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Estimation of combining ability and gene action for yield and its contributing traits in okra [*Abelmoschus esculentus* (L.) Moench]

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Abstract

The estimates of ó² gca / ó² sca indicated predominance of non-additive gene action for most of the characters during both the years. EC169400 and IC117351 were identified as consistent best general combiner for fruit yield and other components. Over the both years consistently, cross combinations *viz*., IC117245 × VRO 6 for fruit yield per plant, IC117245 × VRO 6, IC117351 × Arka Anamika and EC16400 × Arka Anamika for number of fruits per plant, EC169430 × Parbhani Kranti and EC169408 × Arka Anamika for plant height, EC169435 × Parbhani Kranti for 100 seed weight, IC093655 × Arka Anamika for number of seeds per fruit, EC169430 × Parbhani Kranti for primary branches per plant, IC093655 × Parbhani Kranti for inter-nodal length, EC169435 × Arka Anamika for fruit length showed specific combining ability effects of higher order. These crosses have been identified as best hybrids for improving fruit yield per plant and could be further evaluated to confirm their stable superior performance.

Key words: Combining ability, Fruit yield, Gene action, GCA, SCA, Okra

Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] a member of the Malvaceae family is a fast growing warm and rainy season annual herbaceous vegetable. It is an important vegetable crop for both domestic market and export purpose and grown for its tender green fruits throughout India. It has a great potential for foreign exchange and accounts for about 60 per cent of the export of fresh vegetables. India is the largest producer of okra in the world. The total area in the country under okra cultivation is 0.528 million ha with the production of 6.15 million tonnes of green fruits (Anonymous 2017). Despite its recognized potential and significant area and consumption in the country, it is being neglected because of non-availability of high yielding cultivars. Yield plateau seems to have been reached in open-pollinated cultivars of okra. To break the yield barriers in existing open-pollinated cultivars of okra, a hybridization-based breeding strategy would be desirable. The genetic improvement of yield and its contributing characters require the selection of appropriate breeding procedures which is dependent upon the general combining ability (gca) of parents and specific combining ability (sca) of crosses. The general combining ability is the manifestation of additive gene action for the selection of parents, while the specific combining ability in respect of a particular character in the hybrid is the capitalization of non-additive gene action (Singh et al. 2015; Paul et al. 2017). Combining ability analysis is useful for the study and comparison of homozygous inbred lines in hybrid combination (Sprague and Tatum 1942). Line × tester mating design (Kempthrone 1957) is one of the best techniques that provide information about general and specific combining ability of the parents and at the same time it is helpful in estimating heterosis. It is also helpful in understanding the nature of gene action involved in the expression of various traits. The present study was designed to find out the good general combining genotypes for sound breeding program and to select high yielding combiners for the development of productive okra varieties and good specific combiners for selection of transgressive segregates.

Materials and Methods

The present investigation was carried out during rainy season (2015) and warm season (2016 and 2017) at Vegetable Research Center, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar. The experimental material for this study consists of 15 genotypes (12 lines *viz*., IC093591, EC169430, EC169435, EC169506, IC093655, IC117123, IC117245, IC117351, IC117355, EC169400, EC169408 and

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IC117328 and 3 testers *viz*., Arka Anamika, VRO 6 and Parbhani Kranti) which are selected based on their diversity for various traits (Table 1). From these 15 genotypes, 36 crosses were prepared during *kharif* (2015) using Line × Tester mating design. Thus, the 36 crosses and their 15 parents formed the experimental material for the present study. The experimental material, consisting fifty-one entries including fifteen parents and their thirty-six crosses, was laid out in a randomized block design (RBD) with three replications over two years i.e. summer (2016 and 2017). Each entry was presented by a single row plot of ten plants. All recommended agronomic practices along with plant protection measures were followed uniformly and timely. Five competitive plants were randomly selected from each entry in three replications. Average of the five plants in respect of different characters was recorded as given below: All the 14 quantitative characters studied were first flower producing node, first fruit producing node, days to 50 per cent flowering, inter-nodal length (cm), plant height (cm), number of primary branches per plant, stem diameter (mm), fruit length (cm), fruit diameter (mm), number of seeds per fruit, 100 seed weight (g), number of fruits per plant, average fruit weight (g) and fruit yield per plant (g). The mean values were used for the analysis of variance for experimental design as well as combining ability. The data were statistically analyzed for combining ability and gene action as per the method suggested by Kempthorne (1957).

