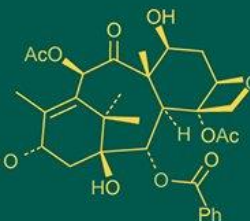
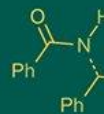


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## Combining ability studies for fruit yield and its component traits through diallel analysis in okra [*Abelmoschus esculentus* (L.) Moench]

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**Abstract**

Combining ability analysis is an effective approach for identifying superior parents and hybrids for yield improvement in okra (*Abelmoschus esculentus* (L.) Moench). In the present study, ten diverse parental genotypes were crossed in a  $10 \times 10$  half-diallel design (excluding reciprocals) to produce 45  $F_1$  hybrids. The hybrids, parents, and a standard check (GJOH-4) were evaluated during kharif 2023 in a randomized complete block design with three replications. Combining ability was estimated for eight yield and related traits using Griffing's Method II, Model I. Significant genetic variation was observed among genotypes, indicating substantial scope for genetic improvement. The parents GAO 8, GO 6, JOL 20-04, and GP1 were identified as superior general combiners, while the hybrids JOL 18-07  $\times$  GAO 5, GAO 5  $\times$  GO 6, JOL 20-04  $\times$  JOL 18-12, GP2  $\times$  GP1, and JOL 18-12  $\times$  GO 6 exhibited significant specific combining ability effects for fruit yield and associated traits. These promising parents and hybrids can be effectively utilized in heterosis breeding and the development of high-yielding okra cultivars.

**Keywords:** Okra, combining ability, general combining ability, specific combining ability, gene action, fruit yield

**Introduction**

Okra (*Abelmoschus esculentus* (L.) Moench), a member of the family *Malvaceae*, is an economically important vegetable crop cultivated widely in tropical and subtropical regions. In India, it occupies approximately 0.531 million hectares with an annual production of 6.46 million tonnes and an average productivity of  $12.17 \text{ t ha}^{-1}$  (Anonymous, 2022) <sup>[1]</sup>. The crop is valued for its nutritional quality, adaptability, short duration, and high market demand. However, productivity is often limited by a narrow genetic base and susceptibility to various biotic and abiotic stresses, necessitating the development of superior high-yielding cultivars. Combining ability analysis is an important tool in plant breeding for identifying superior parents and cross combinations and understanding the nature of gene action governing quantitative traits. Estimation of General Combining Ability (GCA) and Specific Combining Ability (SCA) provides valuable information for selecting suitable parents and exploiting heterosis in hybrid breeding programmes. Therefore, the present investigation was undertaken to evaluate the combining ability of ten diverse okra genotypes using a half-diallel mating design and to identify promising parents and hybrids for fruit yield and its component traits.

**Materials and Methods**

The experiment was carried out during *kharif* (July to October) 2023 at Centre for Vegetable Research, Department of GPB, C. P. college of agriculture, S. D. Agricultural University, Sardarkrushinagar. The basic materials consisted of ten genotypes of okra viz., JOL 20-04, NOL 11-12, JOL 18-07, JOL 18-12, GP2, GP1, GAO 5, GO 6, Pusa Sawani and GAO 8. These varieties were chosen for the current study based on genetic diversity for several agronomic features and maturity parameters. The genotypes were crossed in half diallel fashion without reciprocals to produce 45 hybrids in summer 2023.

These 45  $F_1$  along with their 10 parents and one standard check (GJOH 4) were evaluated in a randomized complete block design with three replicates during *kharif* (July to October) 2023. Inter and intra row spacing was kept 60 and 30 cm, respectively. Agronomic practices followed as per the standard recommendation and sufficient protection measures were taken to raise a healthy crop. So in this experiment analysis based on fruit yield and its other traits present in okra. Observations were recorded on days to 50% flowering, fruits per plant, fruit length (cm), fruit girth (cm), fruit weight (g), fruit yield per plant (g), plant height (cm) and internodal length (cm). Days to 50% flowering, plant height and internodal length was considered as negative trait in okra so low scoring parent considered as a better parent for estimation of heterobeltiosis. The combining ability analysis was done by following Model 1 (fixed effect) and Method 2 (Parents and hybrids without reciprocals) of Griffing (1956<sup>a</sup>) and Griffing (1956<sup>b</sup>)<sup>[3, 4]</sup>

## Results and discussion

### Combining ability and gene action

The analysis of variance for combining ability for eight characters furnished in Table 1. The ratio of  $\frac{2gca}{2sca}$  for fruit yield per plant and other trait under study was found less than unity. Therefore, prime role of preponderance non-additive gene action was observed for inheritance of all the traits.

### General and specific combining ability effects

#### 1. Days to 50% flowering

Parents with negative *gca* effect and hybrids with negative *sca* effect were considered as best for this trait because earliness was desirable trait in okra. The *gca* effects of parents ranged from -2.21 to 1.91. Among parents, the GAO 5 (-2.21) followed by GAO 8 (-0.82) and JOL 20-04 (-0.51) exhibited significant negative *gca* effects which confirmed to be good general combiner for this trait (Table 2). The *sca* effects for days to 50% flowering ranged from -6.02 to 9.70. Among them the crosses viz., JOL 20-04  $\times$  GAO 8 (-6.02) had highest significant negative *sca* effects followed by JOL 18-12  $\times$  Pusa Sawani (-5.96) and JOL 18-07  $\times$  GP2 (-5.43) for this trait so this crosses were good specific combiner (Table 3). The result of days to 50% flowering for *gca* and *sca* effect were in accordance with Budha Ram (2015)<sup>[2]</sup>, Satish *et al.* (2017)<sup>[13]</sup>, Makdooimi *et al.* (2018)<sup>[7]</sup>, Sapavadiya *et al.* (2019)<sup>[12]</sup>, Vekariya *et al.* (2020)<sup>[17]</sup>, Patel *et al.* (2021)<sup>[10]</sup> and Shinde *et al.* (2023)<sup>[14]</sup>.

