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HETEROSIS AND COMBINING ABILITY STUDIES IN OKRA [*ABELMOSCHUS ESCULENTUS* (L.) MOENCH] FOR YIELD AND QUALITY PARAMETERS

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ABSTRACT

A study was conducted in okra to estimate the magnitude of heterosis and to identify the good combiners for yield and quality parameters. Fifty four F_1 hybrids generated by line x tester mating design these F_1s along with 21 parents and commercial check were evaluated in a randomized block design with two replications at K.R.C. College of Horticulture, Arabhavi, Gokak Taluk, Belagavi district of Karnataka. Appreciable heterosis was found over better parent and commercial check for all the traits studied in desirable direction. The maximum positive heterosis was observed in the cross KON-8 x IC90174 over better parent (107.90%) and the commercial check (92.42%) for total yield per hectare.The crosses KON-8 x IC90174 (92.42%), KON-5 x AAN (45.83%), KON-16 x AAN (40.52%), KON-12 x AAN (35.07%) and KON-7 x IC90174 (27.11%) showed significant heterosis over the commercial check in order of meritfor total yield per hectare. The line KON-5 for fruit length (1.31), fruit diameter (1.87), average fruit weight (2.53), total yield per plant (35.40) and for total yield per hectare (2.18), KON-6 (1.87) for number of fruits per plant, KON-4 (0.33) for number of locules per fruit and KON-15 (9.03) for number of seeds per fruit were identified as good general combiners. In order of merit the crosses KON-8 x IC90174 (6.55), KON-16 x AAN (2.95), KON-5 x AAN and KON-17 x KON-19 (2.04) and KON-18 x IC90174 (2.00) were identified as good specific combiners. The present study reveals good scope for commercial exploitation of heterosis in okra.

INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) belonging to the family Malvaceae is an important vegetable crop of the tropics and subtropics. Okra is specially valued for its tender, delicious green fruits which are cooked, canned and consumed in various forms in different parts of the country. India is the largest producer of okra covering an area of 0.530 million hectares with an annual production of 6.350 million tonnes (Anon., 2013). It is a potential export earner accounting for 13% of export of fresh vegetables. The ease in emasculation, very high per cent of fruit set and large number of seeds per fruit makes commercial exploitation of hybrid vigour easy in okra. Being an often cross-pollinated crop, out crossing to an extent of 5~9% by insects is reported which renders considerable genetic diversity (Duggi *et al.*, 2013).

Hence, the first step in okra improvement should involve evaluation of the germplasm for genetic variability. As a second step, it is required to generate crosses employing a suitable mating design to know the extent of heterosis for various economic traits and inheritance pattern of desired characters, which in turn, would help in deciding the breeding strategies as well as identifying potential parents and crosses for further use in breeding programme (Singh and Singh, 2012). Hybrid vigour in okra has been first reported by Vijayaraghavan and Warier (1946). Several workers have reported notable heterosis for growth, yield and yield attributing traits (Lyngdoh *et al.*, 2013, Weerasekara *et al.*, 2007, Krushna *et al.*, 2007 and Manivannan *et al.*, 2007). Combining ability helps in the evaluation of inbreds in terms of their genetic value, selection of suitable parents for hybridization and identification of superior cross combinations, which may be utilized for commercial exploitation of heterosis. At K.R.C. College of Horticulture, Arabhavi several lines have been developed through pedigree and bulk method of breeding involving Yellow Vein Mosaic Virus resistant parents. These lines are at near homozygous state and can be assessed for exploitation of heterosis. Hence an investigation was carried out with an objective of assessing the magnitude of heterosis and combining ability for yield and quality parameters in okra.

MATERIALS AND METHODS

The investigation on heterosis and combining ability studies in okra was undertaken at the department of vegetable science K.R.C. College of Horticulture, Arabhavi, Gokak Taluk, Belagavi district of Karnataka during the year 2013-2014. The experimental farm is situated in Northern Dry Zone of Karnataka state at 16º15′ N latitude, 74º45′ E longitude and at an altitude of 612.03 meters above the mean sea level. From the 40 diverse near isogenic lines 21 parents were selected based on the desirable morphological traits. Thus the experimental material comprised of 21 parents *viz.*, KON-1, KON-2, KON-3, KON-4, KON-5, KON-6, KON-7, KON-8, KON-9, KON-

Table 1: Heterosis (%) over better parent and the commercial check for fruit length, fruit diameter, average fruit weight and number of fruits per plant in okra