Results and Discussion

With the advancement in biometrical genetics, several techniques are now available which permit quantitative genetic analysis and selection of promising parents and crosses (line × tester) for further exploitation. The parents who produce good progenies upon crossing are of immense value to the plant breeder. In a crop improvement programme, success depends upon the isolation of valuable cross combinations as determined in the form of parents with high combining ability. The emphasis is on the importance of testing the combining ability of parents because many times the high yielding parents may not combine well to give good segregates. Combining ability analysis is a powerful tool to identify the lines having good potential to transmit the desirable traits to their off-springs and also helps in sorting out promising crosses for fruit yield and its attributes. At the same time, it also elucidates the nature of gene action (additive and non-additive) involved in the inheritance of characters.

Analysis of variance: Analysis of variance for combining ability with respect to different characters during first year (2016) and second year (2017) are presented in Table 1 and 2, respectively. The total variability among F_1 hybrids was further partitioned into different components and their significance was tested. It is evident from the table that the mean sum of squares due to crosses was significant for all fourteen characters studied during both the years except fruit diameter which was non-significant during first year. Mean sum of squares due to line × tester effect was significant for all the characters under study during both the years except for fruit diameter and stem diameter during the first year and for days to 50 per cent flowering and average fruit weight during the second year. Similar results were also reported by Nagesh et al. (2014) and Paul et al. (2017).

General Combining Ability and Specific Combining Ability: Based on the combining ability effects the parents and crosses were classified as good, average and poor combiners. If crosses showing high sca effects involve parents who are also good general combiners, then these crosses could be exploited by simple methods like pedigree selection, provided the additive x additive component of interaction was significant. The general combining ability (gca) effects of lines and testers, and specific combining ability (sca) effects of hybrids for 14 quantitative traits during two years evaluation are presented in Table 3 to 4.

EC169400 was identified as a best general combiner for maximum number of traits *viz*., inter-nodal length, fruit length, number of primary branches per plant, plant height, number of fruits per plant and fruit yield per plant during first year. Whereas, during second year, EC169400 was recognized as a good general combiner for fruit diameter, fruit length, number of primary branches per plant, plant height, number of fruits per plant and fruit yield per plant followed by EC169408 for fruit length, inter-nodal length, number of primary branches per plant, stem diameter, 100 seed weight and plant height. Over both the years, EC169400 was identified as consistent best general combiner for four traits *viz*., fruit length, plant height, number of fruits per plant and fruit yield per plant. For earliness character (days to 50 per cent flowering) IC093655, IC117123 and EC169430 were identified as consistent good general combiners. The results are in parity with those obtained by Ramesh et al. (1998), Singh et al. (2019), Nagesh et al. (2014), More et al. (2015) and Paul et al. (2017).

In the present study, during first year the best specific crosses were IC117123 × Arka Anamika, IC117351 × Arka Anamika and IC117328 × VRO6 for earliness, EC169430 × VRO6, IC117123 × Parbhani Kranti and

Table 1: Analysis of variance (ANOVA) for line × tester with respect to fourteen quantitative characters of okra during 2016

