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# COMBINING ABILITY AND HETEROSIS OF YIELD AND YIELD RELATED CHARACTERS IN OKRA (*Abelmoschus esculentus* (L.) Moench)

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## ABSTRACT

**Exploitation of hybrid vigour and selection of parents on the basis of combining ability is an important breeding approach in crop improvement. In okra [*Abelmoschus esculentus* (L.) Moench], hybrid seed production is possible, since the pods contain a large number of seeds. Twenty four hybrids were developed utilizing eight lines and three testers, and they were studied during summer in 2006, for the extent of heterosis and determining the combining ability on yield and yield components. Parents and hybrids differed significantly for general combining ability (gca) and specific combining ability (sca) effects. The best general combines among the lines were KAO-25 and KAO-51, while those among the testers were KAO-23 and KAO-AA. Results obtained from different characters in the materials used in okra showed that non additive gene action is an integral component of the genetic architecture. An appreciable amount of heterosis was observed for the pod yield and yield component characters in majority of the crosses. The cross combinations KAO-53 X KAO-18, KAO-35 X KAO-AA, and KAO-17 X KAO-AA showed the highest magnitude of heterosis for pod yield and yield related characters for okra.**

**KEYWORDS:** Okra, GCA, SCA, Hybrid, Heterosis

## INTRODUCTION

Okra (*Abelmoschus esculentus* (L) Moench) or "*Bandakka*" (Sinhala), also known as ladies fingers, is an important vegetable crop in the world and is a native to tropical Africa. It is mainly used for thickening of soup and as a vegetable curry. In India, the major problem in okra cultivation is the lack of high yielding varieties along with locational specificity and disease tolerance. Of the various approaches being used to overcome the problem, the hybrid technology for exploitation of heterosis is considered as one of the desirable and sustainable approaches. The crop okra, which is categorized under "often cross-pollinated" group showed, high potential to produce hybrid seeds due to easy emasculation and high number of seed production per pollination. During the 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 the line *x* tester analysis has appeared to be the best and vastly useful breeding tool, which gives generalized picture of genetics of the characters under study. Studies on combining ability and heterosis help identify the best parents and crosses and provide sufficient genetic information on the inheritance of a character. Hence, the present investigation was undertaken to study the gene action in different quantitative traits, to study the combining ability and estimate the magnitude of heterosis for fruit yield and yield related characters in okra.

## MATERIALS AND METHODS

Experimental material comprised of eight lines, *viz.* KAO-10, KAO-16, KAO-17, KAO-25, KAO-35, KAO-52 (Parbhani Kranthi), KAO-53 and KAO-61, and 3 testers, *viz.* KAO-18, KAO-23 and KAO-AA (Arka Anamika). The testers were crossed with each line and thus, 24 $F_1$s were produced. The 11 parents and 24 $F_1$s along with commercial hybrid 'mahyco-10' were grown in a randomized block design with three replicates at the Botanical garden of the Department of Genetics and Plant Breeding, University of Agricultural Sciences, Dharwad, Karnatake, India, during summer 2006. Dharwad is located in the transitional tract of Karnataka state at 15° 13' N latitude, 75° 07' E longitude and at an altitude of 678 m above mean sea level with an average rainfall of about 800 mm. Row-to-row and plant-to-plant distances were maintained at 60 cm and 30 cm, respectively. The vigourous seedling was retained from 2 to 3 seeds sown at each hill. The crop protection and other cultural practices were carried out as recommended. Five plants of each entry in each replicate were randomly selected for recording the observations on days to 50 per cent flowering, number of branches per plant, plant height, number of pods per plant, days to pod maturity, pod weight, number of seeds per pod and pod yield per plant. The analysis of general and specific combining abilities for the above characters was calculated as the model suggested by Kempthorne (1957).

### Combining ability analysis

The variation among the hybrids was further partitioned into genetic components attributed to general combining ability (gca) and specific combining ability (sca). The analysis was based on the following mathematical model;

$$Y_{ijk} = \mu + g_i + g_j + s_{ij} + e_{ijk}$$

where,

$Y_{ijk}$ = Any character measured of the cross (i x j) in the $k^{th}$ replication.

