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**RESEARCH ARTICLE**

# COMBINING ABILITY ANALYSIS IN *RABI* SORGHUM (*SORGHUM BICOLOR* L. MOENCH)

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**ABSTRACT**

The experiment was undertaken during the period 2014-15 at Sorghum Improvement Project, M.P.K.V., Rahuri with the objectives to estimate the general and specific combining ability of parents and hybrids. To achieve these objectives, four cytoplasmic male sterile lines (females), ten restorers (males) and their forty hybrids were studied by using Line x Tester mating design. Observations were recorded on eight characters viz., days to 50 % flowering, plant height, panicle length, panicle breadth, 1000 grain weight, number of grains per panicle, grain yield per plant and fodder yield per plant. Based on results obtained the hybrids RMS-2010-10A x RSR-999, RMS-2010-16A x RSR-990, 185-A x RSR-992 and 185A x RSR-994 were observed most promising and could be exploited for further hybrid development, while the parents 185-A, RSR-994, RSR-993 and RSR-995 were observed as a good general combiners and need due consideration in future hybridization programme.



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## INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth important cereal crop of the world after wheat, maize, rice and barley. It is originated in Africa and spread all over the world. The large hectarage under this crop occurs in the arid and semi-arid areas of India and Africa. The concept of combining ability plays an important role in identification of superior parents and hybrids. Allard (1960) pointed out that the common approach of selecting the parents on the basis of *per se* performance is not a good indication of their superior combining ability. The choice of parents in any breeding programme has to be based on complete genetic information and knowledge of combining ability of parents and not merely on field performance.

## MATERIALS AND METHODS

The experimental material for the present study comprised of four male sterile line, ten restorers, their resulting 40 hybrids and one hybrid check CSH-15R. During *rabi* 2013-14 four male sterile lines and ten restores were sown at Sorghum Improvement Project, M.P.K.V., Rahuri and these lines and testers were crossed in Line x Tester design to produce 40 possible hybrids. The experiment was conducted during *rabi* 2014-15 by using 14 parents, their 40 hybrids along with one standard check CSH-15R at Sorghum Improvement Project, M.P.K.V., Rahuri. The observations were recorded on eight characters viz., days to 50 % flowering, plant height, panicle length, panicle breadth, number of grains per panicle, 1000 grain weight, grain yield per plant and fodder yield per plant. The data was subjected to the analysis of combining ability as per Kempthorne (1957) and modified by Arunachalam (1974).

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## RESULTS AND DISCUSSION

### Analysis of variance for combining ability

The analysis of variance for combining ability is presented in Table 1. From the data it is observed that, the mean square due to lines, testers as well as lines vs. testers interaction were found significant for almost all the traits.

### General combining ability

The male sterile line 185-A was good general combiner for days to 50 per cent flowering, plant height, panicle breadth, number of grains per panicle, grain yield per plant and fodder yield per plant. The female line RMS-2010-24A was observed good general combiner for fodder yield per plant. The line 185A was found to be suitable for developing high yielding and early maturing hybrids in *rabi* sorghum (Prabhakar *et al.*, 2013; Premalatha *et al.*, 2006). As regards, general combining ability of male parents, RSR-994 was good general combiner for number of grains per panicle, grain yield per plant and fodder yield per plant. Whereas RSR-993 was good general combiner for plant height, panicle length and fodder yield per plant. The male parent RSR-990 was found good general combiner for plant height and fodder yield. The male parent RSR-991 was found good general combiner for days to 50 per cent flowering and plant height. The male parent RSR-992 was good general combiner for panicle length. The male parent RSR-995 was found good general combiner for number of grains per panicle. The male parent RSR-996 was good general combiner for fodder yield per plant. The male parents RSR-997 and RSR-998 were also found good general combiner for plant height. In general good combiners for grain yield also had good or average combiners for one or more yield components. In most of the parents high GCA effects were associated with high *per se* mean for yield and yield components (Badhe and Patil, 1997; Barhate, 1996; Khapre *et al*., 2000a; Patel *et al*., 1990; Pillai *et al*., 1995; Prabhakar *et al*., 2013; Vaidya, 2000).

**Specific combining ability**

The results on specific combining ability of different hybrids for eight characters under study have been discussed as under (Table 3).

**1.Days to 50 per cent flowering**

The hybrids RSH-1303 (high x average) and RSH-1324 (average x average) showed the higher magnitude of negative specific combining ability effect. The data revealed that the hybrids showing significantly high sca effects involves high x average and average x average general combiners, indicated the presence of non-additive type of gene action (Desai *et al*., 1985; Patil, 2008).

