Journal of Applied and Natural Science 9 (1): 324 - 331 (2017)

Combining ability analysis in near homozygous lines of okra [*Abelmoschus esculentus* (L.) Moench] for yield and yield attributing parameters

Y. A. Lyngdoh[1], R. Mulge[2], A. Shadap[3], Jogendra Singh[1*] and Seema Sangwan[4]

[1]Division of Vegetable Science, ICAR-IARI, New Delhi-110012, INDIA
[2] Department of Vegetable Science, K.R.C. College of Horticulture, Arabhavi-591218 (Karnataka), INDIA
[3]Bidhan Chandra Krishi Viswavidyalaya, Mohanpur –741252 (West Bengal), INDIA
[4]Division of Microbiology, ICAR-IARI, New Delhi-110012, INDIA
*Corresponding author. E-mail: jogendra169@gmail.com

Received: May 9, 2016; Revised received: November 4, 2016; Accepted: January 30, 2017

Abstract: Line × tester analysis was carried out with the objective of identifying the good combiners and to decide the breeding strategies for developing potential and productive genotypes or cultivars. Parents and hybrids differed significantly for GCA and SCA effects for all the characters respectively. Specific combining ability (SCA) variance was higher than the general combining ability (GCA) variance which shows the predominance of non-additive gene action for the improvement of all the characters studied. The parents and crosses having highest and significant GCA and SCA effects *viz.,* KO-18 (13.69), KO-6 (9.54) and KO-2 × Parbhani Kranti (19.28) for plant height; KO-12 (0.34), KO-14 (0.19) and KO-5 × V5 (0.60) for number of branches per plant; KO-14 (-0.66) and KO-15 × Arka Anamika(-1.66) for days to first flowering; KO-1(1.10), Arka Anamika (0.46) and KO-9 × VRO-5 (3.28) for fruit length; KO-7 (7.91), VRO-5(1.68) and KO-18 × VRO-6 (8.64) for average fruit weight; KO-2 (1.18) and KO-17 × Arka Anamika (2.80) for number of fruits per plant; KO-9(0.05), VRO-6 (0.01) and KO-11 × VRO-6 (0.10) for total yield per plant were identified as good general and specific combiners. The results establish the worth of heterosis breeding for effective usage of non-additive genetic variance in okra.

Keywords: Combining ability, Okra, Line × tester, Variance

INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench] commonly recognized as bhendi or lady's finger is a fast growing annual crop which has acquired a spectacular status among vegetables in India. Being a native of Tropical Africa it is grown for its tender fruits in tropics, subtropics and warmer seasons of the temperate areas in the world. This crop is gaining its importance as it has multiple uses where it can be used as a vegetable, eaten boiled, sliced and then sundried or canned and dehydrated for off season use.

Combining ability is the capacity of an individual to transmit superior performance to its offspring determining the relative magnitude of additive and non-additive gene effects (Griffing, 1956) for developing potential and productive genotypes or cultivars. General combining ability measures average performance of a parent in hybrid combination and specific combining ability is the performance of a hybrid that is expected on the basis of average performance of parents involved. The main problem for cultivation of okra in India is lack of location specific high yielding varieties. Initially selection of okra was made from locally adapted population and exploitation of hybrid vigour and selection of parents on the basis of combining ability has opened a new line of approach in crop improvement. Therefore, for a systematic breeding programme, it is essential to identify the parents, as well as crosses which could be exploited in order to bring about further genetic improvement in economic characters. The line × tester analysis is one of the techniques where a large number of genotypes could be tested for their combining ability. GCA and SCA effects estimates have a direct bearing on the breeding methods that could be adopted in okra improvement programme (Singh *et al*., 2009; Wammanda *et al*., 2010; Reddy *et al*., 2011; Kumar and Reddy, 2016). Earlier reports of researchers (Kumar *et al*., 2006; Singh *et al*., 2009; Wammanda *et al*., 2010; Reddy *et al*., 2011; Singh and Goswami, 2015; Bhatt *et al*., 2015; Kumar and Reddy, 2016) indicated that both additive and non-additive genetic systems control yield and yield contributing traits in okra. However, higher magnitude of non-additive genetic effects was the major part of genetic variation for yield and yield contributing traits in okra (Kumar *et al*., 2006; Wammanda *et al*., 2010; Reddy *et al*., 2011; Singh and Goswami, 2015; Bhatt *et.al*., 2015; Kumar and Reddy, 2016). However, genetic investigation of transmission of various important characters has remained far from fully explored in okra. Hence an attempt has been made to

