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Mudhalvan S
PG Scholar, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India

N Senthilkumar
Professor, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India

Corresponding Author:
Mudhalvan S
PG Scholar, Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, India

Combining ability, reciprocal effects and heterosis for fruit yield characters in okra (*Abelmoschus esculentus* (L.) Moench)

Mudhalvan S and N Senthilkumar

Abstract
A seven parent diallel including reciprocals were made. The analysis of variance for combining ability revealed the importance of both additive and non-additive gene action in the inheritance of all the 11 traits studied. Reciprocal differences in the estimates of combining ability variances were recorded for all the 11 traits investigated. The parents were identified as good general combiners for most of the characters of interest. The hybrid namely, Varsha Uphar x Thunder portrayed high per se performance coupled with high sca effects for majority of the traits, also evinced high standard heterosis for fruit yield per plant. The standard heterosis was recorded upto the tune of 79.16 per cent by the hybrid Varsha Uphar x Pusa-7 for the trait fruit yield per plant. In the presence of both additive and non-additive gene action coupled with reciprocal differences, reciprocal recurrent selection may be resorted for population improvement.

Keywords: Combining ability, diallel, hybrid, heterosis

Introduction
Bhendi is an ancient vegetable crop. The reproductive biology of the crop offers good scope for exploitation of heterosis. Therefore, proper choice of parents for hybridization is essential in generating heterotic hybrids. Further, relevant information about the inheritance of different fruit yield characters has an important role in deciding proper selection strategies, besides creation of variability. In the present study, seven genotypes of bhendi were utilized in and diallel crossing programme (including reciprocals) to obtain information on the combining ability, inheritance of fruit yield and their component characters and heterotic potential.

Materials and Methods
An experiment involving seven parents of bhendi *viz*., Arka Anamika (P_1), Varsha Uphar (P_2), Thunder (P_3), Dhanya (P_4), Pusa-7 (P_5), Basanthi (P_6), S-51 (P_7) and their 42 crosses, obtained by crossing them in diallel fashion (including reciprocals), were laid out in Randomized Block Design with three replications during July-Oct, 2017. Each entry was grown in a 3 m long single row plot with a spacing of 45 x 30 cm. Observations were recorded on five randomly selected plants in each plot on 11 fruit yield traits and its analysis of combining ability and reciprocal effects based on mean values were done as per Model 2, method 1 of Griffing (1956) [1]. Relative heterosis, heterobeltiosis and standard heterosis were worked out as per the standard methods.

Results and Discussion
The analysis of variance revealed the presence of high genetic variability among the parents and their 42 hybrids (Table 1). Among seven parents studied, the parent P_1 followed by P_5, P_6 and P_4 expressed maximum fruit yield per plant than the parental mean which are recommended to utilize as donors in cross breeding programe (Table 3).
Out of 42 hybrids, altogether (direct and reciprocal) 18 hybrids recorded higher fruit yield per plant than the hybrid mean. Among 18 hybrids, the hybrids namely, $P_2 \times P_5$, $P_2 \times P_6$, $P_4 \times P_2$, $P_5 \times P_4$, $P_4 \times P_5$, $P_6 \times P_3$ and $P_7 \times P_3$ exhibited the maximum fruit yield per plant with the tune of 500g per plant (Table 5). Thus, they stand for merit consideration. The above cross combinations had either both the parents (high × high) or atleast one of the parents (high × low or low × high) with favourable *per se* performance for most of the traits studied. This is in accordance with the findings of Gilbert (1958) [2]. It is quite interesting to conceive that all the hybrids which portrayed higher fruit yield per plant were endowed with more number of fruits per plant, number of branches per plant and average fruit weight.

It is also understood that bhendi breeders can also reduce the plant height and increase the number of fruits by the way of reducing internodal length with more number of branches and can develop early but high yielding short plant type.