#### 2. Fruits per plant

Positive value of *gca* and *sca* effect was considered as desirable for fruits per plant. The *gca* effects of parents ranged from -1.39 to 1.55. JOL 20-04 (1.55) showed highest significant positive *gca* effects followed by GAO 5 (1.24), GP1 (0.84) and GAO 8 (0.71) which indicating good general combiner for fruits per plant (Table 2). The range of *sca* effects for fruits per plant varied from -5.02 to 5.23. The cross JOL 18-07  $\times$  GAO 5 (5.23) considered good specific combiner followed by JOL 20-04  $\times$  JOL 18-12 (5.13) and GAO 5  $\times$  GO 6 (4.72) (Table 3). The results of *gca* and *sca* effects fruit per plant were comparable with findings of Budha Ram (2015)<sup>[2]</sup>, Kumar and Reddy (2016)<sup>[6]</sup>, Satish *et al.* (2017)<sup>[13]</sup>, Makdooimi *et al.* (2018)<sup>[7]</sup>, Vekariya *et al.* (2020)<sup>[17]</sup>, Patel *et al.* (2021)<sup>[10]</sup> and Shinde *et al.* (2023)<sup>[14]</sup>.

#### 3. Fruit length

For fruit length character, significant positive value of *gca* effect for parents and *sca* effect for crosses had to be considered as desirable. The *gca* effect for fruit length

ranged from -0.46 to 0.67. Among parents, GP2 (0.67) exhibited maximum significant positive *gca* effect, which was desirable for the character (Table 2). The cross JOL 20-04  $\times$  GAO 8 (1.78) was found superior specific combiner for fruit length followed by GO 6  $\times$  Pusa Sawani (1.65) and JOL 20-04  $\times$  GAO 5 (1.38) (Table 3). The results of *gca* and *sca* effects for fruit length were in confirmation with findings of Nagesh *et al.* (2014)<sup>[9]</sup>, Budha Ram (2015)<sup>[2]</sup>, Kumar and Reddy (2016)<sup>[6]</sup>, Jupiter and Kandasamy (2017)<sup>[5]</sup>, Paul *et al.* (2017)<sup>[11]</sup>, Vekariya *et al.* (2020)<sup>[17]</sup>, Patel *et al.* (2021)<sup>[10]</sup> and Shinde *et al.* (2023)<sup>[14]</sup>.

#### 4. Fruit girth

The *gca* effects of parents ranged from -0.23 to 0.25 for fruit girth. Four parent exhibited significant positive *gca* effects GP2 (0.25), JOL 18-07 (0.10), GAO 8 (0.09) and JOL 18-12 (0.07) that suggests to be this parents were good general combiner for improving fruit girth (Table 2). The *sca* effect of hybrids ranged from -0.72 to 0.95. 9 cross recorded significant positive *sca* effect for fruit girth. The cross GP2  $\times$  Pusa Sawani (0.95) followed by GP1  $\times$  GAO 8 (0.73), JOL 20-04  $\times$  GAO 8 (0.72) and JOL 18-07  $\times$  GP2 (0.72) possessed significant positive *sca* effect. Thus, this cross considered as good specific combiner for this trait (Table 3). Fruit girth *gca* and *sca* effect conformity with Vekariya *et al.* (2020)<sup>[17]</sup>, Patel *et al.* (2021)<sup>[10]</sup> and Shinde *et al.* (2023)<sup>[14]</sup>.

#### 5. Fruit weight

The *gca* effects of parents ranged from -0.71 to 1.31 for this trait. In addition, the parent, GAO 8 (1.31) depicted significant positive *gca* effects that concludes to be good general combiner for the character (Table 2). The *sca* effects ranged from -2.44 to 2.83 for fruit weight. Top four good specific combiners were GP2  $\times$  GAO 8 (2.83), GAO 5  $\times$  GO 6 (2.56), JOL 20-04  $\times$  JOL 18-12 (2.32) and JOL 18-12  $\times$  GP1 (2.32) for this trait (Table 4). The *gca* and *sca* effects of fruit weight were in accordance with Kumar and Reddy (2016)<sup>[6]</sup>, Jupiter and Kandasamy (2017)<sup>[5]</sup>, Paul *et al.* (2017)<sup>[11]</sup>, Makdooimi *et al.* (2018)<sup>[7]</sup>, Patel *et al.* (2021)<sup>[10]</sup> and Shinde *et al.* (2023)<sup>[14]</sup>.

#### 6. Fruit yield per plant

The *gca* effects of parents ranged from -31.24 to 32.74 for fruit yield per plant. Four parents, GAO 8 (32.74), GO 6 (10.63), JOL 20-04 (9.07) and GP1 (6.50) exhibited significant and positive *gca* effects that suggests to be good general combiner for fruit yield per plant (Table 2). The hybrids, JOL 18-07  $\times$  GAO 5 (90.74) observed highest significant positive *sca* effects followed by GAO 5  $\times$  GO 6 (88.51) and JOL 20-04  $\times$  JOL 18-12 (84.27) that indicated to be good specific combiner for this trait (Table 4). Budha Ram (2015)<sup>[2]</sup>, Kumar and Reddy (2016)<sup>[6]</sup>, Jupiter and Kandasamy (2017)<sup>[5]</sup>, Paul *et al.* (2017)<sup>[11]</sup>, Makdooimi *et al.* (2018)<sup>[7]</sup>, Vekariya *et al.* (2020)<sup>[17]</sup>, Patel *et al.* (2021)<sup>[10]</sup> and Shinde *et al.* (2023)<sup>[14]</sup> recorded similar results and confirmation with *gca* and *sca* effects for fruit yield per plant.

