Elucidation of gene action and combining ability for grain and fodder yield and contributing traits in sorghum [Sorghum bicolor (L.) Moench]

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Abstract
The present investigation was undertaken to achieve information on gene action and combining ability in sorghum [Sorghum bicolor (L.) Moench]. The experimental material consisted of eleven parents and their 28 Line × Tester crosses. The evaluation was carried out during Kharif, 2020 at Sorghum Research Station, S. D. Agricultural University, Deesa. The ratio of \( \sigma_D^2/\sigma_H^2 \) being more than unity was found for days to flowering, which suggested a more significant role of additive genetic variance in the inheritance of this trait. In contrast, the rest of the yield and its component traits showed non-additive genetic variance. The gca effects indicated that parents, SR 3019, CSV 31 and GJ 43 were found as good general combiners for grain yield per plant. While, parents DS 156, CSV 31 and SPV 2682 were good general combiners for dry fodder yield per plant and its contributing traits. Based on estimates of sca effects, the most promising hybrids for grain yield per plant were viz., SR 2980 × CSV 31, SR 3019 × SPV 2573 and DSF 117 × SPV 2682, whereas for dry fodder yield per plant were viz., SR 3048 × CSV 31, GJ 43 × SPV 2573 and DSF 168 × SPV 2573. The good general combiners for yield and contributing traits can be utilized in intensive crossing programme and select transgressive segregants for desired characters in segregating generations to develop superior lines.

Keywords: L × T analysis, Gene action, combining ability, Grain yield, Dry fodder yield

INTRODUCTION
Sorghum [Sorghum bicolor (L.) Moench] is an often cross-pollinated, diploid (2n = 2x = 20) crop with a genome, about 25 per cent the size of maize or sugarcane. It is a C₄ plant with higher photosynthetic efficiency and higher abiotic stress tolerance (Nagy et al., 1995; Reddy et al., 2009). Sorghum is the fifth most important cereal crop globally and is the dietary staple of more than 500 million people in 30 countries (Goswami et al., 2020., Gami et al., 2021). It is grown on 40 million hectares in 105 countries of Africa, Asia, Oceania and America. Africa and India account for the largest share (> 70 %) of the global sorghum area, while the U.S.A., India, Mexico, Nigeria, Sudan and Ethiopia are the major sorghum producers (Kumar et al., 2011). It is the third most important food grain crop in India, next to rice and wheat. In India, sorghum is mainly used as food, feed and forage crop. Besides this, it also provides raw materials for the production of starch, fiber, dextrose, syrup, bio-fuels, vinegar, alcohol and other products.

In a hybridization programme, selecting the right type of parents is a crucial step for a breeder. Combining ability is a relative ability of an inbred or a clone when crossed to another inbred or clone to transmit desirable traits or a specific trait to its progeny. The concept of combining ability as a measure of gene action was proposed.
by Sprague and Tatum (1942). It is a powerful tool to
discriminate between good and poor combiners and
select appropriate parental material. It also provides
information on the nature of gene action involved in the
inheritance of various traits. Thus, it helps plant breeders
to develop improved hybrids, high yielding varieties and
also helps to identify the best combiner in the breeding
procedure. The Line × Tester analysis technique
suggested by Kempthorne (1957) has been extensively
used to compare with the other methods because it
provides a more systematic approach to assess the
combining ability of parents and crosses for different
quantitative characters and contributing characters.
Besides, it gives an overall genetic picture of the materials
under investigation in a single generation.

