3, (-0.55) Pusa Sawni, (-0.31) and it was ideal character for early maturity. Among the parents VRO-6 (-0.90) had high positive GCA effect.Followed by Arka Anamika (0.66) and VRO-4 (-0.30).

Among the 12 crosses were found to have negative SCA effect with highest specific cross VRO 4 x Arka Anamika (-3.39) followed by VRO-4 x VRO-5, (-3.00) VRO-6 x Pusa A4 (-2.49) and VRO-6 x Arka Anamika (-2.40). The cross VRO-5 x VRO-6 (5.03) had high positive SCA effect.

First fruiting node

All the parents and their hybrids for First fruiting node is significant but highest negative GCA effect was noticed in 'VRO-5' (-1.62) followed by VRO-3, (-0.65) PusaA-4, (-0.18) among the parents VRO-6 (1.22) had high positive GCA effect. Followed byVRO-4 (0.68) and Arka Anamika (0.40).

Among the 11 crosses were found to have negative SCA effect with highest specific cross VRO 4 x Arka Anamika (-3.47) followed by VRO 6 x Pusa A4, (-2.90) VRO-4 x VRO-5 (2.51) and VRO 3 x VRO-5 (-2.21) The cross VRO 5 x VRO6 (4.42) had high positive SCA effect.

50% flowering

50% flowering were observed significant for mostly parents and their hybrids but highest negative GCA effect was noticed in 'VRO-3 (-0.89) followed by VRO-5 (-0.66) VRO-4 (0.55), among the parents VRO-6 (0.63) had high positive GCA effect. Followed by Arka Anamika (0.41) and Pusa Sawni (0.06).

Among the 12 crosses were found to have negative SCA effect with highest specific cross VRO 4 x VRO 5 (-4.48) followed by VRO 5 x Pusa A4 -3.28), VRO-6 x PusaA 4 (-2.83) and VRO 6 x Arka Ananika (-2.10). The cross VRO-5 x VRO 6 (2.84) had high positive SCA effect.

Harvest maturity (days)

All the parents and their hybrids for Harvest duration day is significant but highest negative GCA effect was noticed in 'VRO-5' (-2.76) followed by VRO-6 (-1.36), VRO 4 (-0.53), among the parents Pusa Sawni (3.36) had high positive GCA effect. Followed by Pusa A 4 (1.99) and Arka Anamika (0.21).

Table 1: Analysis of variance of combing ability

Sourced of variation	D.F.	First flowering node	First fruting node	50% flowering	Harvest duration day	Plant height	No. of branch/ plant	Inter nodal length	Fruit length	Fruit width	Fruit weight	No. of fruit/ plant	No. of seed/ fruit	Seed yield/ plant
Gca	6	4.80**	7.86**	3.15**	38.66**	10.05**	0.05**	0.28**	0.72**	0.38**	0.47**	1.25**	8.87**	0.28**
Sca	21	5.57**	5.42**	5.20**	11.94**	28.65**	0.13**	0.12**	0.64**	0.76**	0.63**	2.23**	11.52**	0.67**
Error	54	0.21	0.26	0.34	0.80	0.73	0.01	0.03	0.03	0.03	0.04	0.04	0.67	0.02
Var due to gca		0.51	0.84	0.31	4.21	1.03	0.01	0.03	0.08	0.04	0.05	0.14	0.91	0.03
Var due to gca		5.36	5.16	4.86	11.14	27.91	0.12	0.10	0.61	0.72	0.59	2.19	10.84	0.65
Gca/sca ratio		0.10	0.16	0.06	0.38	0.04	0.04	0.29	0.13	0.05	0.08	0.06	0.08	0.04