#### 7. Plant height

Ranged of *gca* effect was from -7.21 to 11.96 for plant height. Plant height was negative trait in okra so, the lower value was considered as desirable for this trait. Out of ten parents under study, three parents reported significant and negative *gca* effect for plant height. Based on the significant negative *gca* effect JOL 18-07 (-7.21) followed by NOL 11-

12 (-6.27) and GP 1 (-5.16) were found good general combiners for plant height (Table 2). For plant height, *sca* effect ranged from -27.77 to 30.67. Seven crosses registered significant and negative *sca* effect. Top three crosses NOL 11-12  $\times$  GO 6 (-27.77), GO 6  $\times$  GAO 8 (-25.51) and GAO 5  $\times$  Pusa Sawani (-23.52) had significant and negative *sca* effect for plant height. Hence, these crosses were considered as good specific combiner for this trait (Table 4). The present investigation of *gca* and *sca* effects for plant height were in agreement with the Singh *et al.* (2006)<sup>[16]</sup>, Mehta *et al.* (2007)<sup>[8]</sup>, Weerasekara *et al.* (2008)<sup>[19]</sup>, Wammanda *et al.* (2010)<sup>[18]</sup>, Singh (2011)<sup>[15]</sup>.

## 8. Internodal length

Internodal length was negative trait in okra so, the lower value was desirable for this trait. Out of the 10 parents under study, three parents NOL 11-12 (-0.65), JOL 18-07 (-0.60) and GP1 (-0.41) registered significant and negative *gca* effect (Table 2). The cross NOL 11-12  $\times$  GO 6 (-2.51) possessed maximum *sca* effect followed by the crosses GO 6  $\times$  GAO 8 (-2.40) and GAO 5  $\times$  Pusa Sawani (-2.12) (Table 4). Kumar and Reddy (2016)<sup>[6]</sup>, Paul *et al.* (2017)<sup>[11]</sup>, Satish *et al.* (2017)<sup>[13]</sup>, Makdooi *et al.* (2018)<sup>[7]</sup>, Vekariya *et al.* (2020)<sup>[17]</sup>, Patel *et al.* (2021)<sup>[10]</sup> and Shinde *et al.* (2023)<sup>[14]</sup> recorded similar results and confirmation with *gca* and *sca* effects for internodal length.

Parents were classified as good, average and poor combiners based on result of *gca* effects for different traits are presented in Table 5. Among all the parental genotypes under study, JOL 20-04 was found promising for other traits like days to 50% flowering and fruit yield per plant. Parental line NOL 11-12 was found good general combiner for plant height and internodal length. JOL-18-07 was found good general combiner for fruit girth, plant height and internodal length. Parent JOL 18-12 was found good general combiner of fruit girth. GP 2 was reported good general combiner for fruit length and fruit girth. GP 1 was reported good general combiner of fruits per plant, fruit yield per plant, plant

height and internodal length. Parent GAO 5 was found good general combiner of days to 50% flowering, fruits per plant, fruit length and fruit yield per plant. These parents have resulted in the production of superior single cross hybrids. GAO 8 was found good general combiner of all the trait except plant height. Hence these parental genotypes could be utilized in future breeding programmes for exploitation of hybrid vigour and also to generate a greater number of desirable segregants for fruit yield and yield attributing characters. The crosses exhibiting high mean performance may results from either good  $\times$  good, good  $\times$  average, average  $\times$  average and poor  $\times$  poor general combining parents. The good general combining parents when crossed do not always produce high *sca* effects. While, poor general combining parents not always produce low *sca* effects. So, any parental combination may result into high *sca* effects. Best performing top five hybrids having high specific combining ability effects for fruit yield per plant and other characters found with desirable direction presented in Table 6. The crosses JOL 18-07  $\times$  GAO 5 (90.74), GAO 5  $\times$  GO 6 (88.51), JOL 20-04  $\times$  JOL 18-12 (84.27), GP 2  $\times$  GP 1 (75.81) and JOL 18-12  $\times$  GO 6 (71.39) were reported with high and significant positive specific combining ability effects for fruit yield per plant. The hybrid JOL 18-07  $\times$  GAO 5 with high mean performance 313.80 g exhibited highest significant positive *sca* effect 90.74 for fruit yield per plant with the desirable and significant *sca* effects for days to 50% flowering, fruits per plant, fruit weight and internodal length. Next superior hybrid, GAO 5  $\times$  GO 6 had mean performance 338.08 g and significant positive *sca* effect 88.51 for fruit yield per plant. This cross also exhibited positive and desirable *sca* effect for days to 50% flowering and fruits per plant. The third crosses JOL 20-04  $\times$  JOL 18-12 had mean performance 321.54 g and significant positive *sca* effect 84.27 for fruit yield per plant. This cross also exhibited positive and desirable *sca* effect for days to 50% flowering, fruits per plant, fruit girth and fruit weight.

