The Pharma Innovation

Shivam Kumar Singh
Research Scholar, Department of Horticulture, Post Graduate College, Ghazipur, Uttar Pradesh, India

Vashistha Yati
Associate Professor, Department of Horticulture, Post Graduate College, Ghazipur, Uttar Pradesh, India

Abhishek Kumar Singh
Senior Research Fellow, Department of Vegetable Science, Indian Agricultural Research Institute, New Delhi, India

Vineet Singh
Senior Research Fellow, Central Institute of Subtropical Horticulture, Lucknow, Uttar Pradesh, India

Shubham Kumar Singh
M.Sc., Department of Horticulture, Post Graduate College, Ghazipur, Uttar Pradesh, India

Combining ability studies in okra (*Abelmoschus esculentus* (L.) Moench) for yield and its component characters

Shivam Kumar Singh, Vashistha Yati, Abhishek Kumar Singh, Vineet Singh and Shubham Kumar Singh

Abstract
The present experiment was conducted with 45 F1s developed through diallel hybridization technique excluding reciprocals along with ten parents in RBD with three replications. The *GCA* and *SCA* mean squares were found to be significant for all the traits. The ratio of *GCA* and *SCA* variances indicated the preponderance of non-additive gene effect for inheritance of all the traits. Genotypes Arka Abhay and IC-43733 showed good general combining ability for fruit yield appear to be worthy for exploitation of segregation and varietal development. The estimates of *SCA* effects revealed that the cross combinations VRO-3 x SB-8 and Sel-4 x Prabhani Kranti were observed most promising for fruit yield and some of its related traits.

Keywords: *Abelmoschus esculentus* (L.) Moench, combining ability, diallel analysis, fruit yield

Introduction
Okra [*Abelmoschus esculentus* (L.) Moench] also known as ladies finger is an important vegetable crop being native of tropical Africa. One of the major problem in okra cultivation in India is lack of location specific high yielding varieties. In often cross-pollinated crops like okra, improvement in the past was based on selection in locally adapted populations. During recent past, exploitation of hybrid vigour and selection of parents on the basis of combining ability effects have opened a new line of approach in crop improvement. Application of biometrical techniques like diallel analysis has appeared to be the best and vastly useful breeding tool, which gives generalized picture of genetics of the characters under study. Understanding the nature of gene action could be helpful in predicting the effectiveness for selection in a population. Clear- cut knowledge of the type of gene action and magnitude and composition of genetic variance is of fundamental importance to a plant breeder. Furthermore, the combining ability studies are useful for the evaluation of newly developed lines for their parental usefulness and to know the gene actions involved in the inheritance of various characters. Hence, the present investigation was undertaken to study the gene action in different quantitative traits and to study the combining ability for yield and its components in okra.

Material and Methods
The materials for the present investigation comprised ten diverse genotypes of okra namely, Arka Abhay, Parbhani Kranti, VRO-3, Sel-4, Pusa-A4, Pusa Makhmali, SB -8, IC- 282272, IC-43733 and IC-43750 obtained by way of diallel mating system without reciprocals. The parents and their F₁s along with standard check were evaluated during summer seasons of 2019, 2020 and rainy season of 2019. Ten parents and total of 45 genotypes were evaluated in a Randomized Block Design (RBD) with three replications at at the Research Farm, Department of Horticulture, Post Graduate College, Ghazipur, Uttar Pradesh. All the recommended package of practices was adopted to raise a good crop. The observations were recorded for 19 quantitative traits *viz.,* plant height (cm), number of branches per plant, node at which first flower appear, number of nodes on main stem, intermodal length (cm), days to first flower, days to 50 per cent flowering, fruit length (cm), fruit width (cm), fruit weight (g), number of ridges on fruit, number of fruits per plant, days to edible fruit maturity, fruit yield per plant (g), fruit yield per ha (q), number of seeds per fruit, seed yield per plant (g), crude fiber content (%) and iodine content (mg/ 100 g).

Corresponding Author:
Shivam Kumar Singh
Research Scholar, Department of Horticulture, Post Graduate College, Ghazipur, Uttar Pradesh, India

Combining ability analysis was performed according to Model - I, Method - II proposed by Griffing (1956) [2].

Results and Discussions

Plant height (cm)
Considering tallness as desirable trait, parents with positive general combining ability effects were considered to be better general combiners. During the study, the effect of GCA ranged from -7.533 (IC-282272) to 14.189 (Arka Abhay). Among the parents, Arka Abhay (14.189), Sel-4 (3.078), Pusa Makhmali (1.550) and VRO-3 (1.244) were good general combiners for plant height (cm) as they showed positive and significant general combining effects. Examination of *per se* performance and GCA effect Arka Abhay (14.189) was the best for this character. For the character under study the SCA effect ranged from -10.338 (IC-282272 x Sel-4) to 11.884 (Arka Abhay x IC- 43733). The best cross combination for these traits, Arka Abhay x IC-43733 (11.884) showed highly significant and positive SCA effect followed by crosses, Arka Abhay x Pusa Makhmali (10.801) and Sel-4 x Prabhani Kranti (10.328). Similar reports have been also reported by Srivastava *et al.* (2008) [7]; Weerasekara *et al.* (2008) [9] and Parmar *et al.* (2012) [3].

Number of branches per plant
Number of branches per plant is a desirable trait, as more number of branches may produce more number of fruitful buds. Hence, parents with positive general combining ability effects were considered to be better general combiners. The GCA effect ranged from -0.228 (IC-43750) to 0.244 (Arka Abhay). On the basis of *per se* performance and GCA effect Arka Abhay (0.244) and IC-282272 were the best for this character. Results revealed that the SCA effect for number of branches per plant ranged from -0.730 (Arka Abhay x Prabhani Kranti) to 1.520 (IC-282272 x IC-43733). On the basis of *per se* performance and SCA effects IC-282272 x IC-43733 was the best cross combination. Similar reports have been also reported by Wammanda *et al.* (2010) [8] and Parmar *et al.* (2012) [3].

