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STUDIES ON GENE ACTION IN BHENDI (*ABELMOSCHUS ESCULENTUS* L. MOENCH)

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Abstract

In a line × tester analysis involving 7 lines and 3 testers in bhendi (*Abelmoschus esculentus* L. Moench), combining ability was estimated for eight traits. The analysis for variance for combining ability revealed that predominance of SCA variance over GCA variance indicated that there traits might be controlled predominantly by non additive gene action. Among the lines Salem local, Theni local and Attur local and tester Dhivya 22 were considered as the best general combiners, while hybrids Salem local × Dhivya 22 and Attur local × Dhivya 22 as good specific combiners for fruit yield and other fruit yield component traits. Biparental mating followed by recurrent selection might hasten the rate of genetic improvement of these traits in bhendi.

Keywords: Bhendi, Combining ability, Gene action, Line × Tester analysis.

Introduction

Okra (*Abelmoschus esculentus* L. Moench) popularly known as ladies finger or bhendi is one of the most important vegetable crops grown in tropical, sub tropical and warm temperate regions of the World. Though Okra is a native of Tropical Africa, it is a highly prized vegetable of India. It is an important fruit vegetable grown for its tender fruits in India. It is an important member of the Malvaceae family with chromosome number 2n=130 and it is an allopolyploid in nature. Bhendi has an average nutritive value (ANV) of 3.21 which is higher than most of the vegetables (Grubben, 1977). Generally the tender fruits are consumed as vegetable.

Bhendi fruit has 88 percent moisture, 41 kcal, protein 2.2 g, carotene 58 mg, fat 0.2 g, thiamine 0.07 mg, fibre 1.2 g, magnesium 43 mg, phosphorus 0.08 g, ascorbic acid 16 mg, iron 1.5 mg, sulphur 54 mg and potassium 332 mg per 100 g of fruit (Swaminathan, 1990). It is a good source of folic acid, vitamin B and vitamin C providing 21.1 percent of daily value for a 2000 calorie and has high dietary fiber content. Drinking "okra water" is a popular new method of using okra which helps in reducing diabetes symptoms. The matured fruits and stem containing crude fibre are used in paper industry. Bhendi seed is a nutritious ingredient and cattle feed, which is a source of vegetable oil.

Okra is cultivated for its green non-fibrous fruits containing round seeds. The roots and stems of okra are used for clarification of sugarcane juice from which brown sugar is prepared (Chauhan, 1972).

This crop has a vast potential as one of the foreign exchange earner accounting for about 60 percent of export of fresh vegetables. Important bhendi importing countries are Middle West, Western Europe and USA.

India is the largest producer of okra in the world and shares nearly 12 percent of the total world output (Joshi and Shukla, 1997). Among the vegetables grown in India, okra occupies an area of 3.91 lakh hectares with an annual production of 39.7 lakh tonnes (Anon, 2009). In India, bhendi is cultivated in an area of 532.66 thousand hectare with a production of 6346 thousand metric tonnes. The productivity accounts for 12 tonnes per ha (Anonymous, 2014). In Tamil Nadu, bhendi is cultivated in an area of 5, 160 ha with an annual production of 38, 227 metric tonnes (FAO, 2007). The major okra producing states in India are Bihar, Andhra Pradesh, West Bengal, Orissa and Gujarat.

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The success of any breeding programme depends on the choice of right parents for hybridization programme. Combining ability analysis of the parents and their crosses provide information on the two variance *viz.,* additive and dominance, which are important to decide the parents and crosses to be selected for eventual crosses and also the appropriate breeding procedures to be followed to select desirable segregants. Hence, a study on combining ability of seven lines and three testers was undertaken. The concept of general and specific combining ability (Sprague and Tatum, 1942) helps the breeder to assess the combining ability effects of the parents and thus select superior combiners for heterosis breeding.

Materials and Methods

The present inquiry was made with 10 bhendi genotypes *viz.,* G_1) Chidambaram local, G_2) Kachirapalayam local, G_3) Villupuram local, G_4) Salem local, G_5) Dharmapuri local, G_6) Attur local, G_7) Theni local, G_8) Arka Anamika, G_9) Ankur and G_{10}) Dhivya 22. The genotypes namely 1-7 were considered as lines and the genotypes *viz.,* 8, 9 and 10 were used as testers. These 7 lines were mated with the aforementioned testers in line × tester mating design, as proposed by Kempthorne (1957). Thus 21 hybrids were evolved during 2018. The crop was raised in randomized block design with three replications during 2018 with a spacing of 45 × 30 cm.