MATERIALS AND METHODS

The experimental material comprises seven females
(DSF 117, DSF 168, DS 156, GJ 43, SR 2980, SR
3048 and SR 3019), four males (CSV 31, CSV 17,
SPV 2682 and SPV 2573) and 28 F$_1$ hybrids. Parents
were crossed in a Line × Tester fashion during summer
2020. Hybridization was carried out through hand
emasculaton and hand pollination. Simultaneously
parental genotypes were also maintained through selfing
to get pure seeds of parents for the experiment. The
experimental materials consisted of 39 entries comprising
28 crosses and 11 parents evaluated in Randomized
Block Design with three replications during
Kharif, 2020 at Sorghum Research Station, SDAU, Deesa. Each
genotype was sown in two rows of two-meter length.
The distance between rows and within rows was 45 cm
and 15 cm, respectively. The observations were
recorded both as visual assessment for days to
flowering, while measurement on randomly
selected five competitive individual plants for total
plant height (cm), the number of leaves per plant,
stem girth (mm), leaf length of the blade (cm), leaf width
of the blade (cm), panicle length (cm), grain yield per
plant (g), dry fodder yield per plant (g), grain protein
content (%), fodder protein content (%), Brix content
(%) and HCN content (ppm). The replication-wise
mean values for all the characters were subjected to
statistical analysis. The analysis of variance was carried
out as per the procedure suggested by Panse and
Sukhatme (1985). The mean value of 39 entries (Parents
and their F$_1$ hybrids) were entered in the computer
and combining ability analysis was carried out according to
the procedure given by Kempthorne (1957).

RESULTS AND DISCUSSION

The analysis of variance for combining ability and
estimates of variance components are given in Table 1.
The analysis of variance for combining ability partitioning
the total genetic variance into general combining ability,
representing the additive type of gene action and specific
combining ability as a measure of the non-additive type
of gene action was carried out for thirteen characters.
The mean sum of squares due to female (lines) and male
(testers) were highly significant for all the traits except
panicle length. The mean sum of squares due to males
was higher in magnitude for days to flowering, stem girth,
leaf length of the blade, leaf width of the blade, panicle
length, dry fodder yield per plant, grain protein content
and brix content than the female indicated the more
outstanding contribution of male towards these traits,
while in rest of traits showed more contribution of female.
The mean sum of squares due to the Line × Tester
interaction was significant for all traits except panicle
length. It signified the contribution of hybrids for specific
combining ability variance components.

The ratio of $\sigma^2_{L}/\sigma^2_{G}$, being more than unity was found for
days to flowering, suggesting a greater role of additive
genetic variance in the inheritance of this trait. This trait can
be improved further as a source of favourable genes for
earliness by selecting desired transgressive segregants
from segregating generations. The predominant
role of additive gene action was observed in days to
flowering is analogous with results reported earlier by
Hariprasanna et al. (2012), Soujanya et al. (2017),
Sen et al. (2018) and Rathod et al. (2019) in sorghum.

The magnitude of specific combining ability variance was
higher than general combining ability variance for rest of
the traits viz., total plant height, the number of leaves per
plant, stem girth, leaf length of the blade, leaf width
of the blade, panicle length, grain yield per plant, dry fodder
yield per plant, grain protein content, fodder protein
content, brix content and HCN content which indicated the
importance of non-additive gene effects in the
inheritance of these traits, which suggesting exploitation
of these traits for improvement of yield through
heterosis breeding. The above results were in
accordance with the findings of Patel et al. (2018),
Parmar et al. (2019), Rathod et al. (2019), Patel et al. (2021)
for total plant height; Sen et al. (2018), Parmar et al. (2019),
Rathod et al. (2019), Patel et al. (2021) for number of leaves per plant; Patel et al. (2018), Sen et al. (2018), Parmar et al. (2019), Patel et al. (2021)
for stem girth; Kumari et al. (2018), Parmar et al. (2019),
Rathod et al. (2019), Patel et al. (2021) for leaf length of
blade; Kumari et al. (2018), Parmar et al. (2019),
Rathod et al. (2019), Patel et al. (2021) for leaf width of
blade; Hariprasanna et al. (2012), Kumar and Chand
(2015), Ingle et al. (2018), Patel et al. (2018) for panicle
length; Jadhav and Deshmukh (2017), Ingle et al. (2018),
Rathod et al. (2019), Patel et al. (2021) for grain
yield per plant; Soujanya et al. (2018), Parmar et al. (2019),
Rathod et al. (2019), Patel et al. (2021) for dry fodder yield per plant; Chaudhari et al. (2017), Vekariya et al. (2017), Rathod et al. (2019),
Patel et al. (2021) for fodder protein content; Dehiwal et al. (2017), Soujanya et al. (2018), Parmar et al. (2019), Patel et al. (2021) for brix content; Kumar et al. (2013), Padmeshree et al. (2014),
Chaudhari et al. (2017), Dehiwal et al. (2017) for HCN
content in sorghum.
Table 1. Analysis of variance (mean square) for combining ability, estimates of components of variance and their ratio for various characters in sorghum