ISSN : 0974-9411 (Print), 2231-5209 (Online)

estimate the GCA and SCA variances in the okra population; to evaluate the breeding potential per se in specific combinations (SCA) and their overall performance in crosses (GCA) respectively, to identify the best combiners among the existing germplasm as well as to study the gene action of different quantitative characters in line × tester analysis for formulation of a sound and effectual breeding programme in okra.

MATERIALS AND METHODS

Choice of parental material: The parental materials available at the Department of Vegetable Science, Kittur Rani Channanna College of Horticulture, Arabhavi were utilized for the study. The lines were near homozygous and were selected based on their *per se* performance for yield and quality attributes and relatively free from yellow vein mosaic virus incidence.

Generating breeding material: 72 hybrids were derived by crossing 18 lines and 4 testers (Parbhani Kranti, Arka Anamika, VRO-5 and VRO-6) in the first season.

Experimental design and crop management: All the 72 hybrids along with their parents, testers and a commercial hybrid (MHY-10) were evaluated in a randomized block design with three replications during 2010-2011 at the Department of Vegetable Science, K.R.C. College of Horticulture, Arabhavi, Gokak Taluk, Belgavi district, Karnataka, India. Each treatment or a genotype in each replication was represented by one row each accommodating 20 plants at a row to row spacing of 60cm and 30cm from plant to plant. The experimental farm is situated at Northern Dry Zone of Karnataka at 16° 15' N latitude, 74° 45' E longitude and at an altitude of 612.03 meters above the mean sea level. Arabhavi, which comes under the Zone-3 of Region-2 among the agro-climatic zones of Karnataka, has benefits of both the South-west and north-east monsoons. The average rainfall of this area is about 522 mm, distributed over a period of five to six months (June to November) with peaks during October. The command area receives water from Ghataprabha Left Bank Canal from mid-July to mid-March.

Recording of biometric data: Five plants were randomly selected for each genotype from each replication and evaluated for the quantitative characters such as plant height (cm), intermodal length (cm), number of branches per plant, number of nodes on main stem, days to first flowering, number of nodes at first flowering, number of nodes at first fruiting, fruit length (cm), fruit diameter (mm), average fruit weight (g), number of fruits per plant, total yield per plant (g), number of ridges per fruit, number of locules per fruit and number of seeds per fruit.

Statistical analysis: The mean values of the data recorded were analyzed statistically adopting the method suggested by Kempthorne (1957).

RESULTS AND DISCUSSION

The analysis of combining ability is one of the potential tools used for identification of prospective parents to develop commercial F_1 hybrids (Griffing, 1956). General and specific combining ability effects and variances obtained from a set of F_1's would enable a breeder to select desirable parents and crosses for each of the quantitative components. General combining ability effects of parents and SCA effects of crosses were highly significant for the characters studied. The variance due to general combining ability (GCA), specific combining ability (SCA) and GCA to SCA ratio for various characters are presented in Table 1. SCA variances estimation was high for all the characters studied, which indicated the importance of non-additive gene action for the improvement of these characters. The estimates of GCA/SCA ratio (variance ratio) indicated that a relatively higher proportion of SCA was responsible for the expression of all the traits. This result is expected as okra is a cross pollinated crop thus exhibiting predominance of dominance genetic variance in comparison to additive component. The results are in conformity with the findings of Kumar *et al.* (2006), Singh and Syamal (2006), Weerasekara (2006), Srivastava *et al.* (2008), Singh *et al.* (2009), Solankey and Singh (2010), Singh and Goswami (2015), Bhatt *et al.* (2015) and Kumar and Reddy (2016) in okra for days to first flowering, plant height, primary branches per plant, fruit length, fruit girth, fruit weight, fruits per plant and fruit yield per plant. A perusal of the result revealed that in most of the cases per se performance of parents bear direct reflection of their respective GCA effects, i.e. parents showing highest GCA effects for a character, were also observed to be good performer with respect to that particular character.