**2.Plant height (cm)**

The hybrids RSH-1313 (average x low), RSH-1326 (low x low) and RSH-1324 (low x high) showed the higher magnitude of positive specific combining ability effect.

**Table 1. ANOVA for combining ability (L x T design)**

| Source | D.F. | Days to 50% flowering | Plant height (cm) | Panicle length (cm) | Panicle breadth (cm) | Number of grains/ panicle | 1000 grain weight (g) | Grain yield/ plant (g) | Fodder yield/ plant (g) |
|---|---|---|---|---|---|---|---|---|---|
| Replications | 1 | 85.33** | 3.60 | 4.46 | 0.17 | 14352.08 | 5.01 | 0.004 | 376.65 |
| Treatments | 53 | 16.08** | 1018.44** | 13.14** | 0.89** | 202272.90** | 33.98** | 351.41** | 6791.56** |
| Parents | 13 | 11.83** | 1588.78** | 20.46** | 0.57** | 165245.15** | 44.70** | 123.50** | 7578.47** |
| Parents Vs. Hybrids | 1 | 195.66** | 7135.67** | 253.44** | 4.89** | 2483536.76** | 486.96** | 7775.95** | 41906.81** |
| Hybrids | 39 | 12.89** | 671.47** | 4.54** | 0.90** | 156121.54** | 18.79** | 237.00** | 5628.87** |
| Lines | 3 | 8.33 | 381.77** | 3.79 | 0.34 | 11545.12 | 8.26 | 16.48 | 1562.19** |
| Testers | 9 | 14.31** | 797.25** | 22.83** | 0.69** | 205564.89** | 59.50** | 167.56** | 6558.16** |
| Lines vs. Testers | 1 | 0.05 | 12333.66** | 49.16** | 0.24 | 263467.57** | 20.80* | 48.06 | 34810.07** |
| Error | 53 | 4.20 | 53.17 | 1.58 | 0.23 | 30359.72 | 4.10 | 44.67 | 279.09 |
| $\sigma^2$ gca | | 1.40 | 78.24 | 0.21 | 0.06 | 20945.16 | 0.10 | 19.40 | 844.59 |
| $\sigma^2$ sca | | 3.02 | 168.78 | 1.24 | 0.35 | 47499.31 | 10.06 | 96.11 | 1285.65 |
| $\sigma^2$ gca/$\sigma^2$ sca | | 0.46 | 0.46 | 0.16 | 0.17 | 0.44 | 0.009 | 0.20 | 0.65 |
| $\sigma^2$ A | | 2.80 | 156.48 | 0.42 | 0.12 | 41890.33 | 0.20 | 38.81 | 1689.19 |
| $\sigma^2$ D | | 3.02 | 168.79 | 1.24 | 0.35 | 47499.31 | 10.06 | 96.11 | 1285.65 |
| $\sigma^2$ A/$\sigma^2$ D | | 0.92 | 0.92 | 0.33 | 0.34 | 0.88 | 0.02 | 0.40 | 1.31 |