Each genotypes (10parents plus 21 hybrids) was grown in two rows plot of 4.5 m length during 2018. Recommended agronomic practices and need based plant protection measures were judiciously followed. Observations were recorded on randomly selected five plants per entry per replication on eight agronomic traits *viz.,* X_1) Days to 50 per cent flowering, X_2) Plant height, X_3) Number of branches per plant, X_4) Fruit length, X_5) Fruit girth, X_6) Number of fruits per plant, X_7) Average fruit weight and X_8) Fruit yield per plant. Combined ability variance and effects were estimated by using the method outline by Kempthorne (1957). Statistical analyses were done with the package Generes.

Results and Discussion

The analysis of variance for combining ability (Table 1) revealed that the variance due to general combining ability (GCA) and specific combining ability (SCA) were highly significant for all the characters. The greater magnitude of SCA variance than GCA variance indicated the role of non-additive gene action for all the eight characters. Similar results were also reported by Jagan *et al.,* (2013) and Ali *et al.,* (2013) for days to 50 percent flowering, Kumar *et al.,* (2014) and Akotkar *et al.,* (2014) for plant height, Satish *et al.,* (2017) for number of branches per plant, Sibsankar Das *et al.,* (2013) for fruit length, Makdoomi (2018) for fruit girth, Lyngdoh *et al.,* (2017) for number of fruits per plant, Wakode *et al.,* (2016) for average fruit weight and Kayande *et al.,* (2018) for fruit yield per plant. The additive variance (s^2A) and dominance variance (s^2D) revealed that dominance variance (s^2D) was greater than the additive variance (s^2A) for all the characters. The ratio of (s^2A)/(s^2D) ranged from 0.0372 (Average fruit weight) to 0.2561 (Fruit girth).

The range and mean performance along with *gca* effects of 10 parents (7 lines and 3 testers) for all the 8 attributes have been presented in Table 2. Based on the combining ability effects, the parents values were categorized in three groups as good (G), average (A) and poor (P) general combiners. The parents with significant *gca* effects towards desirable direction were considered as good general combiners (G), with positive *gca* effects were considered as average general combiners (A) basis of good general combiner was taken as desirable *per se* performance and significance GCA and the parents with negative *gca* effects were designated as poor general combiners (P).

The good combiners on the basis of *per se* performance and significant *gca* effects in desirable direction were observed in line Salem local for days to 50 per cent flowering, plant height, number of branches per plant, fruit length, fruit girth, number of fruits per

Table 1: Analysis of variance for combining ability for 8 characters in bhendi.

Parents & hybrids variation	Days to 50 percent flowering	Plant height	Number of branches per plant	Fruit length	Fruit girth	Number of fruits per plant	Average fruit weight	Fruit yield per plant
GCA	0.5948	2.7181	0.1289	0.2076	0.0470	1.3714	0.0957	136.5331
SCA	4.1278	41.0987	0.7061	1.6969	0.1835	7.5911	2.5692	1653.9643
Estimated variances due to								
s^2A (F=1)	1.1896	5.4361	0.2579	0.4152	0.0939	2.7427	0.1914	273.0662
s^2D (F=1)	4.1278	41.0987	0.7061	1.6969	0.1835	7.5911	2.5692	1653.9643
s^2A/ s^2D	0.2881	0.1322	0.3652	0.2446	0.5117	0.3613	0.0744	0.1650
GCA/SCA	0.1440	0.06613	0.18255	0.12234	0.2561	0.18065	0.03724	0.082549

plant and average fruit weight. Similarly, line Attur local for number of branches per plant, fruit girth, number of fruits per plant, average fruit weight and fruit yield per plant. The line Theni local for days to 50 percent

Table 2: Mean performance of parents along with *gca* effects for fruit yield and its components traits in bhendi.

