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Combining ability and its relationship with gene action in okra [*Abelmoschus esculentus* (L.) Moench]

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ABSTRACT

An experiment was carried out with twelve parental lines of okra viz. Larm -1, IC -282280, IC – 282337, IC -128891, IC -111527, EC – 329380, IC – 282279, VRO -5, IC – 329422, IC – 18537, Hisar Unnat and IC – 43132 along with 66 F_1 hybrids based on half-diallel cross excluding reciprocals to the study of combining ability of okra [Abelmoschus esculentus (L.) Moench] with respect to seventeen characters, at Vegetable Research Farm, Department of Horticulture, Institute of Agriculture Sciences, Banaras Hindu University, Varanasi. This place is situated in South East part of Varanasi city at 25º15' North latitude and 83º03' East longitudes at an elevation of 129.23 m above the mean sea level. The area is characterized by humid subtropical climate with extreme hot weather in summer and cold in winter. The average annual rainfall is about 1110 mm. The major portion of precipitation (about 85 to 90%) is received during July to September. All parental lines and F_1 combinations were grown in Randomized Block Design (RBD) with three replications during rainy season, 2012. The mean square due to gca and sca were significant for all seventeen characters under study indicating the importance of both additive and non-additive genetic components for the characters under study. None of parents were good general combiner for all characters whereas, Hisar Unnat, IC- 128891 and VRO-5 showed significant gca for yield, earliness and different pod characters respectively, which signifies their suitability to be used for further breeding and crop improvement programme. Among the crosses, Larm -1 x IC -111527, IC - 282280 × IC -111527 and IC -282280 x EC – 329380 were most promising combinations for earliness and other desirable characters including yield per plant. The results indicated the importance of heterosis breeding for effective utilization of non-additive genetic variance in okra.

Key words: Combining ability, F_1 hybrid, gca, okra, sca

India is the largest producer of okra in the world. Among the vegetable, contribution of okra is 5.9% in area and 3.9% in production. Andhra Pradesh is the leading state in area and production of okra, while Jammu and Kashmir has maximum productivity (Anon., 2012). Okra pod contains fairly good amount of proteins, carbohydrates, vitamins (*i.e*. A, B and C) and minerals (Owolarafe and Shotonde, 2004; Gopalan *et al*., 2007; Arapitsas, 2008 and Dilruba *et al*., 2009), and plays a vital role in human diet (Kahlon *et al*., 2007 and Saifullah and Rabbani, 2009). Okra seed contains about 20% protein and 20% oil. In okra, so many varieties have been developed but substantial increase in productivity potential could not be realized probably due to ceiling in genetic potential of the genotypes. Therefore, there is urgent need of genetic improvement of the crop for yield which can be done by exploitation of hybrid vigour (heterosis), breeding for efficient plant type and component breeding. Since, yield, which is generally a polygenically inherited character, is the main consideration in heterosis breeding, it is of considerable importance to study the pattern of inheritance of this character as well as various other direct and indirect components related to yield. Keeping in view the above facts, the present investigation was planned and carried out using 12 parents and their 66 F_1 hybrids (excluding reciprocals) with the objective to estimate the combining ability of parents and hybrids with respect to various direct and indirect yield components.

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MATERIALS AND METHODS

The present investigation was conducted at Vegetable Research Farm, Department of Horticulture, Institute of Agriculture Sciences, Banaras Hindu University, Varanasi during Spring-Summer and Rainy season of 2012. This place is situated in south east part of Varanasi city at 25º15' North latitude and 83º03' East longitudes at an elevation of 129.23 m above the mean sea level. The average annual rainfall is about 1110 mm. The major portion of precipitation about 85 to 90% is received during July to September. The experimental materials consist of 12 diverse genotypes of okra which were provided by the Indian Institute of Vegetable

Research, Varanasi are provided in table 1. Each genotype was sown in 12 rows of 3 meters long accommodating 10 plants in each row. These genotypes were crossed in all possible combinations in diallel fashion (excluding reciprocals) by hand emasculation and pollination during spring-summer, 2012 to produce 66 F_1 hybrids. The experiment containing 12 parents and 66 F_1 hybrids was laid out in a Randomized Block Design (RBD) with three replications during rainy season, 2012. The observations were taken from randomly selected five competitive plants of parents and their crosses in each replication. The analysis of variance was used for testing as to whether there exists a significant difference between the treatments or not. It was carried out following the procedure of Randomized Block design (RBD) analysis (Panse and Sukhatme, 1989) for each of the genotypes. The combining ability analysis was carried out by the procedure given by Griffing (1956 a). Model-I and Method-II was adopted for the present study which was formulated through SPSS statistical software.

