Original Research Article

Studies on Combining Ability for Yield and Its Component Traits in Rabi Sorghum [Sorghum bicolor (L.) Moench]

N. Sandeep, B.D. Biradar*, Mruthunjaya C. Wali and R.A. Balikai

Department of Genetics and Plant Breeding
University of Agricultural Sciences, Dharwad – 580 005, Karnataka, India

*Corresponding author

ABSTRACT

The study was carried out to assess the general combining ability of the parents and specific combining ability of the hybrids, using line x tester mating design. Fifty hybrids (derived from mating two testers with twenty-five lines in L x T design) along with their parents and checks (M35-1, BJV 44 and PKV Kranti) were evaluated during the rabi 2018-19. The ratio of $\sigma^2_{GCA}/\sigma^2_{SCA}$ was less than unity for all the characters except for panicle indicating preponderance of non-additive gene action. Among female parents M31-2A was the best combiner for grain yield per plant, number of seeds per plant and 100 seed weight and 104A for panicle length. Among male parents, IS 995, IS 19450, IS 23590 and IS 23891 were found to be the best general combiner for grain yield per plant and number of seeds per panicle. The cross combinations viz., M 31-2A × IS 11619 and M 31-2A × IS 32439 exhibited highest and positive sca effects for grain yield per plant.

Keywords: line × tester, GCA, SCA, Combining ability, Rabi sorghum

Introduction

Sorghum [Sorghum bicolor (L.) Moench] is one of the important cereal crop cultivated globally for food, fodder, feed and fuel. It ranks fifth after wheat, rice, maize and barley in area and production. It is the second cheapest source of energy and micronutrient after pearl millet. It is mainly grown in semi-arid tropics of Asia, Africa, America and Australia. In Africa and Asia sorghum grain is mainly used as food, while in the United States and Australia it is used to feed cattle (Reddy et al., 2013). Globally, sorghum is grown in an area of 42.50 million hectares to produce 59.91 million tonnes, with the productivity of around 1.60 tonnes per hectare.

Sorghum has wide range of adaptability to various agroecological situations of the region. Combining ability studies provide useful information regarding the selection of suitable parents for effective hybridization programme (Sprague and Tatum, 1942). It also indicates the nature and magnitude of various types of gene action involved in the expression of quantitative characters. Such information is of potential use in formulating and executing an efficient breeding programme for achieving maximum genetic gain with minimum
resources and time. Hence, this study was conducted with the aim to estimate the combining ability of the selected lines and testers in sorghum.

**Materials and Methods**

The male sterile lines *viz.*, 104A and M 31-2A representing *milo* and maldandi sources of male sterility, respectively were used as testers. Twenty-five diverse germplasm accessions were selected from minicore collection and were crossed to each of these two male sterile lines in line x tester fashion (Kempthorne, 1957) to obtain 50 hybrids. These 50 hybrids along with their parents and three checks *viz.*, M-35-1, BJV 44 and PKV Kranti were grown in randomized block design during rabi 2018-19 at Dharwad. The hybrids were grown each in a single row of four meters length in three replications with spacing of 45 cm x 15 cm and all the recommended agronomic practises are followed to raise the good crop.

Biometrical observations was recorded on five randomly selected competitive plants in each replication for the traits *viz.*, days to 50 per cent flowering, plant height (cm), number of leaves per plant, panicle length (cm), panicle width (cm), number of primaries per panicle, number of seeds per panicle, panicle weight (g), 100 seed weight (g) and grain yield per plant(g). The mean values of observations were subjected to statistical analysis to estimate general combining ability (gca) and specific combining ability (sca) effects of the parents and crosses (Panse and Sukhatme, 1967).

**Results and Discussion**

The analysis of combining ability variance for yield and yield related traits is presented in Table 1. The mean sum of squares due to crosses was found to be significant for all the traits. The mean sum of squares due to lines was significant for all the traits except for number of primaries per panicle. The traits like plant height, number of leaves, panicle length, panicle weight, grain yield per plant and 100 seed weight have shown peak significant mean sum of squares among the testers. The line x tester effects also shown significant mean sum of squares for all the traits.

The per cent contribution of lines, testers and line × tester along with estimates of GCA and SCA variance are presented in Table 1. The magnitude of SCA variance was higher than GCA variance for all the nine traits studied except for panicle length (Jadhav and Deshmukh 2017) indicating the presence of non-additive variance and non-additive gene action indicates preponderance of non-additive gene action. Prevalence of non-additive gene action in sorghum was reported by Kumar and Chand (2015) and Dehiwai et al. (2017).

It is evident from the table that lines revealed preponderance influencer in the expression all traits studied *viz.*, days to 50 per cent flowering (77.50 %), plant height (57.87%), number of leaves per plant (74.12 %), number of primaries per panicle (53.52 %), panicle length (52.32%), panicle width (53.79 %), panicle weight (58.93 %), grain yield per plant (51.69 %), number of seeds per panicle (71.54 %) and 100 seed weight (71.52 %).