		Source of variation						
		Replications	Crosses	Line effect	Tester effect	Line x tester effect	Error	Total
Mean Sum of Squares	**Degrees of freedom**	**2.00**	**35.00**	**11.00**	**2.00**	**22.00**	**70.00**	**107.00**
	First flower producing node	0.55	0.90**	1.24	0.85	0.74*	0.37	0.55
	First fruit producing node	0.53	0.87**	1.41*	0.68	0.62*	0.36	0.53
	Days to 50 per cent flowering	0.90	18.75**	40.34**	33.04*	6.65**	2.38	7.71
	Fruit diameter (mm)	0.27	4.13	6.23	1.00	3.36	4.23	4.12
	Fruit length (cm)	0.85	7.99**	11.99	12.63	5.58**	0.92	3.23
	Inter-nodal length (cm)	0.10	1.67**	3.76**	1.24	0.67**	0.08	0.60
	Primary branches per plant	0.04	0.63**	1.31**	0.40	0.31**	0.07	0.25
	Stem diameter (mm)	8.09	7.07**	16.46**	3.68	2.69	2.79	4.29
	No. of seeds per fruit	14.38	135.94**	336.85**	29.51	45.16**	4.68	47.79
	100 seed weight	0.24*	1.04**	1.23	2.90*	0.78**	0.07	0.39
	Plant height (cm)	79.59**	326.90**	756.43**	406.22*	104.92**	14.24	117.73
	No. of fruits per plant	3.61	30.95**	38.37	57.00	24.87**	6.58	14.50
	Average fruit weight (g)	6.95**	3.54**	6.73**	4.34	1.87*	0.95	1.91
	Yield per plant (g)	187.06	3074.14**	2860.67	5782.95	2934.63*	1561.87	2030.84

Table 2: Analysis of variance (ANOVA) for line × tester with respect to fourteen quantitative characters of okra during 2017

		Source of variation						
		Replications	Crosses	Line effect	Tester effect	Line x tester effect	Error	Total
Mean Sum of Squares	**Degrees of freedom**	2.00	35.00	11.00	2.00	22.00	70.00	107.00
	First flower producing node	0.56	1.78**	1.49	2.83	1.83**	0.60	0.98
	First fruit producing node	0.30	1.59**	1.33	1.62	1.72**	0.49	0.85
	Days to 50 per cent flowering	8.64	15.70**	33.33**	54.91**	3.32	6.03	9.24
	Fruit diameter (mm)	4.48*	5.43**	7.04	2.70	4.87**	1.12	2.59
	Fruit length (cm)	1.80	11.00**	12.97	12.98	9.83**	0.67	4.07
	Inter-nodal length (cm)	0.65*	1.44**	2.66*	1.07	0.87**	0.21	0.62
	Primary branches per plant	0.01	0.54**	0.93*	0.17	0.38**	0.02	0.19
	Stem diameter (mm)	2.70	7.49**	12.70*	10.02	4.65**	1.96	3.78
	No. of seeds per fruit	37.01*	85.12**	193.19**	14.29	37.52**	11.80	36.25
	100 seed weight	0.40	0.96**	1.35	1.15	0.74**	0.17	0.43
	Plant height (cm)	83.53*	279.58**	548.85**	225.88	149.83**	19.51	105.78
	No. of fruits per plant	22.72	40.35**	59.26	85.68	26.77**	11.64	21.24
	Average fruit weight (g)	1.08	3.54**	6.33**	11.06**	1.47	1.27	2.01
	Yield per plant (g)	2427.79	4348.41**	4650.38	6104.92	4037.74**	1509.80	2455.48

EC169435 × Arka Anamika for fruit length, IC117351 × Arka Anamika, EC169506 × Arka Anamika, EC169400 × Arka Anamika for inter-nodal length, EC169400 × VRO 6 for number of primary branches per plant, EC169435 × Arka Anamika for number of seeds per fruit, EC169435 × Parbhani Kranti for 100 seed weight, EC169430 × Parbhani Kranti, IC117351 × Arka Anamika and EC169408 × Arka Anamika for plant height, EC169430 × Parbhani Kranti, EC16400 × Arka Anamika and EC169408 × VRO 6 for number of fruits per plant, EC169430 × VRO 6 for average fruit weight and IC117245 × VRO 6 and EC169430 × Parbhani Kranti for fruit yield per plant.