Table 1: Name of the genotypes of okra used in the present experiment

Sr. No.	Parents	Genotypes	Sources
1	P_1	Larm -1	IIVR-Varanasi
2	P_2	IC -282280	IIVR-Varanasi
3	P_3	IC - 282337	IIVR-Varanasi
4	P_4	IC -128891	IIVR-Varanasi
5	P_5	IC -111527	IIVR-Varanasi
6	P_6	EC - 329380	IIVR-Varanasi
7	P_7	IC - 282279	IIVR-Varanasi
8	P_8	VRO -5	IIVR-Varanasi
9	P_9	IC - 329422	IIVR-Varanasi
10	P_{10}	IC - 18537	IIVR-Varanasi
11	P_{11}	Hisar Unnat	IIVR-Varanasi
12	P_{12}	IC - 43132	IIVR-Varanasi

RESULTS AND DISCUSSION

General combining ability effects

An overall study of gca (Table 2) revealed that none of parent was good combiner for all characters under investigations. An overview of gca table revealed that IC -282280 (P_2) was the best general combiner for number of pods plant ha^{-1} (1.01), pod yield ha^{-1} (7.50) and plant dry weight (1.74) and 2nd in seed yield hectare^{-1} (0.94); IC -128891 (P_4) was the best general combiner for node at which first flower appeared (-0.78) and 2nd to days to first flowering (-1.10); IC – 18537 (P_{10}) for seed weight per pod (0.13), 100 seed weight (0.28) and intermodal length (0.27) and 2nd to plant height (5.72), dry weight of pod (0.21); VRO-5 (P_8) as the best general combiner for the pod weight (0.98), number of seeds per pod (2.00); Larm -1(P_1) was the best general combiner for pod length (0.72); Hisar Unnat (P_{11}) was the best general combiner for seed yield per hectare (1.23) and 2nd to 100 seed weight (0.04) and number of pod plant^{-1} (0.85). However, IC -111527 (P_5), EC – 329380 (P_6) and IC – 43132 (P_{12}) were best combiners for number of branches (0.72), plant height (7.39) and days to first flowering (-1.65) respectively.

For identification of desirable best parent(s) based gca effects, five best parents were considered for each character separately and finally the common parent(s), if any, was/were identified based on both criteria. Taking the above parameters into consideration, the most desirable parents were identified. P_4 (IC -128891) was good general combiner for days to first flowering, days to 50% flowering and node at which first flower appear; P_8 (VRO-5) for pod quality like length, diameter, weight and number of seed per pod; P_{11} (Hisar Unnat) was the best for pod yield and seed yield per hectare. Thus, P_4 (IC-128891), P_8 (VRO-5), and P_{11} (Hisar Unnat) were considered promising for future heterosis breeding programme for earliness, pod quality traits and yield attributing characters.

In general, the parents who gave the best *per se* performance were also the best combiner indicating to a positive association between the two parameters. This result suggested that the selection of parents that

Table 2: Estimates of general combing ability effects of 12 parents for different characters in 12×12 diallel cross of okra

Line	Name of line/ variety	Days to first flowering	Days to 50% flowering	1st flower appearing node	Plant height (cm)	Number of branches plant^{-1}	Internodal distance (cm)	Number of pods plant^{-1}	Pod length (cm)
P_1	Larm 1	-0.60*	-0.90***	-0.17	-2.09**	0.08	-0.22**	-0.18	0.72***
P_2	IC 282280	-0.31	-0.56*	-0.61***	-3.64***	0.10	-0.19**	1.01***	0.29*
P_3	IC 282337	0.07	0.87***	0.07	5.50***	-0.37**	0.05	0.06	-0.21
P_4	IC 128891	-1.10***	-2.37***	-0.78***	-0.89	-0.43***	0.01	0.14	0.31**
P_5	IC 111527	0.73**	1.84***	1.36***	-0.69	0.72***	-0.01	-0.06	-0.40***
P_6	EC 329380	0.38	-0.04	0.91***	7.39***	0.50***	0.21**	0.23	0.15
P_7	IC 282279	0.04	0.77**	0.37**	-2.97***	-0.21	-0.01	-0.83***	-0.27*
P_8	VRO 5	0.71**	0.63*	-0.32*	-7.58***	0.05	-0.20**	-0.27	0.34**
P_9	IC 329422	0.38	1.13***	-0.26*	-3.50***	-0.67***	-0.05	-1.12***	-0.03
P_{10}	IC18537	1.52***	1.60***	0.14	5.72***	0.28*	0.27***	-0.47**	-0.74***
P_{11}	HRB 55	-0.17	-0.75**	-0.44***	0.44	0.04	0.01	0.85***	-0.19
P_{12}	IC 43132	-1.65***	-2.21***	*-0.26	2.31***	-0.09	0.14*	0.64***	0.03
L.S.D. Comparisons for gca									
Gi (0.05)		**0.60**	**0.56**	**0.27**	**1.56**	**0.25**	**0.15**	**0.34**	**0.25**
Gi (0.01)		**0.84**	**0.79**	**0.39**	**2.20**	**0.35**	**0.21**	**0.49**	**0.36**
Gi—Gj (0.05)		**0.88**	**0.83**	**0.41**	**2.30**	**0.37**	**0.22**	**0.51**	**0.38**
Gi—Gj (0.01)		**1.24**	**1.17**	**0.57**	**3.25**	**0.52**	**0.31**	**0.72**	**0.53**