Sl. No.	Crosses	Fruit length		Fruit diameter		Average fruit weight		Number of fruits per plant	
		BP	CC	BP	CC	BP	CC	BP	CC
1	KON-1 x AAN	2.18**	-1.09	0.00	-18.75**	1.75**	-5.97**	-20.63**	-7.17**
2	KON-1 x KON-19	-17.72**	-20.36**	-13.84**	-30.00**	-12.21**	-18.88**	6.84**	1.74*
3	KON-1 x IC90174	-15.91**	-18.61**	-14.46**	-30.50**	-10.21**	-17.04**	8.40**	3.22**
4	KON-2 x AAN	-10.55**	-8.76**	7.42**	-17.50**	-31.12**	-17.04**	-29.73**	-15.22**
5	KON-2 x KON-19	5.54**	7.66**	8.14**	-17.00**	-21.94**	-5.97**	-28.79**	-14.09**
6	KON-2 x IC90174	-20.57**	-18.98**	-12.37**	-31.66**	-33.57**	-19.99**	-31.67**	-17.57**
7	KON-3 x AAN	10.77**	-0.55	11.32**	-12.50**	-8.41**	-17.77**	-26.69**	-14.26**
8	KON-3 x KON-19	-17.82**	-22.63**	-12.21**	-31.00**	-10.63**	-22.57**	-21.02**	-12.43**
9	KON-3 x IC90174	17.38**	8.18**	7.09**	-15.83**	-21.27**	-31.78**	-12.78**	-3.30**
10	KON-4 x AAN	19.02**	6.86**	13.93**	-12.50**	8.83**	-2.29**	-16.35**	-2.17**
11	KON-4 x KON-19	-7.55**	-12.96**	-8.01**	-29.40**	6.38**	-7.82**	1.37	-0.87
12	KON-4 x IC90174	0.99	-6.93**	0.51	-21.60**	6.38**	-7.82**	23.65**	20.91**
13	KON-5 x AAN	2.81**	-2.77**	3.98**	-18.50**	-16.01**	6.93**	7.80**	26.09**
14	KON-5 x KON-19	-3.51**	-8.76**	-8.51**	-28.30**	-27.02**	-7.08**	-6.73**	-3.04**
15	KON-5 x IC90174	19.79**	13.28**	37.16**	7.50**	-11.67**	12.46**	-8.03**	-4.39**
16	KON-6 x AAN	-5.43**	-14.23**	-6.75**	-23.08**	-35.59**	-29.94**	-0.44	16.43**
17	KON-6 x KON-19	-15.89**	-20.80**	-5.60**	-22.13**	-23.22**	-16.48**	27.24**	19.39**
18	KON-6 x IC90174	1.58*	-6.39**	2.48**	-15.45**	-20.33**	-13.35**	18.44**	11.13**
19	KON-7 x AAN	-6.61**	-9.85**	-32.89**	-36.25**	-25.00**	-22.57**	-14.34**	0.17
20	KON-7 x KON-19	-19.24**	-22.06**	-23.07**	-26.93**	-34.28**	-32.15**	30.20**	13.22**
21	KON-7 x IC90174	24.76**	20.44**	-4.68**	-9.45**	14.28**	17.99**	14.40**	-0.52
22	KON-8 x AAN	-7.84**	-7.45**	-4.81**	-26.90**	-44.48**	-40.63**	-11.45**	3.57**
23	KON-8 x KON-19	-14.97**	-14.60**	-2.60**	-25.25**	-30.96**	-26.18**	-3.53**	-21.61**
24	KON-8 x IC90174	-13.29**	-12.92**	12.17**	-12.50**	31.03**	40.12**	51.66**	26.61**
25	KON-9 x AAN	-3.86**	-13.69**	-11.87**	-25.40**	-29.79**	-36.58**	-13.19**	1.52*
26	KON-9 x KON-19	-6.74**	-12.19**	-10.36**	-24.12**	-6.93**	-15.93**	-8.50**	-12.48**
27	KON-9 x IC90174	-10.17**	-17.23**	-8.41**	-22.47**	-2.04**	-11.50**	15.63**	10.61**
28	KON-10 x AAN	-0.52	-3.07**	-14.81**	-28.10**	-35.29**	-39.16**	-16.84**	-2.74**
29	KON-10 x KON-19	-12.36**	-14.60**	-13.95**	-27.38**	-15.68**	-20.72**	2.46**	3.13**
30	KON-10 x IC90174	-22.09**	-24.09**	-4.53**	-19.43**	-7.84**	-13.35**	-5.01**	-4.39**
31	KON-11 x AAN	-4.58**	-8.83**	9.40**	-15.97**	2.66**	-7.82**	-14.49**	0.00
32	KON-11 x KON-19	-12.91**	-16.79**	1.17	-22.35**	-0.71	-23.67**	-9.15**	-10.30**
33	KON-11 x IC90174	-0.15**	-4.60**	-2.53**	-23.97**	9.22**	-17.04**	-13.95**	-15.04**
34	KON-12 x AAN	8.13**	-2.92**	10.68**	-12.24**	51.95**	36.43**	-21.93**	-8.70**
35	KON-12 x KON-19	10.46**	4.01**	-12.61**	-30.70**	-14.78**	-27.73**	14.75**	2.78**
36	KON-12 x IC90174	-8.11**	-15.33**	-1.32	-21.75**	10.87**	-5.97**	25.04**	12.00**
37	KON-13 x AAN	-10.98**	-9.49**	16.86**	-10.26**	-8.00**	-17.40**	-17.28**	-3.26**
38	KON-13 x KON-19	-11.37**	-9.89**	4.88**	-19.50**	-1.73**	-18.51**	9.12**	5.00**
39	KON-13 x IC90174	-17.44**	-16.06**	-10.00**	-29.80**	-11.07**	-26.25**	-25.75**	-28.57**
40	KON-14 x AAN	-3.93**	-6.39**	2.21*	-21.50**	-9.65**	-18.88**	2.15**	19.48**
41	KON-14 x KON-19	8.61**	5.84**	0.32	-23.00**	21.42**	-5.97**	21.30**	9.65**
42	KON-14 x IC90174	-5.99**	-8.39**	-10.25**	-30.00**	11.90**	-13.35**	-0.48	-10.04**
43	KON-15 x AAN	-8.99**	-9.49**	0.94	-22.47**	-8.00**	-17.40**	-17.91**	-4.00**
44	KON-15 x KON-19	-15.59**	-16.06**	-1.62	-24.50**	1.91**	-21.64**	14.41**	11.78**
45	KON-15 x IC90174	15.78**	15.15**	-5.32**	-26.15**	6.31**	-19.25**	-45.39**	-46.65**
46	KON-16 x AAN	-1.95**	-11.97**	6.57**	-6.75**	27.31**	14.31**	-3.16**	13.26**
47	KON-16 x KON-19	-15.73**	-20.66**	-19.28**	-29.38**	-14.88**	-32.52**	43.02**	18.09**
48	KON-16 x IC90174	-6.13**	-13.50**	-19.42**	-29.50**	8.83**	-13.72**	5.46**	-11.96**
49	KON-17 x AAN	-1.12	-6.72**	-8.98**	-28.10**	-5.54**	-15.19**	-13.27**	1.43*
50	KON-17 x KON-19	4.06**	-1.82*	-10.06**	-28.95**	-2.12**	-15.19**	28.21**	21.13**
51	KON-17 x IC90174	-7.15**	-12.41**	-10.12**	-29.00**	-17.02**	-28.10**	-12.70**	-17.52**
52	KON-18 x AAN	-3.94**	-13.76**	-2.14*	-24.84**	-26.07**	-33.63**	-25.83**	-13.26**
53	KON-18 x KON-19	-11.62**	-16.79**	-6.90**	-28.55**	-4.11**	-22.57**	-5.07**	-13.87**
54	KON-18 x IC90174	-22.17**	-28.29**	2.56**	-20.00**	9.58**	-11.50**	26.88**	15.13**
	SEm ±	0.51	0.51	0.62	0.62	0.44	0.44	0.49	0.49
	CD at 5 %	1.45	1.45	1.76	1.76	1.23	1.23	1.37	1.37
	CD at 1 %	1.92	1.92	2.33	2.33	1.63	1.63	1.82	1.82

