Plant Archives Volume 21, No 1, 2021 pp. 672-677 *e-ISSN:2581-6063 (online), ISSN:0972-5210*

Plant Archives

Journal home page: www.plantarchives.org

DOI Url: https://doi.org/10.51470/PLANTARCHIVES.2021.v21.no1.093

COMBINING ABILITY ANALYSIS FOR FRUIT YIELD AND ITS COMPONENT TRAITS IN BHENDI (*ABELMOSCHUS ESCULENTUS* (L.) MOENCH)

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(Date of Receiving-17-11-2020; Date of Acceptance-16-02-2021)

ABSTRACT

The present investigation was undertaken to evaluate six parents and fifteen hybrids through half-diallel mating system to study general and specific combining ability effects and genetic analysis for various yield and yield attributing characters. Six parents viz., Arka Anamika (P_1), Thanvi 66 (P_2), Villupuram Local (P_3), Dhaanya (P_4), Ankur 41 (P_5) and Varsha Uphar (P_6) were crossed in half-diallel fashion at the Plant Breeding Farm, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University. Resulting fifteen hybrids along with their parents were evaluated for their combining ability. Observations were recorded on single plant basis. The observations were made on characters namely, days to first flowering, plant height at maturity, number of primary branches per plant, number of nodes per plant, number of fruits per plant, number of seeds per fruit, fruit length, fruit girth, single fruit weight and fruit yield per plant. In half-diallel analysis, the variance of the genotype for all the characters were highly significant indicating high genetic variability among the parents studied. The variance due to GCA was higher than the corresponding variance due to SCA for most of the characters except number of fruits per plant, fruit length and fruit girth. The combining ability variance revealed the preponderance of additive gene action for all the characters studied. The parents P_1 and P_6 were found as good general combiner. Based on the sca effects, the hybrid P_1 x P_6 considered as the best followed by crosses P_2 x P_4 and P_3 x P_4 considered as the better hybrids.

Keywords: Bhendi, combining ability, *gca* effects, *sca* effects

INTRODUCTION

Among the vegetables, India is one of the largest producers and consumers of bhendi in the world. In India bhendi is cultivated in area of 528 lakh ha with a production of 61 mt and productivity is 11.60 mt/ha (FAO, 2017). In Tamil Nadu it is cultivated in area of 12.78 lakh ha with a production of 88.07 mt and productivity is 6.89 mt/ha (NHB, 2017).

The young, immature, green, non-fibrous, edible and tender delicious fruits of bhendi which are used as vegetables in salads, soups and sauces are also good sources of iodine, calcium, iron and vitamins A, B, C (Woodroof, 1927; Ephenhuijsen, 1974, Purseglove, 1974; Cobley and Stele, 1976; Martin and Ruberty, 1978). Okra leaves are most frequently cooked as curry or added to soups and stews. It provides vitamins A and protein, calcium and iron (Irvine, 1952). Mature dried seeds of okra and roasted and ground as a coffee substitute, or added to coffee as an adulterant (Burkill, 1935). Okra dry seeds contain 13 to 22 per cent oil. The percentage of oleic acid and linoleic acid is 60 to 65 per cent. Residue of the whole seed contains 18 to 27 per cent protein and relatively high thiamine, niacin, and tocopherol content. It appeared to be a suitable ingredient in diet for rats and chicks (Edwards and Miller, 1947). Okra seed protein is rich in tryptophan (94 mg/g N) and has an adequate content of sulphur containing amino acids (189 mg/g N). The protein of okra could thus complement that of legumes or cereal grain in some dietary combinations (Savello *et al*., 1980).

Many biometrical procedures have been developed to obtain information on combining ability. Among them, partial diallel technique is an ideal method to evaluate the parents and their hybrids. This is also providing information on the nature of gene action which helps in identifying desirable parents and hybrids for further exploitation. It is an extensively used technique for screening the germplasm on the basis of GCA and SCA variances and effects, which is useful in deciding the relative ability of female and male lines to produce desirable hybrid combinations.

