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Combining ability analysis for yield and yield contributing traits in okra

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Abstract
The present investigation was undertaken to study the combining ability for yield and its component traits in okra. The experiment was carried out with six parents and 30 F_1s (including reciprocals) obtained through diallel hybridization technique. The mean squares due to GCA and SCA and reciprocal effects were significant for all characters. Among six parents studied in a full diallel, parents AE-CBE-92 and AE-CBE-93 were adjudged as good general combiner for fruit yield and most of the yield contributing characters. Among hybrids, AE-CBE-93 x AE-CBE-921 (P2xP4) recorded additive gene action for fruit yield and few yield component traits. Selection could be applied in the early generation to improve fruit yield and yield component traits due to the presence of additive type of gene action. Hence the cross AE-CBE-93 x AE-CBE-921 could be subjected into pedigree breeding programme for the fruit yield improvement programme in okra.

Keywords: Diallel, gene action, GCA, SCA, fruit yield

1. Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] is a popular vegetable crop cultivated throughout India. It is a member of Malvaceae family with a chromosome number of 2n=130. Okra is allopolyploid in nature (Joshi and Hardas, 1956) [7]. In India it is grown in an area of 0.51 million ha, with an annual production of 6.17 million tonnes (Anonymous, 2019) [2]. The primary okra growing states in India includes Uttar Pradesh, Bihar, Orissa, Tamil Nadu and West Bengal.

Okra is an often cross pollinated, warm season vegetable crop rich in carbohydrates, minerals and vitamins, which play an important role in healthy diet of humans (Gemede *et al.*, 2015) [5]. Tender fresh fruits of okra are used as vegetables. The fruits of okra are high in Potassium, Calcium, Mg, organic acids etc. (Romdhane *et al.*, 2020) [14]. Leaves of okra contain mucilage which is used to cure inflammation. Root and stems of okra are used for preparing jaggery and gur as it helps in clearing cane juice. Okra has various bioactive components such as polysaccharides, rhamnogalacturonan, pectin, lectin, polyphenolic compounds, etc., which plays a major role in human health (Elkhalifa *et al.*, 2021) [4]. Cultivation of okra is limited by several biotic and abiotic factors.

The main prerequisite of a breeding programme depends on the choice of parents. Allard (1960) [1] suggested that selection of parents with their *per se* performance is not a sound procedure. Therefore it is necessary that parents should be selected based on their combining ability. The full diallel mating design has been used in this present investigation to assess the genetic information for various traits. Keeping this in view, the current study was carried out to study the gene action and combining ability for yield and yield contributing component traits in okra.

2. Materials and methods

The experimental material comprised of six genotypes *viz.*, AE-CBE-92, AE-CBE-93, AE-CBE-94, AE-CBE-921, AE-CBE-943 and AE-CBE-934. These genotypes were crossed in full diallel mating design to obtain 30 F_1s (including reciprocals). These six parents and 30 F_1s were evaluated in randomized complete block design (RCBD) with three replications at the field of Department of Vegetable Science, TNAU, Coimbatore in the year 2021. The spacing of 60 × 45 cm was adopted. Standard agronomic procedures like irrigation, weeding, nutrient and plant protection measures were followed to obtain a productive crop.

Observation for various traits were recorded on five randomly chosen plants for each genotype in each replication *viz.*, plant height (cm), node at which first flower appears, number of primary branches per plant, fruit length (cm), fruit diameter (cm), fruit weight (g), number of fruits per plant and fruit yield per plant (g). The mean data collected from all the parents, F_1's and reciprocals were analysed statistically using TNAUSTAT software (Manivannan, 2014) [9] by following the Griffings (1956) [6] procedures (method1, model 2).