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Table 2 Contd...

Line	Name of line/variety	Pod diameter(cm)	Pod weight (g)	Dry weight of pods (%)	Number of seeds pod^{-1}	Seed weight pod^{-1}	100 Seed weight (g)	Seed yield (q ha^{-1})	Pod yield (q ha^{-1})	Plants dry weight (%)
P_1	Larm 1	-0.01	0.46*	0.17***	0.51	-0.06**	-0.11***	-0.53*	1.73	-1.10***
P_2	IC 282280	-0.02	-0.02	-0.21***	0.11	-0.02	-0.06	0.94***	7.50***	1.74***
P_3	IC 282337	0.03***	-0.03	0.16***	-1.26*	-0.10***	-0.10**	-0.61**	0.39	-1.20***
P_4	IC 128891	0.00	0.34	-0.18***	-1.06*	-0.05*	-0.04	-0.18	2.90*	-0.30**
P_5	IC 111527	-0.02	-0.81***	-0.02	-2.68***	-0.15***	-0.08**	-0.81***	-5.69***	-1.98***
P_6	EC 329380	0.02	0.56**	-0.04	0.80	0.01	-0.08**	0.34	4.87***	0.10
P_7	IC 282279	-0.05***	-0.90***	0.21***	0.74	0.03	-0.04	-0.71**	-10.69***	0.70***
P_8	VRO 5	0.02*	0.98***	-0.16***	2.00***	0.06**	0.04	0.08	3.46**	-0.07
P_9	IC 329422	-0.01	0.18	0.04	0.90	0.07**	0.05	-0.82***	-7.67***	1.83***
P_{10}	IC18537	0.01	-1.04***	0.21***	-0.32	0.13***	0.28***	0.18	-8.52***	-0.60***
P_{11}	HRB 55	0.00	0.10	-0.22***	0.50	0.04*	0.08**	1.23***	6.01***	0.14
P_{12}	IC 43132	0.01	0.18	0.05	-0.23	0.04	0.06*	0.88***	5.69***	0.73***
L.S.D. Comparisons for gca										
Gi (0.05)		**0.02**	**0.47**	**0.10**	**1.14**	**0.05**	**0.07**	**0.50**	**2.61**	**0.24**
Gi (0.01)		**0.03**	**0.67**	**0.14**	**1.61**	**0.07**	**0.10**	**0.70**	**3.69**	**0.33**
Gi—Gj (0.05)		**0.03**	**0.70**	**0.14**	**1.69**	**0.07**	**0.10**	**0.74**	**3.86**	**0.35**
Gi—Gj (0.01)		**0.05**	**0.99**	**0.20**	**2.38**	**0.10**	**0.14**	**1.04**	**5.45**	**0.49**

, ** and * significant at 5%, 1% and 0.1% level respectively.*

Table 3a: Estimates of specific combining ability effects of crosses for different characters in a 12×12 diallel crosses in okra