Node at which first flower appears
The minimum number of first flowering node indicates the earliness of the plant. Hence, the general combiners with negative value are usually desirable for the character under study. The GCA effect ranged from -0.133 (Pusa-A4) to 0.117 (Sel-4). On the basis of *per se* performance and GCA effect Pusa-A4 was the best general combiners. The magnitude of SCA effect ranged from -1.086 (Pusa Makhmali x Prabhani Kranti) to 0.997 (VRO-3 x IC-43750). On the basis of *per se* performance and SCA effect Pusa Makhmali x Prabhani Kranti was the best cross combination. Similar reports have been also reported by Srivastava *et al.* (2008) [7] and Weerasekara *et al.* (2008) [9].

Number of nodes on main stem
The GCA effect of number of nodes on main stem ranged between -0.856 (SB-8) and 1.561 (Arka Abhay). On the basis of *per se* performance and GCA effect Arka Abhay and IC-43733 were the best. The results on number of nodes on main stem revealed that the SCA effect ranged from -2.778 (Prabhani Kranti x SB-8) to 3.778 (Pusa Makhmali x Prabhani Kranti). On the basis of *per se* performance and SCA effect Pusa Makhmali x Prabhani Kranti was the most promising cross combinations. Similar reports have been also reported

by Singh *et al.* (2012) [6]; Reddy *et al.* (2012) [4] and Parmar *et al.* (2012) [3].

Intermodal length (cm)
Considering shortness of length of internode as desirable trait parent with negative GCA effect were considered to be better general combiners. On the present experiment, the GCA effect from this trait ranged from -0.344 (IC-43750) to 0.933 (Arka abhayOn the basis of *per se* performance and GCA effect Arka Abhay found the best. The range of SCA effects varied from -0.934 (Sel-4 x Pusa-A4) to 1.066 (Prabhani Kranti x Pusa-A4). Similar reports have been also reported by Srivastava *et al.* (2008) [7] and Weerasekara *et al.* (2008) [9].

Days to 50 per cent flowering
The GCA effect of days to 50 per cent flowering ranged between -1.467 (IC-43733) and 1.394 (Pusa Makhmali and Parbhani Kranti). On the basis of *per se* performance and GCA effect Pusa Makhmali and Parbhani Kranti were good general combiners. The SCA effects ranged from -4.361 (Pusa Makhmali x Prabhani Kranti) to 4.480 (Pusa Makhmali x Pusa-A4). Similar reports have been also reported by Reddy *et al.* (2012) [4] and Parmar *et al.* (2012) [3].

Fruit length (cm)
The GCA effect for fruit length ranged from -0.706 (IC-282272) to 0.989 (Parbhani Kranti). Based on *per se* performance and GCA effect Parbhani Kranti was found to be good general combiners. The data indicated that the SCA effect ranged from -1.750 (IC-282272 x Prabhani Kranti) to 2.750 (Arka Abhay x IC-282272). Similar reports have been also reported by Srivastava *et al.* (2008) [7]; Weerasekara *et al.* (2008) [9] and Balakrishnan *et al.* (2009) [1].

Fruit width (cm)
Parents with positive general combining ability effect were considered to be better general combiners. The GCA of width of fruit was ranged from -0.178 (Sel-4, IC-43750 and SB-8) to 0.239 (IC-43733 and VRO-3). Based on *per se* performance and GCA effect IC-43733 and VRO-3 were found to be good general combiners. The range of SCA effects varied from -0.826 (Prabhani Kranti x VRO-3) to 0.646 (Arka Abhay x IC-282272). Considering the estimates of SCA effects and *per se* performance Arka Abhay x IC-282272 was found significant. Similar reports have been also reported by Wammanda *et al.* (2010) [8]; Singh *et al.* (2012) [6]; Reddy *et al.* (2012) [4] and Parmar *et al.* (2012) [3].

Fruit weight (g)
Weight of fruit is a desirable trait which fetches more yields. So, parents with positive general combining ability effect were considered to be better general combiners. The range of GCA effect for this trait was from -0.911 (Sel-4) to 0.672 (IC-282272 and IC-43733). Based on *per se* performance and GCA effect IC-282272 and IC-43733 were found to be good general combiners. The range of SCA effects varied from -3.737 (IC-282272 x Pusa-A4) to 6.402 (Arka Abhay x IC-282272). Considering the estimates of SCA effects and *per se* performance Arka Abhay x IC-282272 cross combinations was found significant. Similar reports have been also reported by Srivastava *et al.* (2008) [7] and Wammanda *et al.* (2010) [8].

Number of ridges on fruit
The range of GCA effect for number of ridges was from -

0.261 (IC-282272 and Pusa-A4) to 0.517 (Arka Abhay). Based on *per se* performance and GCA effect Arka Abhay was found to be good general combiners. The range of SCA effects varied from -0.485 (IC-43733 x Sel-4) to 0.654 (Pusa Makhmali x IC-43750). Considering the estimates of SCA effects and *per se* performance Pusa Makhmali x IC-43750 cross combinations were found significant. Similar reports have been also reported by Singh *et al.* (2012) [6]; Reddy *et al.* (2012) [4] and Parmar *et al.* (2012) [3].

Number of fruits per plant
The range of GCA effects varied from -0.800 (SB-8) to 1.922 (Arka Abhay). Parent Arka Abhay, showed good general combining ability followed. Based on *per se* performance and GCA effect Arka Abhay was found to be good general combiner. The range of SCA effects varied form -3.250 (IC-282272 x Prabhani Kranti) to 4.250 (IC-43750 x SB-8). Based on the estimates of SCA effects and *per se* performance IC-43750 x SB-8 was the best specific combination. Similar reports have been also reported by Srivastava *et al.* (2008) [7]; Singh and Kumar (2010) [5] and Wammanda *et al.* (2010) [8].

Days to edible fruit maturity
Says taken to edible maturity the GCA effect ranged from -1.467 (IC-43733) to 1.394 (Pusa Makhmali and Parbhani Kranti). Considering the *per se* performance and GCA effect Pusa Makhmali and Parbhani Kranti were found to be good general combiners. The range of SCA effects varied from -4.631 (Pusa Makhmali x Prabhani Kranti) to 4.480 (Pusa Makhmali x Pusa-A4). The best cross combination, Pusa Makhmali x Prabhani Kranti, for this trait showed significant and negative SCA effect followed by IC-43733 x Prabhani Kranti (-3.104). Similar reports have been also reported by Wammanda *et al.* (2010) [8]; Singh *et al.* (2012) [6]; Reddy *et al.* (2012) [4] and Parmar *et al.* (2012) [3].