$\mu$ = Population mean

gi = GCA effect on $i^{th}$ parent

gj = GCA effect of $j^{th}$ parent

sij = SCA effect of $(i \times j)^{th}$ cross

eijk = Random errors effect associated with $(i \times j)^{th}$ observation in $k^{th}$ replication

I = Number of female parents
J = Number of male parents
K = Number of replicates

**Estimation of variance**

The GCA and SCA variances were expressed in terms of co-variances of full sibs (FS) and half sibs (HS) a indicated below;

COV (FS) = Covariance of full sibs
COV (HS) = Covariance of half sibs

For expectations of the mean sum of squares, the following estimates were worked out;

$$\text{COV (HS)} = \frac{M1 - M3 + M2 - M3}{R\,(t + l)}$$

$$\text{COV (FS)} = \frac{(M1-M4)+(M2-M4)+(M3-M4)}{3r} + \frac{(6r\ \text{COV(HS)} - r(l+t)\text{COV (HS)}}{3r}$$

Variance due to GCA = COV (HS)
Variance due to SCA = COV (FS) – 2COV (HS)

$$\text{GCA variance for lines} = \frac{M1 - M3}{rt}$$

$$\text{GCA variance for testers} = \frac{M2 - M3}{rl}$$

$$\text{SCA variance for hybrids} = \frac{M3 - M4}{r}$$

where,
M1 = Mean sum of squares due to females
M2 = Mean sum of squares due to males
M3 = Mean sum of squares due to females x males
M4 = Mean sum of squares due to error

**Estimation of combining ability effects**

The combining ability effects were estimated as follows;

$$\mu = \frac{X.....}{ltr}$$

$$gi = \frac{Xi.....}{tr} - \frac{X.....}{ltr}$$

$$gj = \frac{Xi.....}{lr} - \frac{X.....}{ltr}$$

$$Sij = \frac{Xi.....}{r} - \frac{X.....}{tr} - \frac{Xi.....}{lt} + \frac{X.....}{ltr}$$

where,

X = Total of all the hybrids
Xi = Total of $i^{th}$ line overall females
Xj = Total of $j^{th}$ testers overall males
Xij = Total of $ij^{th}$ combination

**Estimation of heterosis**

The magnitude of heterosis was estimated in relation to mid-parental, better parental and standard check values. They were thus, calculated as percentage increase or decrease of $F_1$s over the mid-parent (MP), better parent (BP) and standard check (SC) using the methods of Turner (1953) and Hayes *et al.* (1956), as follows;

$$\text{Heterosis over mid parent (MP)} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

Where,

$$\overline{MP} = \frac{P_1 + P_2}{2}$$

$$\text{Heterosis over better parent (BP)} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Heterosis over standard check (SC)} = \frac{F_1 - SC}{SC} \times 100$$

where, $F_1$, BP and SC are mean values of $F_1$ hybrids, better parent and standard check respectively.

The significance of $F_1$ heterosis values was tested by comparing them with CD values obtained separately for MP, BP and SC employing the formula given below;

$$\text{CD for MP} = \sqrt{\frac{3/2 \times MSSe}{R}} \times \text{ t value}$$

$$\text{CD for BP and SC} = \sqrt{\frac{2 \times MSSe}{R}} \times \text{ t value}$$

where,

MSSe = Error mean sum of squares
R = Number of replication
t = Table t value

## RESULTS AND DISCUSSION

The analysis of variance indicated a significant differences ($p<0.01$) for almost all the characters suggesting presence of genetic variability (Table 1). The variance due to parents and crosses showed significant differences for all the characters indicating the presence of wide range of variability among those. Parent *vs* crosses showed significant differences for all the traits except fruit weight. Dharmadasa (2006), Rewale *et al.* (2003b), Dhankhar and Dhankhar (2001), Pawar *et al.* (1999) and Pathak and syamal (1997) also reported a wide range of variability for yield and other related economic characters in okra. In the analysis for combining-ability, the mean squares for females (Table 2) were significant ($p<0.01$) for all the characters except for plant height and days to pod maturity, which may be due to their unrelated origin. The variance due to males was significant for the traits, number of branches per plant, number of pods per plant, number of seeds per pod and pod yield. However, variance due to line and tester interaction, which expressed grater magnitude of mean squares among themselves, was significant for all the characters except pod weight. The higher *sca* variance of the selected characters indicates that the non-additive gene effect play a major role in the inheritance of the characters. These results are in agreement with that of Dharmadasa (2006), Sharma and Mahajan (1978) and Rewale *et al.* (2003a).