Hybrids	Days to first flowering	Days to 50% flowering	Node at which 1st flower appears	Plant height (cm)	Number of branches plant^{-1}	Internodal distance (cm)	Number of pods plants^{-1}	Pod length (cm)	Pod diameter (cm)
$P_1 \times P_2$	1.37	1.26	-0.42	9.02***	0.87*	1.88***	-0.66	0.62	0.08*
$P_1 \times P_3$	0.99	-0.16	-0.11	10.79***	0.88*	0.63*	2.25***	0.40	0.10**
$P_1 \times P_4$	2.16*	3.07**	0.48	17.18***	1.87***	0.11	1.27*	0.64	0.02
$P_1 \times P_5$	0.32	-0.14	0.68	-7.00**	0.38	-1.00***	-0.86	0.06	0.06
$P_1 \times P_6$	3.68***	6.74***	-0.87	-11.91***	-0.67	-0.45	-2.68***	-0.07	0.01
$P_1 \times P_7$	3.01**	2.93**	2.20***	0.38	-0.09	-1.05***	-0.55	0.09	0.05
$P_1 \times P_8$	0.35	0.07	0.35	-2.66	-0.55	-0.26	-0.38	0.08	-0.06
$P_1 \times P_9$	1.01	-2.43*	-1.11*	0.44	-0.96*	-0.07	-0.73	-0.52	-0.09*
$P_1 \times P_{10}$	-1.46	-0.90	-0.71	-10.20***	-0.04	0.43	2.35***	0.40	-0.05
$P_1 \times P_{11}$	0.56	1.45	1.68***	11.43***	0.53	0.68***	1.36*	0.20	0.00
$P_1 \times P_{12}$	-3.30**	-3.09**	0.63	8.77**	0.00	-0.32	2.91***	0.55	0.02
$P_2 \times P_3$	-1.30	-0.50	0.74	-4.10	0.00	-0.52*	-0.37	1.09*	0.02
$P_2 \times P_4$	0.54	-1.26	2.33***	7.22**	1.72***	0.07	-2.12***	-0.38	0.06
$P_2 \times P_5$	0.04	-1.47	0.72	6.55*	1.30**	-0.53*	-0.38	-1.06*	-0.01
$P_2 \times P_6$	-0.61	0.41	0.84	2.36	1.12**	-0.64*	4.66***	0.66	0.06
$P_2 \times P_7$	0.73	-2.40*	0.71	-1.31	-0.04	-0.70**	1.39*	0.98*	0.06
$P_2 \times P_8$	0.06	-0.26	0.40	0.89	-0.10	-0.25	0.63	-0.09	-0.03
$P_2 \times P_9$	0.39	-2.76**	-0.79	-1.48	0.23	-0.09	1.21*	-0.26	-0.04
$P_2 \times P_{10}$	-5.75***	-4.24***	-0.12	9.91***	-0.86*	1.09***	2.37***	0.01	0.01
$P_2 \times P_{11}$	0.94	0.12	0.06	9.61***	0.05	0.80**	0.11	-0.10	0.04
$P_2 \times P_{12}$	3.42***	2.57**	-1.32**	-7.39**	-1.35**	-0.28	-1.55**	-0.36	-0.01
$P_3 \times P_4$	-0.51	0.31	-1.49**	0.62	-0.74	1.00***	1.57**	-0.74	-0.03
$P_3 \times P_5$	2.66**	2.76**	-1.03*	-8.72**	-1.83***	0.23	-1.57**	0.23	-0.03

Contd...

Table 3a contd...

Hybrids	Days to first flowering	Days to 50% flowering	Node at which 1st flower appears	Plant height (cm)	Number of branches plant^{-1}	Internodal distance (cm)	Number of pods plants^{-1}	Pod length (cm)	Pod diameter (cm)
$P_3 \times P_6$	1.01	-1.02	-0.58	-2.23	-0.01	-0.64*	-2.26***	-1.12**	0.01
$P_3 \times P_7$	2.68**	1.17	0.36	4.63	0.10	-0.34	1.01	0.50	0.01
$P_3 \times P_8$	1.01	-0.69	-1.02*	-4.29	-1.16**	-0.68**	-1.69**	0.02	0.01
$P_3 \times P_9$	0.01	-1.19	-0.14	-17.81***	-1.03*	-0.33	-3.70***	-0.21	-0.05
$P_3 \times P_{10}$	1.20	0.34	2.39***	15.01***	2.15***	-0.09	-0.55	-0.65	0.03
$P_3 \times P_{11}$	-2.44*	-1.31	0.57	15.55***	0.65	-0.07	0.59	-0.56	0.05
$P_3 \times P_{12}$	-3.96***	-3.86***	0.19	-4.32	0.59	-0.99***	1.80**	-0.64	-0.05
$P_4 \times P_5$	-2.18*	-0.66	-2.04***	-10.80***	-0.30	-1.01***	-0.12	0.34	-0.10*
$P_4 \times P_6$	3.18**	4.22***	1.08*	1.49	0.25	-0.20	-0.07	-0.41	0.02
$P_4 \times P_7$	1.51	-2.59**	0.21	7.28**	0.49	0.18	3.93**	-0.05	0.18***
$P_4 \times P_8$	0.85	1.55	0.83	6.93**	0.23	0.21	0.69	0.08	0.03
$P_4 \times P_9$	1.18	1.38	0.64	-0.52	-0.44	-0.13	-0.45	0.50	0.00
$P_4 \times P_{10}$	-0.96	-2.43*	0.64	4.46	-0.73	-0.05	1.10	0.63	-0.02
$P_4 \times P_{11}$	-1.27	-0.07	-0.04	-7.13**	-1.76***	0.18	-2.82***	-0.17	-0.02
$P_4 \times P_{12}$	-1.80	-2.62**	0.24	-3.53	-0.96*	-0.22	-2.88***	0.35	0.03
$P_5 \times P_6$	-2.65**	2.00*	0.54	-0.08	-0.44	0.41	-0.67	0.57	0.02
$P_5 \times P_7$	0.68	1.86	-0.79	-8.22**	-0.46	-0.27	-1.61**	-1.16**	-0.03
$P_5 \times P_8$	-0.99	-2.00*	0.83	12.09***	1.41**	0.42	1.69**	-0.97*	0.09*
$P_5 \times P_9$	-0.65	-1.50	0.64	4.21	1.07*	0.20	1.08	-0.67	0.01
$P_5 \times P_{10}$	-1.80	-1.97*	0.17	-0.77	0.99*	-0.03	1.37*	-0.53	-0.12**
$P_5 \times P_{11}$	-0.77	-3.28***	-0.25	2.60	0.09	0.24	3.18***	-0.46	-0.05
$P_5 \times P_{12}$	3.37**	2.84**	1.97***	10.67***	1.36**	0.94***	2.92***	0.31	0.13***
$P_6 \times P_7$	-2.63**	0.07	-0.01	12.41***	0.96*	0.78**	0.90	0.37	-0.01
$P_6 \times P_8$	-0.63	3.22***	0.35	0.88	-0.24	-0.01	-2.26***	-0.31	-0.02
$P_6 \times P_9$	-1.30	-0.28	-0.18	6.33*	0.63	0.18	0.12	-0.19	0.11**
$P_6 \times P_{10}$	-1.44	-2.76**	0.96*	3.85	0.47	-0.18	0.94	0.33	0.08*