Fruit yield per plant (g)
The GCA effects ranged from -0.161 (SB-8) to 0.117 (Arka Abhay). Out of 10 parents none of the parent was highly significant GCA effect. Based on the *per se* performance and GCA effect Arka Abhay and IC-43733 (0.089) were found to be good general combiner. The range of SCA effect varied from -0.619 (VRO-3 x IC-43750) to 0.520 (VRO-3 x SB-8). Considering the estimates of SCA effects and *per se* performance VRO-3 x SB-8 cross combination was the best specific combination. Similar reports have been also reported by Balakrishnan *et al.* (2009) [1]; Singh and Kumar (2010) [5] and Singh *et al.* (2012) [6].

Fruit yield per hectare (q)
The effect of GCA ranged from -17.872 (Pusa Makhmali) to 24.683 (Arka Abhay). The promising parents for fruit yield per hectare (q) in order of merit were Arka Abhay (24.683). On the basis of the *per se* performance and GCA effect Arka Abhay was found to be good general combiner. The range of SCA effect varied from -43.902 (Prabhani Kranti x VRO-3) to 292.321 (Sel-4 x Prabhani Kranti). On the basis of the estimates of SCA effects and *per se* performance Sel-4 x Prabhani Kranti cross combination was the best specific combination. Similar reports have been also reported by Reddy *et al.* (2012) [4] and Parmar *et al.* (2012) [3].

Number of seeds per fruit
The GCA effect for number of seeds per fruit character ranged from -1.556 (Sel-4) to 2.889 (IC-43733). The parents IC-43733 (2.889), VRO-3 (1.00) and Arka Abhay (0.861) were found to be good general combiners in order of merit for number of seeds per fruit. Examination of the *per se* performance and GCA effect IC-43733 were found to be good general combiner. The SCA effect ranged from -3.515 (Prabhani Kranti x VRO-3) to 3.318 (Pusa-A4 x SB-8). Based on the estimates of SCA effects and *per se* performance Pusa-A4 x SB-8 was the best specific combination. Similar reports have been also reported by Singh and Kumar (2010) [5] and Reddy *et al.* (2012) [4].

Seed yield per plant (g)
The GCA effect ranged from -3.244 (IC-43750) to 6.172 (Arka Abhay). In case of Seed yield per plant (g) only two parent i.e., Arka Abhay (6.172) and IC-43733 (3.700) exhibited significant positive GCA effect and three parents showed non-significant positive GCA effect. When comparing the estimates of the *per se* performance and GCA effect Arka Abhay was found to be good general combiner. The SCA effect ranged from -9.672 (Sel-4 x SB-8) to 14.856 (Arka Abhay x IC-282272). Similar reports have been also reported by Wammanda *et al.* (2010) [8] and Singh *et al.* (2012) [6].

Crude fiber content (%)
The GCA effect ranged from -1.100 (IC-282272) to 0.372 (Parbhani Kranti and VRO-3). When comparing the estimates of the *per se* performance and GCA effect Parbhani Kranti and VRO-3 was found to be good general combiner. The SCA effect ranged from -1.654 (IC-282272 x Prabhani Kranti) to 1.596 (Arka Abhay x IC-282272). Similar reports have been also reported by Parmar *et al.* (2012) [3].

Iodine (mg/100 g)
The GCA effect for iodine ranged from -5.856 (IC-43733) to 10.117 (Arka Abhay). Examination of the *per se* performance and GCA effect Arka Abhay were found to be good general combiner. The SCA effect ranged from -6.313 (IC-43733 x VRO-3) to 8.604 (Arka Abhay x Pusa Makhmali). Based on the estimates of SCA effects and *per se* performance Arka Abhay x Pusa Makhmali the best specific combination. Similar reports have been also reported by Srivastava *et al.* (2008) [7] and Wammanda *et al.* (2010) [8].

The results on *per se*, *GCA* and *SCA* effects (Table 3 and 4) revealed that the crosses with high *SCA* effects for fruit yield involved good x average, average x good, average x average and poor x average general combiners. This indicated the role of additive and non-additive gene actions in the genetic control of these traits. The presence of additive gene action would enhance the chances for making improvement through simple selection. For exploitation of dominance and epistatic effects, it appears worthwhile to intermate the selected progenies in early segregating generations, which would result in the accumulation of favourable genes for the characters. Hence, biparental mating or few cycles of recurrent selection followed by pedigree selection may give fruitful results.

Table 1: Estimation of general combining ability (GCA) effect of 10 parents for 19 characters of okra

