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# Heterosis and Combining Ability Studies in Okra [*Abelmoschus esculentus* (L.) Moench] for Yield and Yield Contributing Traits

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**ABSTRACT: Organizing germplasm into various heterotic groups is a crucial aspect for utilizing the benefits of heterosis in hybrid plant breeding. So, the heterosis and combining ability were studied in 48 crosses which were developed using 8 lines and 6 testers as parents. The analysis of variance were significant for all the traits in 48 cross combinations obtained. All the traits studied exhibited the significant difference in mean performance among the parents except fruit diameter, number of seeds and fruit yield. The ratio of GCA and SCA variances indicated the preponderance of non-additive gene effect for inheritance of all the traits. Based on heterosis, OK-2017-010 × Pusa Sawani, OK-2017-010 × Parbhani Kranthi, OK-2017-012 × Parbhani Kranthi crosses were found to be best for fruit yield. Parents IC-69304, VRO-5, OK-2017-010, Pusa Sawani, Parbhani Kranthi and Arka Anamika showed good general combining ability. The estimates of SCA effects revealed that the cross EC-169459 × Parbhani Kranthi, OK-2017-010 × Arka Anamika and OK-2017-012 × Varsha Uphar most promising for fruit yield and other related traits.**

**Keywords:** Okra, Heterosis, Combining ability, Yield.

## INTRODUCTION

Vegetables are the most affordable suppliers of vitamins and minerals for human diet. Okra [*Abelmoschus esculentus* (L.) Moench] is a significant vegetable crop which has 90 per cent water, 3 per cent dietary fibre, 7 percent carbohydrates, 2 per cent proteins and it is also a good source of minerals, vitamin C, vitamin A. It includes magnesium, thiamine and folate. Along with these nutritional benefits it can be grown throughout the year and also had wide range of adaptability for which it had gained importance in foreign exchange. It accounts for the 60 per cent of the total fresh vegetable export from India (Mahesh *et al*., 2017).

Okra (*Abelmoschus esculentus* L. Moench) is a widely cultivated vegetable crop in tropical and subtropical regions, with a chromosome number of 2n=2x=130 (Patil *et al*., 2015). It is native to Tropical Africa (Benchasri, 2012) and is known for its immature green seed pods, which are consumed as a cooked vegetable, fresh or sundried (Liu *et al*., 2021). Okra has a growing importance due to its nutritional, medicinal and industrial value, as well as its role in income generation and subsistence for rural farmers in developing countries such as India.

Okra is commercially grown in the Indian states of Andhra Pradesh, Gujarat, Maharashtra, Karnataka, and Tamil Nadu (Raikar *et al*., 2020), representing 13% of the total fresh vegetable exports, and has the potential to earn foreign currency. Okra is suitable for commercial exploitation of hybrid vigor due to its easy emasculation, high fruit set rate (Varmu, 2011), and large number of seeds per fruit. Being a cross-pollinated crop, it has a high level of genetic diversity (Duggi *et al*., 2013), making it important to evaluate the germplasm for genetic variability as the first step in okra improvement (Singh *et al*., 2012).

The second step is to generate crosses using a suitable mating design, to understand the extent of heterosis for various economic traits and the inheritance pattern of desired characters (Das *et al*., 2020). This will help in determining breeding strategies, identifying potential parents and crosses for further use in breeding programs. Combining ability is also important in assessing the genetic value, selecting suitable parents for hybridization and identifying good hybrid cross combinations that can be used for commercial exploitation of heterosis. Therefore, in depth knowledge of combining ability and heterosis of yield and yield contributing traits is necessary during crop improvement, based on selection and hybridization methods (Karthik *et al*., 2012). The combining ability of the inbreds based on Line × tester analysis gives the clear cut picture of gene action, magnitude of genetic variance and thus helps in identifying superior crosses. Keeping all these in view, the present investigation was carried out to evaluate the okra hybrids using Line × tester analysis based on which superior crosses can be identified for yield and its attributing traits.

## MATERIAL AND METHODS

The present investigation was carried out the Horticulture Research and Extension Centre, Hogalagere, Kolar District during the *summer* 2020. The experimental material consists of eight lines *viz*., VRO-5, IC-69304, OK-2017-012, 21-10-1, OK-2017-010, EC-169459, OK-2017-009, OK-2017-06 and six testers *viz*., Kashi Pragathi, Pusa-A4, Parbhani Kranti, Arka Anamika, Pusa Sawani, Varsha Uphar. These were crossed to obtain forty eight hybrids and these were sown in randomised block design with two replications. All the field operations were conducted as per the package of practices University of Horticutural Sciences, Bagalkot (Anon., 2016). The observations on five randomly selected five plants were recorded for fourteen characters *viz*., days to first flowering, days to fifty percent flowering, plant height at 70 DAS, number of branches per plant, number of nodes per plant, intermodal length, intermodal length, fruit length, fruit diameter, number of seeds per fruit, average fruit weight, number of fruits per plant and yield per plant.

The analysis of variance was performed to find the significant differences among the genotypes for all the characters as suggested by Panse and Sukhatme (1985). The analysis of variance for combining ability for all the fourteen characters was carried-out as suggested by Kempthorne (1957) using statistical software package WINDOSTAT 9.30 Ver.