Table 1: ANOVA for fruit yield and yield component characters in bhendi

Sl. No.	Characters	df	MSS	'F' value
1.	Days to first flowering	48	8.30**	38.91
2.	Plant height	48	1415.16**	203.51
3.	Internode distance	48	2.30**	16.41
4.	Days to fruit maturity	48	0.91**	3.72
5.	Number of immature seeds per fruit	48	102.47**	17.97
6.	Fruit length	48	12.87**	132.80
7.	Fruit girth	48	1.41**	23.36
8.	Number of branches per plant	48	1.06**	69.64
9.	Number of fruits per plant	48	38.42**	25.87
10.	Average fruit weight	48	33.07**	27.98
11.	Fruit yield per plant	48	28719.15**	78.63

**-Significant at 1 per cent level
*-Significant at 5 per cent level

In the present study, the mean sum of square for combining ability variances revealed that the GCA variances and SCA variances were highly significant for most of the traits studied except intermodal distance, days to fruit maturity, fruit girth and number of branches per plant (Table 2). This implied the presence of both additive and non-additive genetic variances in the inheritance of the traits studied. However, the ratios of GCA/SCA were more than unity for most of the traits studied except days to fruit maturity, fruit length, average fruit weight and fruit yield per plant. This indicated the predominance of additive genetic variance for the traits days to first flowering, plant height, internode distance, number of immature seeds per fruit, number of branches per plant, fruit girth and number of fruits per plant followed by non-additive genetic variance for the traits days to fruit maturity, fruit length, average fruit weight and fruit yield per plant in the improvement of the traits of interest in bhendi. Similar results were previously obtained by Medagam Thirupathi Reddy *et al.* (2012) [3], Medagam Thirupathi Reddy *et al.* (2013) [4], Lyngdoh *et al.* (2013) [5] and Rameshkumar *et al.* (2017) [6]. The available additive genetic variance could well be exploited by resorting to simple pure line selection and/or pedigree selection, whereas the non-additive genetic variance could well be exploited in later generations. Both the variances could be simultaneously exploited resorting to population improvement programme.

Table 2: Relationship between *per se* performance and *gca* effects

Sl. No.	Characters	per se performance	*gca* effects	Common parent
1.	Days to first flowering	P_3 (38.00)	P_2	P_1
		P_6 (38.60)	P_1	-
		P_1 (39.00)	P_5	-
2.	Plant height	P_2 (80.00)	P_2	P_2
		P_3 (101.66)	P_5	P_3
		P_1 (103.33)	P_3	-
3.	Internode distance	P_5 (4.86)	P_5	P_5
		P_3 (5.89)	P_3	P_3
		P_7 (6.90)	P_4	-
4.	Days to fruit maturity	P_2 (5.53)	P_3	-
		P_6 (5.56)	P_6	P_6
		P_5 (6.06)	P_4	-
5.	Number of immature seeds per fruit	P_5 (42.47)	P_6	P_6
		P_6 (49.95)	P_7	P_5
		P_3 (51.49)	P_5	-
6.	Fruit length	P_1 (16.03)	P_4	P_1
		P_5 (14.63)	P_1	-
		P_2 (13.07)	P_2	P_2
7.	Fruit girth	P_5 (6.23)	P_5	P_5
		P_6 (5.86)	P_3	-
		P_1 (5.33)	P_7	-
8.	Number of branches per plant	P_3 (3.00)	P_7	-
		P_4 (3.00)	P_1	-
		P_6 (3.00)	P_6	P_6
9.	Number of fruits per plant	P_5 (22.33)	P_4	-
		P_7 (21.63)	P_7	P_7
		P_6 (21.00)	-	
10.	Average fruit weight	P_5 (22.40)	P_2	P_2
		P_1 (20.80)	P_4	P_1
		P_2 (17.80)	P_1	-
11.	Fruit yield per plant	P_1 (377.12)	P_4	P_4
		P_5 (370.40)	P_7	-

		P_6 (367.60)	-	-
		P_4 (363.23)	-	-

*- Significant at 5 per cent level
**- Significant at 1 per cent level

The mean sum of squares due to reciprocals were significant for most of the traits including fruit yield per plant except days to first flowering, internode distance, days to fruit maturity, number of branches per plant and fruit girth (Table 2). Similar findings were earlier reported by Medagam Thirupathi Reddy *et al.* (2012) [3], Medagam Thirupathi Reddy *et al.* (2013) [4], Nagesh *et al.* (2014) [7] and Rameshkumar *et al.* (2017) [6]. In the presence of reciprocal differences for most of the traits, the best scheme to develop hybrids will be reciprocal recurrent selection within the population improvement programme.