The statistical data of general combining ability effects (Table 2) of the lines and testers indicates that none of the parental lines were good combiners for all the traits. The lines, KO-18 and KO-6 were the best general combiner for plant height whereas KO-12 and VRO-6 were the best general combiners for number of branches per plant among lines and testers. For days to first flowering, KO-14 among lines showed as the best general combiner whereas none of the tester expressed significant GCA effect. Among the testers, VRO-5 and line KO-15 were best general combiner for flowering at early node, whereas, KO-6 among lines and Parbhani Kranti among testers came out as best general combiners for shorter internodal length. The lines, KO-1, KO-18 and tester, Arka Anamika were most effective general combiners for fruit length. The best general combiner line and tester for fruit diameter were KO-7 and Arka Anamika, respectively. For average fruit weight, the lines, KO-6 and KO-16 and the tester, VRO-5 were the best general combiners. For number

Table 1. Analysis of variance (mean sum of squares) of line × tester analysis for various characters in okra.

Character	Replications	Genotypes	Parents	Parents vs Crosses	Crosses	Lines	Testers	Line × Tester	Error	GCA	SCA	GCA : SCA
Degrees of freedom	**1**	**93**	**21**	**1**	**71**	**17**	**3**	**51**	**93**			
Growth parameters												
Plant height (cm)	75464.68**	327.37**	311.38*	605.46NS	328.19**	405.65NS	102.48NS	315.64**	152.23	2.799	81.709	0.034
Internodal length (cm)	180.71**	3.41**	1.91**	5.33**	3.82**	4.16NS	6.49NS	3.56**	0.59	0.080	1.486	0.054
Number of branches per plant	9.83**	0.19**	0.23**	0.29NS	0.17**	0.16NS	0.34NS	0.17**	0.07	0.004	0.046	0.081
Number of nodes on main stem	201.63**	2.84**	2.61*	0.04NS	2.95**	3.82NS	0.59NS	2.80**	1.36	0.027	0.720	0.037
Earliness parameters												
Days to first flowering	199.02**	1.89**	1.81**	0.53NS	1.93**	2.08NS	3.04NS	1.82**	0.73	0.034	0.545	0.062
Number of nodes at first flowering	3.56**	0.47**	0.65**	0.36NS	0.41**	0.43NS	2.03**	0.31**	0.09	0.042	0.120	0.380
Number of nodes at first fruiting	5.56**	0.17**	0.09NS	0.24NS	0.19**	0.26NS	0.37NS	0.16**	0.08	0.007	0.036	0.204
Yield parameters												
Fruit length (cm)	125.03**	4.45**	3.75**	14.60**	4.51**	4.32NS	7.45NS	4.40**	0.93	0.067	1.739	0.039
Fruit diameter (mm)	45.41**	3.10**	2.79**	15.20**	3.02**	2.92NS	5.38NS	2.92**	0.34	0.056	1.291	0.043
Average fruit weight (gm)	3534.68**	58.77**	95.23**	11.89NS	48.65**	62.39NS	69.75NS	42.83**	18.35	1.057	12.238	0.086
Number of fruits per plant	523.22**	6.69**	8.48**	14.98**	6.04**	8.46NS	4.00NS	5.36**	1.92	0.040	1.715	0.023
Total yield per plant (kg)	0.68	0.685**	0.007**	0.008**	0.005**	0.007NS	0.003NS	0.005**	0.001	0.000 00211	0.001881	0.001441
Quality parameters												
Number of ridges per fruit	7.20**	0.13**	0.19**	0.03NS	0.11**	0.07NS	0.08NS	0.12**	0.03	0.002	0.044	0.045
Number of locules per fruit	6.00**	0.10**	0.11**	0.04NS	0.10**	0.07NS	0.08NS	0.11**	0.03	0.002	0.042	0.043
Number of seeds per fruit	8652.55**	219.89**	228.66**	170.09NS	218.00**	303.57NS	195.49NS	190.81**	39.52	2.669	75.641	0.035