## RESULTS AND DISCUSSION

**Analysis of variance.** The results of analysis of variance for the combining ability was presented in the table 1. The variance due to parents were significant for all the traits except fruit diameter, number of seeds per fruit, yield per plant. The variance due to testers were significant in most of the traits except fruit length and diameter, number of seeds per fruit, number of fruits per plant and yield per plant. All the crosses were found to be highly significant for all the characters studied indicating substantial genetic variation present in them. Estimates of $\sigma^2$sca effects were greater than $\sigma^2$gca effects due to lines and testers for all characters in all the environments, which suggested the role of non-additive gene action in the inheritance of most of the characters. The preponderance of non-additive gene action was also reported by Mahesh *et al*. (2017); Sapavadiya *et al*. (2019); Chaithanya *et al*. (2021).

**Mean performance.** From the Table 2 it is understood that, in general, all the traits exhibited significant acceptable mean performance. The parents Arka Anmika, IC-69304, Varsha Upahar performed better for most of the growth and yield traits suchas, days to first flowering, days to fifty percent flowering, plant height, number of fruits per plant, average fruit weight, yield per plant and hectare. Yield per plant in IC-69304 (374.61g) and Arka Anamika (355.38g) were found to be highest among the parents. Kalaiselvan and Anuja (2021) also reported highest fruit yield in Arka Anamika in their studies. Keerthana *et al*. (2021) reported that superiority of the crosses depend mainly on the performance of their parents. These results were also supported by the findings of Pitiya *et al*. (2020); Vivek (2017).

**Heterosis.** The estimates of heterosis were computed for all the 14 traits studied in the 48 hybrids of okra and expressed in percentage over mid parental value (MPH-relative heterosis), better parental value (BPH-heterobeltiosis) and standard heterosis over two check hybrid Radhika and MH-10 (SH). Negative heterosis is desirable for days to first flowering because this will help the hybrid to mature earlier. Sixteen hybrids exhibited significant negative relative heterosis values. It was minimum in the hybrid OK-2017-009 × Parbhani Kranthi. The heterobeltiosis (BPH) was the lowest in the hybrid 21-10-1 × Parbhani Kranthi, 21 hybrids registered negative and significant (BPH) values. Fourteen hybrids showed significantly negative standard heterosis (SH) over standard check 1 (OK-2017-009 × Kashi Pragathi). Whereas, for standard check 2, 10 hybrids had negative standard heterosis and was least in (VRO-5 × Kashi Pragathi). Similar results were recorded for number of days to fifty percent flowering. Totally 23 hybrids recorded significant and positive MPH, BPH values, and 17 hybrids for SH values in plant height. Hybrid OK-2017-010 × Parbhani Kranthi recorded highest MPH, BPH, SH for both the checks for plant height, number of branches per plant. Totally 11 hybrids had significant positive MPH values for number of nodes per plant, eight hybrids had BPH, two hybrids showed significant positive SH over both checks. The hybrid OK-2017-010 × Parbhani Kranthi had highest MPH for number of nodes per plant, 21-10-1 × Pusa- A4 had highest BPH value, IC-69304 × Pusa-A4 recorded highest heterosis SH values over both checks. Ten hybrids exhibited positive and significant heterosis values, the VRO-5 × Varsha Uphar had maximum MPH, OK-2017-009 × Arka Anamika had maximum BPH, hybrid OK-2017-012 × Parbhani Kranthi exhibited highest SH over both checks for internodal length. Hybrid OK-2017-010 × Pusa Sawani recorded highest significant and positive MPH and BPH values for yield per plant. 43 hybrids recorded significant and positive MPH values, 41 hybrids recorded positive and significant BPH values and None of the hybrids had positive and significant SH for yield per plant.

Thirteen okra hybrids recorded significant positive MPH values for fruit length, among them OK-2017-006 × Varsha Uphar was highest along with high BPH and SH values over both checks. Totally 15 hybrids showed positive and significant MPH values, six hybrids exhibited positive significant BPH values for fruit diameter. The hybrid OK-2017-010 × Pusa Sawani recorded highest MPH, OK-2017-010 × Pusa- A4 recorded highest BPH and the hybrid OK-2017-010 × Pusa Sawani recorded the highest SH over both the checks. The relative heterosis, heterobeltiosis, standard heterosis was highest in OK-2017-010 × Parbhani Kranthi hybrid for number of ridges per fruit. Totally seven hybrids recorded significant and positive MPH and BPH values. Number of seeds per fruit had highest positive and significant MPH value in VRO-5 × Parbhani Kranthi, BPH value in OK-2017-010 ×

Parbhani Kranthi, the hybrid 21-10-1 × Kashi Pragathi recorded the highest SH over both the checks. Three hybrids recorded significant and positive MPH values, one hybrid for heterobeltiosis values. The heterotsis values MPH, BPH and SH for average fruit weight was highest in OK-2017-012 × Parbhani Kranthi, EC-169459 × Pusa Sawani, EC-169459 × Pusa- A4. 39 hybrids exhibited positive and significant heterosis over mid parental values, 32 hybrids recorded positive and significant MPH values, 20 hybrids registered positive and significant BPH values. Hybrid OK-2017-009 × Pusa Sawani had highest positive significant MPH value for number of fruits per plant. These results indicate that varied degree of dominance is involved in inheritance of these traits. These results were in agreement with the results of Hazem *et al*. (2013); Mahesh *et al*. (2017).