**Note:** *, ** = Significant at 5 % and 1 % level of significance respectively

**Table 2. Estimation of general combining ability effect for 14 parents in *rabi* sorghum**

| S.No. | Parents | Days to 50 % flowering | Plant height (cm) | Panicle length (cm) | Panicle breadth (cm) | Number of grains/ panicle | 1000 grain weight (g) | Grain yield/ plant (g) | Fodder yield/ plant (g) |
|---|---|---|---|---|---|---|---|---|---|
| | Female parents | | | | | | | | |
| 1. | 185 A | -1.80** | 7.55** | 0.33 | 0.40** | 135.26** | -0.45 | 4.06** | 8.61* |
| 2. | RMS-2010-10A | 0.90 | 3.22 | 0.05 | -0.02 | 45.01 | 0.08 | 1.83 | -4.13 |
| 3. | RMS-2010-16A | -0.10 | -5.75** | -0.48 | -0.19 | 53.81 | -0.17 | 1.16 | -32.08** |
| 4. | RMS-2010-24A | 1.00* | -5.02** | 0.10 | -0.19 | -234.08** | 0.54 | -7.06** | 27.60** |
| | S.E. ± | 0.45 | 1.63 | 0.28 | 0.10 | 38.96 | 0.45 | 1.49 | 3.73 |
| | CD at 5 % | 0.92 | 3.29 | 0.56 | 0.21 | 78.80 | 0.91 | 3.02 | 7.55 |
| | CD at 1 % | 1.24 | 4.41 | 0.76 | 0.29 | 105.50 | 1.22 | 4.04 | 10.11 |
| | Male parents | | | | | | | | |
| 5. | RSR-990 | 0.75 | 14.10** | -1.02* | -0.09 | -148.28* | 0.93 | -2.72 | 31.92** |
| 6. | RSR-991 | -2.12** | 11.18** | -1.06* | -0.26 | -139.53* | -1.90* | -7.76** | -4.20 |
| 7. | RSR-992 | -1.00 | -28.19** | 1.76** | -0.50** | 106.96 | -0.96 | 2.15 | 4.50 |
| 8. | RSR-993 | -0.25 | 5.76* | 0.93* | 0.32 | -86.28 | 0.75 | -1.26 | 49.80** |
| 9. | RSR-994 | 2.75** | -0.43 | -0.10 | 0.28 | 190.46** | 0.44 | 7.02** | 28.00** |
| 10. | RSR-995 | 0.62 | -10.06** | -0.69 | -0.01 | 135.83* | -0.92 | 2.23 | -8.28 |
| 11. | RSR-996 | -0.25 | -8.60** | 0.09 | 0.11 | -105.53 | 0.13 | -3.60 | 39.63** |
| 12. | RSR-997 | -1.12 | 10.35** | -0.69 | 0.20 | 64.71 | 0.56 | 2.65 | -29.65** |
| 13. | RSR-998 | 0.37 | 12.64** | 0.22 | -0.21 | -87.91 | -0.07 | -3.14 | -59.86** |
| 14. | RSR-999 | 0.25 | -6.73* | 0.56 | 0.15 | 69.58 | 1.03 | 4.44 | -51.86** |
| | S.E. ± | 0.72 | 2.57 | 0.44 | 0.17 | 61.60 | 0.71 | 2.36 | 5.90 |
| | CD at 5 % | 1.46 | 5.21 | 0.89 | 0.34 | 124.60 | 1.44 | 4.77 | 11.94 |
| | CD at 1 % | 1.96 | 6.98 | 1.20 | 0.46 | 166.81 | 1.94 | 6.39 | 15.99 |