*, ** significant at 5% and 1% level, respectively

Table 2: Gca effects for parents

Sourced of variation	First flowering node	First fruiting node	50% flowering	Harvest duration day	Plant height	No. of branch/ plant	Inter nodal length	Fruit length	Fruit width	Fruit weight	No. of fruit/ plant	No. of seed/ fruit	Seed yield/ plant
1	-0.55 **	-0.65 **	-0.89 **	-0.90 **	1.08 **	-0.09 **	-0.28 **	-0.44 **	-0.05	-0.04	-0.51 **	-1.11 **	0.12 *
2	0.30 *	0.68 **	0.55 **	-0.53	-0.78 **	0.06 *	-0.05	-0.07	-0.40 **	-0.32 **	-0.25 **	-0.22	-0.35 **
3	-1.19 **	-1.62 **	-0.66 **	-2.76 **	-0.27	0.11 **	-0.00	0.08	0.02	0.12	-0.06	-0.18	0.12 *
4	0.90 **	1.22 **	0.63 **	-1.36 **	-0.45	0.06 *	-0.10 *	0.02	0.12 *	-0.03	0.11	1.53 **	0.17 **
5	0.19	-0.18	-0.09	1.99 **	0.06	-0.06 *	0.03	-0.24 **	0.24 **	-0.25 **	-0.22 **	0.16	0.04
6	-0.31 *	0.14	0.06	3.36 **	-1.33 **	-0.02	0.28 **	0.38 **	0.11	0.25 **	0.36 **	0.97 **	-0.08
7	0.66 **	0.40 *	0.41 *	0.21	1.69 **	-0.05 *	0.12 *	0.27 **	-0.03	0.27 **	0.57 **	-1.14 **	-0.02
SE (gi)	0.141	0.157	0.181	0.275	0.264	0.026	0.050	0.052	0.056	0.063	0.059	0.253	0.049
CD at 5%	0.282	0.315	0.362	0.552	0.530	0.052	0.101	0.104	0.111	0.126	0.118	0.508	0.097
CD at 5%	0.282	0.315	0.362	0.552	0.530	0.052	0.101	0.104	0.111	0.126	0.118	0.508	0.097