**Combining ability.** The estimates of gca effects (Table 3) revealed that revealed that none of the parents was found good general combiner simultaneously for all the characters studied. Lines IC-69304, 21-10-1, OK - 2017-010 and testers Pusa A4, Pusa Sawani, Pusa Uphar were proved to be good general combiners for days to first flowering as significant negative values for this trait is considered to be desirable . Lines VRO-5, OK-2017-010, OK - 2017-006 and tester Pusa Sawani were found to be good general combiners for days to fifty percent flowering as both the traits indicated by significant negative GCA effects. IC-69304, OK - 2017-012 lines and Pusa Sawani, Varsha Uphar testers were proved to be good general combiners for plant height as indicated by their significant positive GCA effects. Lines IC-69304, VRO- 5, OK - 2017-010, EC-169459 and tester Varsha Uphar were proved to be good general combiners for number of branches per plant. Line OK - 2017-010, tester Pusa A4 for number nodes per plant. Lines OK - 2017-012, OK - 2017-009 and testers, Pusa Kranthi, Arka Anamika, Pusa Sawani for intermodal length. Line OK - 2017-009 and tester, Pusa Sawani for fruit length, for fruit diameter, lines OK - 2017-010, VRO- 5 and among testers, Pusa Sawani, Pusa A4 were proved tobe good general combiners. Among lines OK - 2017-010 and among the testers, Varsha Uphar, Parbhani Kranthi, Arka Anamika for number of ridges per fruit, for number of seeds per fruit line 21-10-1, lines 21-10-1, IC-69304 and testers, Parbhani Kranthi, Pusa Sawani for average fruit weight, lines IC-69304, VRO-5, OK - 2017-006 and testers, Pusa Sawani, Pusa A4, Varsha Uphar for number of fruits per plant, yield per hectare found to be good general combiners. Similar results were also found by earlier researchers like Singh *et al*. (2012); Makdoomi *et al*. (2018); Patel *et al*. (2021).

The estimates of sca effects (Table 4) reveal that none of the hybrids was found to be superior for all the traits. However, eight hybrids registered significant positive sca effect for yield per plant among which the hybrid EC-169459 × Parbhani Kranthi showed highest sca of 2.83. This cross also had significant positive sca effect for six traits. The cross OK-2017-010 × Varsha Uphar also showed significant positive effect for six traits. Rest of the crosses like VRO-5 × Kashi Pragathi, OK-2017-009 × Arka Anamika, OK-2017-009 × Pusa Sawani, OK-2017-006 × Pusa- A4, OK-2017-010 × Pusa Sawani were found to have highly significant sca effect. It would be desirable to employ these hybrids to increase fruit yield because they could be used for heterosis breeding and could produce transgressive segregants in later generations. Kalaiselvan and Anuja (2021) reported that the crosses EC 102605 × Arka Anamika and EC 169344 × Arka Anamika were found as good specific combiners for fruit girth and yield. Similar results were also reported by More *et al*. (2015b); Satish *et al*. (2017); Kayande *et al*. (2018); Chaithanya *et al*. (2021).

**Table 1: Analysis of variance (mean sum of squares) of line × tester analysis for various characters in okra.**

| Source of variations | Replications | Genotypes | Parents | Lines | Testers | Line Vs. Tester | Parents vs Crosses | Crosses | Line effect | Tester effect | Line Vs. Tester Eff. | Error |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Degrees of freedom | **1** | **61** | **13** | **7** | **5** | **1** | **1** | **47** | **7** | **5** | **35** | **61** |
| Days to first flowering | 0.1 | 5.01 ** | 4.35** | 2.20 ** | 8.13 ** | 0.5 | 4.17 ** | 5.21 ** | 5.5 | 5.5 | 5.12 ** | 0.5 |
| Days to 50 % flowering | 26.20 | 7.39** | 6.43 * | 5.00 * | 9.68 ** | 0.19 | 16.93 ** | 7.46 * | 14.73 | 1.90 | 6.8** | 1.73 |
| Plant height 60DAS (cm) | 11.70 | 547.64 ** | 645.76 ** | 369.59 ** | 478.33 ** | 3416.17 ** | 7359.25 ** | 375.57 ** | 260.84 | 278.78 | 412.34 ** | 46.51 |
| No. of branches per plant | 0.02 | 0.36 ** | 0.38 ** | 0.39 ** | 0.43 ** | 0.08 | 0.04 | 0.37 ** | 0.63 | 0.46 | 0.3 ** | 0.02 |
| No. of nodes per plant | 3.48 | 3.60 ** | 2.01 * | 1.72 | 2.34 * | 2.46 | 10.64 ** | 3.89 ** | 2.65 | 4.96 | 3.99 ** | 0.90 |
| Internodal length (cm) | 0.25 | 2.24 ** | 2.94 ** | 4.90 ** | 0.69 ** | 0.50 * | 0.26 | 2.09 ** | 4.35 ** | 6.06 ** | 1.08 ** | 0.12 |
| Fruit length (cm) | 44.67 ** | 1.80 ** | 1.32 ** | 1.52 ** | 1.21 * | 0.53 | 12.80 ** | 1.70 ** | 1.03 | 0.46 | 2.01 ** | 0.42 |
| Fruit diameter (mm) | 38.07 ** | 3.35 ** | 2.83 ** | 4.01 ** | 0.43 | 6.55 ** | 14.62 ** | 3.26 ** | 10.36 ** | 2.65 | 1.92 ** | 0.51 |
| No. of ridges per fruit | 0.20 | 0.12 ** | 0.07 | 0.09 | 0.05 | 0.08 | 0.02 | 0.14 ** | 0.21 | 0.2 | 0.12 ** | 0.05 |
| No. of seeds per fruit | 9.37 | 43.13 | 25.67 | 37.92 | 11.31 | 11.71 | 21.43 | 48.42 * | 107.80 * | 22.19 | 40.29 | 28.53 |
| Average fruit weight (g) | 0.69 | 4.13 ** | 1.31 ** | 1.18 * | 1.31 * | 2.23 * | 133.97 ** | 2.14 ** | 2.54 | 1.47 | 2.16 * | 0.52 |
| No. of fruits per plant | 39.03 ** | 25.89 ** | 18.27 ** | 27.94 ** | 8.07 | 1.52 | 424.85 ** | 19.51 ** | 34.80 * | 35.55 * | 14.15 ** | 4.57 |
| Yield per plant (g) | 3.81 | 9525.10 ** | 1652.11 | 1843.72 | 1676.64 | 188.14 | 272313.25 ** | 6111.50 ** | 8070.32 | 17250.61 ** | 4128.44 ** | 932.25 |
| Yield per hectare (t) | 0.01 | 13.06 ** | 2.26 | 2.53 | 2.30 | 0.25 | 373.58 ** | 8.38 ** | 11.06 | 23.66 ** | 5.66 ** | 1.27 |