**Table 1:** Analysis of variance components (mean sum of squares) for combining ability of fourteen characters in okra

| Sources of variation        | d.f. | Days to 50 % flowering | Fruits per plant | Fruit length | Fruit girth | Fruit weight | Fruit yield per plant | Plant height | Internodal length |
|-----------------------------|------|------------------------|------------------|--------------|-------------|--------------|-----------------------|--------------|-------------------|
| GCA                         | 9    | 15.62**                | 12.52**          | 1.21**       | 0.24**      | 3.61**       | 3524.43**             | 399.37**     | 3.00**            |
| SCA                         | 45   | 15.31**                | 8.66**           | 0.56**       | 0.13**      | 2.40**       | 2276.43**             | 319.78**     | 2.33**            |
| Error                       | 108  | 0.85                   | 0.53             | 0.07         | 0.01        | 0.31         | 91.36                 | 36.63        | 0.19              |
| $\square 2gca$              |      | 1.23**                 | 1.00**           | 0.10**       | 0.02**      | 0.27**       | 286.09**              | 30.23**      | 0.23**            |
| $\square 2sca$              |      | 14.46**                | 8.14**           | 0.49**       | 0.12**      | 2.08**       | 2185.06**             | 283.15**     | 2.14**            |
| $\square 2gca/\square 2sca$ |      | 0.09                   | 0.12             | 0.19         | 0.16        | 0.13         | 0.13                  | 0.11         | 0.11              |

**Table 2:** Estimation of general combining ability effect associated with each parent for various characters in okra

| Parents     | Days to 50% flowering | Fruits per plant | Fruit length  | Fruit girth   | Fruit weight  | Fruit yield per plant | Plant height   | Internodal length |
|-------------|-----------------------|------------------|---------------|---------------|---------------|-----------------------|----------------|-------------------|
| JOL 20-04   | -0.51*                | 1.55**           | -0.10         | 0.01          | 0.04          | 9.07**                | 0.82           | -0.07             |
| NOL 11-12   | 0.41                  | -0.24            | 0.01          | -0.11**       | -0.20         | -2.50                 | -6.27**        | -0.65**           |
| JOL 18-07   | -0.40                 | -1.08**          | -0.03         | 0.10**        | 0.11          | -15.87**              | -7.21**        | -0.60**           |
| JOL 18-12   | 1.91**                | -0.63**          | -0.05         | 0.07*         | -0.03         | -7.00**               | 3.82*          | 0.36**            |
| GP2         | 1.16**                | -1.39**          | 0.67**        | 0.25**        | -0.13         | -6.07*                | -1.30**        | 0.02              |
| GP1         | -0.34                 | 0.84**           | -0.27**       | -0.15**       | 0.12          | 6.50*                 | -5.16**        | -0.41**           |
| GAO 5       | -2.21**               | 1.24**           | 0.15*         | 0.03          | -0.71**       | 3.74                  | 4.52**         | 0.25*             |
| GO 6        | 0.10                  | -0.20            | -0.46**       | -0.23**       | 0.13          | 10.63**               | -1.01*         | -0.08             |
| Pusa Sawani | 0.71**                | -0.80**          | -0.22**       | -0.05         | -0.62**       | -31.24**              | -0.16          | 0.15              |
| GAO 8       | -0.82**               | 0.71**           | 0.30**        | 0.09**        | 1.31**        | 32.74**               | 11.96          | 1.03**            |
| S.E. (gi)   | 0.25                  | 0.20             | 0.07          | 0.03          | 0.15          | 2.62                  | 1.66           | 0.12              |
| Range       | -2.21 to 1.91         | -1.39 to 1.55    | -0.46 to 0.67 | -0.23 to 0.25 | -0.71 to 1.31 | -31.24 to 32.74       | -7.21 to 11.96 | -0.65 to 1.03     |

\*P  $\leq$  0.05, \*\*P  $\leq$  0.01

**Table 3:** Estimates of specific combining ability effects associated with each cross combination for following four characters in okra