However, during second year best specific cross combinations were identified as EC169400 × Parbhani Kranti and IC117123 × VRO 6 for earliness characters like first flower producing node and first fruit producing node, IC117355 × Parbhani Kranti and IC117328 × Arka Anamika for fruit diameter, IC117328 × Arka Anamika for fruit length, IC117123 × VRO 6, EC169506 × Arka Anamika and IC117351 × Arka Anamika for inter-nodal length, EC169408 × Parbhani Kranti, EC169506 × Arka Anamika and IC117351 × Arka Anamika for number of primary branches per plant, EC169506 × Arka Anamika for stem diameter, EC169506 × Parbhani Kranti for number of seeds per fruit, EC169435 × Parbhani Kranti for 100 seed weight, EC169430 × Parbhani Kranti and EC169408 × Arka Anamika for plant height, IC117245 × VRO 6, IC117351 × Arka Anamika and EC16400 × Arka Anamika for number of fruits per plant and IC117245 × VRO 6 for fruit yield per plant.

Over both the years consistently, the cross combinations *viz*., IC117245 × VRO 6 for fruit yield per plant, IC117245 × VRO 6, IC117351 × Arka Anamika and EC16400 × Arka Anamika for number of fruits per plant, EC169430 × Parbhani Kranti and EC169408 × Arka Anamika for plant height, EC169435 × Parbhani Kranti, IC093591 × Arka Anamika and EC169400 × VRO 6 for

Table 3: Ranking of parents and crosses based on *per se* performance during 2016 and 2017