*and** indicate significance of values at p = 0.05 and p = 0.01, respectively; BP and CC - Heterosis over better parent and commercial check (MHY-10) respectively; AAN - Arka Anamika

10, KON-11,KON-12, KON-13, KON-14, KON-15, KON-16, KON-17 and KON-18 used as lines (females) and Arka Anamika (AAN), KON-19 and IC90174 as testers (males) and mated in Line x Tester mating design developed by Kempthorne (1957).

Table 2: Heterosis (%) over better parent and the commercial check for total yield per plant and total yield per hectare, number of locules per fruit and number of seeds per fruit in okra

Sl. No.	Crosses	Total yield per plant		Total yield per hectare		Number of locules per fruit		Number of seeds per fruit	
		BP	CC	BP	CC	BP	CC	BP	CC
1	KON-1 x AAN	-10.01**	12.13**	-16.81**	-5.36**	0.00	4.17**	-46.69**	-32.56**
2	KON-1 x KON-19	1.67	2.46	-6.23**	-10.63**	5.00**	9.38**	-12.81**	2.09
3	KON-1 x IC90174	1.92	2.71	-2.68**	-7.28**	0.00	4.17**	-3.03*	11.40**
4	KON-2 x AAN	-48.42**	-11.73**	-51.63**	-23.96**	0.00	4.17**	-32.53**	-14.65**
5	KON-2 x KON-19	-43.39**	-3.12	-44.39**	-12.54**	6.00**	10.42**	-6.65**	9.30**
6	KON-2 x IC90174	-53.08**	-19.70**	-54.57**	-28.59**	0.00	4.17**	-40.89**	-32.09**
7	KON-3 x AAN	-28.42**	-10.80**	-32.96**	-23.74**	-0.95**	8.33**	-45.40**	-30.93**
8	KON-3 x KON-19	-26.33**	-15.14**	-29.32**	-26.51**	-4.76**	4.17**	-10.82**	4.42**
9	KON-3 x IC90174	-31.38**	-20.97**	-31.37**	-28.65**	4.76**	14.58**	-13.36**	-0.47
10	KON-4 x AAN	-8.95**	13.46**	-9.34**	3.13**	22.00**	27.08**	-32.26**	-14.30**
11	KON-4 x KON-19	13.23**	18.46**	8.03**	-0.83	0.00	4.17**	-55.31**	-47.67**
12	KON-4 x IC90174	27.56**	33.45**	31.24**	20.48**	7.00**	11.46**	-6.78**	7.09**
13	KON-5 x AAN	0.96	60.77**	1.78**	45.83**	0.00	4.17**	-36.21**	-7.21**
14	KON-5 x KON-19	-32.85**	6.92	-32.35**	-3.07**	2.00**	6.25**	-24.38**	10.00**
15	KON-5 x IC90174	-17.74**	30.97**	-18.84**	16.30**	0.00	4.17**	-27.41**	5.58**
16	KON-6 x AAN	-21.66**	-2.38	-22.52**	-11.88**	-10.71**	4.17**	-54.04**	-41.86**
17	KON-6 x KON-19	-2.89	19.55**	-2.37**	7.93**	-4.46**	11.46**	-8.64**	6.98**
18	KON-6 x IC90174	-5.61*	16.21**	-5.71**	4.20**	1.78**	18.75**	32.59**	52.33**
19	KON-7 x AAN	-21.56**	-2.25	-26.09**	-15.92**	0.00	4.17**	-35.20**	-18.02**
20	KON-7 x KON-19	-6.87*	-1.14	-14.33**	-16.70**	0.00	4.17**	21.15**	41.86**
21	KON-7 x IC90174	34.55**	42.83**	30.72**	27.11**	0.00	4.17**	-15.23**	-2.62*
22	KON-8 x AAN	-38.90**	-23.86**	-41.48**	-33.44**	-10.71**	4.17**	-6.25**	18.60**
23	KON-8 x KON-19	-31.79**	-30.59**	-32.34**	-37.33**	-10.71**	4.17**	2.08	19.53**