**General combining ability (gca) effects**

Significant and negative gca effects are desirable for days to 50 per cent flowering. Out of twenty-five lines, twenty-three lines showed significant gca effect for days to 50 per cent flowering. However, eleven were in negative and twelve were in positive direction. IS 19975 (14.03) and IS 26025 (6.83) accounted for high gca in negative direction which is desirable. None of the testers was found to be significant in either positive or negative direction for gca effect (Table 2).
As regards to plant height the magnitude of variation for \textit{gca} effects for lines ranged from 17.50 (IS 30451) to -29.32 (IS 26617). The lines \textit{viz.}, IS 30451 (17.50) and IS 4581 (17.30) were found to have positive significance. Extreme negative significant \textit{gca} effect was indexed by the line IS 26617. In case of testers, M 31-2A (5.24) had positive significance.

With respect to number of leaves per plant estimates of \textit{gca} were significant for 15 lines and out of which seven were found to be in positive direction. The lines \textit{viz.}, IS 31651 (2.92), IS 30451 (2.08) and IS 11619 (1.92) and tester M 31-2A (0.54) were found having significant \textit{gca} positive effect.

The estimates of \textit{gca} effects for panicle width varied from -0.93 (IS 19450) to 0.90 (IS 26025). Out of 25 lines, 16 indexes for significant \textit{gca} effects. Of all these, the lines \textit{viz.}, IS 26025 (0.90), IS 30451 (0.78), IS 25989 (0.68) and IS 24462 (0.65) have accounted for highest \textit{gca} effect for panicle width. The magnitude of variation of \textit{gca} effects for panicle length among lines varied from 9.41 (IS 602) to -5.41 (IS 11619). Out of 25 lines, 14 exhibited significant \textit{gca} effects, seven lines exhibited significant positive \textit{gca} effect in positive direction. The line \textit{viz.}, IS 602 (9.41) accounted for highest significant \textit{gca} effect in positive direction. Among testers, M 31-2A (2.26) had positive significance.

Among 25 lines, 20 lines accounted for significant \textit{gca} effect for number of primaries per panicle. Out of 9 lines which were showing positive \textit{gca} effects the lines \textit{viz.}, IS 19450 (13.73) and IS 29269 (9.23) accounted for highest significant \textit{gca} effect in positive direction. Among testers, M 31-2A (1.78) was found positively significant.

The range of \textit{gca} effects for panicle weight for lines and testers varied from -21.88 (IS 20679) to 26.83 (IS 32439) and -4.62 (104A) to 4.62 (M 31-2A), respectively. Among lines, IS 32439 (26.83) and IS 19450 (25.36) showed peak positive significant \textit{gca} effect. In contrast, the lines IS 20679 (21.85) and IS 602 (18.50) showed peak negative significant \textit{gca} effect. Among testers, M 31-2A exhibited positive significant \textit{gca} effect.

Grain yield per plant is very important yield contributing trait. Among lines, the magnitude of variation of \textit{gca} effects for grain yield per plant varied from -13.13 (IS 20679) to 13.58 (IS 19450). The lines \textit{viz.}, IS 19450 (13.58), IS 23590 (11.94) and IS 23891 (11.39) accounted for highest significant positive \textit{gca} effects. Among testers, M 31-2A (3.79) exhibited significant positive \textit{gca} effect. For number of seeds per panicle the \textit{gca} effects among lines varied between -561.88 (IS 4581) to 819.94 (IS 23891).

Nine lines recorded significant \textit{gca} effects in positive direction. The line IS 23891 recorded highest significant positive \textit{gca} effects followed by IS 995 (722.11). On the other hand the lines IS 4581 (561.88) and IS 29654 (538.72) recorded highest significant negative \textit{gca} effects. Among testers, M 31-2A (76.56) exhibited significant positive \textit{gca} effects.

Among lines, the estimates of \textit{gca} effect for hundred seed weight varied from -0.63 (IS 23891) to 1.23 (IS 4581). Out of 25 lines, eight were found to have significant effect for \textit{gca}. The line IS 4581 (1.29) topped the list showing positive \textit{gca} effect, whereas the line IS 23891 (0.63) exhibited highest significant \textit{gca} in negative direction. The tester M 31-2A (0.10) recorded significant positive \textit{gca} effect.