**Table 1. Analysis of variance for genetic variability**

| *Component* | *Parents* | *Crosses* | *Parent vs crosses* | *Error* |
|---|---|---|---|---|
| *df* | 10 | 23 | 1 | 46 |
| Days to 50 % flowering | 15.43** | 4.85** | 28.77** | 0.25 |
| No of branches per plant | 1.15** | 1.22** | 0.67** | 0.04 |
| Plant height | 858.72** | 62.56** | 28.02** | 15.73 |
| No of pods per plant | 21.44** | 38.57** | 159.56** | 3.79 |
| Days to pod maturity | 0.62** | 0.76** | 3.88** | 0.02 |
| Pod weight | 39.82** | 11.93** | 0.19 | 3.32 |
| No of seeds per pod | 436.26** | 590.10** | 497.18** | 9.24 |
| Pod yield per plant | 9494.24** | 19546.4** | 75757.4** | 675.48 |

** significant at p= 0.01.

**Table 2. Analysis of variance for the combining ability**

| *Component* | *Female* | *Male* | *Female x Male* | *Error* | $\sigma^2$ *gca* | $\sigma^2$ *sca* |
|---|---|---|---|---|---|---|
| *df* | 7 | 2 | 14 | 46 | | |
| Days to 50 % flowering | 9.66** | 2.35 | 2.81** | 0.25 | 0.047 | 0.859 |
| No of branches per | 2.08** | 4.05** | 0.38** | 0.04 | 0.019 | 0.115 |
| plant | 72.46 | 55.64 | 58.6** | 15.73 | 0.91 | 13.520 |
| Plant height | 58.91** | 90.68** | 12.74** | 3.79 | 0.479 | 2.782 |
| No of pods per plant | 0.53 | 1.31 | 0.8** | 0.02 | -0.001 | 0.264 |
| Days to pod maturity | 28.60** | 9.07 | 4.0 | 3.32 | 0.182 | 0.395 |
| Pod weight | 1516.64** | 524.67** | 136.18** | 9.24 | 10.450 | 41.770 |
| No of seeds per pod | 45407** | 20808.0** | 6435.6** | 675.48 | 301.85 | 1875.9 |
| Pod yield per plant | | | | | | |

** significant at p= 0.01.

Appreciable amount of heterosis, heterobeltiosis and standard heterosis to the extent of 75.68, 56.48 and 51.85 per cent, respectively, was observed for pod yield per plant (Table 3). The cross KAO-25 x KAO-23 exhibited these maximum heterosis values. Seven crosses over mid parent, four crosses over better parent and five crosses over standard check showed significant positive heterosis for number of pods per plant, which is the main component offering pod yield per plant. The extent of heterosis in the present study was relatively moderate when compared to the results of Rewale *et al.* (2003b), but comparable to the results reported by Singh and Mandal (1993) and Sivakumar *et al.* (1997) for these two characters.

Out of 24 hybrids twelve, six and ten crosses had earliness than their mid parent, better parent and standard check, respectively, showing negative significant heterotic values. The heterosis over mid parent and over better parent ranged from –9.15 to 6.08 per cent and –3.37 to 6.08 per cent, respectively for the character 50 per cent flowering. Similar results were reported by Partap *et al.* (1981) and Pawar *et al.* (1999). Out of 24 crosses sixteen, fifteen and eleven crosses showed significant heterosis over mid parent, better parent and standard check, respectively for days to pod maturity in the desired (negative) direction. The cross KAO-52 x KAO-23 showed the highest magnitude of negative heterosis over mid parent (-22.81%) and over better parent (-20.00%). Rewale *et al.* (2003b) also reported significant negative heterosis for this character.

In the case of plant height, 12 crosses showed positive and significant heterosis over mid parent value. The cross KAO-16 x KAO-AA (12.76 %) exhibited the highest magnitude of heterobeltiosis for this trait. Pathak and Syamal (1997) and Rewale *et al.* (2003b) also reported high heterotic values for this trait. Most of the crosses exhibited fair amount of average heterosis and heterobeltiosis for number of branches per plant. The crosses KAO-16 x KAO-AA (52.38 %), KAO-17 x KAO-AA (34.29%) and KAO-52 x KAO-23 (31.43 %) had high magnitude of heterosis over better parent for this trait. These results are in agreement with that of Poshiya and Shukla (1989), Ahmed *et al.* (1999), Dhankhar and Dhankhar (2001) and Rewale *et al.* (2003b).

Out of 24 hybrids, most of the crosses exhibited non-significant or negative heterotic value for fruit weight. Only two crosses KAO-35 x KAO-23 (23.71 %) and KAO-35 x KAO-AA (16.59 %) showed significant positive heterosis over mid parent and five crosses over standard check but, none of the cross combinations exhibited positive heterosis over the better parent for this character. A similar result was also reported by Ahmed *et al.* (1999). In the case of number of seeds per fruit, most of the crosses exhibited positive heterosis over mid parent, over the better parent and also over the standard check (the crosses with negative heterosis were considered as desirable in general). However, five crosses and 3 crosses manifested appreciable amount of average heterosis and heterobeltiosis, respectively for this trait. The crosses KAO-16 x KAO-AA (-17.16 %), KAO-61 x KAO-23 (-13.10 %) and KAO-61 x KAO-AA (-15.65 %) exhibited highly significant negative heterosis over better parent for number of seeds per pod in okra. This is in agreement with the results of Ahmed et al. (1999) who reported significant negative heterobeltiosis for number of seeds per pod.