24	KON-8 x IC90174	125.24**	129.23**	107.90**	92.42**	-10.71**	4.17**	-5.61**	8.43**
25	KON-9 x AAN	-34.85**	-18.82**	-38.68**	-30.27**	-1.92**	6.25**	-7.50**	26.16**
26	KON-9 x KON-19	-11.78**	-8.60**	-14.83**	-20.27**	-3.84**	4.17**	-0.93	35.12**
27	KON-9 x IC90174	15.65**	19.83**	13.29**	6.00**	1.92**	10.42**	-26.68**	0.00
28	KON-10 x AAN	-43.05**	-29.04**	-43.73**	-35.95**	2.00**	6.25**	-55.88**	-44.19**
29	KON-10 x KON-19	-7.52**	4.93	-13.42**	-11.33**	0.00	4.17**	-20.25**	-4.30**
30	KON-10 x IC90174	-11.14**	0.83	-12.38**	-10.25**	0.00	4.17**	-35.56**	-22.67**
31	KON-11 x AAN	-5.55*	17.69**	-12.08**	0.00	-3.77**	6.25**	-49.26**	-35.81**
32	KON-11 x KON-19	5.38*	-13.54**	0.25	-25.76**	-5.66**	4.17**	-2.18	14.53**
33	KON-11 x IC90174	3.01	-15.49**	3.03**	-23.70**	-3.77**	6.25**	-17.61**	-5.35**
34	KON-12 x AAN	27.46**	58.85**	18.73**	35.07**	2.00**	16.67**	-28.30**	-9.30**
35	KON-12 x KON-19	-2.36	-5.59*	-2.20**	-19.43**	0.00	4.17**	13.97**	34.65**
36	KON-12 x IC90174	40.92**	36.26**	38.54**	14.16**	0.00	4.17**	-16.33**	-1.16
37	KON-13 x AAN	-13.70**	7.54**	-23.57**	-13.11**	12.00**	6.25**	-31.71**	-13.60**
38	KON-13 x KON-19	6.45*	4.50	7.15**	-7.34**	0.00	4.17**	-49.35**	-40.70**
39	KON-13 x IC90174	-34.18**	-35.38**	-33.98**	-42.95**	0.00	4.17**	15.48**	32.67**
40	KON-14 x AAN	-9.69**	12.54**	-8.18**	4.44**	7.00**	11.46**	4.41**	32.09**
41	KON-14 x KON-19	54.07**	29.01**	47.76**	11.74**	10.00**	14.58**	-17.97**	-3.95**
42	KON-14 x IC90174	11.67**	-6.49*	11.65**	-15.59**	0.00	4.17**	-30.97**	-20.70**
43	KON-15 x AAN	-23.99**	-5.28*	-24.83**	-14.49**	2.00**	6.25**	5.60**	33.60**
44	KON-15 x KON-19	19.72**	6.06*	18.60**	-5.14**	0.00	4.17**	-10.62**	4.65**
45	KON-15 x IC90174	-41.93**	-48.56**	-41.90**	-53.56**	5.00**	9.38**	14.37**	31.40**
46	KON-16 x AAN	36.17**	69.69**	23.51**	40.52**	12.00**	16.67**	-38.16**	-21.63**
47	KON-16 x KON-19	27.86**	-1.46	21.99**	-13.67**	6.00**	10.42**	20.09**	52.21**
48	KON-16 x IC90174	19.31**	-7.31**	16.07**	-17.87**	2.00	6.25**	-33.57**	-15.81**
49	KON-17 x AAN	-11.49**	10.29**	-17.96**	-6.65**	0.00	4.17**	9.43**	45.70**
50	KON-17 x KON-19	24.98**	24.02**	25.08**	10.92**	0.00	4.17**	-18.42**	8.60**
51	KON-17 x IC90174	-27.83**	-28.39**	-27.62**	-35.79**	0.00	4.17**	-17.90**	9.30**
52	KON-18 x AAN	-43.30**	-29.35**	-45.16**	-37.66**	0.00	4.17**	-2.57**	23.26**
53	KON-18 x KON-19	-7.51**	-17.31**	-8.90**	-27.74**	0.00	4.17**	-6.65**	9.30**
54	KON-18 x IC90174	41.57**	26.59**	38.69**	10.01**	14.00**	18.75**	-3.84**	10.47**
	SEm±	1.85	1.85	0.40	0.40	0.18	0.18	0.92	0.92
	CD at 5 %	5.22	5.22	1.13	1.13	0.51	0.51	2.58	2.58
	CD at 1 %	6.92	6.92	1.51	1.51	0.68	0.68	3.42	3.42