| Sr. No. | Hybrids                 | Days to 50% flowering | Fruits per plant | Fruit length  | Fruit girth   |
|---------|-------------------------|-----------------------|------------------|---------------|---------------|
| 1       | JOL 20-04 × NOL 11-12   | -1.91*                | 3.18**           | -0.27         | 0.05          |
| 2       | JOL 20-04 × JOL 18-07   | 6.23**                | -5.02**          | -0.29         | -0.21*        |
| 3       | JOL 20-04 × JOL 18-12   | -4.74**               | 5.13**           | -0.02         | 0.22*         |
| 4       | JOL 20-04 × GP2         | 2.68**                | -1.68**          | -0.97**       | -0.39**       |
| 5       | JOL 20-04 × GP1         | 4.51**                | 2.39**           | -0.06         | 0.06          |
| 6       | JOL 20-04 × GAO 5       | -0.63                 | -3.44**          | 1.38**        | -0.01         |
| 7       | JOL 20-04 × GO 6        | -1.60*                | -1.20*           | -0.27         | -0.07         |
| 8       | JOL 20-04 × Pusa Sawani | -0.55                 | -0.77            | -0.45*        | -0.23**       |
| 9       | JOL 20-04 × GAO 8       | -6.02**               | 4.13**           | 1.78**        | 0.72**        |
| 10      | NOL 11-12 × JOL 18-07   | 1.65*                 | -2.29**          | 0.03          | 0.09          |
| 11      | NOL 11-12 × JOL 18-12   | 2.01**                | -2.88**          | -0.18         | 0.01          |
| 12      | NOL 11-12 × GP2         | 2.76**                | 2.12**           | 1.04**        | -0.36**       |
| 13      | NOL 11-12 × GP1         | 2.93**                | 3.89**           | -0.29         | 0.13          |
| 14      | NOL 11-12 × GAO 5       | -2.21**               | -3.81**          | -0.41         | 0.03          |
| 15      | NOL 11-12 × GO 6        | -1.85*                | -1.70**          | 0.20          | 0.28**        |
| 16      | NOL 11-12 × Pusa Sawani | 3.87**                | 2.73**           | -0.98**       | -0.56**       |
| 17      | NOL 11-12 × GAO 8       | -4.93**               | -1.04            | -0.76**       | -0.72**       |
| 18      | JOL 18-07 × JOL 18-12   | 4.82**                | 0.63             | -0.11         | -0.17*        |
| 19      | JOL 18-07 × GP2         | -5.43**               | -1.44*           | 0.41          | 0.72**        |
| 20      | JOL 18-07 × GP1         | -4.60**               | -1.11            | 0.07          | 0.14          |
| 21      | JOL 18-07 × GAO 5       | -4.74**               | 5.23**           | -0.88**       | -0.40**       |
| 22      | JOL 18-07 × GO 6        | -5.38**               | -0.46            | 0.15          | 0.13          |
| 23      | JOL 18-07 × Pusa Sawani | -1.99*                | 0.39             | 0.21          | 0.10          |
| 24      | JOL 18-07 × GAO 8       | 0.54                  | -1.28*           | -0.36         | -0.07         |
| 25      | JOL 18-12 × GP2         | 2.59**                | -0.19            | 0.83**        | 0.25**        |
| 26      | JOL 18-12 × GP1         | 3.09**                | -4.09**          | 0.57**        | 0.09          |
| 27      | JOL 18-12 × GAO 5       | 4.95**                | -1.43*           | 0.06          | 0.02          |
| 28      | JOL 18-12 × GO 6        | -4.35**               | 4.42**           | -0.13         | 0.00          |
| 29      | JOL 18-12 × Pusa Sawani | -5.96**               | -1.56*           | -0.23         | -0.12         |
| 30      | JOL 18-12 × GAO 8       | 1.90*                 | -2.23**          | -0.09         | 0.03          |
| 31      | GP2 × GP1               | -3.16**               | 4.51**           | 0.95**        | -0.08         |
| 32      | GP2 × GAO 5             | 0.37                  | -1.89**          | -1.05**       | -0.32**       |
| 33      | GP2 × GO 6              | 2.07**                | -2.92**          | -0.31         | -0.10         |
| 34      | GP2 × Pusa Sawani       | 0.45                  | 0.27             | 0.87**        | 0.95**        |
| 35      | GP2 × GAO 8             | -1.68*                | -2.99**          | -1.25**       | -0.41**       |
| 36      | GP1 × GAO 5             | 1.20                  | -2.76**          | -0.33         | 0.03          |
| 37      | GP1 × GO 6              | 4.23**                | -2.11**          | 0.05          | 0.17          |
| 38      | GP1 × Pusa Sawani       | -3.71**               | -0.19            | 0.25          | -0.04         |
| 39      | GP1 × GAO 8             | -3.85**               | 2.51**           | 1.15**        | 0.73**        |
| 40      | GAO 5 × GO 6            | -3.24**               | 4.72**           | -0.03         | -0.14         |
| 41      | GAO 5 × Pusa Sawani     | 4.48**                | -1.56*           | -0.34         | -0.05         |
| 42      | GAO 5 × GAO 8           | -4.32**               | 4.61**           | 1.08**        | 0.50**        |
| 43      | GO 6 × Pusa Sawani      | 1.51*                 | -1.31*           | 1.65**        | 0.36**        |
| 44      | GO 6 × GAO 8            | 9.70**                | -3.82**          | -0.19         | 0.08          |
| 45      | Pusa Sawani × GAO 8     | 2.09**                | -1.69**          | -0.58**       | -0.15         |
|         | S.E.(Sij)±              | 0.76                  | 0.60             | 0.21          | 0.09          |
|         | Range                   | -6.02 to 9.70         | -5.02 to 5.23    | -1.25 to 1.78 | -0.72 to 0.95 |
|         | Positive significant    | 19                    | 13               | 10            | 09            |
|         | Negative significant    | 20                    | 23               | 08            | 10            |
|         | Total significant       | 39                    | 36               | 18            | 19            |

\*P ≤ 0.05, \*\*P ≤ 0.01

**Table 4:** Estimates of specific combining ability effects associated with each cross combination for following four characters in okra

| Sr. No. | Hybrids                 | Fruit weight | Fruit yield per plant | Plant height | Internodal length |
|---------|-------------------------|--------------|-----------------------|--------------|-------------------|
| 1       | JOL 20-04 × NOL 11-12   | 1.21*        | 38.43**               | 30.42**      | 1.85**            |
| 2       | JOL 20-04 × JOL 18-07   | 1.30**       | -26.53**              | -21.60**     | -2.03**           |
| 3       | JOL 20-04 × JOL 18-12   | 2.32**       | 84.27**               | 21.72**      | 1.67**            |
| 4       | JOL 20-04 × GP2         | 0.07         | -49.52**              | 5.11         | 0.63              |
| 5       | JOL 20-04 × GP1         | 0.18         | 28.97**               | -2.89        | -0.01             |
| 6       | JOL 20-04 × GAO 5       | -1.80**      | -73.87**              | -3.63        | 0.08              |
| 7       | JOL 20-04 × GO 6        | -1.73**      | -42.86**              | 6.14         | 0.86*             |
| 8       | JOL 20-04 × Pusa Sawani | 0.14         | -17.39*               | -6.06        | -0.25             |
| 9       | JOL 20-04 × GAO 8       | 0.65         | 48.57**               | 19.06**      | 1.92**            |
| 10      | NOL 11-12 × JOL 18-07   | 0.36         | -37.63**              | 8.42         | 0.39              |