MATERIALS AND METHODS

The present investigation was carried out at the Plant Breeding Farm, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalai Nagar, during the year 2017. The biological materials used for this study comprised of six parents viz., Arka Anamika (P_1), Thanvi 66 (P_2), Villupuram Local (P_3),

Source	Df	Days to first flowering	Plant height at maturity	Number of primary branches per plant	Number of nodes per plant	Number of fruits per plant	Number of seeds per fruit	Fruit length	Fruit girth	Single fruit weight	Fruit yield per plant
Replication	2	-0.02	0.01	-0.01	2.57	-0.01	-0.03	0.01	0.01	0.01	-1.24
Genotypes	20	26.00**	61.88**	0.49**	14.51**	17.87**	75.29**	11.24**	0.70**	18.69**	22168.13**
Error	40	0.01	0.01	0.01	0.33	0.01	0.01	0.02	0.01	0.01	0.03

Table 1. Analysis of variance *significant at 5% level **significant at 1% level

Source	Days to first flowering	Plant height at maturity	Number of primary branches per plant	Number of nodes per plant	Number of fruits per plant	Number of seeds per fruit	Fruit length	Fruit girth	Single fruit weight	Fruit yield per plant
σ^2GCA	17.69	23.71	0.18	6.51	4.91	6.52	3.32	0.21	8.97	7972.16
σ^2SCA	5.66	19.60	0.16	4.27	6.30	4.28	3.88	0.24	5.31	7195.16
GCA/SCA	3.13	1.21	1.12	1.52	0.77	1.52	0.85	0.92	1.69	1.11

Table 2. Estimation of combining ability variance

	Characters / Genotypes/hybrids	Days to first flowering	Plant height at maturity	Number of primary branches per plant	Number of nodes per plant	Number of fruits per plant	Number of seeds per fruit	Fruit length	Fruit girth	Single fruit weight	Fruit yield per plant
1	P_1	-1.93**	0.67**	0.11**	0.47**	1.06**	-0.39**	0.63**	0.01	1.04**	36.59**
2	P_2	-0.55**	-0.16**	-0.25**	1.16**	-0.04**	0.31**	0.53**	-0.28**	0.41**	6.32**
3	P_3	1.73**	-3.07**	0.03**	-1.01**	-1.03**	-3.37**	-0.97**	0.05**	-1.04**	-34.90**
4	P_4	-1.24**	0.07**	-0.06	0.25*	0.57**	1.88**	-0.29**	-0.06**	0.95**	27.03**
5	P_5	1.51**	0.30**	0.17**	-1.16**	-0.73**	1.92**	-0.38**	0.22**	-1.54**	-40.98**
6	P_6	0.47**	2.19**	0.06**	0.28*	0.16**	-0.34**	0.48**	0.05**	0.18**	6.95**
7	P_1 x P_2	-0.58**	3.14**	-0.31**	0.99**	0.88**	7.32**	-0.41**	0.23**	-0.02**	13.61**
8	P_1 x P_3	-1.21**	0.11**	0.28**	0.70**	1.21**	0.61**	0.49**	0.13**	0.98**	34.12**
9	P_1 x P_4	2.88**	1.33**	0.39**	-0.02	-1.29**	-1.38**	0.69**	0.29**	-1.78**	-58.14**
10	P_1 x P_5	0.60**	-4.09**	0.27**	-2.62**	0.25**	-2.29**	1.49**	-0.60**	0.24**	109.80**
11	P_1 x P_6	-1.53**	8.70**	0.05**	2.92**	3.68**	1.95**	2.10**	-0.09**	3.53**	143.69**
12	P_2 x P_3	2.24**	1.68**	0.28**	2.74**	-0.26**	3.50**	1.51**	-0.57**	-0.39**	-15.56**
13	P_2 x P_4	0.06**	1.84**	0.30**	1.22**	3.18**	7.38**	2.55**	-0.54**	2.84**	115.22**
14	P_2 x P_5	-0.25**	4.13**	-0.36**	1.03**	3.00**	0.92**	1.93**	-0.28**	2.99**	5.48**
15	P_2 x P_6	-3.75**	-3.31**	0.19**	-1.64**	-1.38**	-0.24**	-1.85**	-0.26**	-1.16**	-48.99**
16	P_3 x P_4	-0.60**	6.76**	-0.25**	2.81**	3.14**	-0.26**	-1.65**	-0.38**	3.07**	105.08**
17	P_3 xP_5	1.18**	1.27**	-0.04**	-0.32*	1.45**	2.42**	-0.12**	-0.13**	0.24**	24.73**
18	P_3 x P_6	2.75**	2.55**	0.08**	-1.76**	-1.15**	-8.41**	2.16**	0.21**	-2.00**	-56.41**
19	P_4 x P_5	-4.65**	-2.27**	0.33**	-2.81**	-0.67**	-1.14**	-0.24**	0.33**	-2.67**	-60.66**
20	P_4 x P_6	-0.27**	-4.04**	0.55**	0.15	2.43**	2.30**	2.42**	-0.64**	2.44**	89.71**
21	P_5 x P_6	3.74**	-0.56**	0.32**	1.42**	-0.10**	-2.79**	0.03	-0.37**	-2.44**	-47.58**
	SE for parents	0.01	0.01	0.01	0.10	0.01	0.01	0.02	0.01	0.01	0.03
	SE for hybrids	0.01	0.02	0.01	0.14	0.01	0.01	0.04	0.02	0.01	0.04