*and** indicate significance of values at p=0.05 and p=0.01, NS: Not significant

Table 2. General combining ability effects for yield attributing parameters in okra.

Parent	Plant height	Internodal length	No. of branches per plant	No. Of nodes on main stem	Days to first flowering	No. of nodes at first flowering	No. of nodes at first fruiting	Fruit length	Fruit diameter
lines									
KO-1	-2.43	-0.55*	0.11	0.44	0.34	0.31	-0.07	1.10**	0.42*
KO-2	-1.58	-0.01	0.06	-0.63	0.97**	-0.20*	-0.21*	0.52	0.28
KO-3	-1.59	0.42	0.04	0.63	-0.28	0.06	0.18	0.31	0.29
KO-4	0.34	0.69*	-0.09	-0.60	0.09	0.06	-0.07	0.80*	0.67**
KO-5	1.99	0.92	-0.04	-0.75	-0.43	-0.20*	0.04	0.54	0.42**
KO-6	9.54*	-1.13*	-0.01	1.37**	0.19	0.31**	0.04	0.05	0.18
KO-7	6.52	1.54**	-0.09	0.09	-0.08	-0.07	-0.07	0.09	1.02**
KP-8	5.54	-0.31	-0.14	0.21	-0.28	-0.07	0.04	-0.42	-0.27
KO-9	3.72	-0.03	-0.11	0.11	-0.33	0.31**	0.16	0.33	0.66**
KO-10	-7.83	0.10	0.06	-0.20	1.27**	-0.07	0.04	0.19	0.00
KO-11	-7.23	-0.98*	0.04	-0.25	-0.16	-0.32**	-0.21*	-1.01**	-1.12**
KO12	-1.33	-0.61*	0.34**	0.60	-0.28	0.43**	0.54**	-0.73*	-0.27
KO-13	-2.01	-0.70*	0.01	-0.38	0.59*	-0.07	0.04	-1.43**	-1.04**
KO-14	-7.91	-0.25	0.19*	0.15	-0.66*	0.05	0.04	0.32	0.20
KO-15	-2.63	0.34	-0.29**	0.20	-0.43	-0.3**	-0.25**	-0.24	-0.23
KO-16	-16.01**	0.15	0.11	-1.15**	-0.28	-0.07	-0.21*	-1.34**	-1.02**
KO-17	6.02	-0.56*	-0.06	1.32**	0.09	0.18	0.04	0.03	-0.32
KO-18	13.69**	0.97*	-0.16	-0.74	-0.31	-0.32**	-0.07	0.89*	0.12
S.Em±	4.36	0.26	0.09	0.41	0.30	0.10	0.10	0.34	0.20
CD at 5%	8.67	0.51	0.17	0.81	0.59	0.19	0.19	0.67	0.39
CD at 1%	11.49	1.34	0.23	1.08	0.79	0.26	0.26	0.89	0.52
Testers									
Parbhani kranti	0.95	-0.39**	0.04	0.13	-0.20	0.00	-0.05	-0.62**	-0.53**
Arka Anamika	1.29	0.36**	-0.02	0.04	0.43**	-0.02	0.03	0.46**	0.39**
VRO-5	-2.43	0.37**	-0.13**	-0.170	-0.09	-0.28**	-0.11**	0.01	0.09
VRO-6	0.19	-0.34**	0.10**	0.00	-0.14	0.30**	0.13**	0.16	0.06
S.Em±	2.05	0.12	0.04	0.19	0.14	0.05	0.04	0.16	0.09
CD at 5%	NS	0.23	0.07	NS	0.27	0.09	0.07	0.31	0.17
CD at 1%	NS	0.31	0.10	NS	0.36	0.13	0.10	0.42	0.23

Contd ....