S. No.	Character	Mean basis			
		Best parent		Best F_1	
		2016	2017	2016	2017
1.	First flower producing node	EC169430 (3.73)	A. Anamika (3.92)	EC169430 × P.Kranti (3.42),	IC117245×VRO 6 (3.20)
		IC117328 (3.84)	EC169430 (3.73)	IC093655 × A.Anamika(3.42)	IC093591×VRO 6 (3.22)
		A. Anamika (3.92)	IC117328 (3.84)	EC169506 × VRO 6 (3.63)	IC117355×A. Anamika (3.33)
2.	First fruit producing node	EC169430(3.98)	EC169430 (4.01)	IC093655 × A.Anamika(3.67)	IC093591×VRO 6 (3.60)
		IC117123(4.25)	A. Anamika (4.02)	EC169430 × P.Kranti (3.85)	IC117355×A. Anamika (3.74)
		A. Anamika(4.26)	IC117245 (4.34)	IC117123 × VRO 6(3.95)	EC169506×VRO 6 (3.90)
3.	Days to 50 per cent flowering	EC169506 (47.00)	IC117123 (46.67)	IC117123×A. Anamika (43.67)	IC117123×A. Anamika (45.60)
		IC093655 (47.00)	IC117328 (49.00)	IC093655×A. Anamika (44.67)	IC093655×A. Anamika (46.00)
		IC117351 (47.33)	IC093655 (49.33)	EC169430×A. Anamika (45.00)	EC169430×A. Anamika (46.33)
4.	Fruit diameter (mm)	IC093655 (20.83)	IC117123 (19.20)	IC117355×P. Kranti (20.20)	IC117351×P. Kranti (19.33)
		IC117355 (21.80)	P. Kranti (19.33)	IC117245×P. Kranti (20.33)	EC169400×VRO 6 (19.40)
		IC117351 (22.17)	IC117355 (19.40)	EC169400×A. Anamika (21.73)	IC117355×P. Kranti (19.47)
5.	Fruit length (cm)	IC117355 (16.81)	EC169506 (16.03)	EC169400×VRO 6 (17.83)	EC169400×A. Anamika (17.20)
		EC169435 (16.93)	EC169435 (16.13)	IC117123×P. Kranti (17.93)	EC169400×VRO 6 (17.27)
		IC117351 (17.17)	IC117351 (17.00)	IC117355×P. Kranti (18.28)	IC117123×P. Kranti (17.50)
6.	Inter-nodal length (cm)	VRO 6 (5.67)	VRO 6 (5.61)	EC169400×A. Anamika (5.47)	IC117351×P. Kranti (5.11)
		EC169435 (6.28)	IC117123 (5.84)	IC117351×A. Anamika (5.53)	IC117351×A. Anamika (5.22)
		EC169430 (6.42)	IC093591 (5.94)	EC169400×P. Kranti (5.60)	EC169506×A. Anamika (5.40)
7.	Primary branches per plant	IC117351 (2.17)	A. Anamika (2.00)	EC169400×A. Anamika (2.84)	IC093655×P. Kranti (2.60)
		VRO 6 (2.17)	VRO 6 (2.03)	EC169400×VRO 6 (2.87)	EC169400×VRO 6 (2.60)
		EC169400 (2.33)	EC169400 (2.27)	EC169430×P. Kranti (2.93)	EC169400×A. Anamika (2.63)
8.	Stem diameter (mm)	A. Anamika (19.03)	P. Kranti (20.50)	EC169408×VRO 6 (20.70)	IC117351×P. Kranti (21.00)
		EC169435 (19.07)	IC117328 (20.83)	IC117245×P. Kranti (20.73)	IC117245×P. Kranti (21.16)
		P. Kranti (20.10)	IC093591 (22.03)	IC117328×A. Anamika (20.97)	IC117328×P. Kranti (22.25)
9.	No. of seeds per fruit	VRO 6 (61.67)	VRO 6 (58.68)	EC169430×P. Kranti (68.60)	EC169506×P. Kranti (66.33)
		EC169435 (67.73)	EC169430 (62.30)	IC117355×P. Kranti (69.00)	IC117355×P. Kranti (67.80)
		IC093591 (68.73)	EC169435 (65.40)	EC169430×VRO 6 (76.67)	EC169430×VRO 6 (69.67)
10.	100 seed weight (g)	EC169408 (5.71)	VRO 6 (6.02)	EC169430×P. Kranti (6.80)	EC169430×A. Anamika (6.63)
		IC117355 (6.25)	EC169506 (6.32)	EC169408×P. Kranti (7.00)	EC169435×P. Kranti (6.87)
		EC169506 (6.37)	IC117355 (6.52)	EC169435×P. Kranti (7.57)	EC169408×P. Kranti (7.10)
11.	Plant height (cm)	EC169430 (108.27)	P. Kranti (104.93)	EC169400×VRO 6 (109.40)	EC169400×A. Anamika (109.67)
		IC117351 (110.47)	EC169408 (106.93)	EC169400×A. Anamika (110.33)	EC169408×A. Anamika (110.20)
		IC093655 (113.13)	IC117351 (110.87)	IC093655×P. Kranti (112.60)	IC117355×VRO 6 (113.27)
12.	No. of fruits per plant	IC117351 (20.29)	IC117123 (20.34)	IC117355×P. Kranti (22.10)	IC117123×A. Anamika (25.45)
		VRO 6 (20.48)	IC117245 (21.33)	IC117351×A. Anamika (25.85)	IC117351×A. Anamika (28.15)
		P. Kranti (22.00)	P. Kranti (22.01)	EC169400×A. Anamika (27.25)	EC169400×A. Anamika (28.30)
13.	Average fruit weight (g)	IC117328 (12.35)	IC093655 (13.39)	EC169506×A. Anamika (14.34)	IC117123×P. Kranti (13.09)
		EC169430 (13.22)	IC117355 (13.50)	IC093591×P. Kranti (14.40)	EC169400×P. Kranti (13.17)
		IC093655 (13.23)	EC169400 (15.50)	EC169430×VRO 6 (14.53)	IC093591×VRO 6 (13.34)
14.	Fruit yield per plant (g)	IC117351 (242.75)	IC117355 (235.56)	EC169506×A. Anamika (275.58)	IC093655×P. Kranti (287.22)
		EC169400 (243.48)	P. Kranti (241.97)	IC117351×A. Anamika (299.45)	IC117351×A. Anamika (297.29)
		P. Kranti (245.93)	EC169400 (249.00)	EC169400×A. Anamika (301.20)	EC169400×A. Anamika (309.43)