3. Result and discussion

3.1 Gene action

Analysis of variance for combining ability of eight different characters were presented in Table 1. The mean squares due to GCA and SCA and reciprocal effects were significant for all characters. This indicated that the GCA of parents, SCA of hybrids were significantly different among them. The significant reciprocal effect indicates that the presence of maternal effect and the direction of crosses are important to attain improvement of traits. The ratio between GCA and SCA variances indicates that the proportion of additive gene action is more for all traits. Hence pedigree breeding or heterosis breeding can be adopted to improve yield and contributing traits. These results are in contrast with the findings of Bhatt *et al.* (2015) [3], Wakode *et al.* (2016) [16] and Narkhede *et al.* (2021) [11] for plant height, branches per plant, fruit girth, fruit weight, fruits per plant and yield of fruits per plant.

3.2 General combining ability effects

General combining ability effects of parents for fruit yield and component traits were presented in Table 2. Parents AE-CBE-93, AE-CBE-921 and AE-CBE-934 were good general combiner for shorter plant height. Parent AE-CBE-92 alone recorded significant and negative GCA effect for node at which first flower appears. Parents AE-CBE-93, AE-CBE-943 and AE-CBE-934 recorded significant and positive GCA for number of primary branches. Parents AE-CBE-92 and AE-CBE-93 recorded positive and significant GCA for fruit length, fruit diameter, fruit weight and number of fruits per plant. In addition, parent AE-CBE-934 also recorded significant and positive GCA for fruit length, parent AE-CBE-94 for fruit diameter and AE-CBE-943 for number of fruits per plant. All parents except AE-CBE-934 recorded significantly positive GCA effects for fruit yield per plant. Among these parents, AE-CBE-93 recorded significantly GCA effect for all traits except for nodes at which first flower appears. The parent AE-CBE-92 also recorded significant GCA effects for all traits except for plant height and number of primary branches per plant. Other parents recorded significant GCA effects for few traits only. Hence based on GCA effects, parents AE-CBE 93 and AE-CBE-92 were considered as good general combiner for fruit yield and component traits. These parents can be used in breeding programme to improve fruit yield and component traits. Rajani *et al.* (2006) [13], Pal *et al.* (2009) [11], Wammanda *et al.* (2010) [17], Prakash *et al.* (2012) [12], Kumar *et al.* (2013) [8] and Suganthi *et al.* (2020) [15] also reported the promising general and specific combiners for yield and its other contributing characters.

3.3 Specific combining ability effects of hybrids

Among hybrids, AE-CBE-93 x AE-CBE-921 (P2xP4) alone recorded non significant SCA effects for fruit yield per plant. As both parents are good general combiner for fruit yield per plant, the gene action involved in these crosses is of additive type of gene action. Hence this cross can be subjected in to pedigree breeding programme and early generation selection can be practised to evolve high yielding varieties. As other hybrids are with significant SCA effect, the gene action involved may be of epistasis. In these crosses, if any one of the parents involved are of good GCA parents, the gene action may of additive type of epistasis and hence selection need to be postponed to the later generations.

The AE-CBE-93 x AE-CBE-921 (P2xP4) hybrid also recorded non significant SCA effect for node at which first flower appears, number of primary branches per plant and fruit length. Among the parents, AE-CBE-93 (P2) is a good general combiner for number of primary branches per plant and fruit length. Hence the gene action involved in this cross is of additive type of gene action and this cross can be subjected into pedigree breeding programme and early generation selection to improve these traits.

3.4 Reciprocal effect

The reciprocal effect of all crosses was presented in Table 4. Most of hybrids had significant reciprocal effect for all characters. Hence, while selecting crosses based on combining ability effects, the direction of crosses should be decided. The reciprocal effect of selected cross AE-CBE-93 x AE-CBE-921 (P2xP4) for fruit yield per plant is significant and positive. Hence the desirable direction of cross is AE-CBE-93 x AE-CBE-921 (P2xP4). The reciprocal cross of this cross is a low yielder and should not be selected for further breeding programme.