Parent	Average fruit weight	No. of fruits per plant	Total yield per plant	No. of ridges per fruit	No. of locules per fruit	No. of seeds per fruit	Total		GCA status
lines							+ve	-ve	
KO-1	-1.79	-0.97*	-0.04**	0.05	0.01	-7.26**	4	2	H
KO-2	-0.87	1.18*	0.04**	-0.10	-0.17**	-8.24**	5	2	H
KO-3	-0.87	0.55	-0.01	0.00	0.03	-8.59**	1	0	H
KO-4	0.62	1.06*	0.04**	-0.05	-0.07	0.94	4	1	H
KO-5	-0.42	-1.17*	-0.04**	0.15*	0.13*	8.61**	3	4	L
KO-6	0.83	-0.07	0.00	0.10	0.03	-11.66**	4	1	H
KO-7	7.91**	-0.29	0.02*	-0.02	-0.12*	9.46**	3	3	A
KP-8	-1.73	0.27	-0.02*	-0.10	-0.07	-0.39	0	1	L
KO-9	-2.53	1.11*	0.05**	0.13*	0.18**	6.49**	4	3	H
KO-10	-0.54	0.44	-0.02*	0.20**	0.11*	-1.86	1	3	L
KO-11	-1.58	0.92	0.01	-0.07	0.03	1.91	3	2	H
KO12	-2.13	0.43	0.01	-0.05	-0.04	-1.79	2	2	H
KO-13	-0.54	-2.83**	-0.06**	-0.17**	-0.14*	-4.49*	3	6	L
KO-14	1.56	-0.12	-0.01	0.00	0.01	-0.56	2	0	H
KO-15	-4.33**	0.18	-0.01	-0.05	-0.04	4.31	2	2	A
KO-16	3.62*	-0.97*	-0.01	-0.07	-0.04	5.16*	3	4	L
KO-17	-0.72	0.35	0.02*	0.05	0.11*	3.61	4	0	H
KO-18	3.51*	1.04**	0.04*	-0.02	0.06	4.34	5	2	H
S.Em±	1.51	0.48	0.014	0.06	0.06	2.22			
CD at 5%	3.00	0.95	0.02	0.11	0.11	4.41			
CD at 1%	3.98	1.26	0.03	0.15	0.15	5.85			
Testers									
Parbhani kranti	-1.59*	-0.14	-0.01*	0.04	0.04	2.75**	1	5	L
Arka Anamika	-0.53	0.08	0.00	-0.01	-0.01	-2.955**	3	2	H
VRO-5	1.68*	-0.36	0.00	-0.07**	-0.06*	0.04	4	3	H
VRO-6	0.44	0.42	0.01*	0.03	0.03	0.15	2	3	L
S.Em±	0.71	0.23	0.006	0.03	0.03	1.04			
CD at 5%	1.41	NS	0.01	0.05	0.05	2.06			
CD at 1%	NS	NS	0.02	0.07	NS	2.74			

*and** indicate significance of values at p=0.05 and p=0.01, respectively. NS: Not significant.

Table 3. Top three desirable hybrids with respect to SCA effects for various characters in okra.