Table 3: Specific combined ability (sca) for hybrids

S. No.		First flowering node	First fruiting node	50% flowering	Harvest duration day	Plant height	No. of branch/ plant	Inter nodal length	Fruit length	Fruit width	Fruit weight	No. of fruit/ plant	No. of seed/ fruit	Seed yield/ plant
1	1 2	-1.11 **	-1.58 **	-1.88 **	-1.95 **	-2.96 **	0.08 *	0.31 **	0.30 **	0.40 **	-0.03	-0.66 **	-0.80 *	-0.26 **
2	1 3	-2.02 **	-2.21 **	-0.21	0.27	0.46	-0.07 *	-0.04	0.55 **	-0.63 **	0.54 **	0.99 **	0.36	0.08
3	1 4	-1.49 **	-1.62 **	0.17	0.87 *	-3.56 **	0.39 **	0.50 **	1.34 **	1.14 **	1.57 **	1.92 **	5.16 **	1.36 **
4	1 5	0.80 **	1.58 **	0.22	2.86 **	3.86 **	-0.03	0.43 **	0.47 **	0.78 **	0.17 *	0.64 **	1.62 **	1.02 **
5	1 6	1.17 **	0.16	-0.06	-0.18	5.75 **	0.33 **	0.05	0.39 **	-0.68 **	-1.00 **	0.33 **	1.48 **	-0.65 **
6	1 7	2.39 **	1.50 **	1.25 **	5.30 **	5.83 **	0.16 **	-0.26 **	-0.00	-0.34 **	0.55 **	-0.30 **	1.99 **	0.98 **
7	2 3	-3.00 **	-2.51 **	-4.48 **	-2.10 **	4.46 **	0.21 **	0.10	0.05	-0.51 **	-0.30 **	0.85 **	-1.13 **	0.08
8	2 4	-1.43 **	-1.82 **	-1.93 **	-1.84 **	-3.57 **	-0.14 **	0.13	0.77 **	0.76 **	-0.02	1.22 **	-2.70 **	0.22 **
9	2 5	2.95 **	1.71 **	1.68 **	5.16 **	8.06 **	-0.05	-0.13 *	-0.50 **	-0.36 **	0.32 **	-0.69 **	1.33 **	-0.52 **
10	2 6	2.32 **	1.19 **	1.83 **	3.12 **	1.18 **	0.28 **	0.21 **	0.35 **	0.13	0.52 **	-0.07	-0.28	-0.25 **
11	2 7	-3.39 **	-3.47 **	-1.65 **	0.93 *	3.02 **	0.44 **	0.18 **	-0.14 *	-0.16 *	0.70 **	1.60 **	0.96 **	0.45 **
12	3 4	5.03 **	4.42 **	2.84 **	3.72 **	1.29 **	-0.38 **	-0.15 *	0.49 **	-0.65 **	-0.98 **	-1.66 **	-0.08	-0.17 **
13	3 5	-2.29 **	-1.72 **	-3.28 **	-2.62 **	2.92 **	0.47 **	-0.38 **	-0.38 **	-0.16 *	0.17 *	-1.54 **	0.39	-0.25 **
14	3 6	-0.32	-1.40 **	-0.76 **	-4.32 **	-0.93 **	0.33 **	-0.10	0.26 **	1.65 **	0.28 **	1.61 **	3.95 **	1.15 **
15	3 7	0.70 **	0.50 *	0.22	0.16	4.18 **	-0.08 *	0.47 **	0.97 **	2.09 **	1.20 **	2.21 **	5.72 **	1.15 **
16	4 5	-2.49 **	-2.90 **	-2.83 **	-3.35 **	2.06 **	-0.44 **	-0.21 **	0.14 *	-0.59 **	0.07	0.69 **	1.72 **	-0.57 **
17	4 6	-1.29 **	1.72 **	2.29 **	-0.06	-1.49 **	0.28 **	-0.20 **	0.35 **	0.81 **	1.36 **	2.31 **	5.24 **	0.99 **
18	4 7	-2.40 **	-1.74 **	-2.10 **	-5.91 **	5.89 **	-0.25 **	0.63 **	0.36 **	0.39 **	-0.32 **	-0.42 **	-0.65	-0.64 **
19	5 6	-1.57 **	-1.75 **	-0.23	-0.73 *	-1.26 **	0.37 **	0.01	0.38 **	-0.05	0.35 **	-0.23 **	-2.93 **	0.05
20	5 7	0.32	0.42 *	-0.01	3.42 **	-3.95 **	-0.20 **	-0.50 **	0.43 **	-0.34 **	-0.18 *	0.10	1.85 **	-0.25 **
21	6 7	2.49 **	3.37 **	1.97 **	3.71 **	6.54 **	0.02	-0.02	-0.06	-0.37 **	-0.15	0.32 **	-0.66	0.28 **
	sca (ii)	0.409	0.456	0.525	0.801	0.769	0.075	0.146	0.152	0.161	0.183	0.171	0.737	0.142
	sca (ij)	0.186	0.208	0.239	0.364	0.350	0.034	0.067	0.069	0.073	0.083	0.078	0.335	0.064
	CD at 5%	0.821	0.915	1.053	1.606	1.541	0.150	0.293	0.304	0.323	0.366	0.344	1.477	0.284
	CD at 1%	0.933	1.040	1.197	1.824	1.751	0.170	0.333	0.345	0.367	0.416	0.390	1.678	0.322

Among the 10 crosses were found to have negative SCA effect with highest specific cross VRO 6 x Arka Anamika (-5.91) followed by VRO 5 x Pusa Sawni (-4.32), VRO-6 x Pusa A4 (-3.35) and VRO-5 x Pusa A4 (-2.62). The cross VRO 3 X Arka Anamika (5.30) had high positive SCA effect.

Plant height

All the parents and their hybrids forplant height is mostly significant but highest negative GCA effect was noticed in 'Pusa Sawni (-1.33) followed by VRO-4 (-0.78), VRO-6 (-0.45), among the parents Arka Anamika (1.69) had high positive GCA effect. Followed by VRO-3 (1.08) and Pusa A4 (0.06).