| Sources of variation | d.f. | Days to flowering | Total plant height | Number of leaves per plant | Stem girth | Leaf length of blade | Leaf width of blade | Panicle length |
|----------------------|------|-------------------|--------------------|---------------------------|------------|---------------------|-------------------|--------------|
| Replications         | 2    | 5.91              | 171.50             | 0.005                     | 0.53       | 10.35               | 0.54              | 5.98         |
| Hybrids (Crosses)    | 27   | 70.46**           | 5561.24**          | 10.15**                   | 37.82**    | 149.59**            | 2.24**            | 18.17        |
| Female in hybrid     | 6    | 33.26**           | 13231.40**         | 20.18**                   | 43.09**    | 68.50**             | 1.25**            | 11.56        |
| Male in hybrid       | 3    | 342.90**          | 3339.55**          | 11.38**                   | 78.06**    | 112.98**            | 1.93**            | 23.83        |
| Females × Males (L × T) | 18  | 37.45**           | 3374.80**          | 6.60**                    | 29.36**    | 182.72**            | 2.62**            | 19.44        |
| Error                | 76   | 2.15              | 201.82             | 0.43                      | 5.08       | 15.08               | 0.22              | 11.95        |

Components of variance:
- σ² Females
- σ² Males
- σ² D
- σ² H
- σ² D / σ² H

The general combining ability effects of eleven parents for thirteen traits are depicted in Table 2. Parents’ gca effects explicated that none of the parents consistently good general combiner for all the traits under study. The female parent GJ 43 was a good general combiner for days to flowering, total plant height, number of leaves per plant, grain yield per plant, fodder protein content and HCN content; DS 156 was a good general combiner for total plant height, number of leaves per plant, dry fodder yield per plant, fodder protein content and HCN content; SR 3019 was good general combiner for leaf length of the blade, leaf width of the blade and brix content; SR 2980 was good general combiner for leaf length of the blade, leaf width of the blade and brix content. The gca effects of males indicated that the parent CSV 31 was a good general combiner for days to flowering, total plant height, the number of leaves per plant, leaf length of the blade, leaf width of the blade, grain yield per plant and dry fodder yield per plant; SPV 2682 was good general combiner for total plant height, the number of leaves per plant, dry

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Table 2. The estimates of general combining ability (gca) effects of the parents for various characters in sorghum