100 seed weight, IC093655 × Arka Anamika, EC169430 × VRO 6 and EC169400 × VRO 6 for number of seeds per fruit, EC169430 × Parbhani Kranti, IC093655 × Parbhani Kranti and EC169408 × Parbhani Kranti for number of primary branches per plant, IC093655 × Parbhani Kranti, IC117351 × Arka Anamika and IC1117123 × VRO6 for inter-nodal length, EC169435 × Arka Anamika and EC169430 × VRO 6 and IC1177245 × Parbhani Kranti for fruit length were identified. In general, sca is associated with interaction effects, which may be due to dominance and epistatic component of variation that are non-fixable in nature. It helps in the identification of superior cross combination for development of promising hybrids. Similar results have been reported by Ahmed et al. (1997), Singh et al. (2009), Patel et al. (2015), More et al. (2015) and Singh et al. (2015).

Ranking of desirable parents based on *per se* performance, gca and sca effects for 14 quantitative characters (Table 3 and 4) revealed that it was difficult to pick up a single good combiner for all the characters but, EC169400 was identified as consistent best general combiner for fruit yield per plant and number of fruits per plant whereas, over both the years consistently, the cross combinations *viz*., IC117245 × VRO 6 for fruit yield per plant, IC117245 × VRO 6, IC117351 × Arka Anamika and EC16400 × Arka Anamika for number of fruits per plant were identified.

Table 4: Ranking of parents and crosses based on gca and sca effects during 2016 and 2017