Genotype	Plant height (cm)	Number of branches per plant	Node at which 1st flower appears	Number of nodes on main stem	Intermodal length (cm)	Days to first flowering
Arka Abhay	14.189 ***	0.244	-0.050	1.561 ***	0.933 ***	-1.622 ***
IC-282272	-7.533 ***	0.189	0.006	0.200	-0.233 ***	-1.178 ***
IC-43733	-3.867 ***	0.133	-0.106	0.422	-0.039	-0.844 ***
Sel-4	3.078 ***	0.022	0.117	-0.050	-0.233 ***	-1.094 ***
Pusa Makhmali	1.550 **	-0.200	0.089	-0.078	-0.150 *	1.044 ***
Parbhani Kranti	-3.867 ***	-0.006	0.033	0.367	0.100	1.656 ***
VRO-3	1.244 *	-0.033	-0.050	-0.161	0.294 ***	-0.122
IC-43750	-3.256 ***	-0.228	0.089	-0.744 *	-0.344 ***	1.239 ***
Pusa-A4	-0.561	0.022	-0.133	-0.661 *	-0.178 **	0.183
SB-8	-0.978	-0.144	0.006	-0.856 **	-0.150 *	0.739 ***
CD Comparisons for GCA						
Gi<> 0 at 95%	1.154 ***	0.359 ***	0.271 ***	0.724 ***	0.141 ***	0.492 ***
Gi<> 0 at 99%	1.658 ***	0.516 ***	0.389 ***	1.040 ***	0.203 ***	0.707 ***
Gi- - Gj at 95%	1.721 ***	0.536 ***	0.403 ***	1.080 ***	0.210 ***	0.734 ***
Gi- - Gj at 99%	2.472 ***	0.770 ***	0.579 ***	1.551 ***	0.302 ***	1.054 ***
Genotype	**DF 50%**	**Fruit length (cm)**	**Fruit width (cm)**	**Fruit weight (g)**	**NRF**	**NFPP**
Arka Abhay	-0.467 *	0.156	0.128 ***	0.478 **	0.517 ***	1.922 ***
IC-282272	-0.994 ***	-0.706 ***	-0.150 ***	0.672 ***	-0.261 **	0.644
IC-43733	-1.467 ***	0.906 ***	0.239 ***	0.672 ***	-0.233 **	0.339
Sel-4	-1.078 ***	-0.511 ***	-0.178 ***	-0.911 ***	0.100	-0.272
Pusa Makhmali	1.394 ***	-0.261 **	-0.039	-0.133	0.100	-0.606
Parbhani Kranti	1.394 ***	0.989 ***	0.211 ***	0.283	0.239 **	0.339
VRO-3	-0.550 *	0.572 ***	0.239 ***	0.311	-0.094	-0.217
IC-43750	1.117 ***	-0.428 ***	-0.178 ***	0.006	-0.039	-0.717
Pusa-A4	0.283	-0.317 ***	-0.094 ***	-0.717 ***	-0.261 **	-0.633
SB-8	0.367	-0.400 ***	-0.178 ***	-0.661 ***	-0.067	-0.800
CD Comparisons for GCA						
Gi<> 0 at 95%	0.524 ***	0.207 ***	0.048 ***	0.375 ***	0.180 ***	0.955 ***
Gi<> 0 at 99%	0.753 ***	0.297 ***	0.068 ***	0.539 ***	0.258 ***	1.373 ***
Gi- - Gj at 95%	0.781 ***	0.309 ***	0.071 ***	0.559 ***	0.268 ***	1.424 ***
Gi- - Gj at 99%	1.122 ***	0.443 ***	0.102 ***	0.803 ***	0.385 ***	2.046 ***
Genotype	**DEM**	**SYPP (g)**	**FYPP (Kg)**	**FYPH (q)**	**NSPF**	**CFC (%)**	**Iodine (mg/100 g)**
Arka Abhay	-0.467 *	6.172 ***	0.117	24.683 *	0.861 *	0.122	10.117 ***
IC-282272	-0.994 ***	1.311	0.061	4.794	-0.667	-1.100 ***	-3.383 ***
IC-43733	-1.467 ***	3.700 **	0.089	-3.233	2.889 ***	-0.433 ***	-5.856 ***
Sel-4	-1.078 ***	-2.272	-0.050	17.628	-1.556 ***	0.344 ***	3.311 ***
Pusa Makhmali	1.394 ***	-2.383	0.033	-17.872	-0.750	0.011	-4.411 ***
Parbhani Kranti	1.394 ***	0.339	-0.022	5.433	-0.667	0.372 ***	1.061 **
VRO-3	-0.550 *	0.367	-0.050	-7.150	1.000 *	0.372 ***	3.478 ***
IC-43750	1.117 ***	-3.244 **	-0.022	-5.539	-1.278 **	0.261 **	-0.911 **
Pusa-A4	0.283	-1.939	0.006	-8.650	0.028	0.067	-1.411 ***
SB-8	0.367	-2.050	-0.161 *	-10.094	0.139	-0.017	-1.994 ***
CD Comparisons for GCA						
Gi<> 0 at 95%	0.524 ***	2.741 ***	0.149 ***	27.885 ***	0.942 ***	0.177 ***	0.749 ***
Gi<> 0 at 99%	0.753 ***	3.937 ***	0.214 ***	40.060 ***	1.353 ***	0.255 ***	1.075 ***
Gi- - Gj at 95%	0.781 ***	4.085 ***	0.222 ***	41.568 ***	1.404 ***	0.264 ***	1.116 ***
Gi- - Gj at 99%	1.122 ***	5.869 ***	0.318 ***	59.717 ***	2.017 ***	0.379 ***	1.603 ***

Table 2: Estimation of specific combining ability (SCA) effect of 45 F_1 hybrids for 19 characters of okra

Cross	Plant height (cm)	NBPP	NFF	NNMS	INL (cm)	DFF
Arka Abhay X IC-282272	9.217 ***	0.742	-0.586	1.306	0.621 **	-2.364 **
Arka Abhay x IC-43733	11.884 ***	0.798	-0.141	-0.250	0.093	-1.030
Arka Abhay x Sel-4	-5.061 **	0.242	0.636	0.222	0.621 **	-0.114
Arka Abhay x Pusa Makhmali	10.801 ***	-0.202	-0.003	0.583	-0.129	-0.253
Arka Abhay x Prabhani Kranti	-3.449	-0.730	0.386	-0.528	-0.045	-0.864
Arka Abhay x VRO-3	-5.561 **	0.298	-0.197	2.000	-0.240	0.914
Arka Abhay x IC-43750	0.939	-0.508	-0.003	-0.750	0.399	-1.114
Arka Abhay x Pusa-A4	9.912 ***	0.242	0.220	1.500	-0.434 *	1.609 *
Arka Abhay x SB-8	7.662 ***	0.409	0.081	0.028	0.205	0.386
IC-282272 x IC-43733	0.939	1.520 **	-0.530	3.111 **	-0.407	-1.475 *
IC-282272 x Sel-4	-10.338 ***	0.298	0.247	-0.083	0.121	1.109
IC-282272 x Pusa Makhmali	-0.811	-0.480	0.609	-1.056	0.038	0.636
IC-282272 x Prabhani Kranti	-2.727	-0.008	-0.336	-1.167	-0.879 ***	-3.308 ***