*and** indicate significance of values at p= 0.05 and p= 0.01, respectively.

**Table 2: Mean and per se performance of parents and crosses for yield and its attributing characters in okra.**

| Characters | Parents (P) / Crosses (C) | Mean performance range | | High per se performance |
|---|---|---|---|---|
| | | Minimum | Maximum | |
| Days to first flowering | P | 37.5 | 43 | Arka Anamika, Varsha Uphar, IC-69304, OK-2017-012 |
| | C | 36.5 | 42.5 | VRO-5 × Varsha Uphar, VRO-5 × Pusa Sawani |
| Days to 50 % flower (days) | P | 42 | 47.5 | Varsha Uphar, IC-69304, 21_10_1, Arka Anamika |
| | C | 39 | 46.5 | OK-2017-010 × Varsha Uphar, VRO-5 × Pusa Sawani |
| Plant height (cm) at 70 DAS | P | 72.3 | 126.7 | Arka Anamika, Kashi Pragathi, Varsha Uphar, Pusa Sawani |
| | C | 94.6 | 146.7 | OK-2017-010 × Parbhani Kranthi, IC-69304 × Varsha Uphar |
| Number of branches per plant | P | 1 | 2 | VRO-5, EC-169459 , OK-2017-009, Pusa- A4 |
| | C | 1 | 2.1 | OK-2017-010 × Kashi Pragathi, OK-2017-009 × Varsha Uphar |
| Number of nodes per plant | P | 10.8 | 14.5 | IC-69304, OK-2017-012 , EC-169459 , Kashi Pragathi |
| | C | 9.4 | 16.5 | IC-69304 × Pusa- A4, 21-10-1 × Pusa- A4 |
| Internodal length (cm) | P | 6.28 | 11.33 | Arka Anamika, OK-2017-010 , Pusa- A4, VRO-5 |
| | C | 7.11 | 11.75 | OK-2017-010 × Kashi Pragathi, VRO-5 × Kashi Pragathi |
| Fruit length (cm) | P | 13 | 15.94 | Pusa- A4, EC-169459 , Pusa Sawani, Kashi Pragathi |
| | C | 13.12 | 17.45 | OK-2017-006 × Varsha Uphar, OK-2017-009 × Parbhani Kranthi |
| Fruit diameter (mm) | P | 14.76 | 18.55 | VRO-5 , Kashi Pragathi, Pusa Sawani, OK-2017-012 |
| | C | 15.63 | 21.47 | OK-2017-010 × Pusa Sawani, OK-2017-010 × Pusa- A4 |
| Number of ridges per fruit | P | 5 | 5.5 | OK-2017-006 , VRO-5, OK-2017-009, Pusa Sawani |
| | C | 5 | 6.1 | OK-2017-010 × Parbhani Kranthi, 21-10-1 × Varsha Uphar |
| Number of fruits per plant | P | 15.5 | 26.2 | VRO-5, Arka Anamika, IC-69304, EC-169459 |
| | C | 16.75 | 31.6 | VRO-5 × Pusa Sawani, IC-69304 × Pusa- A4 |
| Average Fruit weight (g) | P | 12.21 | 14.83 | Kashi Pragathi, Varsha Uphar, OK-2017-010 , Arka Anamika |
| | C | 14.07 | 17.89 | EC-169459 × Pusa- A4, 21-10-1 × Parbhani Kranthi |
| Yield per plant | P | 285.86 | 374.61 | IC-69304, VRO-5 , Arka Anamika, Pusa- A4 |
| | C | 248.99 | 536.42 | OK-2017-010 × Pusa Sawani, OK-2017-010 × Varsha Uphar |
| Yield per hectare (g) | P | 10.59 | 13.87 | IC-69304, VRO-5, Arka Anamika, Pusa- A4 |
| | C | 9.22 | 19.87 | OK-2017-010 × Pusa Sawani, OK-2017-010 × Varsha Uphar |