*significant at 5% level **significant at 1% level

Table 3. Estimates of combining ability effects for fruit yield and its contributing characters in bhendi

Dhaanya (P_4), Ankur 41 (P_5) and Varsha Uphar (P_6) which were received from the Indian Institute of Horticultural Research, Bangalore, National Bureau of Plant Genetic Resources, Thrissur and from Villupuram local area. Crosses in all possible combination were made through half diallel method.

The seeds of six genotypes were sown separately for effecting crosses during February 2017. The spacing adopted was 60 cm between rows and 45 cm between plants within a row. The row length was 4.5 meters recommended cultural practices and need based plant protection measures were followed. The flower buds which are likely to open in the following day were selected and bagged with butter paper cover between 4.00 pm and 6.00 pm to ensure selfing and maintain the genetic purity of the parents for further crossing programmes and evaluation.

In the crossing block, the selected immature flower buds which are likely to open during the next day morning were emasculated in the previous day between 3.00 pm and 6.00 pm. The tip of the corolla of the flower bud was cut off and a vertical cut was given to the united calyx. The calyx and corolla were gently removed including stamina column without injuring gynoecium. The emasculated flower buds (female) and the flower buds selected as males were also covered with a butter paper cover. Enough care was taken to not to disturb the style and stigma of the emasculated flower buds.

The anthers dehisced between 7.00 and 9.00 am were collected and used for dusting over the stigma of the emasculated flowers. The pollinated flowers were covered with a butter paper cover and labeled. Thus plant-to-plant crosses were produced. Hybridization process was carried out for 25 days until sufficient quantity of hybrid seeds were produced. The crossed seeds were collected separately by maintaining identity and individuality.

The seeds obtained from the crossing block were sown during August 2017 to raise the hybrids. Six parents and fifteen hybrids were raised in a randomized block design with three replications. The seeds of each entry were sown in a single row of 3m long ridges with a spacing of 45cm x 30 cm and uniform population of 10 plants were maintained. A total of 21 ridges were formed in a plot size of 9.5m x 9m. Cultural and agronomic practices were followed as per the standard recommendation and need based plant protection measures were taken up to maintain healthy crop stand. The biometrical observations like days to first flowering, plant height at maturity, number of primary branches per plant, number of nodes per plant, number of fruits per plant, number of seeds per fruit, fruit length, fruit girth, single fruit weight and fruit yield per plant were taken. The data were analyzed for combining ability.

RESULTS AND DISCUSSION

The variance due to genotypes was significant for all the characters studied. The result of the present study indicated that existence of significant differences among the parents. Therefore, further analyses were appropriate.

The variances due to GCA were greater than SCA for days to first flowering, plant height at maturity, number of primary branches per plant, number of nodes per plant, number of seeds per fruit, single fruit weight and fruit yield per plant. These findings showed that these traits were predominantly controlled by additive gene action. These results are in the corroboration with the findings of Pughazenthi (2017). The variances due to SCA were greater than GCA for fruit length, fruit girth and number of fruits per plant. These findings showed that these traits were predominantly contolled by non-additive gene action. The results are in the corroboration with the findings of Senthil kumar *et al.,* (2006b), Manivannan *et al*., (2007a), Senthil kumar and Sreeparvathy (2008). These characters could be improved by delaying the selection to the later segregating generations until the dominance and epistasis disappear and resorting to intermating of segregants followed by recurrent selection. Anderson (1939); Al.Jibouri *et al*., (1958); Jensen (1970); Hallauer (1981 and 1986); Ramage (1981); Frey (1984) and Delogu *et al.,* (1988) suggested recurrent selection as a basic breeding approach in self-pollinated crops. In addition, diallel type mating could be adopted to get elaborative results. Selective mating design as suggested by Jensen (1970) can also be adopted. It will promote more recombination.