Table 3: Estimates of variance for combining ability

Sources	Mean Sum of Squares										
	Days to first flowering	**Plant height**	**Inter node distance**	**Days to fruit maturity**	**Number of immature seeds per fruit**	**Fruit length**	**Fruit girth**	**Number of branches per plant**	**Number of fruits per plant**	**Average fruit weight**	**Fruit yield per plant**
GCA	5.57**	502.35 **	1.22	0.12	59.09**	0.99	0.58	0.45	19.10**	5.58**	4865.33**
SCA	3.22**	447.46**	0.65	0.48	32.16**	4.41**	0.53	0.33	8.49**	8.53**	7864.12**
Reciprocal variance	1.51	487.22**	0.75	0.19	29.02**	5.12**	0.38	0.35	15.33**	15.06**	13389.03**
GCA/SCA	1.73	1.12	1.88	0.25	1.84	0.22	1.09	1.36	2.25	0.65	0.62

** - Significant at 1 per cent level
* - Significant at 5 per cent level

Relationship between *per se* performance and combining ability effects

The parents which recorded high fruit yield per plant *viz.*, P_1, P_5, P_6 and P_4 were good general combiners for four, five, three and six out of eleven traits studied respectively (Table 3). Parent namely, P_1 exhibited significant positive *gca* effects for the traits days to first flowering, number of branches per plant, fruit length and average fruit weight. The parent P_5 portrayed significant favourable *gca* effects for the traits namely, days to first flowering, plant height, internode distance, number of immature seeds per fruit and fruit girth. The parent P_6 registered favourable *gca* effects for the traits *viz.*, days to fruit maturity, number of immature seeds per, and number of branches per plant. The parent P_4 was good combiner for the six traits namely, internode distance, days to fruit maturity, number of branches per plant, fruit length, average fruit weight and fruit yield per plant. The negative point of the parents *viz.*, P_1, P_5 and P_6 which recorded high fruit yield per plant were that they showed negative *gca* effects for fruit yield per plant. The parent P_4 which recorded high fruit yield per plant alone showed positive *gca* effect for fruit yield per plant. When the parents were assessed for their overall *gca* effects, the parent *viz.*, P_4 was found to be a good combiner followed by P_5, and P_7. The high *per se* performance coupled with high *gca* effects in the parents *viz.*, P_5, and P_4 indicated that these genotypes have enormous amount of additive genetic variability for the aforementioned traits. This indicated that *gca* effects could well be utilized as a biometrical genetic marker for varietal breeding programme in bhendi.

Among the 18 (direct and their reciprocal) hybrids which recorded high mean fruit yield per plant than the hybrid mean, the nine hybrids *viz.*, $P_1 \times P_3$, $P_2 \times P_5$, $P_2 \times P_6$, $P_4 \times P_2$, $P_4 \times P_5$, $P_5 \times P_4$, $P_6 \times P_3$, $P_6 \times P_7$ and $P_7 \times P_3$ were found to be recorded favourable significant *sca* effects for the trait fruit yield per plant. The hybrids namely, $P_2 \times P_5$, $P_2 \times P_6$, $P_4 \times P_2$, $P_5 \times P_4$, $P_4 \times P_5$, $P_6 \times P_3$ and $P_7 \times P_3$ which portrayed maximum mean fruit yield per plant also exhibited favourable *sca* effects for most of the traits studied including the trait fruit yield per plant (Table 5).

The hybrids namely, $P_2 \times P_5$, $P_4 \times P_5$ and $P_4 \times P_5$ which portrayed maximum mean with favourable *sca* effects for fruit yield per plant also exhibited favourable *sca* effects for the traits average fruit weight, fruit length, number of fruits per plant and number of branches per plant. The hybrids namely, $P_4 \times P_2$, $P_2 \times P_6$ and $P_7 \times P_3$ which portrayed maximum mean with favourable *sca* effects for fruit yield per plant also exhibited favourable *sca* effects for the trait average fruit weight (Table 5). The hybrid namely, $P_6 \times P_3$ which portrayed maximum mean with favourable *sca* effects for fruit yield per plant also exhibited favourable *sca* effects for the trait number of fruits per plant. When the cross combinations were assessed for their overall specific combining ability based on eleven traits studied, the hybrids *viz.*, $P_2 \times P_5$, $P_6 \times P_7$, $P_1 \times P_3$, $P_1 \times P_4$, $P_3 \times P_7$, $P_4 \times P_5$, $P_5 \times P_7$, $P_2 \times P_4$ and $P_2 \times P_7$ were found to be good specific combiners.