**Table 3: GCA effects of lines for yield and yield component traits in Okra.**

| Lines | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | X14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VRO-5 | 0.34 | -0.771 * | -1.24 | 0.15** | -0.36 | -0.02 | -0.12 | 0.58 ** | -0.11 | 0.42 | -0.68 ** | 1.59 ** | 21.72 ** | 0.80 ** |
| IC-69304 | -0.57 * | -0.27 | 6.83 ** | 0.27 ** | 0.24 | -0.32** | -0.33 | 0.30 | 0.04 | 0.92 | 0.51 * | 2.30 ** | 34.67 ** | 1.28** |
| OK-2017-012 | 0.01 | 1.14 ** | 6.19 ** | -0.32 ** | -0.72 * | 1.10 ** | -0.15 | 0.17 | -0.04 | -1.91 | -0.35 | -0.67 | -28.17 ** | -1.04 ** |
| 21_10_1 | -0.57 * | 0.06 | 0.65 | -0.34 ** | 0.12 | 0.09 | -0.10 | -0.60 ** | 0.01 | 5.82 ** | 0.55 ** | 0.10 | -9.53 | -0.35 |
| OK-2017-010 | -0.74 ** | -1.6 ** | -0.12 | 0.15 ** | 0.89 ** | -0.93 *** | 0.18 | 1.74 ** | 0.27 ** | 0.36 | -0.34 | -0.12 | 18.184 * | 0.673 * |
| EC-169459 | 1.34 ** | 1.81 ** | -3.77 * | 0.12 * | -0.11 | -0.18 | -0.01 | -1.04 ** | -0.16 * | -1.711 | 0.29 | -2.20 ** | -28.93 ** | -1.07 ** |
| OK-2017-009 | 0.26 | 0.40 | -1.59 | -0.08 | -0.11 | 0.50 ** | 0.63 ** | -1.03 ** | 0.06 | -4.55 ** | 0.25 | -2.32 ** | -25.75 ** | -0.95 ** |
| OK-2017-006 | -0.07 | -0.77 * | -6.95 ** | 0.03 | 0.06 | -0.23 * | -0.11 | -0.12 | -0.06 | 0.65 | -0.24 | 1.30 ** | 17.81 * | 0.65 * |
| **SEm±** | **0.22** | **0.37** | **1.83** | **0.05** | **0.28** | **0.10** | **0.19** | **0.19** | **0.07** | **1.51** | **0.20** | **0.47** | **7.73** | **0.29** |
| **CD at 5%** | **0.45** | **0.75** | **3.69** | **0.10** | **0.56** | **0.19** | **0.39** | **0.38** | **0.14** | **3.04** | **0.40** | **0.95** | **15.55** | **0.58** |
| **CD at 1%** | **0.60** | **1.00** | **4.92** | **0.14** | **0.75** | **0.26** | **0.52** | **0.51** | **0.18** | **4.05** | **0.53** | **1.27** | **20.75** | **0.77** |
| **Testers** | | | | | | | | | | | | | | |
| Kashi pragathi | 0.510 ** | **-0.31** | **-1.44** | **-0.08 ** ** | **0.14** | **-0.49 ** ** | **-0.05** | **-0.17** | **-0.08 * ** | **-0.46** | -0.15 | **-1.97 ** ** | **-53.03 ** ** | **-1.96 ** ** |
| Pusa- A4 | -0.240 * | **0.13** | **-4.04 *** ** | **-0.05 * ** | **0.94 ** ** | **-0.66 ** ** | **-0.22 * ** | **0.42 ** ** | **-0.13 ** ** | **-1.23** | **-0.20 * ** | **0.94 ** ** | **22.39 ** ** | **0.83 ** ** |
| Parbhani Kranthi | 0.63 ** | **0.43 * ** | **0.90** | **-0.05** | **-0.18** | **0.82 ** ** | **-0.14** | **-0.52 ** ** | **0.10 ** ** | **1.30** | **0.40 ** ** | **-1.49 ** ** | **-13.89 ** ** | **-0.51 ** ** |
| Arka Anamika | 0.260 * | **0.19** | **-4.83 ** ** | **-0.15 ** ** | **-0.50 ** ** | **0.55 ** ** | **0.06** | **-0.14** | **0.09 * ** | **1.45** | **-0.41 ** ** | **-0.01** | **-12.98 ** ** | **-0.48 ** ** |
| Pusa Sawani | -0.92 ** | **-0.50 * ** | **4.96 ** ** | **0.02** | **-0.56 ** ** | **0.19 ** ** | **0.23 * ** | **0.55 ** ** | **-0.08 * ** | **-1.19** | **0.20 * ** | **1.92 ** ** | **34.29 ** ** | **1.26 ** ** |
| Varsha Uphar | -0.240 * | **0.06** | **4.45 ** ** | **0.32 ** ** | **0.17** | **-0.419** ** | **0.12** | **-0.14** | **0.115 ** ** | **0.13** | **0.15** | **0.60 * ** | **23.22 ** ** | **0.86 ** ** |
| **SEm±** | **0.19** | **0.32** | **1.59** | **0.04** | **0.24** | **0.08** | **0.17** | **0.17** | **0.06** | **1.31** | **0.17** | **0.41** | **6.69** | **0.25** |
| **CD at 5%** | **0.38** | **0.65** | **3.19** | **0.09** | **0.48** | **0.17** | **0.34** | **0.33** | **0.12** | **2.63** | **0.34** | **0.82** | **13.47** | **0.50** |
| **CD at 1%** | **0.51** | **0.87** | **4.26** | **0.12** | **0.65** | **0.23** | **0.45** | **0.44** | **0.16** | **3.51** | **0.46** | **1.10** | **17.97** | **0.67** |

*and** indicate significance of values at p= 0.05 and p= 0.01, respectively.