The success of any plant breeding programme largely depends on the correct choice good parents. Simmonds (1979) pointed out that it is better to choose parents possessing significant *gca* effects or merely base on mean performance. This assumption is based on the principle that *gca* effects reflects additive gene action. Sometimes, the immediate hybrid may not perform well despite both the parents possessing high *gca* effects for a trait due to the interaction of the parental *gca* effects which may cause distortions on expectations. The reverse trend may also happen with low performing parents showing high hybrid values than expected. This interaction is measured by *sca* effects of the hybrids. The specific combining ability is the deviation from the performance predicted on the basis of general combining ability (Allard, 1960). According to Sprague and Tatum (1942), the specific combining ability is controlled by non-additive gene action. The *sca* effects are an important criterion for the evaluation of hybrids.

Three out of six parents recorded negative significant *gca* effects for days to first flowering. It was maximum with Arka Anamika (P_1) followed by Dhaanya (P_4) and Thanvi 66 (P_2). Eight out of 15 cross combinations showed negative significant *sca* effects. It was maximum with

Dhaanya x Ankur 41(P_4 x P_5) followed by Thanvi 66 x Varsha Uphar (P_2 x P_6) and Arka Anamika x Varsha Uphar (P_1 x P_6). All three cross combinations involved female parent with negative significant *gca* effects and male parent with positive significant *gca* effects. It indicated the non-additive gene effects. Our findings are confirmed by the earlier reports of Praveen Sampath Kumar (2011).

For plant height at maturity, two out of six parents recorded negative significant *gca* effects. It was maximum with Villupuram Local (P_3) followed by Thanvi 66 (P_2). Four out of 15 cross combinations showed negative significant *sca* effects. It was maximum with Arka Anamika x Ankur 41 (P_1 x P_5) followed by Dhaanya x Varsha Uphar (P_4 x P_6) and Dhaanya x Ankur 41 (P_4 x P_5). All three cross combinations involved female parent with positive significant *gca* effects and male parent with positive significant *gca* effects. It indicated the non-additive gene effects. These findings are confirmed by the earlier reports of Mann *et al.,* (1995), Singh (1998), Srivastava *et al.,* (2008) and Javia *et al.,* (2009).

For number of primary branches per plant, two out of six parents recorded positive significant *gca* effects. It was maximum with Villupuram Local (P_3) followed by Thanvi 66 (P_2). Four out of 15 cross combinations showed negative significant *sca* effects. It was maximum with Arka Anamika x Ankur 41 (P_1 x P_5) followed by Dhaanya x Varsha Uphar (P_4 x P_6) and Dhaanya x Ankur 41 (P_4 x P_5). The first cross combination had both the parents with positive significant *gca* effects. The second and third cross combinations had female parent with non-significant *gca* effects and male with positive significant *gca* effects. It may indicate the presence of dominance and epistasis. Similar results are also reported earlier by Langham (1961), Senthil Kumar and Sreeparvathy (2008) and Srivastava *et al.,* (2008).

In number of nodes per plant, four out of six parents recorded positive significant *gca* effects. It was maximum with Thanvi 66 (P_2) followed by Arka Anamika (P_1). Nine out of 15 cross combinations showed negative significant *sca* effects. It was maximum with Arka Anamika x Varsha Uphar (P_1 x P_6) followed by Villupuram Local x Dhaanya (P_3 x P_4) and Thanvi 66 x Villupuram Local (P_2 x P_3). The first cross combination involved both the parents with positive significant *gca* effects. It may indicate the presence of additive x additive gene effects. The second cross combinations had female parent with negative significant *gca* effects and male with positive significant *gca* effects. The reverse was true for the third cross combination. It may indicate the presence of dominance effect between the *gca* effects of the parents. Similar results are also recorded earlier by Mamta Rani and Arora (2003) and Singh and Singh (2003).

For number of fruits per plant, three out of six parents recorded positive significant *gca* effects. It was maximum with Arka Anamika (P_1) followed by Dhaanya (P_4). Nine out of 15 cross combinations showed negative significant *sca* effects. It was maximum with Arka Anamika x Varsha Uphar (P_1 x P_6) followed by Thanvi 66 x Dhaanya (P_2 x P_4) and Villupuram Local x Dhaanya (P_3 x P_4). The first cross combination had both the parents with positive significant *gca* effects. It may indicate the presence of additive and additive x additive gene effects. The second and third cross combinations had female parent with negative significant *gca* effects and male parent with positive significant *gca* effects. It may indicate the presence of dominance effect between the *gca* effects of the parents. Similar results are also reported earlier by Mamta Rani and Arora (2003) and Singh *et al*., (2009b).