**Specific combining ability (sca) effects**

Among 50 crosses, 15 crosses exhibited significant \textit{sca} effects in negative desirable direction for days to 50 per cent flowering.
Table 1 ANOVA for combining ability for yield and yield components in *rabi* sorghum

| Source of variation          | df  | 1 Days to 50% flowering | 2 Plant height(cm) | 3 Number of leaves per plant | 4 Number of primaries panicle | 5 Panicle length (cm) |
|------------------------------|-----|-------------------------|--------------------|-----------------------------|-----------------------------|-----------------------|
| Replication                  | 2   | 0.88                    | 1.047              | 0.060                       | 0.34                        | 5.87                  |
| Crosses                      | 49  | 103.52**                | 590.41**           | 8.44                        | 163.44**                    | 63.91**               |
| Lines effect                 | 24  | 163.81**                | 676.60*            | 12.77**                     | 178.62                      | 68.21*                |
| Testers effect               | 1   | 2.16                    | 4129.12**          | 44.82**                     | 478.82                      | 770.16**              |
| Lines × Testers effect       | 24  | 47.45**                 | 335.77**           | 2.59**                      | 135.11**                    | 30.11**               |
| Error                        | 98  | 2.41                    | 19.94              | 0.64                        | 3.40                        | 6.26                  |
| Total                        | 149 | 35.64                   | 207.29             | 3.20                        | 55.99                       | 25.14                 |
| σ²GCA                        |     | 2.00**                  | 59.21**            | 0.700**                     | 8.03*                       | 10.24**               |
| σ²SCA                        |     | 15.17**                 | 106.92**           | 0.717**                     | 43.89**                     | 8.64**                |
| σ²GCA/ σ²SCA                 |     | 0.13                    | 0.55               | 0.98                        | 0.18                        | 1.18                  |
| Contribution (%) of Lines    |     | 77.50                   | 57.87              | 74.13                       | 53.52                       | 52.32                 |
| Contribution (%) of Testers  |     | 0.04                    | 14.27              | 10.83                       | 5.97                        | 24.59                 |
| Contribution (%) of Line × Tester |     | 22.45                   | 27.85              | 15.02                       | 40.49                       | 23.07                 |

| Source of variation          | df  | 6 Panicle width (cm) | 7 Panicle Weight (g) | 8 Grain yield per plant (g) | 9 Number of seeds per panicle (g) | 10 100 Seed weight (g) |
|------------------------------|-----|----------------------|-----------------------|------------------------------|----------------------------------|------------------------|
| Replication                  | 2   | 0.11                 | 1.44                  | 14.59                        | 10874.33                        | 0.08                   |
| Crosses                      | 49  | 1.35**               | 789.60**              | 336.02**                     | 570629.30**                     | 0.80**                 |
| Lines effect                 | 24  | 1.49                 | 950.08                | 354.62                       | 833580.90**                     | 1.17**                 |
| Testers effect               | 1   | 0.12                 | 3213.68**             | 2158.76**                    | 879215.10                       | 1.77**                 |
| Lines × Testers effect       | 24  | 1.27**               | 528.12**              | 241.48**                     | 294819.90**                     | 0.39**                 |
| Error                        | 98  | 0.06                 | 0.52                  | 5.10                         | 8155.11                        | 0.07                   |
| Total                        | 149 | 0.49                 | 260.03                | 114.06                       | 193166.30                       | 0.31                   |
| σ²GCA                        |     | 0.01                 | 51.37**               | 30.89**                      | 20859.91**                      | 0.03**                 |
| σ²SCA                        |     | 0.40**               | 175.70**              | 78.68**                      | 94416.16**                      | 0.11**                 |
| σ²GCA/ σ²SCA                 |     | 0.025                | 0.29                  | 0.39                         | 0.21                            | 0.27                   |
| Contribution (%) of Lines    |     | 53.79                | 58.93                 | 51.69                        | 71.54                           | 71.52                  |
| Contribution (%) of Testers  |     | 0.19                 | 8.03                  | 13.11                        | 3.14                            | 4.50                   |
| Contribution (%) of Line × Tester |     | 46.07                | 32.75                 | 35.19                        | 25.30                           | 23.97                  |

*, ** significant at 5 and 1 per cent respectively
Table 2: Estimates of general combining ability effects of parents for yield and its attributing traits in *rabi* sorghum