| S. No. Parents | Days to flowering | Total plant height | Number of leaves per plant | Stem girth | Leaf length of blade | Leaf width of blade | Panicle length | Grain yield per plant | Dry fodder yield per plant | Grain protein content | Fodder protein content | Brix content | HCN content |
|----------------|------------------|--------------------|---------------------------|------------|---------------------|-------------------|---------------|----------------------|------------------------|---------------------|---------------------|--------------|------------|
| **FEMALE PARENTS (Lines):** | | | | | | | | | | | | | | |
| 1 | DSF 168 | -0.24 | -23.26** | -1.01** | -0.10 | -1.12 | -0.25 | -0.55 | -1.00 | 3.03 | 0.30 | -0.55** | 0.06 | -0.82 |
| 2 | DSF 117 | -2.49** | -32.14** | -1.30** | -1.47* | -2.00 | 0.05 | -1.12 | -2.62** | -35.25** | 0.01 | 0.02 | 0.08 | 17.06** |
| 3 | SR 2980 | -0.24 | -16.35** | 0.03 | 0.91 | -0.19 | 0.44** | 0.05 | 1.24 | 12.30 | 0.07 | -0.18** | 0.29 | -4.21** |
| 4 | SR 3048 | 2.85** | 16.38** | 0.51** | -2.68** | 0.36 | -0.43** | -0.59 | -4.68** | -31.92** | 0.06 | -0.09 | 0.65* | 0.58 |
| 5 | SR 3019 | 0.43 | -29.66** | -1.26** | -0.88 | 4.85** | 0.39** | 0.67 | 10.59** | -26.16** | 0.09 | 0.09 | -0.05 | 0.37 |
| 6 | GJ 43 | -1.15** | 40.17** | 2.20** | 1.19 | -2.28* | -0.03 | -0.29 | 1.71* | 9.73 | 0.26** | 0.14* | -0.11 | -8.50** |
| 7 | DS 156 | 0.85 | 44.86** | 0.84** | 3.03** | 0.38 | -0.16 | 1.83 | -5.24** | 68.27** | -0.78 | 0.56** | -0.92** | -4.47** |
| | S.E.m. ± | 0.42 | 4.10 | 0.19 | 0.65 | 1.12 | 0.14 | 1.00 | 0.82 | 6.65 | 0.17 | 0.06 | 0.25 | 0.68 |

| **MALE PARENTS (Testers):** | | | | | | | | | | | | | | |
| 1 | CSV 31 | -1.30** | 11.81** | 0.44** | 2.59** | 2.06* | 0.29** | 0.67 | 3.70** | 29.02** | 0.25 | -0.23** | -0.30 | 4.84** |
| 2 | CSV 17 | -5.11** | -14.62** | -0.86** | -0.63 | 1.91* | 0.21* | 0.38 | -0.61 | -43.68** | -0.38** | -0.17** | 0.22 | -0.19 |
| 3 | SPV 2682 | 3.80** | 9.15** | 0.76** | 0.04 | -2.43** | -0.37** | 0.54 | -1.23 | 34.91** | -0.20 | 0.08 | 0.47* | -2.02** |
| 4 | SPV 2573 | 2.61** | -6.33* | -0.33* | -2.00** | -1.53 | -0.13 | -1.59* | -1.86** | -20.25** | 0.32* | 0.32** | -0.40* | -2.63** |
| | S.E.m. ± | 0.32 | 3.10 | 0.14 | 0.49 | 0.84 | 0.10 | 0.75 | 0.62 | 5.18 | 0.13 | 0.04 | 0.19 | 0.51 |

* P ≤ 0.05, ** P ≤ 0.01.

fodder yield per plant, brix content and HCN content; SPV 2573 was good general combiner for stem girth, grain protein content, fodder protein content and HCN content; CSV 17 was good general combiner for days to flowering, leaf length of the blade and leaf width of the blade.

The results based on specific combining ability effects of hybrids revealed that none of the hybrids was consistently superior for all the characters (Table 3). Considering the performance of the sca effects, eight hybrids for grain yield per plant and nine hybrids for dry fodder yield per plant manifested desirable and significant sca effects. In the case of other component traits, seven hybrids for days to flowering, nine hybrids for total plant height, six hybrids for leaf length of the blade, five hybrids for leaf width of the blade, seven hybrids for number of leaves per plant, six hybrids for panicle length, five hybrids for grain protein content, twelve hybrids for fodder protein content and nine hybrids for HCN content manifested significant and desirable sca effects. Based on estimates of sca effects, the most promising hybrids for grain yield per plant were viz., SR 2980 × CSV 31, SR 3019 × SPV 2573 and DSF 117 × SPV 2682 based on significant positive sca effects and for dry fodder yield per plant were viz., SR 3048 × CSV 31, GJ 43 × SPV 2573 and DSF 168 × SPV 2573. These crosses also exhibited positive significant sca effects for other contributing traits viz., total plant height, the number of leaves per plant, leaf length of the blade, leaf width of the blade, panicle length, grain protein content, fodder protein and brix content. So, these hybrids showing significant sca effect can be directly used for hybrid breeding programmes.