Pod yield per plant is the ultimate and the most important trait. Mean value of the hybrids was higher than the mean values of their parents and also mean value of the standard check. However, the highest mean yield (482.47 g/plant) was given by the cross KAO-25 x KAO-23. This is much higher than the best parent KAO-10 (320.53 g/plant) and also the yield of the standard check (317.73 g/plant). Seven hybrids showed significant positive heterosis over the standard check. Four of them showed positive standard heterosis of more than 20 percent. Among these four hybrids, KAO-23 was involved as male parent in the cross KAO-25 x KAO-23 and male parent KAO-AA was involved in the crosses KAO-17 x KAO-AA, KAO-25 x KAO-AA and KAO-35 x KAO-AA indicating the potentiality of these lines as parental lines for improving productivity (Figure 1). Positive heterosis for pod yield was also reported by Dhankar *et al.* (1998), Sood and Kalia (2001) and Thippeswamy (2001). Rewale *et al.* (2003b) also reported positive heterosis to the extent of 208.5 per cent for the trait of pod yield per plant.

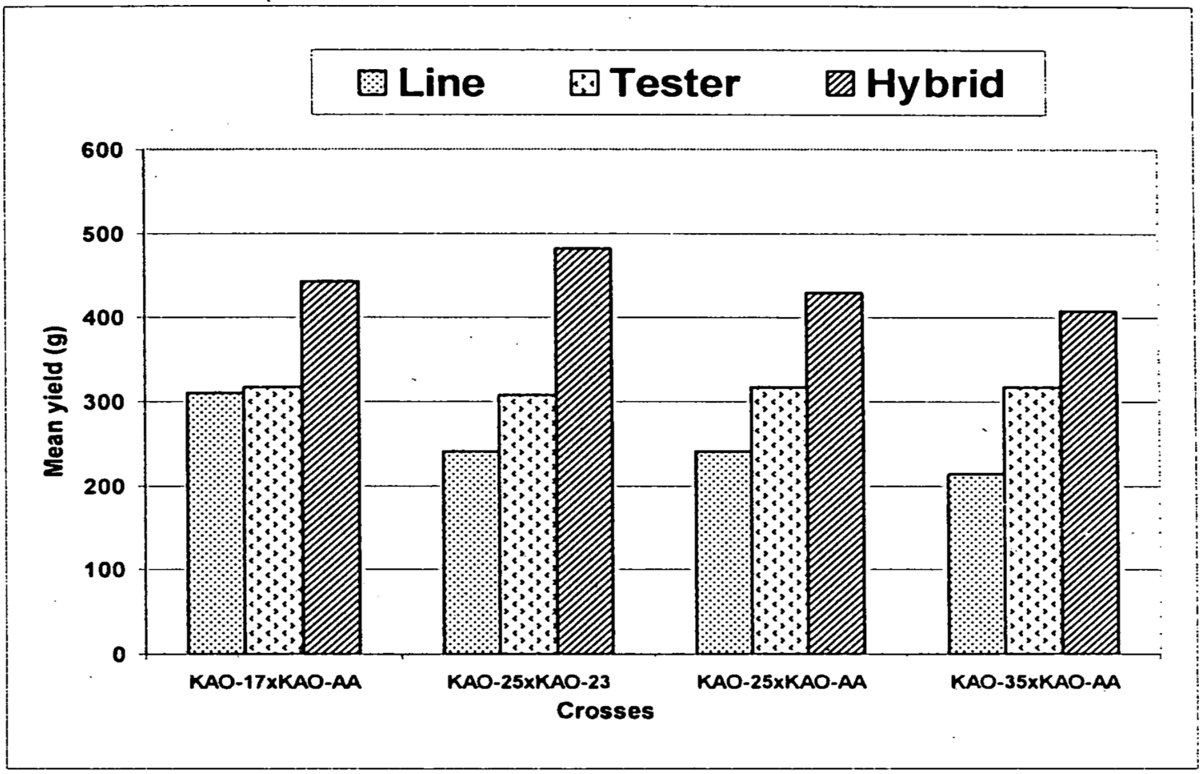


**Figure 1. Yield performance of best four hybrid cross combinations and their parental lines and testers**

**Table 3. Mid parent heterosis, heterobeltiosis and standard heterosis for pod yield and related characters of 24 cross combinations grouped on Line x tester basis in okra.**