Contd...

Table 3a contd...

Hybrids	Days to first flowering	Days to 50% flowering	Node at which 1st flower appears	Plant height (cm)	Number of branches plant^{-1}	Internodal distance (cm)	Number of pods plants^{-1}	Pod length (cm)	Pod diameter (cm)
$P_6 \times P_{11}$	-1.75	-2.40	1.40**	4.19	1.91***	0.09	2.15***	-0.39	-0.08*
$P_6 \times P_{12}$	-2.27*	-3.95***	0.76	3.12	0.44	-0.05	2.03***	-0.16	-0.11**
$P_7 \times P_8$	-2.30*	-4.59***	0.62	7.44**	1.01*	0.39	0.27	0.38	0.03
$P_7 \times P_9$	-0.96	-1.09	-0.04	-5.04	-0.27	0.27	1.99***	-0.45	0.04
$P_7 \times P_{10}$	3.89***	3.10**	0.03	-4.26	-1.22**	-0.19	-1.59**	-0.52	-0.10**
$P_7 \times P_{11}$	-0.42	-0.55	-0.86	-7.25**	-0.45	0.31	-3.12***	-0.09	-0.01
$P_7 \times P_{12}$	1.06	2.24*	-1.11*	-8.05**	-0.05	0.17	-2.44***	-0.88*	-0.06
$P_8 \times P_9$	-0.63	-0.95	-0.55	-4.30	0.27	0.57*	-1.24*	-0.62	-0.01
$P_8 \times P_{10}$	2.23*	2.24*	-0.75	-7.05**	-0.41	0.10	0.64	-1.28**	-0.06
$P_8 \times P_{11}$	0.92	0.93	-1.17*	-12.98***	-0.17	-0.50*	-0.28	-0.33	-0.01
$P_8 \times P_{12}$	0.39	1.38	-0.75	-5.84*	0.63	-0.14	0.13	-0.79	0.06
$P_9 \times P_{10}$	-2.44*	-2.93**	-0.74	-5.41*	0.78	-0.15	0.29	0.24	0.07
$P_9 \times P_{11}$	0.25	3.76***	-0.23	-5.46*	-0.25	-0.76**	-0.96	0.78	0.01
$P_9 \times P_{12}$	1.73	2.88**	0.26	1.81	-0.31	0.15	1.58**	0.87*	0.00
$P_{10} \times P_{11}$	3.11**	3.95***	-0.76	-7.14**	0.47	-0.58*	0.99	0.36	-0.03
$P_{10} \times P_{12}$	-1.42	0.41	-0.94*	2.73	1.40**	0.15	-1.07	0.15	0.00
$P_{11} \times P_{12}$	1.27	0.76	-0.03	1.10	-0.89*	0.02	0.68	-0.09	0.02
L.S. D. Comparisons									
Sij (0.05)	**1.97**	**1.86**	**0.91**	**5.15**	**0.82**	**0.50**	**1.14**	**0.84**	**0.07**
Sij (0.01)	**2.62**	**2.47**	**1.20**	**6.85**	**1.09**	**0.66**	**1.51**	**1.12**	**0.10**
Sij—Sik (0.05)	**2.88**	**2.72**	**1.33**	**7.54**	**1.20**	**0.72**	**1.66**	**1.23**	**0.11**
Sij—Sik (0.01)	**3.83**	**3.62**	**1.76**	**10.01**	**1.60**	**0.96**	**2.21**	**1.63**	**0.14**
Sij—Skl (0.05)	**2.77**	**2.62**	**1.27**	**7.24**	**1.15**	**0.70**	**1.60**	**1.18**	**0.10**
Sij—Skl (0.01)	**3.68**	**3.47**	**1.69**	**9.62**	**1.53**	**0.92**	**2.12**	**1.57**	**0.14**