Cross						
IC-282272 x VRO-3	5.495 **	0.354	0.747	2.361 *	0.260	-1.197
IC-282272 x IC-43750	-2.338	-0.119	-0.391	-0.389	0.232	0.109
IC-282272 x Pusa-A4	-3.366	-0.035	0.164	-1.139	0.066	0.831
IC-282272 x SB-8	6.051 ***	0.131	-0.641	-0.278	-0.295	-0.058
IC-43733 x Sel-4	2.328	0.020	0.692	3.028 **	0.260	1.109
IC-43733 x Pusa Makhmali	1.189	-0.091	0.053	-0.278	-0.157	0.636
IC-43733 x Prabhani Kranti	0.273	-0.619	0.442	-1.389	0.260	-2.308 **
IC-43733 x VRO-3	-8.172 ***	0.409	-0.141	-1.528	-0.268	1.136
IC-43733 x IC-43750	-8.672 ***	-0.063	0.053	1.722	0.371	0.775
IC-43733 x Pusa-A4	-0.366	-0.313	-0.058	-1.361	0.205	0.164
IC-43733 x SB-8	-6.616 ***	-0.146	-0.197	-0.833	-0.490 *	-2.058 **
Sel-4 x Pusa Makhmali	6.245 ***	1.020	-0.169	1.861	0.371	1.220
Sel-4 x Prabhani Kranti	11.328 ***	-0.174	0.220	-0.917	0.121	-1.058
Sel-4 x VRO-3	1.884	-0.480	-0.364	1.278	0.260	-1.614 *
Sel-4 x IC-43750	4.384 *	0.381	-0.503	-1.806	0.566 **	-0.641
Sel-4 x Pusa-A4	4.023 *	-0.202	-0.614	-1.222	-0.934 ***	0.414
Sel-4 x SB-8	-6.894 ***	0.631	-0.419	-0.028	-0.295	-1.141
Pusa Makhmali x Prabhani Kranti	-1.811	0.048	-1.086 **	3.778 **	0.038	-3.864 ***
Pusa Makhmali x VRO-3	-3.255	0.742	-0.003	-1.694	-0.157	1.914 *
Pusa Makhmali x IC-43750	-1.088	-0.396	0.192	-1.778	0.149	0.553
Pusa Makhmali x Pusa-A4	-2.116	-0.646	-0.253	-0.528	0.316	0.942
Pusa Makhmali x SB-8	-0.699	0.187	0.275	2.000	0.955 ***	-0.614
Prabhani Kranti x VRO-3	-3.505 *	0.548	0.720	0.861	-0.740 ***	-1.364
Prabhani Kranti x IC-43750	-0.005	0.409	-0.086	-0.556	-0.434 *	-0.058
Prabhani Kranti x Pusa-A4	-3.699 *	0.492	-0.530	2.694 *	1.066 ***	1.331
Prabhani Kranti x SB-8	-2.283	0.992	0.331	-2.778 *	1.038 ***	1.775 *
VRO-3 x IC-43750	9.550 ***	-0.230	0.997 *	1.306	0.371	-1.614 *
VRO-3 x Pusa-A4	1.856	-0.146	-0.114	-1.444	0.871 ***	-0.558
VRO-3 x SB-8	2.273	0.020	-0.586	1.417	0.843 ***	-2.447 **
IC-43750 x Pusa-A4	1.356	1.048	0.081	-1.194	-0.490 *	1.081
IC-43750 x SB-8	1.773	-0.452	0.609	0.333	-0.518 *	-0.475
Pusa-A4 x SB-8	0.412	-0.035	0.497	0.583	-0.018	-1.419
C. D. Comparisons						
Sij <> 0 at 95%	3.459	1.077	0.811	2.170	0.423	1.475
Sij <> 0 at 99%	4.621	1.439	1.083	2.899	0.565	1.970
Sij – Sik at 95%	5.084	1.584	1.192	3.190	0.622	2.168
Sij – Sik at 99%	6.792	2.115	1.592	4.262	0.830	2.896
Sij – Skl at 95%	4.848	1.510	1.136	3.042	0.593	2.067
Sij – Skl at 99%	6.476	2.017	1.518	4.063	0.792	2.761

Cross	DF 50%	Fruit length (cm)	Fruit width (cm)	Fruith weight (g)	NRF	NFPP
Arka Abhay X IC-282272	-0.381	2.750 ***	0.646 ***	6.402 ***	0.460	4.167 **
Arka Abhay x IC-43733	-1.242	-1.194 ***	0.258 ***	4.068 ***	0.098	2.139
Arka Abhay x Sel-4	-0.965	0.556	-0.326 ***	-3.015 ***	0.098	2.083
Arka Abhay x Pusa Makhmali	0.563	0.306	0.535 ***	-1.460 *	-0.235	0.417
Arka Abhay x Prabhani Kranti	0.896	-1.278 ***	-0.048	-0.876	-0.040	0.472
Arka Abhay x VRO-3	0.841	0.806 *	0.258 ***	-2.571 ***	0.293	0.028
Arka Abhay x IC-43750	0.174	0.139	-0.326 ***	1.068	-0.096	-2.806
Arka Abhay x Pusa-A4	3.341 ***	0.694 *	0.591 ***	-2.543 ***	0.126	-0.556
Arka Abhay x SB-8	0.591	-0.556	-0.326 ***	-0.932	-0.068	-2.389
IC-282272 x IC-43733	-0.715	0.000	-0.465 ***	2.540 ***	0.543 *	3.750 *
IC-282272 x Sel-4	0.896	-0.583	-0.048	-1.210 *	-0.124	1.028
IC-282272 x Pusa Makhmali	2.758 ***	1.833 ***	0.146 *	-1.987 ***	-0.457	0.028
IC-282272 x Prabhani Kranti	-2.909 ***	-1.750 ***	-0.437 ***	-0.737	-0.263	-3.250 *
IC-282272 x VRO-3	-1.298	0.000	0.535 ***	3.902 ***	0.071	2.972 *
IC-282272 x IC-43750	0.702	-0.667 *	-0.048	-2.126 ***	0.015	-2.861
IC-282272 x Pusa-A4	1.202	0.222	-0.131	-3.737 ***	-0.096	0.056
IC-282272 x SB-8	-0.548	-1.028 **	-0.048	0.540	0.043	-2.778
IC-43733 x Sel-4	2.369 **	1.806 ***	0.563 ***	-0.876	-0.485	-0.667
IC-43733 x Pusa Makhmali	-1.104	1.222 ***	0.424 ***	-1.654 **	-0.152	0.000
IC-43733 x Prabhani Kranti	-3.104 ***	0.639 *	0.174 *	4.263 ***	-0.290	2.389
IC-43733 x VRO-3	3.174 ***	-0.611	0.146 *	-2.098 ***	0.043	-0.722
IC-43733 x IC-43750	0.508	0.722 *	0.563 ***	-0.126	-0.013	-0.556
IC-43733 x Pusa-A4	-0.326	0.611	0.480 ***	-0.737	-0.124	-0.639
IC-43733 x SB-8	-1.076	0.694 *	-0.437 ***	-1.793 **	0.015	0.194
Sel-4 x Pusa Makhmali	1.508	-0.028	-0.159 *	0.596	-0.152	1.278
Sel-4 x Prabhani Kranti	-1.159	-0.944 **	-0.409 ***	-2.154 ***	0.376	-2.333
Sel-4 x VRO-3	-1.548	1.139 ***	0.563 ***	5.485 ***	0.043	3.889 **
Sel-4 x IC-43750	-0.215	-0.861 **	-0.020	-0.876	-0.013	0.056