|                      |                         |               |                 |                 |               |
|----------------------|-------------------------|---------------|-----------------|-----------------|---------------|
| 11                   | NOL 11-12 × JOL 18-12   | 0.05          | -8.26           | -22.65**        | -1.86**       |
| 12                   | NOL 11-12 × GP2         | -2.12**       | 45.62**         | 12.47*          | 1.42**        |
| 13                   | NOL 11-12 × GP1         | 1.52**        | 62.09**         | -5.07           | -0.01         |
| 14                   | NOL 11-12 × GAO 5       | -0.64         | -57.12**        | 9.49            | 1.38**        |
| 15                   | NOL 11-12 × GO 6        | 0.66          | 4.34            | -27.77**        | -2.51**       |
| 16                   | NOL 11-12 × Pusa Sawani | 0.50          | 17.18*          | 0.14            | 0.22          |
| 17                   | NOL 11-12 × GAO 8       | -0.86         | -17.71*         | 22.78**         | 1.72**        |
| 18                   | JOL 18-07 × JOL 18-12   | -1.89**       | -27.05**        | 7.37            | 1.00**        |
| 19                   | JOL 18-07 × GP2         | 0.70          | -36.64**        | -2.75           | -0.38         |
| 20                   | JOL 18-07 × GP1         | -2.44**       | -46.58**        | 2.78            | 0.14          |
| 21                   | JOL 18-07 × GAO 5       | 1.62**        | 90.74**         | -1.77           | -0.73*        |
| 22                   | JOL 18-07 × GO 6        | -0.15         | -4.91           | 12.28*          | 1.42**        |
| 23                   | JOL 18-07 × Pusa Sawani | 1.32**        | 12.20           | 13.71**         | 1.50**        |
| 24                   | JOL 18-07 × GAO 8       | -0.66         | -16.10*         | -4.23           | 0.18          |
| 25                   | JOL 18-12 × GP2         | -1.27**       | -44.99**        | -20.51**        | -1.86**       |
| 26                   | JOL 18-12 × GP1         | 2.32**        | -8.55           | 6.44            | 0.77*         |
| 27                   | JOL 18-12 × GAO 5       | -0.90         | -51.21**        | -4.04           | -0.07         |
| 28                   | JOL 18-12 × GO 6        | 1.49**        | 71.39**         | 30.51**         | 2.31**        |
| 29                   | JOL 18-12 × Pusa Sawani | -1.28**       | -18.12*         | -3.23           | -0.13         |
| 30                   | JOL 18-12 × GAO 8       | -1.10*        | -43.73**        | 12.38*          | 0.70          |
| 31                   | GP2 × GP1               | 2.25**        | 75.81**         | 6.06            | 0.67          |
| 32                   | GP2 × GAO 5             | -1.74**       | -52.07**        | 19.16**         | 1.41**        |
| 33                   | GP2 × GO 6              | 0.18          | 24.37**         | -1.97           | -0.09         |
| 34                   | GP2 × Pusa Sawani       | -1.46**       | -20.02*         | 4.13            | 0.40          |
| 35                   | GP2 × GAO 8             | 2.83**        | 28.59**         | -20.59**        | -1.58**       |
| 36                   | GP1 × GAO 5             | -1.36**       | -55.26**        | 6.48            | 0.90*         |
| 37                   | GP1 × GO 6              | 1.34**        | 3.06            | 6.15            | 0.60          |
| 38                   | GP1 × Pusa Sawani       | -1.99**       | -38.53**        | 1.30            | 0.07          |
| 39                   | GP1 × GAO 8             | 1.11*         | 51.48**         | 24.22**         | 1.79**        |
| 40                   | GAO 5 × GO 6            | 2.56**        | 88.51**         | 30.67**         | 2.28**        |
| 41                   | GAO 5 × Pusa Sawani     | 0.21          | -14.49          | -23.52**        | -2.12**       |
| 42                   | GAO 5 × GAO 8           | 1.51**        | 45.88**         | 19.47**         | 1.51**        |
| 43                   | GO 6 × Pusa Sawani      | -1.17*        | -46.07**        | -6.85           | -0.67         |
| 44                   | GO 6 × GAO 8            | 0.95*         | -34.60**        | -25.51**        | -2.40**       |
| 45                   | Pusa Sawani × GAO 8     | 0.91          | -10.20          | 18.52**         | 1.16**        |
| S.E.(Sij)±           |                         | 0.46          | 8.75            | 5.00            | 0.36          |
| Range                |                         | -2.44 to 2.83 | -73.87 to 90.74 | -27.77 to 30.67 | -2.51 to 2.31 |
| Positive significant |                         | 15            | 15              | 14              | 18            |
| Negative significant |                         | 13            | 22              | 07              | 08            |
| Total significant    |                         | 28            | 37              | 21              | 26            |