Genotypes (Parents)	Days to 50 percent flowering		Plant height (cm)		Number of branches per plant		Fruit length (cm)	
Lines	**Mean**	**GCA**	**Mean**	**GCA**	**Mean**	**GCA**	**Mean**	**GCA**
Chidambaram local	38.12	0.65**	81.28	3.65**	3.81	0.08	14.37	-0.87**
Kachirapaliyam local	34.42**	-3.57**	89.76	4.00**	2.96	-0.11*	14.24	-0.86**
Villupuram local	41.25	2.50**	71.89*	1.53**	5.14**	-0.49**	14.38	-0.99**
Salem local	35.35**	-1.90**	68.42**	-1.21*	5.12**	0.44**	16.23**	0.54**
Dharmapuri local	47.14	4.98**	60.74**	4.26**	5.17**	-0.86**	14.18	-1.51**
Attur local	37.22	-1.33**	91.04	-1.67**	5.27**	0.68**	15.21	2.48**
Theni local	36.25**	-1.33**	60.08**	-10.55**	4.85*	0.25**	16.36**	1.21**
SE±	0.29	0.41	0.45	0.64	0.04	0.05	0.12	0.17
Mean		41.12		74.74		4.61		14.99
CD (0.05)		0.82		1.30		0.11		0.35
CD (0.01)		1.10		1.73		0.15		0.47
Tester	**Mean**	**GCA**	**Mean**	**GCA**	**Mean**	**GCA**	**Mean**	**GCA**
Arka Anamika	36.14*	-1.53**	87.51	3.51**	3.63	-0.77**	15.61	-1.35**
Ankur	40.96	1.56**	83.27**	3.62**	3.69	-1.01**	14.92	-0.17**
Dhivya 22	37.15	-0.03	95.22	-7.13**	4.78**	1.78	16.41*	1.52**
SE±	0.19	0.26	0.29	0.42	0.02	0.03	0.08	0.11
Mean		40.93		88.66		4.03		15.64
CD (0.05)		0.54		0.85		0.07		0.23
CD (0.01)		0.72		1.13		0.10		0.31

* Significant at 5 percent level ** Significant at 1 percent level

Table 3: Mean performance of parents along with *gca* effects for fruit yield and its components traits in bhendi.

Genotypes (Parents)	Fruit girth (cm)		Number of fruits per plant		Average fruit weight (g)		Fruit yield per plant (g)	
Lines	**Mean**	**GCA**	**Mean**	**GCA**	**Mean**	**GCA**	**Mean**	**GCA**
Chidambaram local	3.58	-0.81**	16.32	-1.14**	13.71	-1.11**	225.26	-13.74**
Kachirapaliyam local	4.94	0.13**	14.68	-1.07**	15.48	-0.66**	200.08	-26.49**
Villupuram local	4.35	-0.6**	18.06	-0.07	14.09	0.14	190.66	-14.16**
Salem local	5.21*	0.40**	21.33**	2.58**	16.94**	1.42**	230.36	37.71**
Dharmapuri local	4.24	-0.45**	14.86	-5.23**	14.04	-0.86**	192.43	-41.84**
Attur local	5.94**	0.77**	21.98**	3.37**	16.92**	1.78**	248.88**	51.31**
Theni local	5.50**	0.59**	23.34**	1.54**	15.73	-0.71**	278.47**	7.20**
SE±	0.04	0.06	0.20	0.29	0.14	0.20	2.42	3.43
Mean		5.45		18.65		15.27		223.73
CD (0.05)		0.13		0.58		0.41		6.89
CD (0.01)		1.18		0.78		0.55		9.19
Tester	**Mean**	**GCA**	**Mean**	**GCA**	**Mean**	**GCA**	**Mean**	**GCA**
Arka Anamika	5.25	0.29**	19.38	-1.79**	14.21	-1.12**	233.20	-20.73**
Ankur	4.76	-0.77**	18.79	-3.14**	16.45	-0.19	240.24	-30.14**
Dhivya 22	6.02**	0.48**	22.48**	4.94**	16.81**	1.31**	260.47**	50.87**
SE±	0.03	0.04	0.13	0.19	0.09	0.13	1.58	2.24
Mean		5.30		20.21		15.82		244.63
CD (0.05)		0.08		0.38		0.27		4.51
CD (0.01)		0.11		0.51		0.36		6.02

* Significant at 5 percent level ** Significant at 1 percent level

Table 3: Mean performance of crosses along with *sca* effects for fruit yield and its components traits in bhendi.