Table 1: Analysis of variance for combining ability effects of 6×6 diallel in okra

Source	Df	Plant height (cm)	Node at which first flower appears	Number of primary branches per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Number of fruits per plant	Fruit yield per plant (g)
GCA	5	1308.96**	0.70**	1.32**	14.36**	0.17**	18.89*	74.98**	45283.86*
SCA	15	1717.74**	0.29**	0.18**	2.94**	0.03**	20.91**	108.58**	36351.13**
Reciprocal	15	479.30**	0.12**	0.19**	2.15**	0.01**	9.93**	27.69**	30264.15**
Error	70	37.50	0.01	0.03	0.03	0.00	0.14	0.27	99.35
σ^2GCA		105.93	0.05	0.10	1.19	0.01	1.56	6.22	3765.37
σ^2SCA		1680.23	0.28	0.14	2.90	0.03	20.77	108.31	36251.77
σ^2GCA/σ^2SCA		0.06	0.20	0.73	0.41	0.42	0.07	0.05	0.10

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

Table 2: General combining ability effects of parents for fruit yield and component traits in okra

Genotype	Plant height (cm)	Node at which first flower appears	Number of primary branches per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Number of fruits/plant	Fruit yield per plant (g)
AE-CBE-92	5.34 **	-0.45**	-0.61**	0.28**	0.11**	1.41**	4.12**	92.94**
AE-CBE-93	-15.09 **	0.09**	0.31**	1.65**	0.03**	1.02**	1.61**	74.27**
AE-CBE-94	2.99	0.27**	0.08	-1.13**	0.15**	0.33**	0.01	18.28**
AE-CBE-921	-3.24 *	0.08**	-0.15**	-0.43**	-0.18**	-2.11**	-0.58**	43.00**
AE-CBE-943	15.48 **	0.07*	0.23**	-1.10**	-0.07**	-0.14	3.36**	49.88**
AE-CBE-934	-5.48 **	-0.06	0.12*	0.72**	-0.03**	0.51**	-0.29*	-6.50*
SE (gi)	1.61	0.03	0.05	0.05	0.00	0.10	0.14	2.63

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

Table 3: Specific combining ability effects of hybrids for different characters in okra

	Crosses	Plant height (cm)	Node at which first flower appears	Number of primary branches per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Number of fruits per plant	Fruit yield per plant (g)
P1XP2	AE-CBE-92 X AE-CBE-93	20.49**	-0.15*	-0.32**	-1.19**	0.03**	-2.32**	-4.39**	-155.72**
P1XP3	AE-CBE-92 X AE-CBE-94	-1.90	-0.02	-0.08	2.07**	0.05**	4.99**	-7.43**	-91.03**
P1XP4	AE-CBE-92 X AE-CBE-921	-15.86**	0.01	0.03	2.29**	0.17**	5.98**	8.37**	366.86**
P1XP5	AE-CBE-92 X AE-CBE-943	-1.44	-0.11	-0.24*	1.89**	0.11**	4.18**	-2.46**	80.30**
P1XP6	AE-CBE-92 X AE-CBE-934	26.07**	-0.02	-0.39**	-1.08**	-0.14**	-2.94**	-1.53**	-112.16**
P2XP3	AE-CBE-93 X AE-CBE-94	26.39**	-0.40**	0.17	-0.16	-0.13**	-0.56*	0.37	-12.94*
P2XP4	AE-CBE-93 X AE-CBE-921	-11.09**	0.01	0.17	-0.09	-0.07**	0.75**	-1.69**	10.35
P2XP5	AE-CBE-93 X AE-CBE-943	-12.72**	-0.28**	-0.36**	1.56**	0.15**	4.66**	-0.21	165.57**
P2XP6	AE-CBE-93 X AE-CBE-934	16.88**	-0.22**	-0.14	-0.01	-0.02*	1.69**	-1.42**	14.85*
P3XP4	AE-CBE-94 X AE-CBE-921	29.51**	-0.26**	0.05	0.28*	-0.02**	0.29	-0.83**	16.02**
P3XP5	AE-CBE-94 X AE-CBE-943	10.52**	0.07	-0.10	-1.25	-0.24**	-2.55**	-2.21**	-97.07**
P3XP6	AE-CBE-94 X AE-CBE-934	-0.93	-0.21**	0.00	-0.41**	-0.06**	0.93**	0.95**	61.42**
P4XP5	AE-CBE-921 X AE-CBE-943	24.82**	-0.03	-0.14	-1.04**	-0.10**	-4.40**	-10.18**	-228.27**
P4XP6	AE-CBE-921 X AE-CBE-934	-9.67*	-0.23**	0.01	-0.05	0.05**	0.05	-3.74**	-41.72**
P5XP6	AE-CBE-943 X AE-CBE-934	16.43**	-0.22**	-0.63**	0.95**	0.09**	2.39**	-7.59**	-80.68**