\*P ≤ 0.05, \*\*P ≤ 0.01

**Table 5:** Classification of parents with respect to general combining ability for different characters in okra

| Traits                | Parents   |           |           |           |      |      |       |      |             |       |
|-----------------------|-----------|-----------|-----------|-----------|------|------|-------|------|-------------|-------|
|                       | JOL 20-04 | NOL 11-12 | JOL 18-07 | JOL 18-12 | GP-2 | GP-1 | GAO 5 | GO 6 | Pusa Sawani | GAO 8 |
| Days to 5%flowering   | G         | A         | A         | P         | P    | A    | G     | A    | P           | G     |
| Fruits per plant      | G         | A         | P         | P         | P    | G    | G     | A    | P           | G     |
| Fruit length          | A         | A         | A         | A         | G    | P    | G     | P    | P           | G     |
| Fruit girth           | A         | P         | G         | G         | G    | P    | A     | P    | A           | G     |
| Fruit weight          | A         | A         | A         | A         | A    | A    | P     | A    | P           | G     |
| Fruit yield per plant | G         | A         | P         | P         | P    | G    | A     | G    | P           | G     |
| Plant height          | P         | G         | G         | P         | A    | G    | P     | A    | A           | P     |
| Internodal length     | A         | G         | G         | P         | A    | P    | P     | A    | A           | P     |

P: Poor combiner, A: Average combiner and G: Good combiner.

**Table 6:** Best performing parents and crosses on the basis of combining ability effects and mean performance for fruit yield per plant in okra

| S.N. | Parent                | gca effects | Mean (g) | Other traits found with desirable direction |
|------|-----------------------|-------------|----------|---------------------------------------------|
| 1    | GAO 8                 | 32.74**     | 274.60   | DF, FPP, FL, FG, FW                         |
| 2    | GO 6                  | 10.63**     | 224.84   | -                                           |
| 3    | JOL 20-04             | 9.07**      | 258.30   | DF, FPP                                     |
| 4    | GP1                   | 6.50**      | 211.95   | FPP, IL                                     |
| S.N. | Crosses               | sca effects | Mean (g) | Other traits found with desirable direction |
| 1    | JOL 18-07 × GAO 5     | 90.74**     | 313.80   | DF, FPP, FW, IL                             |
| 2    | GAO 5 × GO 6          | 88.51**     | 338.08   | DF, FPP                                     |
| 3    | JOL 20-04 × JOL 18-12 | 84.27**     | 321.54   | DF, FPP, FG, FW                             |
| 4    | GP2 × GP1             | 75.81**     | 311.44   | DF, FPP, FL, FW                             |
| 5    | JOL 18-12 × GO 6      | 71.39**     | 310.22   | DF, FPP, FW                                 |

\*P ≤ 0.05, \*\*P ≤ 0.01 DF = Days to 50% flowering, FPP = Fruits per plant, FL = Fruit length, FG = Fruit girth, FW = Fruit weight, PH = Plant height, IL = Inter nodal length.

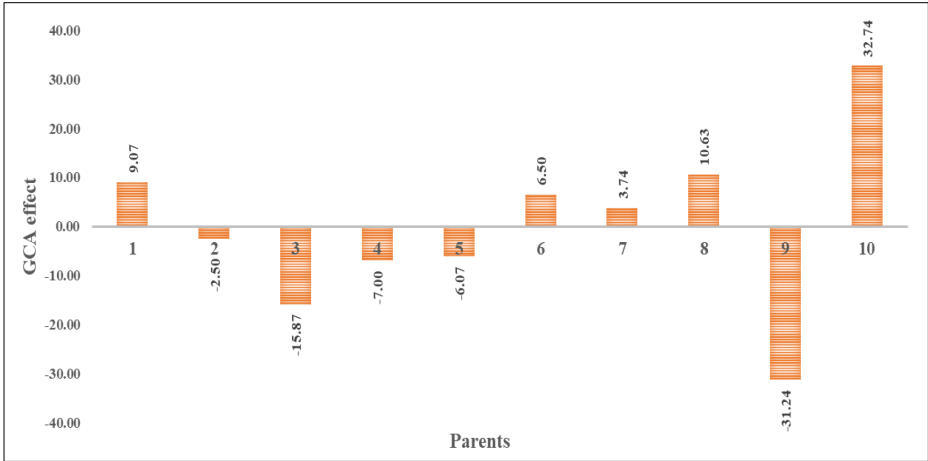


Fig 1: Graphical representation of *gca* effect of parents in okra for fruit yield per plant

|   |           |   |           |   |             |    |       |
|---|-----------|---|-----------|---|-------------|----|-------|
| 1 | JOL 20-04 | 4 | JOL 18-12 | 7 | GAO 5       | 10 | GAO 8 |
| 2 | NOL 11-12 | 5 | GP 2      | 8 | GO 6        |    |       |
| 3 | JOL 18-07 | 6 | GP 1      | 9 | Pusa Sawani |    |       |

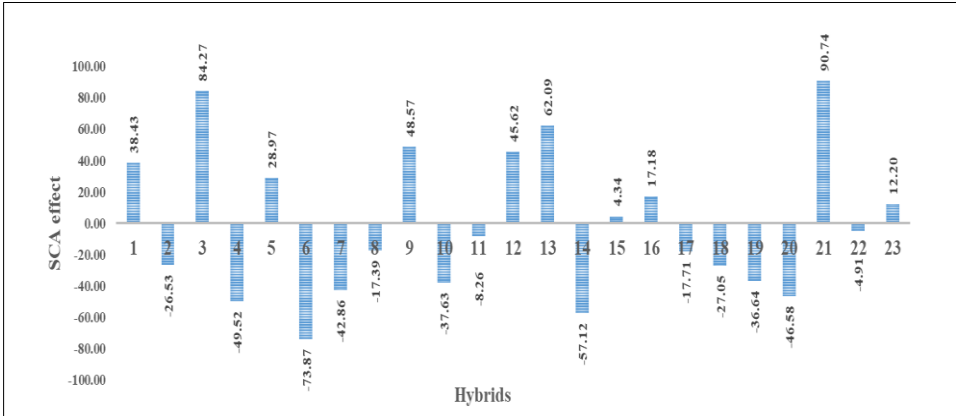


Fig 2: Graphical representation of *sca* effect of hybrids in okra for fruit yield per plant