*and** indicate significance of values at p=0.05 and p=0.01, respectively; BP and CC - Heterosis over better parent and commercial check (MHY-10) respectively; AAN - Arka Anamika

Fifty four F_1 hybrids were derived by crossing 18 lines with each of three testers and these were evaluated along with parents and commercial check (MHY-10) in randomized block design with two replications. Each treatment in each replica-

Table 3: General combining ability effects for yield and quality parameters in okra

Sl. No.	Lines	Fruit length	Fruit diameter	Average fruit weight	Numberof fruits per plant	Total yield per plant	Total yield per hectare	Number of locules per fruit	Number of seeds per fruit
1.	KON-1	-0.60	-0.80	0.08	-0.02	0.14	-0.02	-0.07	-3.69**
2.	KON-2	0.31	0.08	0.03	-1.73**	-22.33**	-1.14**	-0.05	-6.32**
3.	KON-3	0.54	0.53	-1.29**	-1.08**	-27.68**	-1.50**	0.08	-4.82**
4.	KON-4	0.63	0.25	1.16**	0.75	20.97**	1.21**	0.33*	-8.82**
5.	KON-5	1.31**	1.87**	2.53**	0.78	35.40**	2.18**	-0.12	0.25
6.	KON-6	-0.66	0.44	-0.73*	1.87**	7.11**	0.60	0.20	1.55*
7.	KON-7	0.71	-0.35	0.31	0.56	9.73**	0.45	-0.15	2.09**
8.	KON-8	-0.37	0.18	0.77*	0.40	25.05**	1.18**	-0.15	5.72**
9.	KON-9	-0.74	-0.31	-0.92*	0.05	-10.64**	-0.59	-0.02	7.83**
10.	KON-10	-0.68	-0.51	-1.34**	-0.09	-17.44**	-0.94**	-0.12	-11.15**
11.	KON-11	-0.15	0.33	-0.22	-0.90*	-12.27**	-0.72*	-0.08	-4.77**
12.	KON-12	0.58	0.18	2.10**	0.30	31.43**	1.39**	0.05	2.51**
13.	KON-13	-0.39	0.52	-0.84*	-0.96*	-17.47**	-1.09**	-0.12	-4.05**
14.	KON-14	0.82	-0.48	0.25	0.80*	7.84**	0.62	0.13	0.11
15.	KON-15	0.75	-0.39	-0.66	-1.42**	-28.06**	-1.35**	-0.03	9.03**
16.	KON-16	-0.88*	0.11	0.53	0.81*	19.05**	0.84*	0.18	1.16
17.	KON-17	0.27	-1.25*	-0.67	0.26	-4.79**	-0.24	-0.15	8.16**
18.	KON-18	-1.46**	-0.41	-1.09**	-0.39	-16.05**	-0.88**	0.08	5.21**
	SEm ±	0.29	0.36	0.25	0.28	1.07	0.23	0.10	0.53
	CD at 5 %	0.83	1.01	0.70	0.79	3.02	0.65	0.28	1.49
	CD at 1 %	1.11	1.35	0.93	1.05	4.02	0.87	0.38	1.98
	Testers								
1.	AAN	0.28	0.47	-0.02	0.14	1.99*	0.05	0.04	-3.45**
2.	KON-19	-0.40	-0.72**	-0.60**	0.18	-5.95**	-0.32	-0.05	2.79**
3.	IC90174	0.11	0.25	0.62**	-0.32	3.96**	0.27	0.02	0.67
	SEm ±	0.15	0.18	0.12	0.14	0.53	0.12	0.05	0.26
	CD at 5 %	0.42	0.51	0.35	0.40	1.51	0.33	0.14	0.75
	CD at 1 %	0.55	0.67	0.47	0.53	2.01	0.43	0.19	0.99

*and** indicate significance of values at p=0.05 and p=0.01, respectively; AAN - Arka Anamika

tion was represented by 20 plants at a spacing of 60 x 30 cm. five plants were randomly selected from each genotype for recording the observations.