X1- Days to first flowering
X2- Days to 50 % flowering
X3 -Plant height 60DAS (cm)
X4- Number of branches per plant
X5- Number of nodes per plant
X6- Internodal length (cm)
X7- Fruit length (cm)
X8- Fruit diameter (mm)
X9- Number of ridges per fruit
X10- Number of seeds per fruit
X11- Average fruit weight (g)
X12- Number of fruits per plant
X13- Yield per plant (g)
X14- Yield per hectare (t)

**Table 4: Specific combining ability effects for yield and yield component traits in Okra.**

| Crosses | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | X14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VRO-5 × Kashi Pragathi | 2.40 ** | 1.15 | -1.38 | 0.36 ** | 1.42 * | -0.95 *** | 0.45 | 0.49 | 0.04 | -5.87 | 1.82 ** | 2.09 | 55.100 ** | 2.03 ** |
| VRO-5 × Pusa- A4 | -1.34 * | -0.29 | 5.73 | 0.34 ** | 0.72 | -0.55 * | -0.03 | -1.86 ** | 0.09 | -2.24 | 0.43 | 0.77 | 19.52 | 0.72 |
| VRO-5 × Parbhani Kranthi | 1.78 ** | 2.39 * | -1.11 | 0.32 * | -2.05 ** | 0.57 * | -1.00 * | -0.26 | -0.15 | 7.98 * | -0.33 | -0.49 | -23.28 | -0.86 |
| VRO-5 × Arka Anamika | 1.65 ** | 1.65 | -20.18 ** | -0.35 ** | -3.62 ** | 0.35 | -0.28 | 1.18 * | -0.04 | -1.04 | 0.04 | -0.97 | -21.91 | -0.81 |
| VRO-5 × Pusa Sawani | -1.65 ** | -2.66 ** | 1.61 | 0.26 * | 2.73 ** | -1.36 ** | -0.12 | -0.27 | 0.23 | 1.78 | -1.04 * | 0.989 | 5.114 | 0.191 |
| VRO-5 ×Varsha Uphar | -2.84 ** | -2.22 * | 15.32 ** | -0.94 ** | 0.79 | 1.94 ** | 0.98 * | 0.72 | -0.16 | -0.61 | -0.91 | -2.38 * | -34.54 | -1.28 |
| IC-69304 × Kashi pragathi | -2.17 ** | -1.35 | -19.54 ** | 0.25 | -0.58 | -0.62 * | 0.12 | -0.11 | -0.12 | 3.17 | -1.62** | 0.97 | 5.98 | 0.22 |
| IC-69304 × Pusa- A4 | 3.07 ** | 3.20 ** | 15.55 ** | 0.03 | 1.42 * | 0.20 | -0.17 | 0.07 | -0.07 | -3.58 | -0.26 | 1.15 | 28.86 | 1.07 |
| IC-69304 × Parbhani Kranthi | -0.80 | -0.60 | 8.62 | -0.58 ** | 0.95 | -0.51 * | 0.52 | -0.19 | -0.20 | 5.55 | 0.45 | 0.60 | -13.69 | -0.51 |
| IC-69304 × Arka Anamika | 0.07 | -0.85 | -1.73 | 0.32 * | -0.93 | 0.31 | 0.20 | 0.44 | 0.31 | 2.42 | 1.08 * | -0.09 | 18.25 | 0.68 |
| IC-69304 × Pusa Sawani | 0.76 | 0.83 | -12.75 ** | 0.15 | -1.07 | 0.08 | 0.16 | -0.28 | -0.12 | 0.30 | 0.63 | -1.43 | 0.33 | 0.01 |
| IC-69304 × Varsha Uphar | -0.93 | -1.23 | 9.85 * | -0.16 | 0.20 | 0.55 * | -0.83 | 0.07 | 0.19 | -7.85 * | -0.28 | -1.21 | -39.72 * | -1.47 * |
| OK-2017-012 × Kashi pragathi | -1.76 ** | -2.27 * | 14.39 ** | -0.15 | 0.39 | 0.39 | 0.78 | -0.22 | -0.03 | -2.17 | -1.61** | 0.35 | -5.47 | -0.20 |
| OK-2017-012 × Pusa- A4 | 0.99 | 1.29 | -22.50 ** | 0.03 | -2.71 ** | -0.24 | -0.32 | -0.76 | 0.02 | -2.54 | 0.02 | -1.77 | -34.45 | -1.28 |
| OK-2017-012 × Kranthi | 0.62 | 0.48 | -14.84 ** | -0.19 | 0.62 | 0.59 * | -1.13 * | -0.43 | 0.48 ** | 2.73 | 0.85 | 0.57 | 22.64 | 0.84 |
| OK-2017-012 × Arka Anamika | 0.99 | 1.73 | 11.48 * | -0.08 | 0.54 | -0.75 | -0.33 | -0.05 | -0.21 | 4.32 | 0.66 | -0.92 | 14.20 | 0.53 |