The analysis of variance for combining ability revealed that the mean sum of squares due to female (lines) and male (testers) was highly significant for all the traits except panicle length. The ratio of $\sigma^2_A/\sigma^2_H$, being more than unity was found for days to flowering, suggesting a more significant role of additive genetic variance in inheriting this trait. Parents’ gca effects explicated that the parents SR 3019, CSV 31 and GJ 43 were found good general combiners for grain yield per plant. While, parents DS 156, CSV 31 and SPV 2682 were good general combiners for dry fodder yield per plant and its contributing traits. These good general combiners for yield and contributing traits can be utilized in intensive crossing programmes and select transgressive segregants for desired characters in segregating generations to develop superior lines. The most promising hybrids for grain yield per plant were viz., SR 2980 × CSV 31, SR 3019 × SPV 2573 and DSF 117 × SPV 2682 based on significant positive sca effect and for dry fodder yield per plant were viz., SR 3048 × CSV 31, GJ 43 × SPV 2573 and DSF 168 × SPV 2573.
Table 3. The estimates of specific combining ability (sca) effects of the hybrids for various characters in sorghum

| S.No. | Hybrids           | Days to flowering | Total plant height | Number of leaves per plant | Stem girth | Leaf length of blade | Leaf width of blade | Panicle length |
|-------|-------------------|-------------------|--------------------|---------------------------|------------|---------------------|-------------------|---------------|
| 1     | DSF 168 × CSV 31  | 0.38              | -7.81              | 2.48**                    | -0.25      | -1.49               | -0.11             | 0.76          |
| 2     | DSF 168 × CSV 17  | 0.19              | 23.04**            | 0.45                      | 1.56       | -0.32               | 0.80**            | 0.77          |
| 3     | DSF 168 × SPV 2682| 0.29              | -18.57*            | -3.43**                   | -2.92*     | 1.54                | -0.21             | -1.84         |
| 4     | DSF 168 × SPV 2573| -0.86             | 3.34               | 0.50                      | 1.60       | 0.27                | -0.49             | 0.31          |
| 5     | DSF 117 × CSV 31  | -1.70*            | 1.40               | -0.84*                    | -0.25      | 11.79**             | 1.10**            | -1.07         |
| 6     | DSF 117 × CSV 17  | 1.77*             | 19.25*             | -0.64                     | 0.77       | -14.52**            | -1.80**           | -0.78         |
| 7     | DSF 117 × SPV 2682| -7.46**           | -11.94             | 1.52**                    | 3.12*      | 0.95                | 0.32              | 6.90**        |
| 8     | DSF 117 × SPV 2573| 7.39**            | -8.71              | -0.05                     | -3.63**    | 1.78                | 0.38              | -5.05*        |
| 9     | SR 2980 × CSV 31  | -1.62             | -7.97              | -0.98*                    | -1.29      | -10.69**            | -1.75**           | -0.08         |