S. No.	Characters	Estimates basis					
		Best general combiner			Best specific combiner		
		2016	2017	During both years	2016	2017	During both years
1.	First flower producing node	-	-	-	-	EC169400×PK(-0.990*) IC117123×AA(-0.920*) IC117123×VRO6(-0.892*)	-
2.	First fruit producing node	-	IC117355(-0.599**) EC169506 (-0.449*)	-	IC117328×PK (-0.738*) - -	IC117123×VRO6(-1.08**) IC117245×VRO6(-0.917*) EC169400×PK(-0.812*)	-
3.	Days to 50 per cent flowering	EC169430 (-4.093**) IC093655 (-2.759**) IC117123 (-2.315**)	IC093655(-2.830**) IC117123(-1.741**) EC169430(-1.719**)	IC093655 IC117123 EC169430	IC117123×AA (-2.519**) IC117351×AA (-2.296**) IC117328×VRO6 (-2.296**)	-	-
4.	Fruit diameter (mm)	-	EC169400 (1.291**) IC093655 (1.047**) IC117245 (0.982**)	-	-	IC117355×PK(2.127**) IC117328×AA(2.114**) EC169408×VRO6(1.61**)	-
5.	Fruit length (cm)	EC169400 (2.484**) IC117355 (0.975**) IC1177245 (0.655*)	EC169400 (2.774**) IC117355 (0.975**) EC169408 (0.662**)	EC169400 IC117355 EC169408	EC169430×VRO6(2.224**) IC117123×PK (1.883**) EC169435×AA(1.769**)	IC117328×AA(2.342**) EC169435×AA(2.565**) IC093655×VRO6(2.208**)	EC169435×AA EC169430×VRO6 IC1177245×PK
6.	Inter-nodal length (cm)	EC169400 (-1.053**) EC169435 (-0.675**) EC169506 (-0.535**)	IC117351 (-0.701**) EC169435 (-0.603**) EC169506 (-0.472**)	EC169435 EC169506 IC117351	IC117351×AA(-0.955**) IC093591×VRO6(-0.664**) IC093655×PK(-0.631**)	IC1117123×VRO6(-0.852**) IC093655×PK(-0.829**) EC169506×AA(-0.586*)	IC093655×PK IC117351×AA IC1117123×VRO6
7.	Primary branches per plant	EC169400(0.713**) IC093655 (0.524**) EC169430 (0.318**)	EC169400 (0.654**) IC093655 (0.346**) EC160408 (0.205*)	EC169400 IC093655 EC160408	EC169430×PK (0.638**) EC169408× PK (0.410**) EC169400×VRO 6(0.387**)	EC169408×PK (0.458**) EC169435×VRO6 (0.413(**) IC093655×PK (0.384**)	EC169430× PK IC093655×PK EC169408×PK
8.	Stem diameter (mm)	IC117328 (2.042**) EC169408 (1.675*) -	IC117351(1.229*) IC117328(1.166*) EC169408(1.004*)	IC117328 EC169408 -	- -	EC169506 ×AA (2.841**) - -	-
9.	No. of seeds per fruit	EC169430 (12.013) IC117355 (6.946) IC093591 (4.413)	EC169430 (6.460**) IC117355 (6.037**) EC169435 (3.464**)	EC169430 IC117355 EC169435	EC169435×AA(5.426**) EC169430×VRO6(5.065**) IC117328×AA(4.976**)	EC169506×PK (6.614**) EC169430×VRO6(4.48*) EC169400×VRO6(4.313*)	IC093655×AA EC169430×VRO6 EC169400×VRO6
10.	100 seed weight	EC169408 (0.746**) EC169430(0.410**) EC169435 (0.337**)	EC169408 (0.945**) IC117245 (0.300*) -	EC169408 IC117245 -	EC169435×PK (1.079**) EC169506×AA (0.615**) EC169400×VRO6 (0.658**)	EC169435×PK (0.739**) IC117351×PK (0.664**) EC169400×VRO6 (0.555*)	EC169435×PK IC093591× AA EC169400×VRO6
11.	Plant height (cm)	EC169400(11.434**) IC093655(8.767**) IC11355(6.589**)	IC117355 (9.564**) EC169400 (8.875**) EC169408 (5.719**)	EC169400 IC117355 IC117351	EC169430×PK(10.000**) IC117351× AA(8.619**) EC169408× AA(8.619**)	EC169430×PK(9.834**) EC169408×AA(8.927*) -	EC169430×PK EC169408×AA -
12.	No. of fruits per plant	EC169400 (3.309**) IC117355 (2.009*) IC117351 (2.596**)	EC169400 (3.261**) A. Anamika (1.695*) -	EC169400 A.Anamika	EC169430×PK (3.762**) EC16400×AA (3.748**) EC169408×VRO 6(3.536*)	IC117245×VRO 6(5.249**) IC117351 × AA(3.908**) EC16400 × AA(3.894**)	IC117245×VRO 6 IC117351 × AA EC16400 × AA
13.	Average fruit weight (g)	IC093591 (1.363**) EC169506 (0.816*)	IC093591 (1.792**) EC169506 (0.824*)	IC093591 EC169506	EC169430×VRO 6(1.325*)	-	-
14.	Fruit yield per plant (g)	EC169400(29.645*)	EC169400(39.987**)	EC169400	IC117245×VRO 6(48.264*) EC169430×PK (49.202*)	IC117245×VRO6(72.645**)	IC117245×VRO 6