The five hybrids namely, $P_2 \times P_5$, $P_4 \times P_2$, $P_2 \times P_6$, $P_7 \times P_3$ and $P_5 \times P_4$ which exhibited high heterobeltiosis for fruit yield per plant mostly showed favourable heterobeltiosis for almost all other traits studied except number of branches per plant, fruit length and girth (Table 4). Thus, the characters studied in the present inquiry are justifiable for the fruit yield improvement of bhendi. Similar observations were made by Ashwani Kumar *et al.* (2013) [8], Kishor *et al.* (2013) [9], Aware *et al.* (2014) [10] and Tapas Paul *et al.* (2017) [11]. Among the three types of heterosis, the need for computing standard heterosis for exploitation of hybrid vigour has been stressed by Swaminathan *et al.* (1972) [12] and Kadambavanasundaram (1983) [13]. Hence, in the present study, the hybrids of cross combinations were evaluated over the ruling variety namely, Arka Anamika and the promising hybrids were selected based on standard heterosis.

The hybrids (direct and reciprocal) namely, $P_2 \times P_5$ (79.16), $P_2 \times P_6$ (45.15), $P_4 \times P_2$ (45.04), $P_5 \times P_4$ (35.71) and $P_4 \times P_5$ (34.88) which recorded the maximum standard heterosis (above thirty five per cent) for fruit yield per plant also exhibited favourable significant standard heterosis for almost all traits studied except plant height, fruit length and girth (Table 5). The hybrids which recorded high standard heterosis for fruit yield per plant also exhibited around 25 per cent of standard heterosis for another important productive trait namely number of fruits per plant. Similar observations were made by Ashwani Kumar *et al.* (2013), Kishor *et al.* (2013), Aware *et al.* (2014), Arti Verma and Sonia Sood (2015) [14] and Tapas Paul *et al.* (2017)

Relationship between *per se* performance, standard heterosis, *sca* effects/reciprocal effects and *gca* effects

Most of the crosses which portrayed high commercial heterosis were endowed with high mean performance and with favourable significant *sca* effects for most of the traits studied except fruit length (Table 5). This indicated a good agreement between *per se* performance, *sca* effects and standard heterosis. Hence, *sca* effects could well be utilized as a biometrical genetic marker for hybrid breeding in bhendi. Raghavaiah and Joshi (1986) suggested that *sca* effects for a particular combination could be useful for the improvement of self pollinated crops, if it is accompanied by high *gca* effects of the respective parents.

The *sca* effects of the cross combinations exhibited no specific trend between parents having high, medium or low *gca* effects. Most of the cross combinations which exhibited high *sca* effects for all the eleven traits studied had both the parents and/or at least one of the parents of the cross combination with high *gca* effects. It is also noticed that the cross combinations with non-significant or significant negative *sca* effects had parents with significant *gca* effects for both the parents and/or at least one of the parents for some of the traits studied (Table 5). In many cases, both the parents with significant negative *gca* effects of the cross combination registered significant positive *sca* effects. It indicted that the hybrids of parents with high *gca* effects need not be good specific combiners or parents with low *gca* effects may be good specific combiners. This is in harmony with the findings of Kishor *et al.* (2013), Arti Verma and Sonia Sood (2015) and Tapus Paul *et al.* (2017).

If both the parents of specific cross combination with non-significant *sca* effects showed high *gca* effects, it revealed the presence of additive × additive gene action and hence high yielding segregants would be isolated from the segregating generations (recombination breeding). In case of cross combinations with high *sca* effects and one of the parents with low *gca* effects (additive × non-additive), it would throw transgressive segregants for effective selection. On the other hand, high×high *gca* combinations with high *sca* effects might be due to inter-allelic interactions like complementary recessive epistatic gene action and hence it could be used in heterosis breeding (Kishor *et al.*, 2013, Arti Verma and Sonia Sood, 2015 and Tapus Paul *et al.*, 2017).