| Sl. No. | Parents  | Days to 50 per cent flowering | Plant height | Number of leaves | Panicle length | Panicle width | Primaries panicle\(^{-1}\) | Panicle weight | Number of seeds panicle\(^{-1}\) | Grain yield plant\(^{-1}\) | 100 seed weight |
|---------|----------|-------------------------------|--------------|-----------------|----------------|--------------|------------------|----------------|-----------------------------|---------------------|-----------------|
|        | Testers  |                               |              |                 |                |              |                  |                |                             |                     |                 |
| 1       | 104B     | -0.12                         | -5.24**      | -0.54**         | 2.26**         | 0.029        | -1.78**          | -4.62**        | -76.56**        | -3.79**             | -0.109**         |
| 2       | M 31-2B  | 0.12                          | 5.24**       | 0.54**          | -2.26**        | -0.029       | 1.78**           | 4.62**         | 76.56**         | 3.79**             | 0.109**          |
|         | CD at 5% | 0.31                          | 0.88         | 0.15            | 0.46           | 0.05         | 0.42             | 0.23           | 24.64           | 0.53                | 0.05             |
| 3       | IS 602   | -3.03**                       | -7.87**      | -1.58**         | 9.41**         | -0.14        | -10.43**         | -18.50**       | 63.13           | -6.08**             | -0.59**          |
| 4       | IS 995   | -4.70**                       | 13.17**      | -3.08**         | 5.36**         | 0.36**       | 3.90**           | 10.60**        | 722.11**        | 10.26**             | -0.50**          |
| 5       | IS 4515  | 5.46**                        | 1.67         | -1.58**         | -3.04**        | -0.17        | -0.10            | 1.06**         | -497.55**       | -11.43**            | 0.16             |
| 6       | IS 4581  | 7.36**                        | 17.30**      | 0.25            | -0.31          | 0.25**       | 6.56**           | -10.50**       | -561.88**       | -6.21**             | 1.29**           |
| 7       | IS 4698  | -1.03                         | -1.66        | -1.58**         | -4.41**        | -0.29**      | 2.06**           | 2.53**         | 108.44**        | 1.44                | -0.22**          |
| 8       | IS 11619 | 7.636**                       | 15.00**      | 1.92**          | -5.41**        | -0.03        | -3.26**          | 7.54**         | -163.88**       | 0.81                | 0.19             |
| 9       | IS 15945 | 6.96**                        | 7.50**       | 1.42**          | 3.73**         | 0.11         | -3.60**          | 7.54**         | 258.44**        | -0.28               | -0.54**          |
| 10      | IS 19450 | 3.13**                        | -4.32**      | -2.58**         | -1.61          | 0.90**       | 13.73**          | 25.36**        | 436.94**        | 13.58**             | -0.02            |
| 11      | IS 19975 | -14.03**                      | -4.82**      | 0.92**          | 2.55**         | -0.13        | -7.43**          | -6.67**        | -164.72**       | -4.50**             | -0.07            |
| 12      | IS 20743 | -1.20*                        | -0.99        | 0.25            | -2.64**        | -0.66**      | -1.93**          | -2.20**        | 262.94**        | 1.46                | -0.42**          |
| 13      | IS 20679 | -1.36*                        | -7.99**      | 0.42            | -0.64          | -0.74**      | -2.43**          | -21.85**       | -521.88**       | -13.13**            | 0.09             |
| 14      | IS 22720 | -1.70**                       | -4.49**      | -1.58**         | -1.89**        | -0.08        | 0.40             | -12.67**       | -377.88**       | -8.76**             | 0.09             |
| 15      | IS 23590 | 3.96**                        | 12.84**      | 0.75**          | -1.61          | 0.51**       | 1.23             | 11.59**        | 503.94**        | 11.94**             | -0.20**          |
| 16      | IS 23891 | -0.96                         | -6.82**      | 0.25            | 0.23           | 0.31**       | 1.40             | 16.44**        | 819.94**        | 11.39**             | -0.63**          |
| 17      | IS 24462 | 1.53**                        | 2.00         | -0.24           | 2.35**         | 0.65**       | 1.40             | -0.05          | 82.11           | 1.11                | -0.05            |
| Sl. No. | Parents     | Days to 50% flowering | Days to maturity | Plant height | Number of leaves | Panicle length | Panicle width | Primaries panicle⁻¹ | Panicle weight | Number of seeds panicle⁻¹ | Grain yield plant⁻¹ | 100 seed weight |
|--------|-------------|------------------------|------------------|--------------|------------------|----------------|---------------|---------------------|----------------|---------------------------|----------------------|------------------|
| 18     | IS 25989    | -1.94**                | -2.32**          | 2.34         | 1.58**           | 1.03           | 0.68**        | 6.56**              | 4.51**         | 152.44**                  | 1.61                 | -0.22*          |
| 19     | IS 26025    | -6.83**                | -6.98**          | -12.87**     | -0.08            | 2.75**         | -0.93**       | -4.43**             | -6.32**        | 6.61                      | -3.06**              | -0.27**         |
| 20     | IS 26617    | 1.13*                  | 3.18**           | -29.32**     | -0.58*           | -1.09          | -0.58**       | -4.43**             | -9.27**        | -132.05**                 | -2.25*               | 0.02             |
| 21     | IS 27887    | -5.53**                | -5.48**          | -0.99        | -0.08            | -2.06*         | 0.40**        | 1.56*               | -14.68**       | -277.05**                 | -6.30**              | 0.04             |
| 22     | IS 28313    | 3.96**                 | 2.51**           | 2.00         | 0.42             | -1.18          | -0.59**       | -6.26**             | -2.42**        | -154.22**                 | -0.43                | 0.27**          |
| 23     | IS 29269    | -3.86**                | -4.98**          | 4.67**       | 0.42             | -1.38          | 0.05          | 9.23**              | 5.01**         | -233.38**                 | 1.04                 | 0.57**          |
| 24     | IS 29654    | 8.63**                 | 6.84**           | -4.49**      | -1.08**          | -4.88**        | -0.31**       | -1.60*              | -15.85**       | -538.72**                 | -11.26**             | 0.39**          |
| 25     | IS 30451    | -1.20*                 | 1.18*            | 17.50**      | 2.08**           | 0.16           | 0.78**        | 1.56*               | 3.36**         | 23.28                     | 9.98**               | 0.61**          |
| 26     | IS 31651    | -3.70**                | -3.65**          | -14.66**     | 2.92**           | 1.25           | -0.16         | -6.26**             | -1.42**        | 119.78**                  | -0.36                | -0.39**         |
| 27     | IS 32439    | 1.13*                  | 1.01             | 5.17**       | 0.42             | 3.60**         | -0.16         | 2.56**              | 26.83**        | 63.11                     | 9.42**               | 0.39**          |
| C.D @ 5%| 1.12        | 1.03                   | 3.13            | 0.70         | 1.65             | 0.19           | 1.50          | 0.81                | 87.14          | 1.88                       | 0.17                 |                 |