| *Cross combination* | *Characters* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Days to 50 % flowering* | | | *No of branches/ plant* | | | *Plant height (cm)* | | | *No of pods/ plant* | | |
| Tester Line | MP | BP | SC | MP | BP | SC | MP | BP | SC | MP | BP | SC |
| KAO-18 x KAO-10 | -2.30** | 0.69 | 0.69 | -18.59* | -26.8** | -41.9** | 31.00** | -3.66 | -2.71 | 12.24 | 0.77 | -2.13 |
| x KAO-16 | -1.36 | -0.70 | -2.03** | 21.95* | 4.17 | -33.9** | -6.93* | -10.0** | -9.18** | -6.13 | -6.20 | -27.5** |
| x KAO-17 | 6.08** | 6.08** | 6.08** | 8.47 | -8.57 | -15.8** | -0.87 | -4.09 | -3.14 | 10.45 | 7.88 | -16.63 |
| x KAO-25 | -9.15** | -2.70** | -2.70** | 3.13 | -17.5** | -13.04 | 8.62** | 0.78 | 1.77 | 52.96** | 46.61** | 13.28 |
| x KAO-35 | -1.35 | -1.34 | -1.34 | -8.33 | -31.2** | -13.04 | 25.90** | -2.54 | -1.57 | 20.59* | 11.63 | 1.28 |
| x KAO-52 | -2.36** | -2.03** | -2.03** | -22.2** | -30.0** | -44.7** | 4.97 | 2.04 | 3.05 | -10.72 | -11.28 | -30.5** |
| x KAO-53 | -3.38** | -3.37** | -3.37** | -13.64 | -20.8** | -49.8** | 4.01 | 2.47 | 3.48 | 21.90** | 20.20 | -7.13 |
| x KAO-61 | -3.97** | -2.03** | -2.03** | -29.6** | -36.7** | -49.8** | 3.73 | -0.07 | 0.92 | 6.07 | -1.25 | -11.51 |
| KAO-23 x KAO-10 | -4.29** | -0.70 | -2.03** | 4.53 | -2.86 | -10.28 | 30.59** | -2.30 | -6.41 | 2.33 | -7.36 | 10.96 |
| x KAO-16 | 0.68 | 0.68 | -0.67 | 42.31** | 5.71 | -2.37 | -1.99 | -2.82 | -6.91* | 0.85 | -17.1* | -0.73 |
| x KAO-17 | 4.76** | 5.47** | 4.05** | 17.14** | 17.14* | 7.91 | 1.01 | 0.30 | -3.92 | 16.65 | -5.80 | 12.85 |
| x KAO-25 | -7.30** | 0.00 | -1.34 | 38.67** | 30.00** | 37.15** | 13.75** | 8.17* | 3.63 | 58.15** | 25.85** | 50.73** |
| x KAO-35 | -1.36 | -0.70 | -2.03** | -10.84* | -22.9** | -2.37 | 18.08** | -6.84 | -10.7** | 1.83 | -10.51 | 7.19 |
| x KAO-52 | -0.34 | 0.68 | -0.67 | 41.54** | 31.43** | 21.34** | 8.04* | 7.80* | 3.27 | 3.04 | -14.81 | 2.01 |
| x KAO-53 | 4.76 | 5.47** | 4.05** | -23.6** | -40.0** | -44.6** | -2.02 | -3.12 | -5.06 | -18.75* | -33.9** | -20.83* |
| x KAO-61 | -4.00** | -1.38 | -2.70** | -20.0** | -25.7** | -31.6** | 10.56** | 9.29* | 4.70 | 15.29 | 0.78 | 20.71* |
| KAO-AA x KAO-10 | -5.23** | -2.70** | -2.03** | 9.70 | -6.82 | -26.1** | 43.08** | 6.78 | 3.05 | 3.43 | -3.31 | 7.98 |
| x KAO-16 | 3.05** | 4.11** | 2.72** | 68.42** | 52.38** | -15.8** | 14.15** | 12.76** | 8.82** | 3.12 | -12.82 | -2.68 |
| x KAO-17 | 3.70** | 2.00** | 4.05** | 67.86** | 34.29** | 23.72** | 4.51 | 3.39 | -0.21 | 46.08** | 21.24* | 35.38** |
| x KAO-25 | -6.29** | 0.00 | 0.69 | 21.31** | -7.50 | -2.37 | 12.30** | 6.42 | 2.70 | 43.05** | 16.91 | 30.51** |
| x KAO-35 | -0.34 | 0.00 | 0.00 | 36.23** | -2.08 | 23.72** | 22.96** | -3.24 | -6.62 | 33.2** | 20.73* | 34.77** |
| x KAO-52 | -2.68 | -2.7** | -2.03** | 41.18** | 20.0* | -5.14 | 5.64 | 5.01 | 1.35 | -1.66 | -16.36 | -6.64 |
| x KAO-53 | -0.34 | 0.00 | 0.00 | 7.32 | 4.76 | -41.9** | 0.48 | -0.29 | -2.28 | -9.13 | -24.0** | -15.16 |
| x KAO-61 | -2.31 | -0.68 | 0.00 | 37.25** | 16.67* | -7.91 | 2.81 | 1.25 | -2.28 | -1.56 | -11.27 | -0.91 |