| 10    | SR 2980 × CSV 17  | -1.14             | 7.79               | -0.51                     | -3.43*     | 1.79                | 0.63*             | -1.56         |
| 11    | SR 2980 × SPV 2682| 0.95              | -2.73              | 0.86*                     | 1.51       | 3.30                | 0.74**            | -1.04         |
| 12    | SR 2980 × SPV 2573| 1.81*             | 2.92               | 0.63                      | 3.22*      | 5.60*               | 0.39              | 2.68          |
| 13    | SR 3048 × CSV 31  | -3.37**           | 55.63**            | 0.13                      | 3.86**     | 9.41**              | 0.83**            | 1.25          |
| 14    | SR 3048 × CSV 17  | 0.11              | -28.44**           | 0.09                      | -0.75      | 1.45                | 0.46              | 1.00          |
| 15    | SR 3048 × SPV 2682| 6.20**            | 5.20               | 1.64**                    | 0.82       | -2.81               | -0.21             | 0.16          |
| 16    | SR 3048 × SPV 2573| -2.94**           | -32.39**           | -1.85**                   | -3.93**    | -8.04**             | -1.08**           | -2.41         |
| 17    | SR 3019 × CSV 31  | 1.05              | -3.49              | -0.69                     | 3.83**     | 5.38*               | -0.11             | -1.18         |
| 18    | SR 3019 × CSV 17  | 0.19              | 18.85*             | 0.53                      | 2.70*      | 0.09                | -0.49             | 0.39          |
| 19    | SR 3019 × SPV 2682| 0.62              | -33.59**           | -1.34**                   | -4.62**    | -6.30**             | -0.63*            | -0.65         |
| 20    | SR 3019 × SPV 2573| -1.86*            | 18.23*             | 1.50**                    | -1.91      | 0.83                | 1.22**            | 1.44          |
| 21    | GJ 43 × CSV 31    | 0.96              | 32.09**            | 0.60                      | -2.73*     | -2.40               | 0.12              | -0.61         |
| 22    | GJ 43 × CSV 17    | -1.56             | -50.65**           | 0.40                      | -1.57      | -1.02               | 0.19              | -0.34         |
| 23    | GJ 43 × SPV 2682  | 1.20              | 33.99**            | -0.80*                    | 1.46*      | -0.01               | -0.66*            | -1.35         |
| 24    | GJ 43 × SPV 2573  | -0.61             | -15.44             | -0.21                     | 2.84*      | 3.42                | 0.35              | 2.31          |
| 25    | DS 156 × CSV 31   | 4.30**            | -69.85**           | -0.71                     | -3.17      | -11.99**            | -0.08             | 0.92          |
| 26    | DS 156 × CSV 17   | 0.44              | 10.16              | -0.32                     | 0.73       | 12.53**             | 0.20              | 0.53          |
| 27    | DS 156 × SPV 2682 | -1.80*            | 27.64**            | 1.55**                    | 0.63       | 3.33                | 0.65*             | -2.18         |
| 28    | DS 156 × SPV 2573 | -2.94**           | 32.04**            | -0.52                     | 1.81       | -3.87               | -0.77**           | 0.72          |