* and ** indicates significant at 5 and 1 per cent, respectively.
### Table 3a

Estimates of specific combining ability effects of crosses for yield and its attributing traits in *rabi* sorghum

| Sl. No. | Crosses       | Days to 50 per cent flowering | Plant height | No of leaves | Panicle length | Panicle width |
|---------|---------------|-------------------------------|--------------|--------------|----------------|---------------|
| 1       | 104A × IS 602 | 3.95**                        | 8.74**       | 0.04         | -2.01          | -0.22         |
| 2       | 104A × IS 995 | 2.62**                        | -16.92**     | 0.54         | -4.83**        | 0.12          |
| 3       | 104A × IS 4515| -2.88**                       | 2.91         | 0.04         | 2.08           | 0.14          |
| 4       | 104A × IS 4581| -1.38                         | 0.91         | -0.12        | 0.45           | 0.40**        |
| 5       | 104A × IS 4698| 0.28                          | 12.58**      | 0.04         | -2.08          | -0.27*        |
| 6       | 104A × IS 11619| 0.95                          | 0.54         | -0.49        | 0.04           |               |
| 7       | 104A × IS 15945| -1.71*                        | -4.58*       | 0.04         | -2.03          | -0.82**       |
| 8       | 104A × IS 19450| 0.78                          | 8.91**       | 0.04         | 5.03**         | 0.35**        |
| 9       | 104A × IS 19975| 0.28                          | 1.74         | 1.54**       | -0.81          | 0.45**        |
| 10      | 104A × IS 20743| -1.54                         | 0.24         | -0.78*       | 0.48           | 0.38**        |
| 11      | 104A × IS 20679| -0.04                         | -4.42        | 0.04         | -0.31          | -0.09         |
| 12      | 104A × IS 22720| 2.28**                        | -2.25        | 0.04         | 1.60           | -0.02         |
| 13      | 104A × IS 23590| 0.28                          | 6.41**       | -0.28        | 1.01           | 0.63**        |
| 14      | 104A × IS 23891| -5.21**                       | -1.58        | -0.78*       | -0.86          | 0.03          |
| 15      | 104A × IS 24462| 5.28**                        | 6.24**       | -0.28        | -0.26          | 0.40**        |
| 16      | 104A × IS 25989| -0.21                         | -1.75        | 0.54         | -0.83          | -0.02         |
| 17      | 104A × IS 26025| -0.54                         | -8.25**      | -0.45        | -1.83          | 0.48**        |
| 18      | 104A × IS 26617| 2.78**                        | -9.08**      | 0.04         | 4.33**         | 0.33**        |
| 19      | 104A × IS 27887| -2.21**                       | -0.42        | -0.45        | 1.30           | -0.01         |
| 20      | 104A × IS 28313| -6.38**                       | -1.42        | 0.04         | -1.04          | 0.02          |
| 21      | 104A × IS 29269| 1.45                          | 2.91         | 0.04         | 1.68           | -0.56**       |
| 22      | 104A × IS 29654| -0.71                         | 7.41**       | -1.45**      | 1.31           | 0.23          |
| 23      | 104A × IS 30451| -3.21**                       | -0.58        | 1.38**       | 0.03           | -0.62**       |
| 24      | 104A × IS 31651| 0.28                          | 10.24**      | 0.54         | 1.98           | -0.01         |
| 25      | 104A × IS 32439| 4.78**                        | -16.58**     | -0.95*       | -3.83**        | -1.37**       |
| 26      | M 31-2A × IS 602| -3.95**                       | -8.74**      | -0.04        | 2.01           | 0.22          |