Gene Action: The perusal of data presented in Table 5 revealed that the estimates of ó^2 gca/ ó^2 sca indicated predominance of non-additive gene action for most of the characters except days to 50 per cent flowering during first year. Whereas, during second year, the estimate of ó^2 gca/ ó^2 sca indicated predominance of non-additive gene action for all fourteen different traits. Results presented earlier by Adiger et al. (2013), Bhatt et al. (2015) and Patel et al. (2015) also indicated preponderance of non-additive gene action in the expression of various quantitative traits. The most efficient way for utilizing the non-additive genetic variance is through the exploitation of heterosis. Since it was observed that sca was the predominant contributor to genetic variance, thus, it is suggested that selection of sca is likely to be the most effective method to exploit hybrid vigour. Inbreeding and crossing will be the better means of improvement than selection without inbreeding in the presence of over-dominance (Falconer 1960). While, in case of additive (fixable) components such as for trait like days to 50 per cent flowering (only during first year), selection scheme would be useful to achieve homozygous lines.

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ए^{2}जीसीए/ए^{2}एससीए का आंकलन दर्शाता है कि दोनों वर्ष सभी लक्षणों में प्रभावी रूप से अयोज्य (नॉन–एडिटिव) जीन क्रिया उपस्थित है। सबसे अच्छा सामान्य संयोजन क्षमता के लिए वंशक्रमों ईसी169400 और आईसी117351 का फल उपज तथा अन्य लक्षणों के लिए पहचान किया गया। लगातार दोनों वर्ष, विशिष्ट संयोजन क्षमता के

Table 5: General and specific combining ability variances for fourteen traits of okra

Character	σ^2 (gca)		σ^2 (sca)		GCA/SCA ratio	
	2016	2017	2016	2017	2016	2017
First flower producing node	0.032	0.071	0.140	0.422	0.230	0.168
First fruit producing node	0.033	0.048	0.108	0.441	0.310	0.109
Days to 50 per cent flowering	1.530	1.706	1.460	-0.808	1.048	-2.111
Fruit diameter (mm)	-0.014	0.161	-0.187	1.209	0.074	0.134
Fruit length (cm)	0.511	0.554	1.591	3.104	0.321	0.178
Inter-nodal length (cm)	0.107	0.076	0.193	0.238	0.553	0.319
Primary branches per plant	0.035	0.024	0.082	0.122	0.433	0.194
Stem diameter (mm)	0.280	0.412	-0.363	0.855	-0.770	0.482
No. of seeds per fruit	7.902	4.213	13.255	9.523	0.596	0.442
100 seed weight	0.087	0.047	0.228	0.182	0.383	0.258
Plant height (cm)	25.061	15.624	29.156	38.002	0.860	0.411
No. of fruits per plant	1.858	2.727	6.335	5.220	0.293	0.522
Average fruit weight (g)	0.199	0.320	0.267	-0.009	0.742	-36.959
Fruit yield per plant (g)	130.541	173.059	516.660	851.305	0.253	0.203

लिए गुणित संयोजन जैसे–फल उपज प्रति पौध के लिए आईसी117245 x वीआरओ 6, फल संख्या प्रति पौध के लिए आईसी117245 x वीआरओ 6, आईसी 117245 x अर्का अनामिका और ईसी169400 x अर्का अनामिका, पौध ऊँचाई के लिए ईसी169430 x परभनी क्रांति और ईसी169408 x अर्का अनामिका, 100 बीज भार के लिए ईसी169435 x परभनी क्रांति, बीज संख्या प्रति फल आईसी093655 x अर्का अनामिका, प्राथमिक शाखा प्रति पौध के लिए ईसी169430 x परभनी क्रांति, इंटर नोडल लम्बाई के लिए आईसी093655 x परभनी क्रांति तथा फल की लम्बाई के लिए ईसी169435 x अर्का अनामिका पहचाने गयी। ये सभी गुणित संयोजन उपज के मामले में अच्छे संकर के लिए पहचान किया गया तथा बेहतर स्थिर प्रदर्शन के लिए इन सभी युग्मकों का आगे भी मूल्यांकन किया जा सकता है।

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