Parents	Days to 50 per cent flowering		Plant height (cm)		No. of branc-hes per plant		Fruit length (cm)		Fruit girth (cm)		No. of fruits per plant		Average fruit weight (g)		Fruit yield per plant (g)	
	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA	Mean	SCA
Chidambaram Local ´Arka Anamika	39.04	0.51	83.56	2.05*	3.18	-0.63**	15.37	0.98**	4.30	-0.06	20.94	-0.02	12.64	-1.00**	249.92	16.65**
Chidambaram Local ´Ankur	41.45	-0.18	78.52	-3.09**	4.21	0.63**	14.23	-1.34**	3.75	0.46**	18.47	-1.14**	15.14	0.56*	225.09	1.23
Chidambaram Local ´Dhivya 22	39.70	-0.33	71.92**	1.04	6.37**	0.00	17.62**	0.36	4.15	-0.40**	28.85**	1.16**	16.51	0.43	286.98**	-17.88**
Kachirapalayam Local ´Arka Anamika	33.64**	-0.68	81.60	-0.26	3.39	-0.24**	15.15	0.74**	5.54**	0.25**	20.56	-0.47	12.15	-1.95**	251.50	30.99**
Kachirapalayam Local ´Ankur	40.01	2.60**	85.43	3.46**	3.20	-0.20**	16.04	0.45*	3.91	-0.32**	18.09	-1.59**	15.81	0.78**	230.49	19.39**
Kachirapalayam Local ´Dhivya 22	33.89**	-1.92**	68.02**	-3.20**	6.62**	0.44**	16.08	-1.20**	5.55**	0.07	29.81**	2.05**	17.69**	1.16**	241.73	-50.38**
Villupuram Local ´Arka Anamika	41.90	1.52**	80.73	1.34	3.04	-0.20**	13.04	-1.23**	4.32	-0.22**	18.27	-3.76**	14.38	-0.51*	220.55	-12.29**
Villupuram Local ´Ankur	40.39	-3.09**	75.98	-3.51**	3.66	0.65**	16.23	0.78**	4.02	0.55**	25.42**	4.74**	17.72**	1.90**	260.41	36.98**
Villupuram Local ´Dhivya 22	43.45	1.57**	70.93**	2.18**	5.34**	-0.46**	17.59**	0.45*	4.40	-0.33**	27.79**	-0.97**	15.94	-1.38**	279.76*	-24.68**
Salem Local ´Arka Anamika	34.70**	-1.29**	75.10	-1.55	4.32	0.15	16.90	1.10**	5.62**	0.05	24.68	-0.00	16.91	0.74**	259.87	-24.85**
Salem Local ´Ankur	40.67	1.59**	84.06	7.31**	3.26	-0.68**	15.24	-1.74**	4.42	-0.08	22.34	-0.99	16.29	-0.82**	240.48	-34.82**
Salem Local ´Dhivya 22	37.18**	-3.27**	60.25**	-5.76**	7.26**	0.53**	19.32**	0.64**	5.79**	0.35**	32.40**	0.99**	18.69**	0.08	415.98**	59.67**
Dharmapuri Local Arka Anamika	44.40	1.53**	88.13	6.01**	3.31	0.44**	13.62	-0.14	4.31	-0.40**	17.90	1.03**	13.26	-0.63*	207.37	2.21
Dharmapuri Local ´Ankur	42.69	-0.30	72.31	-9.91**	3.77	1.13**	15.96	1.03**	4.00	0.03	18.67	3.15**	15.88	1.05**	224.51	28.76**
Dharmapuri Local ´Dhivya 22	46.10	1.74**	75.38	3.90**	3.87	-1.56**	15.74	-0.89**	4.95	0.05	19.42	-4.18**	15.91	-0.42	245.79	-30.97**
Attur Local ´Arka Anamika	36.02**	-0.53	74.98	-1.21	4.93**	0.51**	15.72	-2.02**	6.30**	0.36**	26.89**	1.42**	17.29**	0.76**	274.38	-23.93**
Attur Local ´Ankur	41.47	1.83**	83.78	7.48**	3.17	-1.01**	20.29**	1.37**	4.10	-0.77**	21.73	-2.39**	16.79*	-0.68**	250.25	-38.65**
Attur Local ´Dhivya 22	36.75**	-1.30*	59.29**	-6.27**	7.48**	0.50**	21.26**	0.65**	6.54**	0.41**	33.17**	0.97**	18.90**	-0.08	432.49**	62.58**
Theni Local ´Arka Anamika	35.50**	-1.06	60.94**	-6.37**	3.97	-0.02	17.04	0.57*	5.76**	0.01	25.45**	1.81**	16.64*	2.60**	265.44	11.23*
Theni Local ´Ankur	40.16	0.51	65.68**	-1.73*	3.23	-0.52**	17.09**	-0.56*	4.50	-0.19**	20.51	-1.78**	12.18	-2.80**	231.89	-12.90**
Theni Local ´Dhivya 22	38.60	0.55	64.78**	8.11**	7.09**	0.54**	19.34**	-0.01	6.12**	0.18*	30.34**	-0.03	16.69*	0.21	327.47**	1.67
SE	0.50	0.71	0.79	0.12	0.07	0.10	0.21	0.30	0.08	0.11	0.35	0.50	0.25	0.35	4.20	5.94
Mean		41.03		74.35		4.51		16.61		6.01		23.89		15.88		267.73
CD (P=0.05)		1.43		2.25		0.20		0.61		0.23		1.01		0.71		11.94
CD (P=0.01)		1.91		3.00		0.27		0.82		0.31		1.35		0.95		15.93

* Significant at 5 percent level ** Significant at 1 percent level.

flowering, plant height, number of branches per plant, fruit length, fruit girth, number of fruits per plant and fruit yield per plant. Line Kachirapaliyam local for days to 50 per cent flowering. Tester Arka Anamika was found to be significant *per se* with good general combiner for days to 50 per cent flowering. Tester, Dhiva 22 for fruit length, fruit girth, number of fruits per plant, average fruit weight and fruit yield per plant. A close examination of the result revealed that the lines Salem local and Theni local combined well for the highest number of seven characters each. Line Attur local and tester Dhivya 22 for five characters each. Line Kachirapaliyam local and tester Arka Anamika for one character each was good general combiner based on *per se* and general combining ability effects.