| Sl. No. | Parents                  | Days to 50 per cent flowering | Plant height | No of leaves | Panicle length | Panicle width |
|--------|--------------------------|------------------------------|--------------|--------------|----------------|---------------|
| 27     | M 31-2A × IS 995        | -2.62**                      | 16.92**      | -0.54        | 4.83**         | -0.12         |
| 28     | M 31-2A × IS 4515       | 2.88**                       | -2.91        | -0.04        | -2.08          | -0.15         |
| 29     | M 31-2A × IS 4581       | 1.38                         | -0.91        | 0.12         | -0.45          | -0.40**       |
| 30     | M 31-2A × IS 4698       | -0.28                        | -12.58**     | -0.04        | 2.08           | 0.279*        |
| 31     | M 31-2A × IS 11619      | -0.95                        | 1.42         | -0.54        | 0.49           | -0.05         |
| 32     | M 31-2A × IS 15945      | 1.71*                        | 4.58*        | -0.04        | 2.03           | 0.83**        |
| 33     | M 31-2A × IS 19450      | -0.78                        | -8.91**      | -0.04        | -5.03**        | -0.36**       |
| 34     | M 31-2A × IS 19975      | -0.28                        | -1.74        | -1.54**      | 0.81           | -0.45**       |
| 35     | M 31-2A × IS 20743      | 1.54                         | -0.27        | 0.78*        | -0.48          | -0.38**       |
| 36     | M 31-2A × IS 20679      | 0.04                         | 4.42         | -0.04        | 0.31           | 0.09          |
| 37     | M 31-2A × IS 22720      | -2.28**                      | 2.25         | -0.04        | -1.60          | 0.03          |
| 38     | M 31-2A × IS 23590      | -0.28                        | -6.41**      | 0.28         | -1.01          | -0.637**      |
| 39     | M 31-2A × IS 23891      | 5.21**                       | 1.58         | 0.78*        | 0.86           | -0.03         |
| 40     | M 31-2A × IS 24462      | -5.28**                      | -6.24**      | 0.28         | 0.26           | -0.40**       |
| 41     | M 31-2A × IS 25989      | 0.21                         | 1.75         | -0.54        | 0.83           | 0.03          |
| 42     | M 31-2A × IS 26025      | 0.54                         | 8.25**       | 0.45         | 1.88           | -0.48**       |
| 43     | M 31-2A × IS 26617      | -2.78**                      | 9.08**       | -0.04        | -4.33**        | -0.33*        |
| 44     | M 31-2A × IS 27887      | 2.21**                       | 0.42         | 0.45         | -1.30          | 0.01          |
| 45     | M 31-2A × IS 28313      | 6.38**                       | 1.42         | -0.04        | 1.04           | -0.02         |
| 46     | M 31-2A × IS 29269      | -1.45                        | -2.91        | -0.04        | -1.68          | 0.56**        |
| 47     | M 31-2A × IS 29654      | 0.71                         | -7.41**      | 1.45**       | -1.31          | -0.23         |
| 48     | M 31-2A × IS 30451      | 3.21**                       | 0.58         | -1.38**      | -0.03          | 0.62**        |
| 49     | M 31-2A × IS 31651      | 0.28                         | -10.24**     | -0.54        | -1.98          | 0.01          |
| 50     | M 31-2A × IS 32439      | -4.78**                      | 16.58**      | 0.95*        | 3.83**         | 1.37**        |
| CD @ 5%|                           |                              |              |              | 1.59           | 4.43          | 0.75 | 2.34 | 0.26 |

* and **indicates significant at 5 and 1 per cent, respectively.
Table 3b: Estimates of specific combining ability effects of crosses for yield and its attributing traits in *rabi* sorghum