, ** and * significant at 5%, 1% and 0.1% level, respectively*

Table 3b: Estimates of specific combining ability effects of crosses for different characters in a 12×12 diallel crosses in okra

Hybrids	Pod weight (g)	Dry weight of pods in (%)	Number of seeds pod^{-1}	Seed weight pod^{-1} (g)	100 seed weight (g)	Seed yield (q ha^{-1})	Pod yield (q ha^{-1})	Plants dry weight (%)
$P_1 \times P_2$	1.82*	0.49**	2.30	0.01	-0.05	-0.56	5.99	0.93*
$P_1 \times P_3$	1.86*	0.29	3.34	-0.16*	-0.29*	1.08	29.71***	2.64***
$P_1 \times P_4$	0.34	0.57***	0.34	-0.07	-0.09	0.79	12.11**	-4.45***
$P_1 \times P_5$	1.06	-0.82***	1.69	-0.06	-0.11	-1.36	-0.62	0.58***
$P_1 \times P_6$	0.14	-1.19***	1.88	-0.04	-0.19	-3.00***	-21.12***	-0.73
$P_1 \times P_7$	1.90*	0.18	-0.47	-0.15	-0.23*	-1.35	4.77	-0.42
$P_1 \times P_8$	-1.85*	0.25	1.21	0.09	-0.06	0.06	-14.98***	-0.97*
$P_1 \times P_9$	-1.92*	-0.43*	0.31	0.06	-0.04	-0.47	-15.49***	4.13***
$P_1 \times P_{10}$	-0.12	0.01	-3.47	0.16*	0.37**	3.70***	13.97**	2.17***
$P_1 \times P_{11}$	0.23	0.04	4.84*	0.25**	0.00	3.38***	12.32**	1.63***
$P_1 \times P_{12}$	0.85	-0.38*	-1.62	-0.14	-0.22	1.92*	29.12***	-0.02
$P_2 \times P_3$	2.63**	-0.93***	0.48	0.08	0.05	0.18	13.99**	-1.64***
$P_2 \times P_4$	0.26	0.15	2.21	0.06	0.00	-1.83*	-14.26**	-3.97***
$P_2 \times P_5$	-1.91*	0.29	1.70	0.11	0.02	0.24	-15.99***	1.84***
$P_2 \times P_6$	1.55	0.10	-0.19	-0.04	0.09	4.44***	50.56***	-2.76***
$P_2 \times P_7$	1.16	-0.03	4.14*	0.11	-0.06	2.34**	16.69***	1.34**
$P_2 \times P_8$	-1.71*	-0.02	-0.52	-0.06	-0.19	0.41	-6.53	9.17***
$P_2 \times P_9$	-1.75*	0.15	-0.49	0.01	0.11	1.49	-2.26	1.43***
$P_2 \times P_{10}$	0.95	-0.63***	-0.93	-0.12	-0.32**	1.77*	21.56***	-2.28***
$P_2 \times P_{11}$	0.19	-0.16	-2.09	-0.10	-0.08	-0.60	2.98	-3.83***
$P_2 \times P_{12}$	-0.86	-0.06	-0.55	-0.09	-0.09	-2.18*	-18.34***	-3.88***
$P_3 \times P_4$	-1.41	-0.18	2.91	0.09	-0.08	2.22**	2.31	-6.11***
$P_3 \times P_5$	-0.30	0.19	2.40	0.08	-0.06	-1.11	-12.26**	2.22***
$P_3 \times P_6$	-1.44	0.30	-4.08*	-0.11	0.08	-2.84**	-24.46***	0.32
$P_3 \times P_7$	-0.66	0.08	3.38	0.07	-0.11	1.51	1.91	2.78***

Contd...

Table 3b contd...