Three out of six parents recorded positive significant *gca* effects for number of seeds per fruit. It was maximum with Ankur 41 (P_5) followed by Dhaanya (P_4). Eight out of 15 cross combinations showed negative significant *sca* effects. It was maximum with Thanvi 66 x Dhaanya (P_2 x P_4) followed by Arka Anamika x Thanvi 66 (P_1 x P_2) and Thanvi 66 x Villupuram Local (P_2 x P_3). The first cross combination had both the parents with positive significant *gca* effects. It may indicate the presence of additive and additive x additive *gca* effects. The second cross combinations had female parent with negative significant *gca* effects and male parent with positive significant *gca* effects. The reverse was true for the third cross combination. It may indicate the presence of dominance effect between the *gca* effects of the parents. The result is in agreement with the findings of Dabandata *et al.,* (2010).

In fruit length, three out of six parents recorded positive significant *gca* effects. It was maximum with Arka Anamika (P_1) followed by Thanvi 66 (P_2). Ten out of 15 cross combinations showed negative significant *sca* effects. It was maximum with Thanvi 66 x Dhaanya (P_2 x P_4) followed by Dhaanya x Varsha Uphar (P_4 x P_6) and Villupuram Local x Varsha Uphar (P_3 x P_6). The first cross combination involved female parent with positive significant *gca* effects and male parent with negative significant *gca* effects. The reverse was true for the second and third cross combinations. It may indicate the presence of dominance effect between the *gca* effects of the parents. Similar results are also reported earlier by Yadav *et al*., (2007) and Srivastava *et al*., (2004).

Four out of six parents recorded positive significant *gca* effects for fruit girth. It was maximum with Ankur 41 (P_5) followed by Villupuram Local (P_3). Five out of 15 cross combinations showed negative significant *sca* effects. It was maximum with Dhaanya x Ankur 41 (P_4 x P_5) followed by Arka Anamika x Dhaanya (P_1 x P_4) and Arka Anamika x Thanvi 66 (P_1 x P_2). The first cross combination had female parent with positive significant *gca* effects. It may indicate the presence of dominance effect between the *gca* effects of the parents. The second and third cross combinations had female parent with non-significant *gca* effects and male with negative significant *gca* effects. It may indicate the presence of dominance and epistasis. This result is in accordance with the findings of Dabandata *et al.,* (2010).

For single fruit weight, four out of six parents recorded positive significant *gca* effects. It was maximum with Arka Anamika (P_1) followed by Dhaanya (P_4). Eight out of 15 cross combinations showed negative significant *sca* effects. It was maximum with Arka Anamika x Varsha Uphar (P_1 x P_6) followed by Villupuram Local (P_3 x P_4) and Thanvi 66 x Ankur 41 (P_2 x P_5). The first cross combination had both the parents with positive significant *gca* effects. It may indicate the presence of additive and additive x additive gene effects. The second cross combinations had female parent with negative significant *gca* effects and male parent with positive significant *gca* effects. The reverse was true for the third cross combination. It may indicate the presence of dominance effect between the *gca* effects of the parents. Similar results are also reported earlier by Srivastava *et al.,* (2004).

Four out of six parents recorded positive significant *gca* effects for fruit yield per plant. It was maximum in Arka Anamika (P_1) followed by Dhaanya (P_4). Nine out of 15 cross combinations showed negative significant *sca* effects. It was maximum with Arka Anamika x Varsha Uphar (P_1 x P_6) followed by Thanvi 66 x Dhaanya (P_2 x P_4) and Villupuram Local x Dhaanya (P_3 x P_4). The first two cross combinations had both the parents with positive significant *gca* effects. It may indicate the presence of additive and additive x additive gene effects. The third cross combination had female parent with negative significant *gca* effects and male parent with positive significant *gca* effects. It may indicate the presence of dominance effect between the *gca* effects of the parents. Similar results are also reported earlier by Singh and Singh (2003) and Mamta Rani and Arora (2003).

Considering the *gca* effects of parents, Arka Anamika (P_1) was adjudged as the best source as it had significant desirable *gca* effects for number of fruits per plant, fruit girth, fruit weight and fruit yield per plant. Varsha Uphar (P_6) exhibited significant desirable *gca* effects for days to first flowering, fruit length, fruit weight and fruit yield per plant. Based on *sca* effects of hybrids, Anamika x Varsha Uphar (P_1 x P_6) for all the characters and the crosses Thanvi 66 x Dhaanya (P_2 x P_4), Villupuram Local x Dhaanya (P_3 x P_4), Thanvi 66 x Ankur 41(P_2 x P_5) and Villupuram Local x Varsha Uphar (P_3 x P_6) for six different traits including fruit yield per plant were adjudged as the best hybrid and suitable for exploitation of heterosis.

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