**Table 3 Continued.**

| *Cross combination* | *Characters* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Days to 50 % flowering* | | | *No of branches/ plant* | | | *Plant height (cm)* | | | *No of pods/ plant* | | |
| Tester Line | MP | BP | SC | MP | BP | SC | MP | BP | SC | MP | BP | SC |
| KAO-18 x KAO-10 | 15.0** | 23.66** | 10.68** | 10.02 | 3.35 | 25.58** | 40.87** | 69.89** | 115.4** | 20.94** | 2.82 | 4.70 |
| x KAO-16 | 0.90 | 4.67** | 7.79** | 2.14 | -10.62 | -4.55 | 5.26 | 15.33** | 22.77** | -3.97 | -16.14 | -40.2** |
| x KAO-17 | -12.9** | -12.1** | -9.52** | 1.69 | -14.5* | 34.15** | -9.23** | 9.09* | 38.33** | 12.84 | -2.52 | -4.48 |
| x KAO-25 | -6.54** | -6.54** | -3.75** | 7.61 | -0.26 | 24.75** | 25.22** | 25.89** | 57.94** | 58.71** | 53.98** | 16.77** |
| x KAO-35 | -5.21** | -3.85* | -3.75** | 9.59 | -0.80 | 5.93 | 35.34** | 41.15** | 64.83** | 32.74** | 29.3** | -7.78 |
| x KAO-52 | -10.2** | -5.61** | -2.89 | 2.35 | -7.31 | -1.02 | 26.18** | 43.81** | 42.53** | -8.77 | -17.51 | -41.2** |
| x KAO-53 | 3.14* | 7.48** | 10.68** | 3.55 | 1.74 | 8.63 | 8.71* | 20.78** | 53.16** | 25.57** | 21.30* | -13.5* |
| x KAO-61 | 5.31** | 5.80** | 7.94** | -11.69 | -12.33 | -4.97 | 3.57 | 7.79 | 36.69** | 5.52 | -2.45 | -18.0** |
| KAO-23 x KAO-10 | -0.49 | 8.60** | -2.89 | 4.27 | -7.0 | 13.0 | 17.46** | 43.15** | 68.43** | 22.35** | 19.47** | 21.65** |
| x KAO-16 | -15.6** | -13.6** | -8.66** | 17.13 | 7.82 | 2.70 | -2.01 | 6.33 | 13.18** | 16.86* | -9.51 | -12.19 |
| x KAO-17 | 5.02** | 5.50** | 10.68** | -3.62 | -22.6** | 21.57** | 0.94 | 22.6** | 52.71** | 21.73** | 21.15** | 18.71** |
| x KAO-25 | -2.30 | -0.93 | 2.02 | -0.78 | -0.26 | 9.29 | 48.26** | 48.8** | 85.34** | 75.68** | 56.48** | 51.85** |
| x KAO-35 | -7.48** | -4.81** | -4.76** | 23.71** | 18.05* | 12.46 | 33.62** | 38.08** | 61.24** | 20.69** | 2.40 | -0.63 |
| x KAO-52 | -22.8** | -20.0** | -15.3** | 10.54 | 5.54 | 0.54 | 1.47 | 14.50* | 13.47** | 13.31 | -9.69 | -12.36 |
| x KAO-53 | -10.6** | -8.18** | -2.89 | -4.64 | -8.26 | -5.45 | -4.98 | 6.61 | 32.79** | -21.1** | -33.5** | -35.5** |
| x KAO-61 | -6.48** | -4.72** | -2.89 | 0.19 | -5.88 | 1.98 | -17.3** | -13.1** | 8.24 | 15.77* | 8.00 | 4.81 |
| KAO-AA x KAO-10 | -8.0** | -1.08 | -11.5** | -12.54 | -19.05* | -1.62 | 15.38** | 49.2** | 68.43** | -9.83 | -10.76 | -9.13 |
| x KAO-16 | -9.91** | -6.34** | -3.75** | -3.31 | -14.21 | -11.26 | -19.6** | -17.2** | -11.81* | -3.11 | -25.7** | -25.8** |
| x KAO-17 | -4.63** | -3.74* | -0.87 | -8.49 | -24.1** | 19.17* | 10.96** | 42.97** | 61.40** | 40.95** | 39.72** | 39.34** |
| x KAO-25 | -6.54** | -6.54** | -3.75** | 5.07 | -4.02 | 20.07* | 39.45** | 47.21** | 66.18** | 54.20** | 35.72** | 35.36** |
| x KAO-35 | 3.32* | 4.81** | 4.91** | 16.59* | 7.07 | 10.72 | 43.02** | 45.49** | 64.23** | 53.74** | 28.99** | 28.64** |
| x KAO-52 | -18.2** | -14.0** | -11.5** | 4.71 | -3.80 | -0.48 | -8.19 | -1.81 | -2.69 | 11.13 | -12.31 | -12.55 |
| x KAO-53 | -9.42** | -5.61** | -2.89 | -5.46 | -5.64 | -2.40 | -8.33* | 8.75 | 22.77** | -14.15* | -28.5** | -28.6** |
| x KAO-61 | -6.57** | -6.13** | -4.33** | -9.85 | -11.91 | -4.55 | -23.8** | -15.6** | -4.78 | -11.34 | -18.3** | -18.5** |