| Crosses | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 | X9 | X10 | X11 | X12 | X13 | X14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | ** | | | | | | | | |
| OK-2017-012 × Pusa Sawani | -0.82 | -0.08 | 9.68 * | -0.05 | 0.20 | 0.58 * | 0.63 | 1.01 * | -0.03 | -3.72 | -0.45 | -1.20 | -12.40 | -0.46 |
| OK-2017-012 × Varsha Uphar | -0.01 | -1.15 | 1.79 | 0.43 ** | 0.97 | -0.58 * | 0.38 | 0.45 | -0.23 | 1.38 | 0.54 | 2.969 * | 15.48 | 0.57 |
| 21-10-1 × Kashi pragathi | 1.32 * | 1.31 | 8.94 | -0.13 | 0.04 | 0.53 * | 0.79 | 0.18 | -0.08 | 6.10 | 0.74 | 0.68 | 21.80 | 0.81 |
| 21-10-1 × Pusa- A4 | -0.93 | -2.12 * | -0.36 | -0.16 | 1.44 * | 0.15 | -0.28 | 0.38 | 0.17 | 0.40 | -1.33 ** | -0.34 | -39.96 * | -1.47 * |
| 21-10-1 × Parbhani Kranthi | -1.30 * | 0.56 | -14.69 ** | -0.07 | -1.14 | -0.41 | -0.81 | -0.31 | -0.27 | -11.49 ** | 0.69 | 1.70 | 51.93 ** | 1.92 ** |
| 21-10-1 × Arka Anamika | -1.92 ** | -1.69 | 2.64 | 0.14 | -0.41 | -0.75 ** | -0.48 | -0.10 | -0.26 | 0.80 | 0.79 | -0.52 | -17.37 | -0.64 |
| 21-10-1 × Pusa Sawani | 0.76 | -0.50 | 6.04 | -0.23 | -0.15 | 0.78 ** | 0.48 | -0.64 | -0.08 | -0.68 | -1.69 ** | -2.32 | -47.03 * | -1.74 * |
| 21-10-1 × Varsha Uphar | 2.07 ** | 2.43 * | -2.56 | 0.45 ** | 0.22 | -0.31 | 0.30 | 0.49 | 0.51 ** | 4.87 | 0.80 | 0.80 | 30.64 | 1.13 |
| OK-2017-010 × Kashi pragathi | 0.49 | 0.98 | -24.69 ** | 0.46 ** | -0.33 | -0.68 ** | -0.65 | -1.73 ** | 0.15 | -1.41 | 0.31 | 2.30 | 25.07 | 0.93 |
| OK-2017-010 × Pusa- A4 | 0.24 | 1.04 | -13.59 ** | -0.65 ** | -1.23 | 0.11 | 0.92 | 0.80 | -0.30 | 1.84 | -1.09 * | -2.02 | -14.79 | -0.55 |
| OK-2017-010 × Parbhani Kranthi | 0.87 | 0.23 | 25.07 *** | 0.13 | 1.49 * | 0.00 | 1.33 ** | -1.12 * | 0.56 ** | -2.96 | -0.05 | -8.32 ** | -107.58 ** | -3.98 ** |
| OK-2017-010 × Arka Anamika | -0.26 | 0.48 | -6.70 | 0.44 ** | 0.32 | -0.33 | 0.64 | 0.18 | 0.18 | 2.73 | -0.18 | 3.93 ** | 4.96 | 0.18 |
| OK-2017-010 × Pusa Sawani | -0.07 | 0.17 | 4.90 | -0.33 * | -0.72 | 0.74 ** | -0.79 | 1.57 ** | -0.25 | 6.19 | 0.90 | 1.50 | 46.53 * | 1.723 * |
| OK-2017-010 × Varsha Uphar | -1.26 * | -2.89 ** | 15.00 ** | -0.05 | 0.45 | 0.16 | -1.46 ** | 0.30 | -0.34 * | -6.39 | 0.12 | 2.61 * | 45.80 * | 1.69 * |
| EC-169459 × Kashi pragathi | -2.09 ** | 0.06 | 18.65 ** | -0.20 | 1.17 | 0.93 ** | -2.28 ** | -0.23 | 0.09 | -1.51 | 0.27 | -2.11 | -1.18 | -0.04 |
| EC-169459 × Pusa- A4 | 0.66 | 0.63 | 9.058 * | 0.18 | -0.43 | 0.16 | 1.31 ** | 1.13 * | 0.14 | 2.78 | 1.61 ** | 0.97 | 33.51 | 1.24 |
| EC-169459 × Parbhani Kranthi | -0.22 | -0.69 | 12.22 ** | 0.36 ** | 0.50 | -0.63 * | 0.77 | 1.61 ** | -0.10 | -1.67 | -0.16 | 4.81 ** | 76.63 ** | 2.83 ** |
| EC-169459 × Arka Anamika | 0.66 | -0.94 | -4.35 | -0.52 ** | 1.12 | 0.49 * | 0.31 | -0.78 | -0.09 | -2.97 | -1.25 * | -3.17 ** | -51.70 ** | -1.91 ** |
| EC-169459 × Pusa Sawani | 0.84 | 0.25 | -21.74 ** | 0.30 * | -1.81 * | -0.38 | 0.76 | -0.96 * | 0.09 | -0.43 | 0.45 | -0.21 | -20.72 | -0.77 |
| EC-169459 × Varsha Uphar | 0.16 | 0.69 | -13.84 ** | -0.11 | -0.55 | -0.57 * | -0.86 | -0.78 | -0.12 | 3.80 | -0.92 | -0.29 | -36.54 | -1.35 |
| OK-2017-009 × Kashi pragathi | 2.49 ** | 1.48 | -6.72 | -0.30 * | -1.72 * | -0.12 | 0.87 | 2.028 ** | -0.13 | 2.79 | -1.41 ** | -6.04 ** | -109.64 ** | -4.06 ** |
| OK-2017-009 × Pusa- A4 | -2.26 ** | -2.45 * | -3.62 | -0.23 | 0.97 | 0.74 ** | -1.78 ** | -1.20 * | -0.08 | 3.52 | 0.46 | 1.08 | -35.89 | -1.33 |
| OK-2017-009 × Parbhani Kranthi | -1.63 ** | -3.77 ** | -4.86 | 0.262 * | -0.70 | -0.46 | 1.239 * | -0.20 | -0.32 | -1.10 | -0.14 | 2.72 * | 35.14 | 1.30 |
| OK-2017-009 × Arka Anamika | 0.24 | 0.48 | 14.59 ** | -0.32 * | 1.32 | 0.81 ** | 0.66 | 0.23 | 0.29 | -3.09 | -0.54 | 2.04 | 67.21 ** | 2.48 ** |
| OK-2017-009 × Pusa Sawani | -0.07 | 1.67 | 11.12 * | 0.300 * | 0.59 | -0.10 | -0.49 | -0.43 | -0.03 | -0.72 | 0.50 | 1.70 | 40.02 * | 1.48 * |
| OK-2017-009 × Varsha Uphar | 1.24 * | 2.60 ** | -10.52 * | 0.28 * | -0.45 | -0.89 ** | -0.50 | -0.41 | 0.27 | -1.40 | 1.14 * | -1.50 | 3.15 | 0.12 |
| OK-2017-006 × Kashi pragathi | -0.67 | -1.35 | 10.34 * | -0.30 * | -0.39 | 0.519 * | -0.06 | -0.41 | 0.09 | -1.10 | 1.50 ** | 1.77 | 8.34 | 0.31 |
| OK-2017-006 × Pusa- A4 | -0.43 | -1.29 | 9.74 * | 0.47 ** | -0.19 | -0.57 * | 0.34 | 1.45 ** | 0.04 | -0.19 | 0.18 | 0.15 | 43.20 * | 1.60 * |
| OK-2017-006 × Parbhani Kranthi | 0.70 | 1.40 | -10.39 * | -0.24 | 0.33 | 0.84 ** | -0.91 | 0.89 | 0.00 | 0.96 | -1.30 ** | -1.60 | -41.79 * | -1.54 * |
| OK-2017-006 × Arka Anamika | -1.42 * | -0.85 | 4.24 | 0.37 ** | 1.65 * | -0.14 | -0.72 | -1.10 * | -0.19 | -3.17 | -0.59 | -0.29 | -13.64 | -0.50 |
| OK-2017-006 × Pusa Sawani | 0.26 | 0.33 | 1.14 | -0.40** | 0.22 | -0.35 | -0.63 | 0.00 | 0.19 | -2.72 | 0.71 | 0.97 | -11.85 | -0.44 |
| OK-2017-006 × Varsha Uphar | 1.57 ** | 1.77 | -15.05** | 0.09 | -1.61 * | -0.29 | 1.97 ** | -0.84 | -0.12 | 6.22 | -0.49 | -1.01 | 15.73 | 0.58 |
| **SEm±** | **0.55** | **0.92** | **4.48** | **0.13** | **0.68** | **0.24** | **0.48** | **0.47** | **0.17** | **3.70** | **0.48** | **1.16** | **18.94** | **0.70** |
| **CD at 5%** | **1.10** | **1.84** | **9.03** | **0.26** | **1.37** | **0.48** | **0.96** | **0.94** | **0.34** | **7.44** | **0.97** | **2.33** | **38.09** | **1.41** |
| **CD at 1%** | **1.46** | **2.46** | **12.05** | **0.34** | **1.83** | **0.64** | **1.28** | **1.25** | **0.45** | **9.93** | **1.30** | **3.11** | **50.83** | **1.88** |