RESULTS AND DISCUSSION

Heterosis for yield and quality parameters are presented in Table 1 and 2 and gca and sca effects are presented in Table 4 and 5 respectively. The yield components greatly influence yield and higher magnitude of heterosis was observed for the yield components in the present investigation. For fruit length 13 crosses over the better parent and eight crosses over the commercial check recorded positive and highly significant heterosis (Table 1). The cross KON-7 x IC90174 expressed maximum heterosis over the better parent (24.76%) and commercial check (20.44 %).The line KON-5 (1.31) exhibited significant and positive gca effects (Table 3). Four crosses showed highly significant positive sca effects and the highest positive sca effects was observed in the cross KON-7 x IC90174 (3.21) followed by KON-15 x IC90174 (2.44) (Table 4). Similar magnitude of standard heterosis reported by Solankey *et al.*, 2013 (Upto 18.38 %) and Singh *et al.*, 2013 (-15.06 to 24.84 %). Fifteen crosses exhibited positive and highly significant heterosis over better parent and only one cross over the commercial check and the maximum heterosis over the better parent (37.16%) and commercial check (7.50 %) was exhibited by the cross KON-5 x IC90174 for fruit diameter (Table1).The line KON-5 (1.87) showed significant and positive gca effects for fruit diameter (Table 3). Three crosses showed significant and positive sca effects and the highest positive sca effects was noticed in the cross KON-5 x IC90174 (3.87) followed by KON-7 x IC90174 (2.70) (Table 4). Similar reports for commercial heerosis from Singh *et al.*, 2013 (-12.64 to 6.42 %) and Medagam *et al.*, 2013 (-8.80 to 7.36 %).Out of the 54 crosses, 17 crosses over better parent and six crosses over the commercial check exhibited positive and highly significant heterosis and the maximum heterosis over the better parent (51.95%)was exhibited by the cross KON-12 x AAN and the cross KON-8 x IC90174 over the commercial check (40.12%) for average fruit weight (Table1). Four lines expressed significantly positive gca effects and the maximum was observed in the line KON-5 (2.53) followed by KON-12 (2.10) (Table 3). Six crosses exhibited significantly positive sca effects and the highest sca effects was noticed in the cross KON-8 x IC90174 (6.03) followed by KON-12 x AAN (4.84) (Table 4). The standard heterosis is comparable with the findings of Jindal *et al.*, 2010 (upto 38.10 %).

For number of fruits per plant 21 crosses each over better parent and the commercial check exhibited positive and highly significant heterosis and the maximum heterosis was observed in the cross KON-8 x IC90174 over the better parent (51.66%) and the commercial check (26.61 %) (Table1).Three lines KON-6 (1.87), KON-16 (0.81) and KON-14 (0.80) exhibited significant and positive gca effects for number of fruits per plant (Table 3). Six crosses exhibited highly significant positive

Table 4: Specific combining ability effects for yield and quality parameters in okra

Sl. No.	Crosses	Fruit length	Fruit diameter	Average fruit weight	Number of fruits per plant	Total yield per plant	Total yield per hectare	Number of locules per fruit	Number of seeds per fruit
1	KON-1 x AAN	1.40	1.06	1.10	-0.88	6.28*	0.14	-0.12	-7.81**
2	KON-1 x KON-19	-0.56	0.00	-0.07	0.11	1.65	0.09	0.22	0.85
3	KON-1 x IC90174	-0.83	-1.07	-1.04	0.77	-7.94**	-0.23	-0.10	6.97**
4	KON-2 x AAN	-0.57	0.44	-0.35	-0.09	-2.27	-0.23	-0.14	-7.81**
5	KON-2 x KON-19	2.36**	1.73	1.73	0.00	16.87**	1.05	0.25	0.85
6	KON-2 x IC90174	-1.80*	-2.17*	-1.39*	0.09	-14.59**	-0.82	-0.12	6.97**
7	KON-3 x AAN	0.33	0.99	0.87	-0.63	4.29	0.15	-0.07	-5.98**
8	KON-3 x KON-19	-2.02**	-1.53	0.80	-0.46	6.60*	0.31	-0.18	2.98*
9	KON-3 x IC90174	1.69*	0.54	-1.67**	1.09	-10.89**	-0.46	0.25	3.00*
10	KON-4 x AAN	1.25	1.26	0.52	-1.07	-12.82**	-0.41	0.58*	5.17**
11	KON-4 x KON-19	-0.78	-0.93	0.35	-0.96	1.62	-0.35	-0.43	-15.42**
12	KON-4 x IC90174	-0.47	-0.34	-0.87	2.04**	11.20**	0.76	-0.15	10.25**
13	KON-5 x AAN	-0.74	-1.55	0.40	2.15**	34.25**	2.04**	-0.07	-0.85
14	KON-5 x KON-19	-0.88	-2.32*	-0.92	-1.24	-27.80**	-1.50*	0.12	0.31
15	KON-5 x IC90174	1.63**	3.87**	0.51	-0.90	-6.45*	-0.54	-0.05	0.53
16	KON-6 x AAN	-0.34	-1.04	-1.34*	-0.05	-19.56**	-1.01	-0.39	-17.05**
17	KON-6 x KON-19	-0.56	0.34	1.07	0.25	16.91**	0.95	0.05	-2.29
18	KON-6 x IC90174	0.90	0.71	0.27	-0.20	2.65	0.06	0.33	19.33**
19	KON-7 x AAN	-1.11	-2.88**	-1.38*	-0.61	-22.01**	-1.18*	-0.04	-7.34**
20	KON-7 x KON-19	-2.10**	0.17	-2.10**	0.85	-12.63**	-0.86	0.05	12.17**
21	KON-7 x IC90174	3.21**	2.70**	3.48**	-0.24	34.64**	2.04**	-0.02	-4.83**
22	KON-8 x AAN	0.29	-1.54	-4.28**	-0.06	-65.42**	-3.30**	-0.04	4.78**
23	KON-8 x KON-19	-0.01	-0.02	-1.74**	-2.99**	-66.22**	-3.24**	0.05	-1.06
24	KON-8 x IC90174	-0.29	1.56	6.03**	3.05**	131.64**	6.55**	-0.02	-3.72**
25	KON-9 x AAN	-0.19	-0.75	-2.05**	0.05	-23.17**	-1.28*	-0.07	5.92**
26	KON-9 x KON-19	0.69	0.69	1.33*	-1.60*	-1.94	-0.11	-0.08	3.53**
27	KON-9 x IC90174	-0.50	0.06	0.71	1.55*	25.11**	1.40*	0.15	-9.45**
28	KON-10 x AAN	1.20	-1.10	-1.98**	-0.30	-29.66**	-1.40*	0.03	-5.35**
29	KON-10 x KON-19	0.30	0.24	1.10	0.34	22.45**	0.95	0.02	5.56**
30	KON-10 x IC90174	-1.51*	0.86	0.88	-0.03	7.21**	0.44	-0.05	-0.22