Hybrids	Pod weight (g)	Dry weight of pods in (%)	Number of seeds pod^{-1}	Seed weight pod^{-1} (g)	100 seed weight (g)	Seed yield (q ha^{-1})	Pod yield (q ha^{-1})	Plants dry weight (%)
$P_3 \times P_8$	-0.20	0.49**	1.65	0.02	-0.07	-1.61	-14.39**	0.64
$P_3 \times P_9$	-0.77	0.09	0.29	0.03	-0.04	-3.63***	-30.27***	-1.75***
$P_3 \times P_{10}$	-0.15	0.40*	-0.03	0.04	0.08	-0.28	-6.39	-3.28***
$P_3 \times P_{11}$	-1.15	-0.95***	1.22	0.02	-0.14	0.71	-2.86	-1.65***
$P_3 \times P_{12}$	-1.11	0.19	2.09	0.10	-0.21	2.65**	4.28	-1.08**
$P_4 \times P_5$	-0.49	0.85***	-0.20	0.00	0.00	-0.26	-3.76	6.50***
$P_4 \times P_6$	-0.26	-0.02	3.79*	0.09	-0.16	0.27	-2.59	0.43
$P_4 \times P_7$	2.46**	-0.52**	-1.16	-0.04	0.00	3.78***	44.84***	-1.83***
$P_4 \times P_8$	0.17	-0.34*	-0.21	-0.06	-0.24*	0.41	7.13	-8.88***
$P_4 \times P_9$	0.05	-0.54**	0.62	0.02	0.02	-0.27	-2.68	3.87***
$P_4 \times P_{10}$	1.12	-0.48**	-1.30	-0.06	-0.01	0.99	13.26**	3.68***
$P_4 \times P_{11}$	-0.39	-0.07	-3.91*	-0.16*	-0.13	-3.83***	-22.26***	-0.62
$P_4 \times P_{12}$	0.54	-0.37*	-0.65	-0.02	-0.01	-3.11***	-19.52***	-0.51
$P_5 \times P_6$	0.77	0.13	1.47	0.00	-0.01	-0.86	-0.64	-1.07**
$P_5 \times P_7$	-1.91*	-0.09	-6.00**	-0.29***	-0.19	-3.04***	-19.00***	-4.73***
$P_5 \times P_8$	0.48	-0.17	3.27	0.08	0.08	2.03*	14.21**	-2.15***
$P_5 \times P_9$	-0.94	-0.05	2.10	0.01	-0.04	1.13	2.85	-2.80***
$P_5 \times P_{10}$	-0.51	-0.65***	-0.21	0.02	0.05	1.56	4.42	-2.04***
$P_5 \times P_{11}$	-0.56	0.02	-1.43	0.10	0.23*	3.82***	15.65***	-0.06
$P_5 \times P_{12}$	1.71*	-0.26	3.57	0.12	-0.27*	3.64***	33.97***	-3.82***
$P_6 \times P_7$	0.12	-0.13	1.31	0.17*	-0.10	1.99*	6.33	0.81*
$P_6 \times P_8$	-0.58	0.34*	-2.08	-0.17*	-0.32**	-3.36***	-21.07***	-2.42***
$P_6 \times P_9$	1.81*	-0.50**	1.42	0.03	0.02	0.31	11.60**	-3.85***
$P_6 \times P_{10}$	1.54	-0.52**	3.24	0.09	-0.17	1.67*	15.69***	-0.25
$P_6 \times P_{11}$	-1.37	-0.10	0.62	0.10	0.09	3.05***	7.47	0.29
$P_6 \times P_{12}$	-1.86*	-0.28	-0.58	-0.03	0.05	1.96*	2.12	0.67
$P_7 \times P_8$	0.31	-0.30	4.31*	0.10	-0.02	0.80	2.56	0.39
$P_7 \times P_9$	-0.87	-0.27	-1.99	-0.10	-0.01	1.58	8.44	-3.09***

Contd...

Table 3b contd...