**Note :** *, ** = Significant at 5 % and 1 % level of significance respectively

**Table 3. Estimation of specific combining ability effects for eight characters in *rabi* sorghum**

| S. No. | Hybrids | Days to 50 % flowering | Plant height (cm) | Panicle length (cm) | Panicle breadth (cm) | Number of grains/ panicle | 1000 grain weight (g) | Grain yield/ plant (g) | Fodder yield/ plant (g) |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 185-A x RSR-990 | -1.95 | -8.60 | -1.54 | -0.41 | 64.98 | 0.93 | 2.89 | -21.24 |
| 2. | 185-A x RSR-991 | -0.57 | -6.51 | 1.33 | -0.90* | 104.73 | -0.17 | 2.43 | -0.95 |
| 3. | 185-A x RSR-992 | -3.70* | 8.69 | 0.66 | 0.00 | 405.73** | 2.89 | 19.18** | -14.15 |
| 4. | 185-A x RSR-993 | 1.05 | 11.40* | 0.83 | -0.49 | -170.01 | -0.50 | -4.73 | -25.78* |
| 5. | 185-A x RSR-994 | -0.95 | 9.27 | 1.04 | 1.21** | 435.23** | 0.21 | 15.14** | -41.49** |
| 6. | 185-A x RSR-995 | -1.32 | 4.73 | 1.29 | 0.50 | -198.63 | 1.51 | -3.56 | 5.30 |
| 7. | 185-A x RSR-996 | 0.05 | -0.89 | 0.16 | 0.55 | 72.73 | -5.26** | -7.39 | 16.88 |
| 8. | 185-A x RSR-997 | 2.92 | -2.35 | -0.70 | -0.03 | -267.01* | 2.47 | -4.98 | -15.99 |
| 9. | 185-A x RSR-998 | 1.42 | -7.93 | -1.29 | -0.11 | -189.38 | -3.87* | -13.52** | 15.38 |
| 10. | 185-A x RSR-999 | 3.05* | -7.76 | -1.78 | -0.32 | -258.38* | 1.80 | -5.44 | 82.05** |
| 11. | RMS-2010-10A x RSR-990 | 0.35 | 4.89 | 2.90** | 0.02 | -198.26 | -5.01* | -15.70** | 55.34** |
| 12. | RMS-2010-10A x RSR-991 | 2.72 | 3.65 | -0.71 | 0.35 | -219.01 | -2.82 | -11.33* | 29.63* |
| 13. | RMS-2010-10A x RSR-992 | 0.10 | 28.02** | -2.21* | -0.55 | -125.01 | 1.57 | -2.08 | -11.40 |
| 14. | RMS-2010-10A x RSR-993 | 0.85 | -15.93** | -2.05* | -0.38 | -112.76 | 5.89** | 4.83 | -30.86* |
| 15. | RMS-2010-10A x RSR-994 | -0.65 | 2.77 | 0.82 | 0.31 | -112.01 | -2.91* | -9.12 | -1.74 |
| 16. | RMS-2010-10A x RSR-995 | 1.97 | -27.59** | -0.59 | -0.39 | -33.88 | -2.09 | -4.66 | 1.54 |
| 17. | RMS-2010-10A x RSR-996 | -0.15 | -6.55 | -1.04 | -1.01** | -35.01 | 0.98 | 0.50 | 18.30 |
| 18. | RMS-2010-10A x RSR-997 | -1.27 | 0.31 | -0.75 | -0.26 | 0.73 | 2.36 | 4.91 | 29.75* |
| 19. | RMS-2010-10A x RSR-998 | -1.27 | 4.69 | 0.49 | 0.31 | 240.86 | 1.77 | 11.54* | -40.20** |
| 20. | RMS-2010-10A x RSR-999 | -2.65 | 5.73 | 3.15** | 1.60** | 594.36** | 0.24 | 21.12** | -50.36** |
| 21. | RMS-2010-16A x RSR-990 | 0.85 | -6.11 | -1.22 | 0.19 | 201.43 | 6.97** | 19.29** | 13.79 |
| 22. | RMS-2010-16A x RSR-991 | -1.27 | 4.30 | -0.34 | 0.69* | -102.81 | 1.06 | -1.49 | -46.25** |
| 23. | RMS-2010-16A x RSR-992 | 3.60* | -33.82** | 0.81 | 0.77* | -110.31 | -2.17 | -7.75 | 40.20** |
| 24. | RMS-2010-16A x RSR-993 | -3.65* | 14.71** | 0.48 | 0.43 | 62.43 | -3.12* | -3.33 | 11.58 |
| 25. | RMS-2010-16A x RSR-994 | 1.35 | 1.92 | -1.13 | -1.35** | -187.31 | 0.18 | -5.45 | -5.28 |
| 26. | RMS-2010-16A x RSR-995 | -2.02 | 23.88** | -0.72 | -0.22 | 272.31* | -3.32* | 2.49 | -3.50 |
| 27. | RMS-2010-16A x RSR-996 | -2.65 | 9.92 | 1.31 | 0.15 | 105.18 | 4.54** | 12.16* | -51.41** |
| 28. | RMS-2010-16A x RSR-997 | 0.22 | -8.20 | 0.94 | 0.06 | 202.4 | -4.93** | -2.41 | 11.37 |
| 29. | RMS-2010-16A x RSR-998 | 1.72 | -3.82 | 0.36 | -0.01 | -203.43 | 0.94 | -4.95 | 16.58 |
| 30. | RMS-2010-16A x RSR-999 | 1.85 | -2.78 | -0.47 | -0.72* | -239.93 | -0.16 | -8.54 | 12.91 |
| 31. | RMS-2010-24A x RSR-990 | 0.75 | 9.81 | -0.14 | 0.18 | -68.16 | -2.89 | -6.47 | -47.89** |
| 32. | RMS-2010-24A x RSR-991 | -0.87 | -1.43 | -0.26 | -0.14 | 217.08 | 1.93 | 10.40* | 17.56 |
| 33. | RMS-2010-24A x RSR-992 | 0.10 | -2.89 | 0.73 | -0.22 | -170.41 | -2.29 | -9.34 | -14.64 |
| 34. | RMS-2010-24A x RSR-993 | 1.75 | -10.18 | 0.73 | 0.44 | 220.33 | -2.26 | 3.23 | 45.06** |
| 35. | RMS-2010-24A x RSR-994 | 0.25 | -13.97** | -0.72 | -0.18 | -135.91 | 2.51 | -0.55 | 48.52** |
| 36. | RMS-2010-24A x RSR-995 | 1.37 | -1.01 | 0.02 | 0.10 | -39.78 | 3.90** | 5.73 | -3.35 |
| 37. | RMS-2010-24A x RSR-996 | 2.75 | -2.47 | -0.43 | 0.31 | -142.91 | -0.26 | -5.26 | 16.23 |
| 38. | RMS-2010-24A x RSR-997 | -1.87 | 10.23 | 0.52 | 0.23 | 63.83 | 0.09 | 2.48 | -25.14* |
| 39. | RMS-2010-24A x RSR-998 | -1.87 | 7.10 | 0.44 | -0.18 | 151.96 | 1.15 | 6.94 | 8.23 |
| 40. | RMS-2010-24A x RSR-999 | -2.25 | 4.81 | -0.89 | -0.55 | -96.03 | -1.88 | -7.14 | -44.59** |
| | S.E. ± | 1.44 | 5.15 | 0.88 | 0.34 | 123.20 | 1.43 | 4.72 | 11.81 |
| | CD at 5 % | 2.93 | 10.42 | 1.79 | 0.68 | 249.20 | 2.89 | 9.55 | 23.89 |
| | CD at 1 % | 3.92 | 13.96 | 2.40 | 0.92 | 333.63 | 3.88 | 12.79 | 31.98 |