Cross						
Sel-4 x Pusa-A4	1.952 *	0.028	-0.104	-0.821	0.543 *	-1.694
Sel-4 x SB-8	-0.798	-0.889 **	-0.020	2.790 ***	0.015	-2.861
Pusa Makhmali x Prabhani Kranti	-4.631 ***	0.139	-0.548 ***	5.402 ***	-0.290	1.000
Pusa Makhmali x VRO-3	3.980 ***	-0.778 *	-0.576 ***	-0.960	0.376	-0.778
Pusa Makhmali x IC-43750	-0.687	-1.111 ***	-0.159 *	0.013	0.654 *	0.722
Pusa Makhmali x Pusa-A4	4.480 ***	-0.222	-0.242 **	0.402	0.210	-1.028
Pusa Makhmali x SB-8	-2.270 **	-0.139	-0.159 *	-0.654	0.348	1.139
Prabhani Kranti x VRO-3	-2.020 *	0.306	-0.826 ***	-3.376 ***	0.571 *	-2.056
Prabhani Kranti x IC-43750	0.313	0.639 *	0.591 ***	-0.404	-0.152	-0.556
Prabhani Kranti x Pusa-A4	1.813 *	2.528 ***	0.508 ***	5.318 ***	0.404	4.028 **
Prabhani Kranti x SB-8	2.730 **	0.611	0.591 ***	-2.071 ***	-0.124	0.861
VRO-3 x IC-43750	-0.409	0.389	-0.437 ***	0.902	-0.152	-3.000 *
VRO-3 x Pusa-A4	-1.576 *	-0.722 *	-0.520 ***	-1.043	-0.263	0.583
VRO-3 x SB-8	-2.326 **	2.028 ***	0.563 ***	5.902 ***	-0.124	3.417 *
IC-43750 x Pusa-A4	0.424	0.611	-0.104	0.929	-0.318	1.750
IC-43750 x SB-8	-0.659	0.694 *	-0.020	0.207	-0.179	4.250 **
Pusa-A4 x SB-8	-0.492	-0.083	-0.104	-0.404	-0.290	0.167
C. D. Comparisons						
Sij <> 0 at 95%	1.570	0.620	0.143	1.124	0.539	2.863
Sij <> 0 at 99%	2.097	0.829	0.191	1.502	0.720	3.825
Sij – Sik at 95%	2.308	0.912	0.210	1.652	0.792	4.209
Sij – Sik at 99%	3.083	1.218	0.280	2.208	1.058	5.622
Sij – Skl at 95%	2.200	0.870	0.200	1.576	0.755	4.013
Sij – Skl at 99%	2.940	1.162	0.267	2.105	1.009	5.360