| Sl. No. | Crosses                   | Primaries panicle\(^{-1}\) | Panicle weight | Grain yield per plant | Number of seeds per panicle | 100 seed weight |
|---------|---------------------------|-----------------------------|----------------|-----------------------|----------------------------|-----------------|
| 1       | 104A × IS 602             | -5.71**                     | 6.76**         | 3.29*                 | 242.39**                   | -0.19           |
| 2       | 104A × IS 995             | -0.38                       | -5.14**        | 0.68                  | 346.72**                   | -0.34**         |
| 3       | 104A × IS 4515            | 2.95**                      | -13.17**       | -3.82**               | -77.27                     | -0.21           |
| 4       | 104A × IS 4581            | -4.04**                     | 9.03**         | 6.16**                | 198.73**                   | -0.37**         |
| 5       | 104A × IS 4698            | 5.79**                      | -4.17**        | -5.34**               | -111.61                    | -0.16           |
| 6       | 104A × IS 11619           | -1.54                       | -6.45**        | -16.47**              | -408.27**                  | -0.31**         |
| 7       | 104A × IS 15945           | 2.12                        | -3.35**        | 1.99                  | 128.73*                    | -0.07           |
| 8       | 104A × IS 19450           | -1.55                       | -3.89**        | -0.60                 | 9.23                       | -0.03           |
| 9       | 104A × IS 19975           | 6.62**                      | -16.64**       | -6.75**               | -287.11**                  | 0.09            |
| 10      | 104A × IS 20743           | 5.12**                      | -0.32          | 0.17                  | 176.56**                   | -0.26**         |
| 11      | 104A × IS 20679           | 0.28                        | 10.18**        | 7.24**                | 137.39*                    | 0.29**          |
| 12      | 104A × IS 22720           | -2.88**                     | 17.76**        | 7.98**                | 163.73**                   | 0.26**          |
| 13      | 104A × IS 23590           | -0.71                       | 1.96**         | 2.43                  | -7.77                      | 0.16            |
| 14      | 104A × IS 23891           | 1.12                        | -3.69**        | -3.123*               | -192.44**                  | 0.07            |
| 15      | 104A × IS 24462           | 7.12**                      | 17.28**        | 9.46**                | 481.73**                   | -0.29**         |
| 16      | 104A × IS 25989           | -1.38                       | -0.65          | 0.96                  | -162.27*                   | 0.34**          |
| 17      | 104A × IS 26025           | -0.71                       | -0.02          | -0.89                 | -214.77**                  | 0.32**          |
| 18      | 104A × IS 26617           | 6.29**                      | 1.29*          | 0.46                  | 14.23                      | -0.008          |
| 19      | 104A × IS 27887           | -4.71**                     | 11.48**        | 7.84**                | 136.89*                    | 0.31**          |
| 20      | 104A × IS 28313           | 2.45*                       | 2.24**         | 3.24*                 | -71.61                     | 0.44**          |
| 21      | 104A × IS 29269           | 5.28**                      | -3.15**        | -0.07                 | 88.89                      | -0.26**         |
| 22      | 104A × IS 29654           | 2.12                        | 10.24**        | 4.24**                | 129.56*                    | -0.04           |
| 23      | 104A × IS 30451           | -4.38**                     | 1.69**         | 2.29                  | -89.11                     | 0.41**          |
| 24      | 104A × IS 31651           | -10.55**                    | -15.55**       | -9.05**               | -289.94**                  | -0.12           |
| 25      | 104A × IS 32439           | -8.71**                     | -13.77**       | -12.31**              | -342.60**                  | -0.04           |
| 26      | M 31-2A × IS 602          | 5.71**                      | -6.76**        | -3.29*                | -242.39**                  | 0.19            |
| Sl. No. | Parents                  | Primaries panicle | Panicle weight | Grain yield per plant | Number of seeds per panicle | 100 seed weight |
|--------|--------------------------|-------------------|----------------|-----------------------|----------------------------|-----------------|
| 27     | M 31-2A × IS 995         | 0.38              | 5.13**         | -0.68                 | -346.73**                  | 0.34**          |
| 28     | M 31-2A × IS 4515        | -2.95**           | 13.17**        | 3.82**                | 77.27                      | 0.21            |
| 29     | M 31-2A × IS 4581        | 4.05**            | -9.02**        | -6.16**               | -198.73**                  | 0.37**          |
| 30     | M 31-2A × IS 4698        | -5.79**           | 4.17**         | 5.34**                | 111.61                     | 0.16            |
| 31     | M 31-2A × IS 11619       | 1.55              | 6.45**         | 16.47**               | 408.27**                   | 0.31**          |
| 32     | M 31-2A × IS 15945       | -2.12             | 3.35**         | -1.99                 | -128.73*                   | 0.07            |
| 33     | M 31-2A × IS 19450       | 1.55              | 3.83**         | 0.60                  | -9.23                      | 0.02            |
| 34     | M 31-2A × IS 19975       | -6.62**           | 16.64**        | 6.76**                | 287.11**                   | -0.09           |
| 35     | M 31-2A × IS 20743       | -5.12**           | 0.32           | -0.19                 | -176.56**                  | 0.26*           |
| 36     | M 31-2A × IS 20679       | -0.29             | -10.18**       | -7.24**               | -137.39**                  | -0.29*          |
| 37     | M 31-2A × IS 22720       | 2.88**            | -17.76**       | -7.98**               | -163.73**                  | -0.26*          |
| 38     | M 31-2A × IS 23590       | 0.71              | -1.96**        | -2.43                 | 7.77                       | -0.16           |
| 39     | M 31-2A × IS 23891       | -1.12             | 3.69**         | 3.12*                 | 192.44**                   | -0.07           |
| 40     | M 31-2A × IS 24462       | -7.12**           | -17.28**       | -9.46**               | -481.73**                  | 0.29*           |
| 41     | M 31-2A × IS 25989       | 1.38              | 0.65           | -0.96                 | 162.27*                    | -0.34*          |
| 42     | M 31-2A × IS 26025       | 0.71              | 0.02           | 0.89                  | 214.77**                   | -0.32*          |
| 43     | M 31-2A × IS 26617       | -6.29**           | -1.29*         | -0.46                 | -14.23                     | 0.008           |
| 44     | M 31-2A × IS 27887       | 4.71**            | -11.48**       | -7.84**               | -136.89*                   | -0.31*          |
| 45     | M 31-2A × IS 28313       | -2.45*            | -2.24**        | -3.24*                | 71.61                      | -0.44**         |
| 46     | M 31-2A × IS 29269       | -5.29**           | 3.15**         | 0.07                  | -88.89                     | 0.26*           |
| 47     | M 31-2A × IS 29654       | -2.12             | -10.2**        | -4.24**               | -129.56*                   | 0.041           |
| 48     | M 31-2A × IS 30451       | 4.38**            | -1.70**        | -2.29                 | 89.11                      | -0.41**         |
| 49     | M 31-2A × IS 31651       | 10.55**           | 15.5**         | 9.06**                | 289.94**                   | 0.12            |
| 50     | M 31-2A × IS 32439       | 8.71**            | 13.77**        | 12.31**               | 342.61**                   | 0.04            |