In the present investigation, most of the high yielding hybrids which also showed high standard heterosis exhibited favourable high significant *sca* effects ($P_2 \times P_5$, $P_2 \times P_6$, $P_4 \times P_2$, $P_5 \times P_4$, $P_4 \times P_5$, $P_6 \times P_3$ and $P_7 \times P_3$) for most of the traits including fruit yield per plant. However, among the high yielding hybrids with high standard heterosis, the crosses like $P_2 \times P_5$, $P_2 \times P_6$, and $P_6 \times P_3$ which registered significant *sca* effects with unfavourable *gca* effects for both the parents of the cross combinations showed significant reciprocal effect for most of the traits including fruit yield per plant. Among other high yielding hybrids with high standard heterosis, the crosses *viz.*, $P_4 \times P_2$, and $P_7 \times P_3$ which registered favourable *sca* effects with significant *gca* effects for atleast one of the parents of the cross combinations also showed significant reciprocal effects. $P_5 \times P_4$ and $P_4 \times P_5$ which showed high mean with standard heterosis exhibited favourable high significant *sca* effects with significant *gca* effects for one of the parents while these hybrids registered non-significant reciprocal effect for most of the traits including fruit yield per plant. It implies that a proper choice of seed parent and pollen parent must be made to obtain still better *sca* effects in the selected crosses.

Reciprocal effects

Significant reciprocal effects imply that a proper choice of male and female parent must be made to obtain a better *sca* effects in the selected crosses. Out of 21 direct and reciprocal crosses studied 19 cross combinations registered significant reciprocal effects (irrespective of positive and negative sign) for the minimum of six traits and the maximum of ten traits out of eleven traits studied. The crosses namely, $P_6 \times P_2$ registered significant reciprocal effects for ten traits including fruit yield per plant followed by the cross $P_3 \times P_2$ for nine traits, $P_3 \times P_1$, $P_6 \times P_1$ and $P_7 \times P_6$ for eight traits, $P_5 \times P_2$ for seven traits and $P_4 \times P_1$ for six traits.

Out of 21 direct and reciprocal hybrids studied, the hybrid namely, $P_6 \times P_2$ excelled other hybrids with significantly favourable reciprocal effects for seven characters including fruit yield per plant, average fruit weight and number of fruits per plant followed by the crosses $P_6 \times P_1$, $P_3 \times P_2$, and $P_5 \times P_2$ for six characters including the traits *viz.*, fruit yield per plant and average fruit weight. The hybrid $P_7 \times P_6$ registered significant favourable reciprocal effects for five traits including fruit yield per plant and number of fruits per plant. The other hybrid $P_4 \times P_1$ registered significant favourable reciprocal effects for four traits including fruit yield per plant and average fruit weight. The hybrids $P_5 \times P_4$ and $P_7 \times P_5$ alone registered significant reciprocal effects for only two and one trait, respectively. None of the hybrids recorded significant reciprocal effects for all the eleven traits studied.

Almost all the seven parents which involved in the cross combinations showed reciprocal effects for atleast one or upto ten out of eleven traits studied. One can conclude that these significant reciprocal effects with positively or negatively shown by the parents in all the cross combinations for one or more characters arise due to cytoplasmic determinance of zygote (maternal effect) or confounded effect of plasma gene and nuclear gene for which all practical purpose only came from female gametes. The combinations identified for favourable combining ability effects revealed that choice of male and female parents needs to be considered for the introgression of fruit yield, average fruit weight and number of fruits per plant with earliness, since most of the crosses showed reciprocal effects. Thus, these large cytoplasmic heterotic effects may be utilized commercially or for the development of desirable segregants through hybridization and selection for high fruit yield coupled with earliness.