## Estimates of gca effects

The estimates of gca effects (Table 4) showed that the parents KAO-52, KAO-61, KAO-10, KAO-25 and KAO-35 were good general combiners for days to 50 per cent flowering, the parent KAO-52 was for days to pod maturity and parents KAO-16, KAO-61, KAO-52 and KAO-AA were good general combiners for number of seeds per pod with negative significant gca effects, which is preferred. High gca effect was also observed in KAO-25, KAO-17, KAO-35 and KAO-23 for number of branches per plant, KAO-25 for plant height, KAO-17 and KAO-25 for pod weight and KAO-25, KAO-17, KAO-35, KAO-10 and KAO-23 for pod yield per plant. It was observed that performance of parents bear direct relation for their respective gca effects. In the parents that showed highest gca effects for different characters, good performance was also observed with respect to respective characters. For example, line KAO-17 which yielded high, also showed high gca effects for this trait. But this was not true always. This confirmed the findings of Sharma and Mahajan (1978).

## Estimates of sca effects

The best hybrids possessing sca effects in the desired direction for pod yield and yield related characters are presented in Table 5 along with their *per se* performance. Negative effects are considered to be desirable for days to 50 per cent flowering (as earliness is preferred over lateness), days to pod maturity and number of seeds per pod. The crosses KAO-52 x KAO-23 for number of branches per plant, KAO-16 x KAO-AA for plant height, KAO-53 x KAO-18 for number of pods per plant, KAO-10 x KAO-18 for pod weight and KAO-53 x KAO-18, KAO-35 x KAO-AA and KAO-17 x KAO-AA for pod yield per plant were found to be the specific combinations showing favorable sca effects for the characters mentioned. The specific combining ability, which represents the predominance of non-additive gene action, is a major component that may be utilized in heterosis breeding. Heterosis in the cross involving low x high combiners might be due to dominant x additive type of interaction, which is partially fixable and the crosses involving both the poor combining parents showing high sca must be due to intra and inter allelic interactions. Similar results have been reported by Dhankar *et al.* (1998).

The cross KAO-53 x KAO-18 showed the highest ($p<0.05$) sca for pod yield per plant. But both the parents showed negative gca effect due to complementation of favorable genes for this character (Table 4). Therefore, it cannot be generalized that the parents with high gca effects could only produce good hybrids. Similar results were observed by Sivagamasundari *et al.* (1992), Dhankar and Dhankar (2001) and Rewale *et al.* (2003a).