*and** indicate significance of values at p=0.05 and p=0.01, respectively; AAN - Arka Anamika

sca effects and the highest sca effects was observed in the cross KON-8 x IC90174 (3.05) followed by KON-15 x KON-19 (2.67) (Table4).Same magnitude of heterosis as that of findings of Singh *et al.*, 2013 (-11.98 to 24.33 %) over the commercial check. For total yield per plant 15 crosses over better parent and 21 crosses over the commercial check showed positive and highly significant heterosis and the maximum heterosis was observed in the cross KON-8 x IC90174 over the better parent (125.24%) and the commercial check (129.23 %) (Table 2).The magnitude of standard heterosis is high as compared to Ashwani *et al.*, 2013 (8.75 to 40.00 %) and this attributes to use of different genetic stocks in these experiments. The crosses KON-8 x IC90174 (129.23 %), KON-16 x AAN (69.69 %), KON-5 x AAN (60.77 %), KON-12 x AAN (58.85 %), and KON-12 x IC90174 (36.26 %) showed significant heterosis over the commercial check in order of merit.Eight lines showed positive and significant gca effects, the highest was observed in the line KON-5 (35.40) followed by KON-12 (31.43), KON-8 (25.05), KON-4 (20.97) and KON-16 (19.05). Among the testers, IC90174 (3.96) and AAN (1.99) exhibited positive and significant gca effects (Table 3). Nineteen crosses exhibited highly significant and positive sca effect and the highest sca effects was recorded in the cross KON-8 x IC90174 (131.64), followed by KON-16 x AAN (62.20), KON-18 x IC90174 (39.31), KON-12 x AAN (35.72) and KON-15 x KON-19 (34.53) (Table 4).Out of the 54 crosses, 18 crosses over better parent and 16 crosses over the commercial check showed positive and highly significant heterosis and the maximum positive heterosis was observed in the cross KON-8 x IC90174 over better parent (107.90%) and the commercial check (92.42 %)(Table 2) for total yield per hectare. The standard heterosis is in accordance with findings of Reddy *et al.*, 2013 (-15.60 to 86.68 %). The crosses KON-8 x IC90174 (92.42 %), KON-5 x AAN (45.83 %), KON-16 x AAN (40.52 %), KON-12 x AAN (35.07 %) and KON-7 x IC90174 (27.11 %) showed significant heterosis over the commercial check in order of merit for total yield per hectare. Five lines exhibited positive and significant gca effects, the highest was observed in the line KON-5 (2.18) followed by KON-12 (1.39), KON-4 (1.21) and KON-8 (1.18) (Table 3). Eight crosses exhibited highly significant and positive sca effects and the highest sca effects was observed in the cross KON-8 x IC90174 (6.55), followed by KON-16 x AAN (2.95), KON-5 x AAN (2.04), KON-17 x KON-19 (2.04) and KON-18 x IC90174 (2.00) (Table 4).

For number of locules per fruit 18 crosses over better parent and 54 crosses over the commercial check exhibited positive and highly significant heterosis (Table 2). The cross KON-4 x AAN exhibited maximum heterosis over the better parent (22.00%) and the commercial check (27.08 %).The line KON-4 (0.33) showed significantly positive gca effects (Table 3). Among the crosses, the cross KON-4 x AAN (0.58) exhibited significant sca effects in the desirable direction (Table 4). For number of seeds per fruit nine crosses over better parent and 28 crosses over the commercial check exhibited positive and

Table 4: Continued....