The estimates for *gca* effects of the parental lines for different characters revealed that none of the parental lines excelled in *gca* effects for all the characters studied. The parents evaluated both *per se* and *gca* effects leads to the identification of the lines Salem local and Theni local followed by the line Attur local and tester Dhivya 22 as best. These may be used for exploiting additive type genetic variability which is fixable type and selection may be effective in segregating population for development of better genotype with regards to yield. However, line Kachirapaliyam local and tester Arka Anamika which possessed favourable *per se* performance and *gca* effects may be used for multiple parent participation through multiple crossing to effect substantial improvement having for broad genetic base population. Similar results were reported by Khatik *et al.,* (2013) and Kumar *et al.,* (2014) for fruit yield per plant. The *sca* effects represent the non-additive gene action which is non-fixable (Table 3). The estimation of specific combining ability (*sca* effects for 21 hybrids along with mean performance for all the eight characters are presented in Table 3, significant positive or negative *sca* effects were observed in F_1 generation for fruit yield and various attributing traits. In the present investigation, one cross expressed good specific combining ability effect for all the traits *viz.,* Villupuram local × Ankur. Out of 21 crosses, five for days to 50 per cent flowering, ten for number of branches per plant, eleven for fruit length, seven for fruit girth, nine for number of fruits per plant and eight crosses showed significant and positive *sca* effect for plant height, average fruit weight and fruit yield per plant.

The cross combinations *viz.,* Chidambaram local × Arka Anamika, Kachirapalayam local × Arka Anamika, Kachirapalayam local × Ankur, Villupuram local × Ankur, Salem local Dhivya 22, Dharmapuri local × Ankur, Attur local × Dhivya 22 and Theni local × Arka Anamika which showed significant positive *sca* effects for fruit yield per plant. The cross combinations *viz.,* Salem local × Dhivya 22 and Attur local × Dhivya 22 which showed good *per se* performance and significant positive *sca* effects for fruit yield per plant, also showed significant *sca* effects for other important component traits. The two crosses *viz.,* Salem local × Dhivya 22 and Attur local × Dhivya 22 which showed highest significant *per se* performance and significant *sca* effect for fruit yield may be used in breeding programme and might be expected to give transgressive segregation in F_2. On the other hand, the crosses *viz,* Salem local × Dhivya 22 and Attur local × Dhivya 22 with good *per se* performance and significant *sca* effect were common for days to 50 percent flowering, plant height, number of branches per plant, fruit length, fruit girth, number of fruits per plant and fruit yield per plant. Hence, these crosses may be exploited for developing hybrid/genotypes with better fruit yield and other traits. These cross combinations may be exploited in heterosis breeding programme for developing genotype having broad genetic base by multiple crossing programme.

The crosses involving high gca parents generally give high *sca* effects (Amarnath and Subramanyam, 1992). In the present study, the hybrids Salem local × Dhivya 22 and Attur local × Dhivya 22 which recorded high *sca* effects for fruit yield per plant had parents with high × high *gca* effects suggesting the presence of additive × additive type of gene interaction (Akotkar *et al.,* 2014 and Annapurna and Singh, 2018) also reported interaction between positive and positive alleles in cross involving high × high combiners which can be fixed in subsequent generations if no repulsion phase linkage are involved. The promising parents namely for lines Salem local and Theni local and tester for Dhivya 22 which are having *per se* performance and *gca* effects in desirable direction for fruit yield and other traits may be in corporated in crossing programme to have better genotypes for better and fruit yield. The crosses Salem local Dhivya 22 and Attur local × Dhivya 22 with good *per se* performance and significant *sca* effect for major fruit yield and other components were also found superior for days to 50 percent flowering, plant height, number of branches per plant, fruit length, fruit girth, number of fruits per plant and fruit yield per plant may be exploited for better fruit yield and other traits by exploiting them through heterosis breeding or involving them in multiple cross breeding programme for obtaining transgressive segregants and broad genetic base population in bhendi for improvement in fruit yield.

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