*and** indicate significance of values at p= 0.05 and p= 0.01, respectively.

X1- Days to first flowering
X2- Days to 50 % flowering
X3 -Plant height 60DAS (cm)
X4- Number of branches per plant
X5- Number of nodes per plant
X6- Internodal length (cm)
X7- Fruit length (cm)
X8- Fruit diameter (mm)
X9- Number of ridges per fruit
X10- Number of seeds per fruit
X11- Average fruit weight (g)
X12- Number of fruits per plant
X13- Yield per plant (g)
X14- Yield per hectare (t)

## CONCLUSION

Line × tester analysis revealed that analysis of variance due to parents and hybrids showed significant difference for most of the traits indicating the presence of sufficient variation in genetic material. Based on the magnitude of relative heterosis, heterobeltosis and standard heterosis values significance for number of traits, the hybrids, OK-2017-010 x Pusa Sawani, OK-2017-010 x Parbhani Kranthi, OK-2017-012 × Parbhani Kranthi, OK- 2017-010 × Pusa- A4, EC-169459 × Pusa- A4, 21-10-1 × Kashi pragathi and OK-2017-006 × Varsha Uphar should be considered for increase yield through selection. According to combining ability IC-69304, VRO-5, OK-2017-010, OK - 2017-006, Pusa Sawani, Pusa-A4, Arka Anamika and Varsha Uphar parents performed better for most of the traits and could be used for developing desirable okra hybrids.Among hybrids EC-169459 × Parbhani Kranthi, OK-2017-010 × Varsha Uphar, OK-2017-010 × Arka Anamika and OK-2017-012 × Varsha Uphar revealed significant positive SCA effects indicating good specific combining ability for number of fruits per plant, yield per plant and yield per hectare. These hybrids could be exploited through heterosis breeding and may also give transgressive segregants in subsequent generations. Therefore, it would be worthwhile to use them for improvement in fruit yield.

## FUTURE SCOPE

From this experiment it is suggested that parental lines IC-69304 and 21-10-1 can be used as a parents in future breeding programmes due to high GCA effect in positive direction. The cross EC-169459 × Parbhani Kranthi showed significant positive SCA effect for most of the traits. The cross OK-2017-010 × Pusa Sawani exhibited superior performance in terms of heterosis so these crosses can be considered for further breeding development programmes.

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**Conflict of Interest**. None.

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