Character	Crosses	SCA	Mean	GCA Status	
				Female	Male
Plant height	KO-2 × Parbhani kranti	19.28	98.70	High	Low
	KO-12 × VRO-6	18.78	97.70	High	Low
	KO-7 × Parbhani Kranti	17.88	105.40	Average	Low
Internodal length	KO-5 × VRO-5	-2.87	5.05	Low	High
	KO-10 × Arka Anamika	-2.19	4.90	Low	High
	KO-13 × VRO-5	-1.99	4.30	Low	High
No. of branches per plant	KO-5 × VRO-5	0.60	1.90	Low	High
	KO-12 × VRO-5	0.43	2.10	High	High
	KO-15 × VRO-6	0.42	1.70	Average	Low
No. of nodes on main stem	KO-4 × VRO-6	2.18	36.50	High	Low
	KO-6 × Parbhani Kranti	1.97	37.90	High	Low
	KO-1 × Arka Anamika	1.69	36.50	High	High
Days to first flowering	KO-15 × Arka Anamika	-1.66	13.20	Average	High
	KO-10 × Parbhani Kranti	-1.32	15.10	Low	Low
	KO-16 × VRO-5	-1.28	13.80	Low	High
No. of nodes at first flowering	KO-2 × VRO-6	-0.81	2.50	High	Low
	KO-6 × VRO-6	-0.80	3.02	High	Low
	KO-16 × Parbhani Kranti	-0.64	2.50	Low	Low
No. of nodes at first fruiting	KO-2 × VRO-6	-0.55	2.50	High	Low
	KO-12 × VRO-5	-0.50	3.07	High	High
	KO-9 × VRO-6	-0.43	3.00	High	Low
Fruit length	KO-9 × VRO-5	3.28	20.86	High	High
	KO-3 × Parbhani Kranti	2.30	19.23	High	Low
	KO-16 × Parbhani Kranti	2.22	17.50	Low	Low
Fruit Diameter	KO-9 × VRO-5	2.25	20.07	High	High
	KO-6 × Parbhani Kranti	2.13	18.85	High	Low
	KO-3 × Parbhani Kranti	1.94	18.77	High	Low
Average Fruit Weight	KO-18 × VRO-6	8.64	44.17	High	Low
	KO-14 × Arka Anamika	7.91	40.52	High	High
	KO-2 × Parbhani Kranti	7.43	36.55	High	Low
No. of fruits per plant	KO-17 × Arka Anamika	2.80	14.74	High	High
	KO-9 × VRO-5	2.59	14.86	High	High
	KO-7 × Parbhani Kranti	2.35	13.44	Average	Low
Total yield per plant	KO-11 × VRO-6	0.10	0.407	High	Low
	KO-2 × Parbhani Kranti	0.09	0.409	High	Low
	KO-14 × Arka Anamika	0.09	0.359	High	High
No. of ridges per fruit	KO-18 × VRO-6	-0.43	4.90	High	Low
	KO-17 × VRO-5	-0.41	4.90	High	High
	KO-2 × Parbhani Kranti	-0.36	4.90	High	Low
No. of locules per fruit	KO-18 × Parbhani Kranti	0.83	6.20	High	High
	KO-2 × VRO-5	0.36	5.40	High	High
	KO-5 × Parbhani Kranti	0.36	5.80	Low	Low
No. of seed per fruit	KO-9 × Arka Anamika	19	66.90	High	High
	KO-8 × Arka Anamika	18.77	59.80	Low	High
	KO-3 × Parbhnai Kranti	16.97	55.50	High	Low

of fruits per plant, KO-2 among lines presented as best general combiner. On the basis of fruit yield KO-9 and KO-18 among lines and VRO-6 among testers were recorded to be best general combiners.

Based on the total scoring values it was observed that among the female parents, line KO-17 had higher GCA score and is a good combiner for intermodal length, number of nodes on main stem, fruit yield per plant and number of locules per fruit. It was followed by line KO-18 which is good combiner for plant height, fruit length, average fruit weight, number of fruits per plant and total yield per plant. Among the testers, VRO-5 and Arka Anamika had high GCA score. Therefore, on the basis of per se performance and general combining ability effects of the lines/ testers, the lines viz., KO-17, KO-18, KO-2, KO-4 and KO-6 and testers viz., Arka Anamika and VRO-5 appeared to be desirable parents which could be used in hybridization programme.