Among the seven crosses were found to have negative SCA effect with highest specific cross Pusa A 4 x Arka Anamika (-3.95) followed by VRO 4 x VRO 6 (-3.57), VRO-3 x VRO-6 (-3.56) and VRO 3 x VRO-4 (-2.96). The cross VRO 4 x Pusa A4 (8.06) had high positive SCA effect.

No. of branch/plant

No of branch/plant were observed significant for mostly parents and their hybrids but highest negative GCA effect was noticed in 'VRO-3' (-0.09) followed by Pusa A 4 (-0.06), Arka Anamika (-0.05) and Pusa Sawni (-0.02), Among the parents VRO-5 (0.11) had high positive GCA effect followed by VRO 4 (0.06) and VRO -6 (0.06).

The 9 crosses were found to have negative SCA effect with highest specific cross VRO 6 x Pusa A 4 (-0.44) followed by VRO 5 x VRO 6 (-0.380, VRO-6 x Arka Anamika (-0.25) and Pusa A 4 x Arka Anamika (-0.200. The cross VRO 5 x Pusa A 4 (0.47) had high positive SCA effect.

Internodal length

Internodal length were observed significant for mostly parents and their hybrids but highest negative GCA effect was noticed in 'VRO-3 (-0.28), followed by VRO-6 (-0.10), VRO 4 (-0.05), and VRO 5 (-0.00), Among the parents Pusa Sawni (0.28) had high positive GCA effect. Followed by Arka Anamika (0.12).

Among the Ten crosses were found to have negative SCA effect with highest specific cross Pusa A 4 X Arka Anamika (-0.50) followed by VRO 5 x Pusa A4 (-0.38), VRO-3 x Arka Anamika (-0.26) and VRO-6 x Pusa A 4 (0.21). The cross VRO-3 x VRO 6 (0.50) had high positive SCA effect.

Fruit length

All the parents and their hybrids for fruit length is mostly significant but highest negative GCA effect was noticed in 'VRO 3 (-0.44) followed by Pusa A4 (-0.24), VRO 4 (-0.07) Among the parents Pusa Sawni (0.38) had high positive GCA effect. Followed by Arka Anamika (0.27) and VRO 5 (0.08).

Among the 5 crosses were found to have negative SCA effect with highest specific cross VRO 4 x Pusa A-4 (-0.50) followed by VRO-5 x Pusa A-4 (-0.380, VRO-4 x Arka Anamika (-0.14) and Pusa Sawni x Arka Anamika (-0.06). The cross VRO 3x VRO 6 (1.34) had high positive SCA effect.

Fruit width

Fruit width were observed significant for mostly parents and their hybrids but highest negative GCA effect was noticed in 'VRO-4 (-0.40) followed by VRO-3 (-0.05), Arka Anamika (-0.03), among the parents Pusa A 4 (0.24) had high positive GCA effect. Followed by VRO-6 (0.12).

Among the 12 crosses were found to have negative SCA effect with highest specific cross VRO 3 x Pusa Sawni (-0.68), followed by VRO-5 x VRO-6 (-0.68), VRO-3 x VRO-5 (-0.63) and VRO-6 x Pusa A-4 (-0.59). The cross VRO 5 x Arka Anamika (2.09) had high positive SCA effect.

Fruit weight

All the parents and their hybrids for Fruit weight is significant but highest negative GCA effect was noticed in 'VRO-4 (-0.32) followed by Pusa A4 (-0.25), VRO-3 (-0.04) among the parents Arka Anamika (0.27) had high positive GCA effect, followed by Pusa Sawni (0.25) and VRO-5 (0.12).

Among the 8 crosses were found to have negative SCA effect with highest specific cross VRO-3 x Pusa Sawni (-1.00) followed by VRO 5 x VRO-6 (-0.98), VRO-6 x Arka Anamika (-0.32) and VRO-4 x VRO-5 (-0.30). The cross VRO 3 x VRO 6 (1.57) had high positive SCA effect.

No. of fruit/plant

No. of fruit/plant were observed significant for mostly parents and their hybrids but highest negative GCA effect was noticed in 'VRO-3' (-0.51) followed by VRO-4 (-0.25), VRO-5 (-0.06), among the parents Arka Anamika (0.57) had high positive GCA effect. Followed by Pusa Sawni (0.36).