|   |                       |    |                         |    |                         |    |                         |
|---|-----------------------|----|-------------------------|----|-------------------------|----|-------------------------|
| 1 | JOL 20-04 × NOL 11-12 | 7  | JOL 20-04 × GO 6        | 13 | NOL 11-12 × GP 1        | 19 | JOL 18-07 × GP 2        |
| 2 | JOL 20-04 × JOL 18-07 | 8  | JOL 20-04 × Pusa Sawani | 14 | NOL 11-12 × GAO 5       | 20 | JOL 18-07 × GP 1        |
| 3 | JOL 20-04 × JOL 18-12 | 9  | JOL 20-04 × GAO 8       | 15 | NOL 11-12 × GO 6        | 21 | JOL 18-07 × GAO 5       |
| 4 | JOL 20-04 × GP 2      | 10 | NOL 11-12 × JOL 18-07   | 16 | NOL 11-12 × Pusa Sawani | 22 | JOL 18-07 × GO 6        |
| 5 | JOL 20-04 × GP 1      | 11 | NOL 11-12 × JOL 18-12   | 17 | NOL 11-12 × GAO 8       | 23 | JOL 18-07 × Pusa Sawani |
| 6 | JOL 20-04 × GAO 5     | 12 | NOL 11-12 × GP 2        | 18 | JOL 18-07 × JOL 18-12   |    |                         |

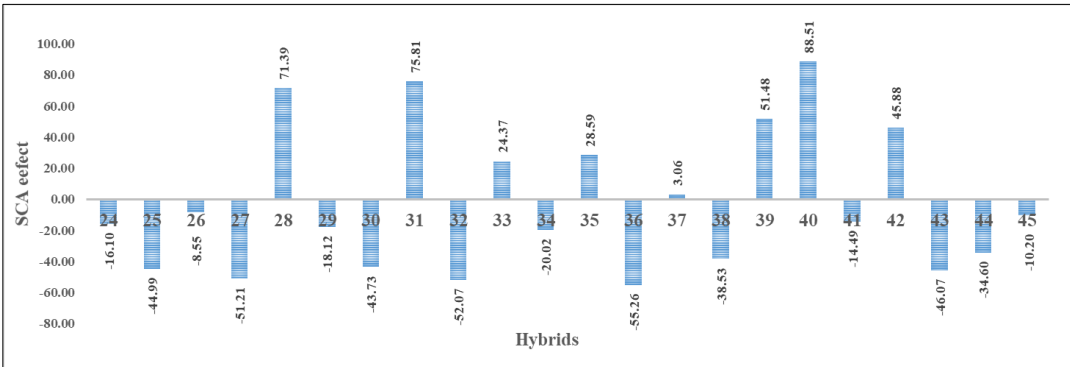


Fig 3: Graphical representation of *sca* effect of hybrids in okra for fruit yield per plant

|    |                         |    |                    |    |                     |    |                     |
|----|-------------------------|----|--------------------|----|---------------------|----|---------------------|
| 24 | JOL 18-07 × GAO 8       | 30 | JOL 18-12 × GAO 8  | 36 | GP 1 × GAO 5        | 42 | GAO 5 × GAO 8       |
| 25 | JOL 18-12 × GP 2        | 31 | GP 2 × GP 1        | 37 | GP 1 × GO 6         | 43 | GO 6 × Pusa Sawani  |
| 26 | JOL 18-12 × GP 1        | 32 | GP 2 × GAO 5       | 38 | GP 1 × Pusa Sawani  | 44 | GO 6 × GAO 8        |
| 27 | JOL 18-12 × GAO 5       | 33 | GP 2 × GO 6        | 39 | GP 1 × GAO 8        | 45 | Pusa Sawani × GAO 8 |
| 28 | JOL 18-12 × GO 6        | 34 | GP 2 × Pusa Sawani | 40 | GAO 5 × GO 6        |    |                     |
| 29 | JOL 18-12 × Pusa Sawani | 35 | GP 2 × GAO 8       | 41 | GAO 5 × Pusa Sawani |    |                     |

## Conclusion

The present study identified significant variation in combining ability among the parental genotypes and hybrids for fruit yield and its component traits in okra. The parents GAO 8, GO 6, JOL 20-04, and GP1 were recognized as superior general combiners, indicating their potential as valuable donors in future breeding programmes. Among the hybrids, JOL 18-07 × GAO 5, GAO 5 × GO 6, JOL 20-04 × JOL 18-12, GP2 × GP1, and JOL 18-12 × GO 6 exhibited high and significant specific combining ability effects for fruit yield per plant along with several important yield-contributing traits, making them promising candidates for hybrid development.

The  $\sigma^2\text{GCA}/\sigma^2\text{SCA}$  ratio was less than unity for fruit yield and all other traits studied, indicating the predominance of non-additive gene action in their inheritance. These findings suggest that heterosis breeding would be an effective approach for improving fruit yield and related traits in okra. Furthermore, the exploitation of non-additive genetic effects through biparental mating followed by selection in early segregating generations may facilitate the accumulation of favourable alleles and the identification of desirable transgressive segregants. Overall, the superior parents and cross combinations identified in this study provide valuable genetic resources for developing high-yielding and improved okra cultivars.

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