**Table 4. Estimates of general combining ability effects of parents**

| *Parent* | *50 % flowe ring* | *No. of bran Ches/ plant* | *Plant height* | *No of pods/ plant* | *Days to pod maturity* | *Pod weight* | *No of seeds/ pod* | *Pod yield per plant* |
|---|---|---|---|---|---|---|---|---|
| Line | | | | | | | | |
| KAO-10 | -0.46** | -0.31** | -0.94ns | 0.33 ns | 0.03 ns | 0.85 ns | 19.61** | 26.03 ** |
| KAO-16 | 0.10 ns | -0.08ns | -1.32ns | -2.27** | 0.01 ns | -1.94** | -15.73 ** | -75.12 ** |
| KAO-17 | 2.43 ** | 0.49** | -1.32ns | 1.14 ns | 0.12** | 2.95 ** | 3.32 ** | 64.52 ** |
| KAO-25 | -0.46** | 0.54 ** | 3.48 * | 4.59 ** | -0.01 ns | 1.80 ** | 11.78 ** | 117.90 ** |
| KAO-35 | -0.46** | 0.43 ** | -4.97** | 1.79 * | 0.03 ns | 0.41 ns | 8.94 ** | 29.21 ** |
| KAO-52 | -0.68** | 0.12 ns | 3.34 * | -2.51** | -0.57 ** | -1.27 * | -11.39 ** | -62.19 ** |
| KAO-53 | 0.21 ns | -0.79** | -0.26ns | -2.94** | 0.23 ** | -1.17 * | -3.17 ** | -74.46 ** |
| KAO-61 | -0.68** | -0.39** | 1.99 ns | -0.13ns | 0.14 ** | -1.63** | -13.35 ** | -25.88 ** |
| S.E. ± | 0.2267 | 0.0948 | 2.0013 | 0.9888 | 0.0582 | 0.7915 | 1.5532 | 13.3999 |
| <u>*Tester*</u> | | | | | | | | |
| KAO-18 | | | | | | | | |
| KAO-23 | -0.32** | -0.47** | 0.09 ns | -2.24** | 0.27 ** | 0.63 ns | 4.72 ** | -33.40 ** |
| KAO-AA | 0.01 ns | 0.28 ** | -1.56ns | 1.12 * | -0.09 ** | -0.04ns | -0.09 ns | 22.21 ** |
| S.E. ± | 0.31 ** | 0.19 ** | 1.48 ns | 1.13 * | -0.17 ** | -0.59ns | -4.63 ** | 11.18 ns |
| | 0.1388 | 0.0580 | 1.2255 | 0.6055 | 0.0357 | 0.4847 | 0.9511 | 8.2057 |

**Table 5. Hybrid possessing sca effects in the desired direction for fruit yield and yield components.**

| *Character* | *Hybrids with desired sca effects* | *Per se performance of hybrids* | *gca effects of parents involved* |
|---|---|---|---|
| Days to 50 % flowering | KAO-53 x KAO-18 | 47.67 | H X L |
| | KAO-10 x KAO-AA | 48.33 | L X H |
| | KAO-16 x KAO-18 | 48.33 | A X L |
| Number of branches/ plant | KAO-52 x KAO-23 | 3.07 | H X H |
| | KAO-25 x KAO-23 | 3.47 | H X H |
| | KAO-53 x KAO-18 | 1.27 | L X L |
| Plant height | KAO-16 x KAO-AA | 101.93 | A X H |
| | KAO-61 x KAO-23 | 98.07 | L X H |
| | KAO-53 x KAO-18 | 96.93 | L X L |
| Number of pods per plant | KAO-53 x KAO-18 | 15.25 | L X L |
| | KAO-17 x KAO-AA | 22.23 | L X H |
| | KAO-35 x KAO-AA | 22.13 | L X H |
| Days to pod maturity | KAO-17 x KAO-18 | 6.27 | L X L |
| | KAO-10 x KAO-AA | 6.13 | L X H |
| | KAO-35 x KAO-18 | 6.67 | L X L |
| Pod weight | KAO-10 x KAO-18 | 20.96 | L X L |
| | KAO-16 x KAO-23 | 17.14 | A X H |
| | KAO-25 x KAO-AA | 20.04 | H X H |
| Number of seeds per pod | KAO-17 x KAO-18 | 61.06 | L X L |
| | KAO-25 x KAO-18 | 70.33 | H X L |
| | KAO-52 x KAO-AA | 43.33 | H X H |
| Pod yield per plant | KAO-53 x KAO-18 | 274.87 | L X L |
| | KAO-35 x KAO-AA | 408.73 | L X H |
| | KAO-17 x KAO-AA | 442.73 | L X H |

## CONCLUSIONS

Hybrid vigour can be exploited in okra for increasing pod yield through increased plant height and increased number of branches and pods per plant. Heterosis for traits such as the number of seeds per pod, pod weight and days to pod maturity reduced pod yield in okra hybrids as they were in undesired direction. Genotype KAO-25, KAO-17, KAO-35, KAO-10, KAO-23 can be recommended for use as one of the parents to generate high yielding and better quality hybrids, as well as in the varietal improvement programme due to their high gca effects for many characters.

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