Among the 8 crosses were found to have negative SCA effect with highest specific cross VRO 5 x VRO-6 (-1.56) followed by VRO 5 x Pusa Sawni (1.61), VRO-3 x VRO-4 (-0.66) and VRO 6 x Arka Anamika (-0.42). The cross VRO 6 x Pusa Sawni (2.31) had high positive SCA effect.

No. of seed/fruit

All the parents and their hybrids for No. of seed/fruit mostly significant but highest negative GCA effect was noticed in 'Arka Anamika' (-1.14) followed by VRO-3, (-1.11). Among the parents VRO-6 (1.53) had high positive GCA effect. Followed by Pusa Sawni (0.97) and Pusa A-4 (0.16).

Among the 8 crosses were found to have negative SCA effect with highest specific cross Pusa A-4 X Pusa Sawni (-2.93) followed by VRO-4 x VRO-6, (-2.70) VRO-4 x VRO-5 (-1.13) and VRO 3 x VRO-4. (-0.80) The cross VRO 5 x Arka Anamika (1.48) had high positive SCA effect.

Seed yield/plant

All the parents and their hybrids for seed yield/plant is mostly significant but highest negative GCA effect was noticed in 'VRO-4' (-0.35) followed by Pusa Sawni (-0.08), Arka Anamika (-0.02), Among the parents VRO-6 (0.17) had high positive GCA effect. Followed by VRO-3 (0.12) and VRO-5 (0.12).

Among the 9 crosses were found to have negative SCA effect with highest specific cross VRO-3 x Pusa Sawni (-0.65) followed by VRO 6 x Arka Anamika, (-0.64) VRO-6 x Pusa A-4 (-0.57) and VRO 4 x Pusa A-4. (-0.52) The cross VRO-3 x VRO-6 (1.36) had high positive SCA effect.

General combining ability

The general combining ability is primarily a function and additive and additive x additive gene action. In the present study none of the genotype exhibited significant, GCA effects for all the characters. However, The genotype identified as promising combiners were VRO-3 for characters First flowering node, first fruiting node, No of branch/Plant, No of fruit/Plant, No of fruit/plant, Seed yield/Plant.VRO-4 for the characters First flowering node, first fruiting node, 50%

flowering, No of branch/Plant, No of fruit/Plant.VRO-5 for the characters First fruiting node, Plant height, Inter nodal length, No of fruit/plant, Seed yield/Plant. VRO-6 for the characters First flowering node, first fruiting node, Plant height, Inter nodal length, Pusa A4 for the characters first fruiting node, 50% flowering, No of branch/Plant, No of fruit/Plant, Seed yield/Plant. Pusa sawni for the characters first flowering node, first fruiting node, No of branch/Plant, No of fruit/plant, seed yield/plant. Arka Anamika first fruiting node, No of branch/Plant, No of fruit/plant, seed yield/plant. Were found best general combiner for higher fruit yield/plant.

This indicate that parent showing high GCA for fruit yield/plant, might have been because of their high GCA for fruit weight, fruit length, fruit width, internodal length, number of fruits/plant, number of seeds/fruit. It is therefore suggested that these genotype may be used in improvement for earliness and yield traits in okra. GCA effects represents additive x additive interaction effects. In often pollinated crop like okra additive x additive based epistasis are important. Many workers like Bhatt *et al*. (2015) [3], Govind *et al.* (2018) [5], Suganthi *et al*. (2020) [15], Janarthanan *et al*. (2020) [8].

Specific combining ability

The specific combining ability effects obtained the present investigation were of high SCA effect for different traits involved in various hybrids cross combinations. SCA which represents the predominance of non-additive gene action is a major component that may be utilized in heterosis breeding programme. In the present study, none of the cross combination was found to have high SCA for all the characters under study.