Hybrids	Pod weight (g)	Dry weight of pods in (%)	Number of seeds pod^{-1}	Seed weight pod^{-1} (g)	100 seed weight (g)	Seed yield (q ha^{-1})	Pod yield (q ha^{-1})	Plants dry weight (%)
$P_7 \times P_{10}$	-0.98	0.25	-6.43**	-0.31***	-0.04	-3.18***	-15.76***	-0.40
$P_7 \times P_{11}$	-0.01	0.24	4.15*	0.15	0.06	-2.83**	-22.72***	-2.27***
$P_7 \times P_{12}$	-1.97*	0.95***	-3.32	-0.12	0.10	-3.19***	-26.94***	-0.13
$P_8 \times P_9$	-0.97	-0.34*	0.36	0.04	-0.01	-1.18	-14.92***	-0.39
$P_8 \times P_{10}$	-1.62*	-0.47**	-5.42**	-0.27***	0.00	-0.89	-6.67	-2.25***
$P_8 \times P_{11}$	-0.64	-0.06	-3.24	-0.02	0.56***	-0.42	-5.00	-1.61***
$P_8 \times P_{12}$	3.41***	0.50**	0.56	0.16*	0.24*	1.16	23.46***	-2.72***
$P_9 \times P_{10}$	3.81***	-0.07	7.34***	0.19*	-0.34**	1.38	22.37***	-3.20***
$P_9 \times P_{11}$	2.14**	0.16	-3.14	-0.07	0.09	-1.41	5.24	-2.93***
$P_9 \times P_{12}$	-0.49	0.34*	-3.88*	-0.17*	0.08	0.64	8.09	6.57***
$P_{10} \times P_{11}$	0.16	0.32	0.54	-0.13	-0.15	0.41	6.46	0.70
$P_{10} \times P_{12}$	1.04	-0.86***	3.81*	0.27***	0.24*	0.47	-3.89	-1.20**
$P_{11} \times P_{12}$	-0.49	-0.29	4.19*	0.04	-0.18	1.08	2.51	-1.83***
L.S.D. Comparisons								
Sij (0.05)	**1.56**	**0.32**	**3.77**	**0.16**	**0.22**	**1.65**	**8.64**	**0.78**
Sij (0.01)	**2.07**	**0.43**	**5.01**	**0.21**	**0.30**	**2.19**	**11.48**	**1.04**
Sij—Sik (0.05)	**2.28**	**0.47**	**5.52**	**0.23**	**0.33**	**2.41**	**12.64**	**1.14**
Sij—Sik (0.01)	**3.03**	**0.62**	**7.33**	**0.31**	**0.43**	**3.20**	**16.79**	**1.52**
Sij—Skl (0.05)	**2.19**	**0.45**	**5.30**	**0.22**	**0.31**	**2.32**	**12.14**	**1.10**
Sij—Skl (0.01)	**2.92**	**0.60**	**7.04**	**0.29**	**0.42**	**3.08**	**16.13**	**1.46**

, ** and * significant at 5%, 1% and 0.1% level, respectively* to be included in hybridization could also be judged on *per se* performance, besides, general combining ability effects. Similar link between these two parameters was also observed by Wankhade *et al*., (1991b) and Desai (2007).

Specific combining ability effects

From table 3a and 3b,out of 66 cross combinations studied, 9 for days to first flowering; 18 for days for 50% flowering; 9 for node at which first flower appear; 18 for plant height; 15 for number of branches per plant; 12 for internodal length; 19 for number of pods per plant; 3 for pod length; 6 for pod diameter; 10 for pod weight; 9 for dry weight of pod; 8 for number of seeds per pod; 6 for seed weight per pod; 5 for 100 seed weight; 33 for plant dry weight; 16 for seed yield per hectare and 20 for pod yield per hectare exhibited significant sca effects indicating predominance presence of non-additive type of gene interactions. Overall it indicates possibility of exploitation of hybrid vigour in the characters studied except inter nodal length, number of branches per plant, days to first flower, days to 50% flower and pod length.

Out of 66 crosses, considering five best crosses for sca effects identified for 17 characters, only 11 crosses were the produce of low × low gca effect and the remaining crosses had at least one parents with high sca effects, suggesting thereby the importance of parents having high gca in the production of crosses expected to give high sca effects. The present findings are conformity with the previous result observed in okra by Desai (1991). However, earlier Rao (1977) indicated that parents with good general combining ability effects need not necessarily produce superior crosses with good specific combining effects. He also emphasized that *per se* performance of parents is a good indications of general combining ability.

Common combining ability effects and it's relationship with gene action

The common cross combinations on the basis of the significant sca effects and both the parents involved showing significant gca (high gca × high gca) was/were $P_2 \times P_{10}$ for days to first flowering; $P_3 \times P_{12}$ for days to 50% flower; $P_8 \times P_{11}$ and $P_3 \times P_{10}$ for plant height; $P_8 \times P_{11}$ node at which first flower appear; $P_1 \times P_5$ for internodal length; $P_6 \times P_9$ for pod diameter; $P_7 \times P_{12}$ for pod dry weight; $P_1 \times P_{11}$ number of seed per pod; $P_{10} \times P_{12}$ seed weight per pod; $P_8 \times P_{12}$ 100 seed weight; and $P_2 \times P_6$ and $P_1 \times P_{12}$ for pod yield per hectare, indicating that their performances were contributed by additive gene action and thus, they may be further improved through conventional selection method like pedigree or recurrent selection. Other crosses showing heterotic performance along with significant sca effect and involved with no parents or one parent showing significant gca, thus, revealing that non-additive gene action play predominant role in their expression and worthwhile for exploitation of heterosis.

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