Table 4: Performance of the best five crosses selected for fruit yield per plant based on heterobeltiosis (d_{ii}), for other traits in per cent

S. No.	Characters	P_2 x P_5 d_{ii}=82.41**	P_4 x P_2 d_{ii}=50.57**	P_2 x P_6 d_{ii}=48.91	P_7x P_3 d_{ii}=42.35**	P_5x P_4 d_{ii}=38.17**
1.	Days to first flowering	-8.53**	0.83**	-9.50**	-7.66**	0.17
2.	Plant height	39.88**	-16.18**	23.81**	-17.78**	-10.87**
3.	Internode distance	-24.29**	-0.74	7.78*	6.23*	-5.68
4.	Days to fruit maturity	-17.07**	-9.34	1.80	-16.42**	-16.10**

5.	Number of immature seeds per fruit	-4.70	3.24	10.92	-0.50	-18.09**
6.	Fruit length	0.23**	-38.54**	0.23**	-12.79**	-2.96**
7.	Fruit girth	5.88*	7.14	-31.82**	-6.00	-17.11**
8.	Number of branches per plant	0.01	-26.67	0.01	13.33**	0.01
9.	Number of fruits per plant	53.70**	4.48*	7.94**	9.40	13.43**
10.	Average fruit weight	9.29**	31.60**	36.28**	21.06	-9.67*

* - Significant at 5 per cent level
**** -** Significant at 1 per cent level

Table 5: Relationship between *per se* performance, standard heterosis (d_{iii}), *sca* effects/ reciprocal effects and *gca* effects