Cross	DEM	SYPP (g)	FYPP (Kg)	FYPH (q)	NSPF	CFC (%)	Iodine (mg/100 g)
Arka Abhay X IC-282272	-0.381	14.856 ***	0.131	14.237	2.624	1.596 ***	7.909 ***
Arka Abhay x IC-43733	-1.242	7.134	0.104	15.265	0.402	1.263 ***	5.715 ***
Arka Abhay x Sel-4	-0.965	6.106	-0.091	-10.596	0.179	-0.515	0.215
Arka Abhay x Pusa Makhmali	0.563	0.217	-0.174	18.904	-0.626	0.152	8.604 ***
Arka Abhay x Prabhani Kranti	0.896	2.828	0.215	-1.735	1.624	-0.543 *	-2.202
Arka Abhay x VRO-3	0.841	-2.866	-0.091	1.848	-2.043	0.457	-5.619 ***
Arka Abhay x IC-43750	0.174	-5.922	0.215	-5.763	1.902	0.235	5.437 ***
Arka Abhay x Pusa-A4	3.341 ***	-1.894	-0.146	1.015	-0.071	-0.571 *	-1.396
Arka Abhay x SB-8	0.591	-5.783	-0.313	4.793	1.152	-1.487 ***	1.854
IC-282272 x IC-43733	-0.715	10.662 *	0.159	3.154	-0.071	1.152 ***	6.215 ***
IC-282272 x Sel-4	0.896	3.301	0.298	-18.374	0.707	-0.293	-6.285 ***
IC-282272 x Pusa Makhmali	2.758 ***	0.078	-0.119	12.793	0.235	-0.626 *	2.437 *
IC-282272 x Prabhani Kranti	-2.909 ***	-8.311 *	-0.396	-8.513	1.485	-1.654 ***	-3.702 **
IC-282272 x VRO-3	-1.298	9.662 *	0.298	10.071	1.152	0.013	-2.785 *
IC-282272 x IC-43750	0.702	-5.394	-0.396	3.793	2.763	-0.543 *	-4.063 ***
IC-282272 x Pusa-A4	1.202	-1.033	-0.091	3.571	-1.210	-1.015 ***	-0.896
IC-282272 x SB-8	-0.548	-8.588 *	-0.258	5.015	-1.321	-0.265	-2.313 *
IC-43733 x Sel-4	2.369 **	-1.088	-0.063	-25.013	0.818	0.040	-5.146 ***
IC-43733 x Pusa Makhmali	-1.104	-0.644	0.187	15.487	-0.321	-0.293	1.909
IC-43733 x Prabhani Kranti	-3.104 ***	10.301 *	0.242	-8.818	2.929 *	0.013	0.770
IC-43733 x VRO-3	3.174 ***	-1.727	-0.063	0.432	0.263	-0.654 *	-6.313 ***
IC-43733 x IC-43750	0.508	-1.116	-0.091	1.154	0.540	-0.210	-0.924
IC-43733 x Pusa-A4	-0.326	-1.755	-0.119	2.598	0.235	-1.015 ***	-2.424 *
IC-43733 x SB-8	-1.076	-0.977	0.048	4.043	-1.543	-0.598 *	-3.174 **
Sel-4 x Pusa Makhmali	1.508	2.995	-0.008	-16.374	-0.210	0.263	7.076 ***
Sel-4 x Prabhani Kranti	-1.159	-6.727	-0.285	292.321 ***	-0.626	-0.626	0.235
Sel-4 x VRO-3	-1.548	12.578 **	0.409	-26.096	1.707	1.707	0.902 **
Sel-4 x IC-43750	-0.215	-0.144	0.048	-30.707	-0.015	-0.015	0.013
Sel-4 x Pusa-A4	1.952 *	-3.783	0.020	-26.263	1.013	1.013	-0.126
Sel-4 x SB-8	-0.798	-9.672 *	-0.480 *	-25.818	-2.765	-2.765	0.290
Pusa Makhmali x Prabhani Kranti	-4.631 ***	5.717	0.298	-14.846	3.235 *	3.235 *	0.235
Pusa Makhmali x VRO-3	3.980 ***	-3.977	-0.008	-6.596	-2.098	-2.098	-0.432
Pusa Makhmali x IC-43750	-0.687	3.967	-0.035	-7.540	1.846	1.846	0.013
Pusa Makhmali x Pusa-A4	4.480 ***	-3.005	-0.063	-2.429	-0.460	-0.460	0.874 **
Pusa Makhmali x SB-8	-2.270 **	3.106	0.104	-5.652	-0.237	-0.237	0.624 *
Prabhani Kranti x VRO-3	-2.020 *	-9.033 *	-0.285	-43.902	-3.515 *	-3.515 *	0.207
Prabhani Kranti x IC-43750	0.313	-2.422	0.020	-39.179	-0.904	-0.904	0.318
Prabhani Kranti x Pusa-A4	1.813 *	12.606 **	0.326	-33.068	1.124	1.124	1.846 ***
Prabhani Kranti x SB-8	2.730 **	1.717	-0.174	-35.957	-0.987	-0.987	0.263
VRO-3 x IC-43750	-0.409	-6.783	-0.619 **	9.737	1.763	1.763	0.318
VRO-3 x Pusa-A4	-1.576 *	1.912	-0.313	14.515	0.457	0.457	0.179
VRO-3 x SB-8	-2.326 **	11.689 **	0.520 *	17.960	2.013	2.013	0.596 *
IC-43750x Pusa-A4	0.424	2.523	0.326	18.904	-2.598	-2.598	-0.043

IC-43750 x SB-8	-0.659	8.967 *	0.492 *	20.682	-2.043	-2.043	-0.293
Pusa-A4 x SB-8	-0.492	3.328	0.131	9.126	3.318 *	3.318 *	0.902 **
C. D. Comparisons							
Sij <> 0 at 95%	1.570	8.212	0.445	83.560	2.823	2.823	0.531
Sij <> 0 at 99%	2.097	10.971	0.595	111.625	3.771	3.771	0.709
Sij – Sik at 95%	2.308	12.072	0.655	122.828	4.150	4.150	0.781
Sij – Sik at 99%	3.083	16.126	0.875	164.082	5.543	5.543	1.043
Sij – Skl at 95%	2.200	11.510	0.624	117.112	3.956	3.956	0.744
Sij – Skl at 99%	2.940	15.376	0.834	156.446	5.285	5.285	0.994

Table 3: Ranking of three desirable parents on the basis of *per se* performance and GCA effects for 19 characters of okra

Characters	Best general combiners	Desirable parents based on *per se* performance	Best parents based on *per se* performance and GCA effects
Plant height (cm)	Arka Abhay, Sel-4, Pusa Makhmali	VRO-3, Pusa Makhmali	Arka Abhay
Number of branches per plant	Arka Abhay, IC-282272, IC-43733	Sel-4, Pusa-A4	Arka Abhay
Node at which 1st flower appears	Sel-4, Pusa Makhmali, IC-43750	Prabhani Kranti	Sel-4
Number of nodes on main stem	Arka Abhay, IC-43733, Pusa Makhmali	Prabhani Kranti, SB-8	Arka Abhay
Intermodal length (cm)	Arka Abhay, VRO-3, Prabhani Kranti	Prabhani Kranti, Pusa-A4	Arka Abhay
Days to first flower	Arka Abhay, IC-282272, Sel-4	IC-43733, SB-8	Arka Abhay, IC-282272
Days to 50% flowering	IC-43733, Sel-4, IC-282272	IC-282272, VRO-3	IC-43733, Sel-4
Fruit length (cm)	Prabhani Kranti, IC-43733, VRO-3	Arka Abhay	Prabhani Kranti, IC-43733
Fruit width (cm)	IC-43733, VRO-3, Prabhani Kranti	Arka Abhay, Pusa Makhmali	IC-43733
Fruit weight (g)	IC-282272, IC-43733, Arka Abhay	VRO-3, Prabhani Kranti	IC-282272, IC-43733
Number of ridges on fruit	Arka Abhay, Prabhani Kranti, Sel-4	Pusa Makhmali, Pusa-A4	Arka Abhay
Number of fruits per plant	Arka Abhay, IC-282272, IC-43733	Prabhani Kranti	Arka Abhay, IC-43733
Days to edible fruit maturity	IC-43733, Sel-4 IC-282272	VRO-3, Arka Abhay	IC-43733
Seed yield per plant (g)	Arka Abhay, IC-43733, IC-282272	VRO-3, Prabhani Kranti	Arka Abhay
Fruit yield per plant (Kg)	Arka Abhay, IC-43733, IC-282272	Pusa Makhmali, Pusa-A4	Arka Abhay
Fruit yield per ha (q)	Arka Abhay, Sel-4 IC-282272	Prabhani Kranti	Arka Abhay, Sel-4
Number of seeds per fruit	IC-43733, Arka Abhay, VRO-3	Pusa-A4, SB-8	IC-43733
Crude Fibre content (%)	VRO-3, Prabhani Kranti, Sel-4	IC-43750, Arka Abhay	VRO-3
Iodine (mg/100g)	Arka Abhay, VRO-3, Sel-4	Prabhani Kranti	Arka Abhay