SEm (±) 0.84 8.20 0.38 1.30 2.24 0.84 8.20

Range
Minimum -7.46 -69.85 -3.43 -4.62 -14.52 -1.80 -5.05
Maximum 7.39 55.63 2.48 3.86 12.53 1.22 6.9

Number of +ve significants 5 9 6 7 5 7 1
Number of -ve significants 7 6 6 6 5 6 1

* P ≤ 0.05, ** P ≤ 0.01.
Table 3 Continued…

| S.No. | Hybrids             | Grain yield per plant | Dry fodder yield per plant | Grain protein content | Fodder protein content | Brix content | HCN content |
|-------|---------------------|-----------------------|----------------------------|-----------------------|------------------------|--------------|-------------|
| 1     | DSF 168 × CSV 31    | 4.70**                | 4.90                        | 0.93**                | -0.68**                | -0.83        | -4.93**     |
| 2     | DSF 168 × CSV 17    | -2.32                 | -1.69                       | -1.06**               | 0.89**                 | 0.41         | 2.11        |
| 3     | DSF 168 × SPV 2682  | -0.48                 | -84.12**                    | 0.70*                 | 0.11                   | -0.89        | -4.61**     |
| 4     | DSF 168 × SPV 2573  | -1.90                 | 80.91**                     | -0.57                 | -0.32**                | 1.31*        | 7.43**      |
| 5     | DSF 117 × CSV 31    | -3.02                 | -20.58                      | 0.10                  | 0.29*                  | 1.19*        | 22.22**     |
| 6     | DSF 117 × CSV 17    | 0.78                  | 31.72*                      | 1.01**                | 0.77**                 | 0.11         | 1.51        |
| 7     | DSF 117 × SPV 2682  | 5.48**                | 68.43**                     | -0.46                 | -1.31**                | 0.18         | -17.62**    |
| 8     | DSF 117 × SPV 2573  | -3.25                 | -79.57**                    | -0.65                 | 0.26*                  | -1.49**      | -6.11**     |
| 9     | SR 2980 × CSV 31    | 10.05**               | 4.81                        | -1.54**               | -0.20                  | -1.43**      | -12.89**    |
| 10    | SR 2980 × CSV 17    | -5.43**               | -45.21**                    | 0.25                  | -0.05                  | -1.04*       | -3.50*      |
| 11    | SR 2980 × SPV 2682  | -4.54**               | 42.23**                     | 0.33                  | 0.12                   | 2.58**       | 10.37**     |
| 12    | SR 2980 × SPV 2573  | -0.08                 | -1.83                       | 0.96**                | 0.14                   | -0.11        | 6.01**      |
| 13    | SR 3048 × CSV 31    | 3.48*                 | 111.62**                    | 0.34                  | 0.02                   | 1.29*        | 1.95        |
| 14    | SR 3048 × CSV 17    | 2.86                  | -45.10**                    | 0.59                  | 0.63**                 | 0.97         | -2.25       |
| 15    | SR 3048 × SPV 2682  | -0.89                 | 14.63                       | -0.48                 | 0.04                   | -3.48**      | -6.18**     |
| 16    | SR 3048 × SPV 2573  | -5.45**               | -81.15**                    | -0.44                 | -0.68**                | 1.22*        | 6.48**      |
| 17    | SR 3019 × CSV 31    | -5.79**               | -33.84*                     | 0.64                  | 1.31**                 | -0.59        | -2.61       |
| 18    | SR 3019 × CSV 17    | 4.70**                | 33.90*                      | -1.16**               | -1.55**                | -0.27        | -1.80       |
| 19    | SR 3019 × SPV 2682  | -6.86**               | -42.38**                    | -1.00**               | -1.06**                | 0.49         | 1.07        |
| 20    | SR 3019 × SPV 2573  | 7.95**                | 42.32**                     | 1.53**                | 1.30**                 | 0.37         | 3.33*       |
| 21    | GJ 43 × CSV 31      | -3.73*                | -89.74**                    | -0.44                 | -1.15**                | 0.80         | -6.64**     |
| 22    | GJ 43 × CSV 17      | -1.58                 | 30.40*                      | -0.43                 | -1.48**                | -0.50        | 0.87        |
| 23    | GJ 43 × SPV 2682    | 3.27*                 | -22.96                      | 0.91**                | 1.80**                 | -0.13        | 3.75**      |
| 24    | GJ 43 × SPV 2573    | 2.04                  | 82.30**                     | -0.05                 | 0.83**                 | -0.17        | 2.03        |
| 25    | DS 156 × CSV 31     | -5.69**               | 22.84                       | -0.03                 | 0.42**                 | -0.44        | 2.90*       |
| 26    | DS 156 × CSV 17     | 0.99                  | -4.02                       | 0.81*                 | 0.80**                 | 0.33         | 3.06*       |
| 27    | DS 156 × SPV 2682   | 4.02*                 | 24.18                       | 0.01                  | 0.31**                 | 1.24*        | 13.21**     |
| 28    | DS 156 × SPV 2573   | 0.69                  | -42.99**                    | -0.78*                | -1.52**                | -1.12*       | -19.17**    |
| SEm (±)|                     | 1.64                  | 13.71                       | 2.24                  | 0.34                   | 0.12         | 0.51        |

SEm: Standard Error of the Mean

Range

Minimum: -6.86
Maximum: 10.05

Number of +ve significants: 8
Number of -ve significants: 7

* P ≤ 0.05, ** P ≤ 0.01.
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