From the data it is quite evident that none of the hybrids were having higher SCA effect for all the characters. Therefore, top three crosses exhibiting high SCA effects were selected for each character and GCA status of respective parents was presented as either low or high (Table 3). The results obtained from the present investigation indicated that the majority of the crosses exhibited high SCA effects as a result of either high × low, high × high or low × high GCA parents, indicating a genetic interaction of the additive × dominance, additive × additive or dominance × additive type.

Earliness is an important trait in okra as it helps in realizing the potential economic yield in as less time as possible to catch early market. Days to first flowering, number of nodes at first flowering and fruiting are indications of earliness. The crosses showing better performance for the characters determining earliness involved the parents with high × low, average × high GCA parents, indicating both additive and non-additive gene action.

For fruit length and fruit width, KO-9 × VRO-5 had the highest specific combining ability effect. Further, the cross KO-18 × VRO-6 had the highest positive specific combining ability along with superior performance for average fruit weight. The cross, KO-16 × Arka Anamika was the most efficient with high SCA effect for number of fruits per plant. In these characters studied majority of the crosses exhibited high SCA effects as a result of either high × high, low × low, high × low general combining ability effects indicating the presence of both additive and non-additive gene action. Similar findings were also reported by Singh and Syamal (2006) for plant height, number of nodes per plant, number of fruits per plant, average fruit weight, total yield per plant and number of seeds per fruit; Weerasekara (2006) for plant height, intermodal length, number of branches per plant, number of nodes at first flowering, fruit length, fruit diameter, average fruit weight, number of fruit per plant, number of ridges per fruit and number of seeds per fruit; Manivannan *et al*. (2007) for plant height, fruit length, number of ridges per fruit and number of seeds per fruit; Solankey and Singh (2010) for plant height, intermodal length, number of branches per plant, number of nodes on main stem, days to first flowering, fruit length, fruit diameter, average fruit weight, number of fruits per plant, number of ridges per fruit and number of seeds per fruit; Bhatt *et al.* (2015) for days to first flowering, days to first picking, plant height (cm), number of nodes per plant, length of internode (cm), number of primary branches per plant, stem girth (cm), fruit length, fruit girth (cm), fruit weight (g), number of fruits per plant and Kumar and Reddy (2016) for plant height, intermodal length, fruit length, fruit weight, number of fruits per plant in okra.

Yield is the foremost and economically important character for any breeding programme. The results obtained from the present investigation revealed that fruit yield was high in crosses with lines exhibiting high × low and high × high GCA effects. Therefore, for the improvement of fruit yield in okra both additive and non-additive gene effects can be utilized which was further confirmed by the crosses exhibiting highest per se performance also manifested high SCA effects. Thus, justifying the existence of high degree of dominance and additive gene action and results are in the agreement of findings of Vijay and Manohar (1986) and Dhankar *et al*. (1998), Sheela *et al*. (1998), Weerasekara (2006), Eswaran *et al*. (2007), Solankey and Singh (2010), Bhatt *et al.* (2015) and Kumar and Reddy (2016) for total yield per palnt.

Conclusion

The parental per se performance is a good indicator of its GCA effects, both general combining ability and per se performance of breeding lines should be considered together for assessing their breeding potentiality. GCA to SCA ratio was very low for the traits yield per plant indicating preponderance of non-additive gene action and hence these traits can be improved through recurrent selection for specific combining ability or heterosis breeding. Non-additive component of genetic variance was higher than additive component for number of fruits per plant, plant height, fruit length, days to first flowering, number of branches per plant and average fruit weight and can be improved through recurrent selection schemes. From this study it is concluded that parental lines KO-9 (0.05), KO-2 (0.04) and KO-4 (0.04) with higher GCA effects for yield and yield attributing characters could be exploited beneficially in future okra breeding programs by adopting appropriate breeding strategy. The crosses KO-11 × VRO-6 (0.10), KO-2 × Parbhani Kranti (0.9) and KO-14 × Arka Anamika (0.9) with significantly high SCA effects for yield could be exploited for the production of F_1 hybrids after further testing in multiple locations in the state. Therefore, it has a great scope for heterosis breeding to exploit the non-additive genetic variance observed for yield and yield components.