Table 4: Ranking of three desirable parents on the basis of *per se* performance and SCA effects for 19 characters of okra

Characters	Best general combiners	Desirable parents based on *per se* performance	Best parents based on *per se* performance and SCA effects
Plant height (cm)	Arka Abhay x IC-43733 Sel-4 x Prabhani Kranti Arka Abhay x Pusa Makhmali	Arka Abhay x Pusa-A4 VRO-3 x IC-43750	Arka Abhay x IC-43733 Sel-4 x Prabhani Kranti
Number of branches per plant	IC-282272 x IC-43733 IC-43750 x Pusa-A4	Prabhani Kranti x SB-8 Arka Abhay x IC-43733	IC-282272 x IC-43733

	Sel-4 x Pusa Makhmali		
Node at which 1st flower appears	VRO-3 x IC-43750 Prabhani Kranti x VRO-3 IC-282272 x VRO-3	IC-43733 x Sel-4 Arka Abhay x Sel-4	VRO-3 x IC-43750
Number of nodes on main stem	Pusa Makhmali x Prabhani Kranti IC-282272 x IC-43733 IC-43733 x Sel-4	IC-282272 x VRO-3 Prabhani Kranti x Pusa-A4	Pusa Makhmali x Prabhani Kranti IC-282272 x IC-43733
Intermodal length (cm	Prabhani Kranti x Pusa-A4 Prabhani Kranti x SB-8 Pusa Makhmali x SB-8	VRO-3 x Pusa-A4 VRO-3 x SB-8	Prabhani Kranti x Pusa-A4
Days to first flower	Pusa Makhmali x VRO-3 Prabhani Kranti x SB-8 Arka Abhay x Pusa-A4	Prabhani Kranti x Pusa-A4 Sel-4 x Pusa Makhmali	Pusa Makhmali x VRO-3 Prabhani Kranti x SB-8
Days to 50% flowering	Pusa Makhmali x Prabhani Kranti IC-43733 x Prabhani Kranti IC-282272 x Prabhani Kranti	VRO-3 x SB-8 Pusa Makhmali x SB-8	Pusa Makhmali x Prabhani Kranti
Fruit length (cm)	Arka Abhay X IC-282272 Prabhani Kranti x Pusa-A4 VRO-3 x SB-8	IC-282272 x Pusa Makhmali IC-43733 x Sel-4	Arka Abhay X IC-282272
Fruit width (cm)	Arka Abhay x IC-282272 Arka Abhay x Pusa-A4 Prabhani Kranti x IC-43750	Prabhani Kranti x SB-8 VRO-3 x SB-8	Arka Abhay X IC-282272
Fruit weight (g)	Arka Abhay X IC-282272 VRO-3 x SB-8 Sel-4 x VRO-3	Pusa Makhmali x Prabhani Kranti Prabhani Kranti x Pusa-A4	Arka Abhay X IC-282272
Number of ridges on fruit	Pusa Makhmali x IC-43750 Prabhani Kranti x VRO-3 Sel-4 x Pusa-A4	IC-282272 x IC-43733 Arka Abhay X IC-282272	Pusa Makhmali x IC-43750
Number of fruits per plant	IC-43750 x SB-8 Prabhani Kranti x Pusa-A4 Arka Abhay X IC-282272	IC-282272 x IC-43733 Sel-4 x VRO-3	IC-43750 x SB-8
Days to edible fruit maturity	Pusa Makhmali x Prabhani Kranti IC-43733 x Prabhani Kranti IC-282272 x Prabhani Kranti	VRO-3 x SB-8 Pusa Makhmali x SB-8	Pusa Makhmali x Prabhani Kranti IC-43733 x Prabhani Kranti
Seed yield per plant (g)	Arka Abhay X IC-282272 Prabhani Kranti x Pusa-A4 Sel-4 x VRO-3	VRO-3 x SB-8 IC-282272 x IC-43733	Arka Abhay X IC-282272 Prabhani Kranti x Pusa-A4
Fruit yield per plant (Kg)	VRO-3 x SB-8 IC-43750 x SB-8 Sel-4 x VRO-3	Prabhani Kranti x Pusa-A4 IC-43750 x Pusa-A4	VRO-3 x SB-8
Fruit yield per ha (q)	Sel-4 x Prabhani Kranti IC-43750 x Pusa-A4 IC-43750 x SB-8	Arka Abhay x Pusa Makhmali VRO-3 x SB-8	Sel-4 x Prabhani Kranti
Number of seeds per fruit	Pusa-A4 x SB-8 Pusa Makhmali x Prabhani Kranti IC-43733 x Prabhani Kranti	IC-282272 x IC-43750 Arka Abhay X IC-282272	Pusa-A4 x SB-8
Crude Fibre content (%)	Prabhani Kranti x Pusa-A4 Arka Abhay X IC-282272 Arka Abhay x IC-43733	IC-282272 x IC-43733 Pusa-A4 x SB-8	Prabhani Kranti x Pusa-A4 Arka Abhay X IC-282272
Iodine (mg/100g)	Arka Abhay x Pusa Makhmali Arka Abhay X IC-282272 Sel-4 x Pusa Makhmali	Prabhani Kranti x Pusa-A4 VRO-3 x IC-43750	Arka Abhay x Pusa Makhmali Arka Abhay X IC-282272

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