Characters	Best five crosses with high per se	Best five crosses with high d_{iii}	Common crosses	*sca* / reciprocal effects	*gca* effects
Days to first flowering	P_3 x P_5 (35.40)	P_3 x P_5	P_3 x P_5	-1.49** / -0.30	-0.56** x -0.27**
	P_1 x P_6 (35.60)	P_1 x p_6	P_1 x p_6	-0.26 / -1.50**	-0.51** x -0.15*
	P_3 x P_1 (35.80)	P_3 x p_1	P_3 x P_1	-0.35* / 0.80**	-0.56** x -0.51**
	P_5 x P_1 (35.80)	P_5 x P_1	P_5 x P_1	-1.15** / 0.30	-0.27** x -0.51**
	P_5 x P_3 (36.00)	P_5 x P_3	P_5 x P_3	-1.49** / -0.30	-0.27** x -0.56**
Plant height	P_6 x P_2 (78.33)	P_6 x p_2	P_6 x P_2	1.46 / 36.67**	4.43** x -5.80**
	P_5 x P_6 (87.50)	P_5 x p_6	P_5 x P_6	-11.74** / -15.00**	-5.10** x 4.43**
	P_2 x P_3 (90.00)	P_2 x p_3	P_2 x p_3	-4.49** / -9.58**	-5.80** x -5.03**
	P_3 x P_5 (90.00)	P_3 x P_5	P_3 x P_5	-9.36** / -5.41**	-5.03** x -5.10**
	P_3 x P_7 (90.00)	P_3 x p_7	P_3 x p_7	-12.56** / -11.67**	-5.03** x 4.35**
Internode distance	P_6 x P_3 (4.66)	P_6 x p_3	P_6 x p_3	-0.43** / 1.72**	0.22** x -0.29**
	P_5 x P_3 (5.05)	P_5 x P_3	P_5 x p_3	-9.36** / 0.77**	-0.43** x -0.29**
	P_2 x P_7 (5.21)	P_2 x p_7	P_2 x p_7	-1.01** / -0.67**	0.09 x 0.07
	P_2 x P_5 (5.38)	P_2 x P_5	P_2 x p_5	-0.26* / -0.89**	0.09 x -0.43**
	P_3 x P_1 (5.83)	P_3 x p_1	P_3 x p_1	0.40 / 1.24**	-0.29** x 0.44**
Days to fruit maturity	P_1 x P_4 (4.40)	P_1 x p_4	P_1 x p_4	-1.03** / -0.15	0.05 x -0.07
	P_3 x P_6 (4.50)	P_3 x p_6	P_3x p_6	-0.44** / -0.45*	-0.12 x -0.08
	P_4 x P_1 (4.70)	P_4 x p_1	P_4 x p_1	-1.03** / -0.15	-0.07 x 0.05
	P_2 x P_7 (4.86)	P_2 x p_7	P_2 x p_7	-0.56** / -0.33	0.10 x 0.04
	P_2 x P_1 (5.00)	P_2 x p_1	P_2 x p_1	0.23 / 1.00**	0.10 x 0.05
Number of immature seeds per fruit	P_2 x P_7 (41.00)	P_2 x p_7	P_2 x p_7	-5.26** / -5.36**	0.84* x -1.36**
	P_6 x P_1 (41.09)	P_6 x p_1	P_6 x p_1	-4.82** / 7.84**	-2.42** x 4.02**
	P_5 x P_6 (42.06)	P_5 x p_6	P_5 x p_6	-5.44** / -1.46	-0.77* x -2.42**
	P_6 x P_5 (44.97)	P_6 x p_5	P_6 x p_5	-5.44** / -1.46	-2.42** x -0.77*
	P_4 x P_7 (45.71)	P_4 x p_7	P_4 x p_7	-0.75 / -4.40**	-0.30 x -1.36**
Fruit length	P_4 x P_3 (18.33)	P_4 x p_3	P_4 x p_3	2.60** / -3.31**	0.33** x -0.08*
	P_7 x P_2 (17.20)	P_7 x p_2	P_7 x p_2	1.69** / -3.26**	-0.01 x 0.09*
	P_2 x P_3 (15.33)				
	P_2 x P_5 (14.66)				
	P_4 x P_1 (14.36)				
Fruit girth	P_2 x P_3 (6.96)	P_2 x P_3	P_2 x p_3	1.07** / 0.62**	-0.08* x 0.18*
	P_2 x P_5 (6.60)	P_2 x p_5	P_2 x p_5	0.39** / 0.77**	-0.08*x 0.36**
	P_5 x P_6 (6.10)	P_5 x p_6	P_5 x p_6	0.17 / 0.48**	0.36** x -0.08*
	P_5 x P_3 (5.96)	P_5 x p_3	P_5 x p_3	0.26** / -0.01	0.36** x 0.18**
	P_3 x P_5 (5.96)	P_3 x p_5	P_3 x p_5	0.26** / -0.01	0.18** x 0.36**
Number of branches per plant	P_1 x P_3 (3.80)	P_1 x p_3	P_1 x p_3	0.26** / 0.90**	0.09** x -0.14**
	P_7 x P_4 (3.66)	P_7 x p_4	P_7 x p_4	-0.17** / -0.83**	0.26** x 0.07**
	P_6 x P_1 (3.40)	P_7 x p_3	P_7 x p_3	0.40** / -0.20**	0.26** x -0.14**
	P_7 x P_3 (3.40)	P_7 x p_1	P_7 x p_1	-0.04 / -0.33**	0.26** x 0.09**
	P_7 x P_1 (3.33)	P_4 x p_6			
Number of fruits per plant	P_2 x P_5 (27.66)	P_2 x P_5	P_2 x P_5	4.84** / 3.50**	-0.87** x -0.43*
	P_6 x P_3 (27.33)	P_6 x p_3	P_6 x p_3	2.23** / -5.33**	-0.08 x -0.78**
	P_6 x P_7 (27.33)	P_6 x p_7	P_6 x p_7	1.03* / 3.67**	-0.08 x 0.08**
	P_4 x P_7 (27.00)	P_4 x p_7	P_4 x p_7	0.01 / 3.17**	1.11** x 0.08**
	P_7 x P_1 (27.00)	P_7 x p_1	P_7 x p_1	0.99* / -4.33**	0.08** x -1.04**
Average fruit weight	P_2 x P_3 (26.33)	P_2 x p_3	P_2 x p_3	-0.31 / 7.88**	0.94* x -0.03
	P_2 x P_5 (24.48)	P_7 x p_1			
	P_2 x P_6 (24.26)	P_2 x P_5	P_2 x p_5	0.78* / 5.33**	0.94** x -0.42**
	P_4 x P_3 (23.68)	P_2 x p_6	P_2 x p_6	2.36** / 3.58**	0.94 x -0.46**
	P_4x P_2 (23.43)	P_4 x p_3	P_4 x p_3	0.77* / -4.59**	0.50** x -0.03
Fruit yield per plant	P_2 x P_5 (675.64)	P_2 x P_5	P_2 x P_5	119.03** / 195.18**	4.76 x -12.56**
	P_2 x P_6 (547.60)	P_2 x p_6	P_2 x p_6	20.42** / 164.54**	4.76 x -11.56**
	P_4 x P_2 (546.96)	P_4 x p_2	P_4 x p_2	32.77** / -108.42**	31.78** x 4.76
	P_5x P_4 (511.80)	P_5 x P_4	P_5 x P_4	121.77** / -1.57	-12.56** x 31.78**
	P_4 x P_5 (508.66)	P_4 x P_5	P_4 x P_5	121.77** / -1.57	31.78** x -12.56**
	P_6x P_3 (500.03)	P_6 x P_3	P_6 x P_3	51.80** / -104.83**	-11.56** x -14.30**
	P_7 x P_3 (498.03)	P_7 x P_3	P_7 x P_3	38.54** / -87.73**	17.59** x -14.30**