REFERENCES

Bhatt, J.P., Kathiria, K.B., Christian, S. S. and Acharya, R.R. (2015). Combining ability studies in okra (*Abelmoschus esculentus* (l.) moench) for yield and its component characters. *Electronic J. of Plant Breeding*, 6(2):479-485

Dhankar, S.K., Dhankar, B.S. and Tewatia, A.S. (1998). A note on heterosis and combining ability in okra (*Abelmoschus esculentus* (L.) Moench). *Haryana J. Hort. Sci*., 27(3): 211-214

Eswaran, R., Thirugnanakumar, S., Sampathkumar, C.P., Anandan, A. and Padmanaban, C. (2007). Studies on the genetic causes of heterosis in okra [*Abelmoschus esculentus* (L.) Moench]. *Plant Archives*, 7(2): 721-724

Griffing, B. (1956). Concept of general combining ability in relation to diallel crossing system. *Australian J. of Biological Sci*., 9: 463-493

Kempthorne, O. (1957). An introduction to genetic statistics. John Wiley and Sons, New York, pp. 408-711

Kumar, P., Dixit, J. and Singh, B.P. (2006). Heterosis studies in okra. *Haryana J. Hort. Sci*., 35(1&2): 120-123

Kumar, S. and Reddy, M.T. (2016). Combining Ability of

Inbred Lines and Half-Diallel Crosses for Economic Traits in Okra (Abelmoschus esculentus (L.) Moench). *Jordan J. of Agricultural Sci*., 12(2):479-497

Manivannan, M.I., Rajangam, J. and Aruna, P. (2007). Heterosis for yield and yield governing traits in okra. *The Asian J. Hort*., 2(2): 96-103

Sheela, M.N., Manikantan, N.P. and Gopinathan, N.V., 1998, Heterosis in bhendi. *Agric. Res. J. of Kerala*, 26 (1): 23-28

Singh, D.R. and Syamal, M.M. (2006). Heterosis in okra [*Abelmoschus esculentus* (L.) Moench]. *Orissa J. Hort*., 34(2): 124-127.

Singh, D.R., Singh, P.K., Syamal, M.M. and Gautam, S.S. (2009). Studies on combining ability in okra. *Indian J. Hort*., 66(2): 277-280.

Singh, B. and Goswami, A. (2015). Combining ability analysis in okra (Abelmoschus esculentus). *Indian J. of Agricultural Sci*., 85 (9): 1237–44

Solankey, S.S. and Singh, A.K. (2010). Studies on combining ability in okra [*Abelmoschus esculentus* (L.) Moench]. *The Asian J. Hort*., 5(1): 49-53

Srivastava, M.K., Kumar, S. and Pal, A.K. (2008). Studies on combining ability in okra through diallel analysis. *Indian J. Hort*., 65(1): 48-51

Reddy, M. T., Haribabu, K., Ganesh, M. and Begum, H. (2011). Combining ability analysis for growth, earliness and yield attributes in okra (*Abelmoschus esculentus* (L.) Moench). *Thai J. Agric. Sci*., 44(3):207-218

Vijay, O.P. and Manohar, M.S. (1986). Combining ability in okra. *Indian J. Hort*., 43: 133-139

Wammanda, D.T., Kadams, A.M. and Jonah, P. M. (2010). Combining ability analysis and heterosis in a diallel cross of okra (Abelmoschus esculentus (L.) Moench). *Afr. J. Hortic.,* 5(16):2108-2115

Weerasekara, D. (2006). Genetic analysis of yield and quality parameters in okra (*Abelmoschus esculentus* (L.) Moench.). *M.Sc. Thesis*, Univ. Agric. Sci., Dharwad.