Sl. No.	Crosses	Fruit length	Fruit diameter	Average fruit weight	Number of fruits per plant	Total yield per plant	Total yield per hectare	Number of locules per fruit	Number of seeds per fruit
31	KON-11 x AAN	-0.11	0.49	1.15	0.83	25.92**	1.27*	0.00	-8.13**
32	KON-11 x KON-19	-0.52	0.40	-0.42	-0.39	-6.74*	-0.42	-0.02	7.28**
33	KON-11 x IC90174	0.64	-0.89	-0.74	-0.44	-19.18**	-0.85	0.02	0.85
34	KON-12 x AAN	-0.03	1.40	4.84**	-1.37	35.72**	1.96**	0.36	-4.01**
35	KON-12 x KON-19	1.60*	-1.11	-3.28**	-0.09	-40.11**	-2.02**	-0.15	8.65**
36	KON-12 x IC90174	-1.56*	-0.29	-1.55*	1.46*	4.39	0.06	-0.22	-4.63**
37	KON-13 x AAN	0.04	1.45	0.47	0.51	17.92**	0.59	0.03	0.70
38	KON-13 x KON-19	0.66	0.79	0.90	1.43*	21.92**	1.42*	0.02	-17.19**
39	KON-13 x IC90174	-0.69	-2.24*	-1.37*	-1.94**	-39.84**	-2.02**	-0.05	16.48**
40	KON-14 x AAN	-0.75	0.20	-0.81	1.37	-0.89	0.29	0.03	16.19**
41	KON-14 x KON-19	1.60*	1.08	1.52*	0.20	28.48**	1.25*	0.27	-5.55**
42	KON-14 x IC90174	-0.85	-1.28	-0.70	-1.57**	-27.59**	-1.53**	-0.30	-10.63**
43	KON-15 x AAN	-1.11	-0.09	0.30	0.89	11.85**	0.74	-0.05	7.92**
44	KON-15 x KON-19	-1.33	0.69	0.30	2.67**	34.53**	1.86**	-0.07	-10.77**
45	KON-15 x IC90174	2.44**	-0.60	-0.60	-3.56**	-46.38**	-2.60**	0.12	2.85*
46	KON-16 x AAN	0.18	2.56**	3.40**	0.64	62.20**	2.95**	0.23	-7.96**
47	KON-16 x KON-19	-0.33	-0.78	-2.37**	1.16	-22.35**	-1.01	0.02	17.55**
48	KON-16 x IC90174	0.14	-1.77*	-1.04	-1.80*	-39.85**	-1.94**	-0.25	-9.58**
49	KON-17 x AAN	-0.25	-0.35	0.60	-0.17	8.82**	0.26	-0.04	13.99**
50	KON-17 x KON-19	1.10	0.66	1.18	2.06**	34.61**	2.04**	0.05	-8.20**
51	KON-17 x IC90174	-0.86	-0.31	-1.79**	-1.89**	-43.43**	-2.30**	-0.02	-5.78**
52	KON-18 x AAN	0.52	-0.55	-1.48*	-1.20	-31.45**	-1.58**	-0.27	7.29**
53	KON-18 x KON-19	0.78	-0.10	0.60	-1.31	-7.86**	-0.42	-0.18	-4.95**
54	KON-18 x IC90174	-1.30	0.65	0.88	2.52**	39.31**	2.00**	0.45	-2.33
	SEm ±	0.51	0.62	0.43	0.48	1.85	0.40	0.17	0.91
	CD at 5 %	1.44	1.75	1.22	1.37	5.23	1.13	0.49	2.58
	CD at 1 %	1.92	2.33	1.62	1.82	6.96	1.50	0.65	3.44

*and** indicate significance of values at p = 0.05 and p = 0.01, respectively; AAN – ArkaAnamika

Table 5: Variance due to general and specific combining ability for yield and quality parameters in okra

S. No.	Character	GCA	SCA	GCA:SCA
1	Fruit length	0.0039	1.85	0.0021
2	Fruit diameter	0.0084	2.32	0.0036
3	Average fruit weight	0.0141	5.04	0.0028
4	Number of fruits per plant	0.0053	2.69	0.0020
5	Total yield per plant	5.9268	1682.91	0.0035
6	Total yield per hectare	0.0120	4.26	0.0028
7	Number of locules per fruit	0.00003	0.03	0.0012
8	Number of seeds per fruit	0.0508	117.73	0.0004

GCA-Variance due to general combining ability; SCA-Variance due to specific combining ability

highly significant heterosis (Table 2) and the maximum positive heterosis over the better parent (32.59%)and commercial check (52.33 %) was observed in the cross KON-6 x IC90174. Standard heterosis is low as compared to Weerasekara *et al.*, 2007 (-11.81 to 115.43 %) and it is due to use of different genotypes in the studies. Eight lines showed significantly positive gca effects and the maximum gca effects was exhibited by the line KON-15 (9.03) followed by KON-17 (8.16). The tester KON-19 (2.79) showed significantly positive gca effects (Table 3). Seventeen crosses exhibited highly significant positive sca effects and the highest sca effects was observed in the cross KON-6 x IC90174 (19.33) followed by KON-13 x IC90174 (16.48) (Table 4).

Ratio of general combining ability variance (GCA) to specific combining ability variance (SCA) is an indication of predominance of additive or non-additive genetic variance. GCA to SCA ratio (Table 5) was very low for the traits number of seeds per fruit, fruit length, fruit diameter, average fruit weight, number of fruits per plant, total yield per plant, total yield per hectare, number of locules per fruit and number of seeds per fruit indicating preponderance of non-additive gene action and hence these trait can be improved through recurrent selection for specific combining ability or heterosis breeding. Hence there is great scope for heterosis breeding to exploit the non-additive genetic variance observed for yield and quality parameters in okra.

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