References

1. Griffing B. Concept of general and specific combining ability in relation to diallel crossing systems. Aus. J Biol. Sci 1956;9:463-493.
2. Gilbert NEG. Diallel cross in Plant breeding. Heredity 1958;12:477-492.
3. Medagam Thirupathi Reddy, Kadiyala Hari Babu, Mutyala Ganesh, Konda Chandrasekhar Reddy, Hameedunnisa Begum, Reddivenkatagari Subbarama Krishna Reddy. Genetic analysis for yield and its components in okra (*Abelmoschus esculentus* (L.) Moench). Songklanakarin J Sci. Tech 2012;34(2):133-141.
4. Medagam Thirupathi Reddy, Kadiyala Hari Babu, Mutyala Ganesh, Hameedunnisa Begum, Jampala Dilibabu, Reddivenkatagari Subbarama Krishna Reddy. Gene action, combining ability of yield and its components for late *kharif* season in okra (*Abelmoschus esculentus* (L.) Moench). Chilean J Agrl. Res 2013;73(1):9-16.
5. Lyngdoh YA, Mulge R, Shadap A. Heterosis and combining ability studies in near homozygous lines of okra (*Abelmoschus esculentus* (L.) Moench). Int. Quart. J Life Sci 2013;8(4):1275-1279.
6. Rameshkumar D, Gunasekar R, Sankar R. Gene action studies for quantitative and qualitative traits in okra (*Abelmoschus esculentus* (L.) Moench). Int. J Chem. Stud 2017;5(5):2309-2312.
7. Nagesh GC, Mulge R, Rathod LB, Basavaraj, Mahaveer SM. Heterosis and combining ability studies in okra (*Abelmoschus esculentus* (L.) Moench), for yield and quality parameters. Int. Quart. J Life Sci 2014;9(4):1717-1723.
8. Aswani Kumar DK, Baranwal, Judy Aparna, Srivastava K. Combining ability and heterosis for yield and its contributing characters in okra (*Abelmoschus esculentus* (L.) Moench). Madras Agric. J 2013;100(1-3):30-35.
9. Kishor DS, Arya K, Shrishail Duggi, Santoshkumar Magadum NR, Raghavendra Challa Venkateshwaralu, Peddi Sudharshan Reddy. Studies on heterosis for yield and yield contributing traits in okra (*Abelmoschus esculentus* (L.) Moench). Mol. Plant Breed 2013;4(35):277-284.
10. Aware SA, Deshmukh DT, Thakare SV, Zambre SM. Heterosis and inbreeding depression studies in okra (*Abelmoschus esculentus* (L.) Moench), Int. J Curr. Microbiol. Appl. Sci 2014;3(12):733-747.
11. Tapas Paul RT, Desai, Choudhary R. Genetical studies on assessment of heterosis for fruit yield and attributing characters in okra (*Abelmoschus esculentus* (L.) Moench). Int. J Curr. Microbiol. Appl. Sci 2017;6(6):153-159.
12. Swaminathan MS, Siddiq EA, Sharma SD. Outlook for hybrid rice in India. In: Rice breeding. Int. Rice Res. Inst. Los Banos, Philippines 1972, 609-613.
13. Kadambavanasundaram M. Heterotic system in cultivated species of *Gossypium*. An appraisal (Abst.). Genetic and crop improvement of heterotic systems. Pre-congress Scientific meeting of IV international congress of genetics, 7-9, December, TNAU, Coimbatore 1983, 20.
14. Arti Verma, Sonia Sood. Genetic expression of heterosis for fruit yield and yield components in intraspecific hybrids of okra (*Abelmoschus esculentus* (L.) Moench). SABRAO J Breed. Gen 2015;47(3):221-230.