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

Table 4: Reciprocal effects of hybrids for different characters in okra

	Crosses	Plant height (cm)	Node at which first flower appears	Number of primary branches per plant	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Number of fruits per plant	Fruit yield per plant (g)
P1XP2	AE-CBE-93 X AE-CBE-92	-16.75**	-0.06	-0.04	-1.43**	0.16**	0.51	-1.58**	-19.28**
P1XP3	AE-CBE-94 X AE-CBE-92	11.52**	0.31**	0.06	-0.77**	-0.03**	0.99**	0.72	37.85**
P1XP4	AE-CBE-921 X AE-CBE-92	19.99**	-0.11	0.14	0.54**	0.05**	1.32**	-3.70**	163.37**
P1XP5	AE-CBE-943 X AE-CBE-92	13.68**	0.00	0.03	0.18	0.00	-3.06**	2.13**	-13.18
P1XP6	AE-CBE-934 X AE-CBE-92	-8.71*	-0.05	-0.05	0.27	-0.06**	-0.89**	2.24**	18.10*
P2XP3	AE-CBE-94 X AE-CBE-93	12.94**	-0.17*	-0.13	0.76**	0.00	0.19	-5.61**	-120.96**
P2XP4	AE-CBE-921 X AE-CBE-93	-8.93*	-0.23**	0.19	0.79**	0.10**	2.09**	-2.13**	17.93*
P2XP5	AE-CBE-943 X AE-CBE-93	-21.04**	-0.28**	-0.03	1.53**	0.00	0.80**	-4.52**	-84.87**
P2XP6	AE-CBE-934 X AE-CBE-93	19.18**	0.36**	0.61**	0.57**	-0.02*	0.45	-1.88**	-27.60**
P3XP4	AE-CBE-921 X AE-CBE-94	-8.68*	-0.17*	-0.17	0.56**	0.07**	1.21**	0.97*	46.63**
P3XP5	AE-CBE-943 X AE-CBE-94	-8.00	0.07	0.00	0.23	-0.06	1.64**	-1.34**	21.31**
P3XP6	AE-CBE-934 X AE-CBE-94	15.63**	-0.27**	0.64**	1.14**	0.09**	2.86**	6.42**	230.21**
P4XP5	AE-CBE-943 X AE-CBE-921	-4.04	-0.24**	-0.14	1.17	0.00	0.66*	4.28**	76.03**
P4XP6	AE-CBE-934 X AE-CBE-921	9.93*	0.33**	0.08	0.15	0.00	0.50	1.63**	43.96**
P5XP6	AE-CBE-934 X AE-CBE-943	33.33**	0.51**	-0.04	-1.14**	-0.01	-3.02**	0.43	-61.93**

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

4. Conclusion

Based on the foregoing discussion, it can be concluded that among six parents studied in a full diallel, parents AE-CBE-92 and AE-CBE-93 were adjudged as good general combiner for fruit yield and most of the yield contributing characters. Among hybrids, AE-CBE-93 x AE-CBE-921 (P2xP4) recorded additive gene action for fruit yield and few yield component traits. Selection could be applied in this cross in the early generation itself to improve fruit yield and yield component traits due to the presence of additive type of gene action. Hence this cross could be selected for pedigree breeding programme for the fruit yield improvement programme in okra.

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