* and ** indicates significant at 5 and 1 per cent, respectively.
The cross 104A × IS 31651 (10.54) exhibited highest *sca* towards negative direction. At the same time 15 crosses noticed positive *sca* effect among them M 31-2A × IS 31651 (10.54) accounted high positive *sca* effect. For plant height, 12 were found to have positive significance. The crosses *viz.*., M 31-2A × IS 995 (16.92) and M 31-2A × IS 32439 (16.58) topped the list of hybrids showing positive *sca* effects for plant height (Table 3).

Among 50 crosses, 12 crosses showed significant for *sca* effects for number of leaves per plant and out of which six were having positive *sca* effects. The crosses *viz.*, 104A × IS 19975 (1.54), M 31-2A × IS 29654 (1.45) and 104A × IS 30451 (1.38) expressed significant positive *sca* effect. For panicle width, out of 50 hybrids evaluated twenty-six recorded significant *sca* effects and of these 13 had positive and other 13 had negative significant *sca* effects. The cross M 31-2A × IS 32439 (1.37) showed peak significant positive *sca* effect.

Eight hybrids accounted for significant *sca* effects for panicle length and of these four had positive and other four had negative *sca* effects. The hybrids *viz.*, 104A × IS 19450 (5.03), 104A × IS 26617 (4.33), M 31-2A × IS 602 (4.83) and M 31-2A × IS 32439 (3.83) were found to have positive *sca* effects.

Thirty crosses accounted for significant *sca* effect for number of primaries per panicle of all these 15 crosses showed positive *sca* effects. The crosses *viz.*, M 31-2A × IS 31651 (10.54) and M 31-2A × IS 32439 (8.71) showed highest positive significant *sca* effect. In contrast crosses *viz.*, 104 A × IS 31651 (10.54) and 104 A × IS 32439 (8.71) showed highest negative significant *sca* effects.

For panicle weight, the crosses *viz.*, 104A × IS 22720 (17.76), 104A × IS 24462 (17.29) and M 31-2A × IS 19975 (16.63) accounted for highest significant *sca* effect in positive direction. The values of *sca* variance for number of seeds per panicle varied from -481.72 (M 31-2A × IS 24462) to 481.62 (104A × IS 24462). Among 50 crosses, 17 crosses showed positive and other 17 showed negative significant *sca* effects for number of seeds per panicle. The hybrid 104A × IS 24462 (481.62) have shown the highest positive *sca* effect and was succeeded by M 31-2A × IS 11619 (408.27).

It is concluded that the female parent M 31-2A observed as a good general combiner for plant height, number of leaves per plant, number of primaries per panicle, panicle weight, number of seeds per panicle, grain yield per plant and 100 seed weight. From the studies it was observed that the hybrids *viz.*, M 31-2A × IS 11619, M 31-2A × IS 32439, M 31-2A × IS 31651 and 104A × IS 24462 were best specific combiners for grain yield per plant. The higher magnitude of SCA variance over GCA variance was observed for all the characters studied except for panicle length which indicates the prevalence of non-additive gene action for these characters. Thus, it can be concluded that both inter and intra allelic interactions were involved in the expression of these quantitative traits. The parental lines in this study were having
diverse genetic background of their source populations, and hence their hybrids exhibited high specific combining ability effects.

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How to cite this article:

Sandeep, N., B.D. Biradar, Mruthunjaya C. Wali and Balikai, R.A. 2019. Studies on Combining Ability for Yield and Its Component Traits in Rabi Sorghum [Sorghum bicolor (L.) Moench]. Int.J.Curr.Microbiol.App.Sci. 8(09): 353-364.

doi: https://doi.org/10.20546/ijcmas.2019.809.042