The crosses exhibited the high SCA effects for days First flowering node VRO-4 x Arka Anamika, VRO-4 x VRO-5, VRO-6 x Pusa Pusa A4, VRO-6 x Arka Anamika, for fruiting node VRO-5 x VRO-6, Pusa sawni x Arka Anamika, VRO-4 x VRO-5, VRO-3 x VRO-5, and for 50% flowering VRO-4 x VRO-5, VRO-5 x Pusa A4, VRO-6 x Pusa A4, VRO-6 x Arka Anamika, as these crosses have showed high negative SCA effects. The cross combinations showing high SCA effects for The cross combinations showing high SCA effects for Fruit length were VRO-4 x Pusa A4, VRO-5 x Arka Anamika, VRO-4 x Arka Anamika, Pusa sawni x Arka Anamika. For Harvest duration day VRO-6 x Arka Anamika VRO-5 X Pusa sawni, VRO-6 X Pusa A4, VRO-6 X Arka Anamika and Plant height crosses Pusa A4 x Arka Anamika, VRO-4 x VRO-6, VRO-3 x VRO-6, VRO-3 X VRO-4, The superior combinations for No of branch/plant VRO-6 x Pusa A4, VRO-5 X VRO-6, VRO-6 X Arka Anamika, PusaA4 x Arka Anamika, Cross combinations Inter nodal length Pusa A4 x Arka Anamika, VRO-5 x Pusa A4, VRO-3 x Arka Anamika, VRO-6 X Pusa A4, were good specific combiners, The cross combinations showing a desirable SCA effects for number of fruits/plant were VRO-5 x VRO-6, VRO-5 X Pusa A4, VRP-3 X VRO-6, VRO-6 X Arka Anamika, Fruit width VRO-3 X Pusa sawni, VRO-5 X VRO-6, VRO-3 X VRO-5, VRO-3 X Pusa A4, The cross combinations showing high SCA effects for potential fruit weight Were VRO-3 x VRO-6, VRO-5 x VRO-6, VRO-5 x Arka Anamika, VRO-4 X VRO-5, for potential No of seed/fruit crosses Pusa A4 x Pusa sawni, VRO-4 X VRO-6, VRO-4 X VRO-5, VRO-3 X VRO-4, Seed yield/Plant whereas crosses VRO-3 x Pusa sawni, VRO-6 x Arka Anamica, VRO-6 X Pusa A4, VRO-4 X Pusa A4, were found specific combiner.

The above are in conformity with the findings of Ravindra *et al*. (2020) [9], Sapavadiya *et al*. (2019) [12], a similar study has also shown that there was exploitation of heterosis, Okra revealing occurrence of high SCA estimates not only in crosses involving high x high combiner parent but also from other combinations like high x low (HxL) and Low x Low (LxL) combiner parents. Sapavadiya *et al*. (2019) [12] also reported that a majority of crosses showing significant positive and desirable SCA effects for a character involved at least one good general combiner parent for the characters which is also indicated by the results of present study, Satish *et al*. (2017) [13], Sapavadiya *et al*, (2019) [12], Suganthi *et al.* (2020) [15] were reported spccilic combining ability in okra for different crosses for different characters. Desirable SCA effects for earliness yield and yield related characters were also reported by Bhatt *et al*. (2015) [3], Karthiika *et al*. (2019) [9], for assessing superiority of hybrid generally its SCA effects. Further, it was also evident that the best combinations for most of the characters generally involved one good and one poor general combiner or both poor general combiners' crosses with high SCA where at least one of the parents was good combiner in these crosses. The high SCA observed may be due to a complementary type of gene action which can be fixed to a great extent in the segregating generations, whereas crosses with high SCA effects which involved poor x poor combinations, these crosses can be used for commercial exploitation of hybrid vigour as the non-additive, non-fixable genes.

Conclusion

Based on sca effects of hybrid VRO-4 × VRO-5 days to 50 percent flowering, number of branches per plant, number of fruits per plant, fruit length, fruit weight and seed yield per plant, Pusa A4 x Pusa Sawni for plant height at maturity and Pusa A4 × Arka Anamika for fruit girth were adjudged as the best hybrid and suitable for exploitation of heterosis.

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