**Note :** *, ** = Significant at 5 % and 1 % level of significance respectively

The data revealed that the hybrids showing significantly high sca effects involves average x low, low x low and low x high general combiners, indicated the presence of non-additive type of gene action (Patil, 2008).

### 3.Panicle length (cm)

The hybrids RSH-1320 (average x average) and RSH-1311 (average x low) showed the higher magnitude of positive specific combining ability effect. The data revealed that the hybrids showing significantly high sca effects involves average x average and average x low general combiners, indicated the presence of non additive type of gene action (Patil, 2008).

### 4.Panicle breadth (cm)

The hybrids RSH-1320 (average x average), RSH-1305 (high x average) and RSH-1323 (average x low) showed the higher magnitude of positive specific combining ability effect.

The data revealed that the hybrids showing significantly high sca effects involves average x average, high x average and average x low general combiners, indicated the presence of non additive type of gene action (Patil, 2008).

### 5.Number of grains per panicle

The hybrids RSH-1320 (average x average), RSH-1305 (high x high) and RSH-1303 (high x average) showed the higher magnitude of positive specific combining ability effect. The data revealed that the hybrids showing significantly high sca effects involves average x average, high x high and high x average general combiners, indicated the presence of non additive type of gene action (Patil, 2008).

### 6.1000 grain weight (g)

The hybrids RSH-1321 (average x average), RSH-1314 (average x average) and RSH-1327 (average x average) showed the higher magnitude of positive specific combining ability effect. The data revealed that the hybrid showing significantly high sca effects involves average x average general combiners, indicated the presence of non additive type of gene action (Ghorade *et al*., 2014b; Hariprasanna *et al*., 2012; Khapre *et al*., 2000a).

**7.Grain yield per plant (g)**

The hybrids RSH-1320 (average x average) and RSH-1303 (high x average) showed the higher magnitude of positive specific combining ability effect. The data reveled that the hybrid showing significantly high sca effects involves average x average and high x average general combiners, indicated the presence of non additive type of gene action (Desai *et al*., 1985; Ghorade, 1991; Ghorade *et al*., 2014b; Hariprasanna *et al*., 2012; Khapre *et al*., 2000a; Patel *et al*., 1990; Vaidya, 2000; Wadikar *et al*., 2006).

**8.Fodder yield per plant (g)**

The hybrids RSH-1310 (high x low), RSH-1311 (average x high) and RSH-1335 (high x high) showed the higher magnitude of positive specific combining ability effect. The data revealed that the hybrid showing significantly high sca effects involves high x low, average x high and high x high general combiners, indicated the presence of non additive type of gene action (Vaidya, 2000; Wadikar *et al*., 2006). In general the female parent 185-A observed good general combiner for days to 50 per cent flowering, plant height, panicle breadth, number of grains per panicle, grain yield per plant and fodder yield per plant. Among the male parents, RSR-994 was good general combiner for number of grains per panicle, grain yield per plant and fodder yield per plant. RSR-993 was also good general combiner for plant height, panicle length and fodder yield per plant. The hybrids which exhibited higher SCA for grain yield having average or good general combiner for other traits are RSH-1320, RSH-1321 and RSH-1303. The higher magnitude of variances of sca over gca indicated that non additive portion of gene action was predominant in all characters. Considering non additive type of gene actions, it is suggested that yield improvement in *rabi* sorghum could be possible through heterosis breeding.

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