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# GENE ACTION AND COMBINING ANALYSIS FOR YIELD AND ITS ATTRIBUTING TRAITS IN FORAGE SORGHUM [*SORGHUM BICOLOR* (L.) MOENCH]

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## SUMMARY

The experiment in forage sorghum [*Sorghum bicolor* (L.) Moench] was carried out in Randomized Block Design (RBD) with three replications to study gene action and combining ability of nine females and three males with their 27 F1's for fodder yield, its quality and other yield related traits. The ratio of $\sigma 2$*gca* /$\sigma 2$sca was found less than unity for all the traits under study, suggesting greater role of non-additive genetic variance in the inheritance of all these traits. The parents, DSF-123, DSF-138 and DSF-146 were found good general combiners for green fodder yield per plant and its contributing traits *viz*. number of leaves per plant, leaf width, brix %, dry matter yield per plant and leaf area. On the basis of *sca* effects, the crosses DSF-130 × CSV 21 F, DSF-140 × GFS 5 and DSF-138 × CSV 21 F were found promising for green fodder yield per plant. These crosses were also manifested high *sca* values for its contributing traits *viz.* plant height, number of leaves per plant, leaf length, leaf width, brix %, dry matter yield per plant and leaf area. The crosses exhibiting high *sca* effects for green fodder yield per plant involved average × average or good × average combining parents. Better performance of these hybrids for green fodder yield per plant reflected involvement of interaction of dominant and epistasis type of gene action.

**Keywords :** L × T analysis, Gene action, Combining ability, Green fodder yield

Sorghum [*Sorghum bicolor* (L.), Moench] is the fifth most important crop after wheat, rice, maize and barley in the world and popularly known as *jowar* is an annual crop, which belongs to the family *Poaceae*, having 2n=20 chromosomes. Sorghum is preferred over maize and pearl millet for forage because of its high tolerance to wide variation in soil and moisture conditions as well as better regeneration capacity. In dairy production, the cost of feed constitutes about 60-65% of the total cost of milk production. To reduce the cost of milk production, continuous supply of green fodder to the animal is necessary. There is need for continuous and steady supply of green fodder to increase milk production potential of animal under different intensive programmes executed to sustain of white revolution in the state.

The fodder sorghum is most nutritive for animal among all the fodder crops. Fodder requirement is increasing due to the fast development of dairy industry in the state. To meet this requirement, it is difficult to increase the area under fodder crops on account of even increasing pressure on land by commercial crops and cereals, over and above the industrial and housing occupation. Therefore, only alternative is by way of increasing the production per unit time and per unit area through providing improved technology in the form of improved varieties and agronomic practices as well as improving quality of fodder sorghum. In order to make fodder sorghum more remunerative crop, obviously there is an urgent need to initiate research for development of varieties and hybrids having faster growth, multicut habit with high regeneration capacity, early to medium maturity and higher biomass coupled with high protein content and minimum toxic constituents like HCN. Srinivasa *et al* (2006) and AL-Sultan (2003) reported high HCN content in the sorghum plant in early growth stage, which decreased with plant maturity.

The information on the magnitude and nature of prevalent genetic variation is essentially needed to infer about genetic potential of a particular population.

Study of combining ability helps to select good combining parents, which on crossing would produce more desirable segregants. Such studies also elucidate nature and magnitude of gene action in an inheritance of yield and its components, which will help to decide the breeding programme to be followed in segregating generations. Different mating designs have been used by different workers as an aid in the choice of parent and to understand their genetic nature. The line × tester analysis suggested by Kempthorne (1957) to analyze polygenic system is useful technique for screening large number of lines for identifying the best combiner. Similarly, knowledge about nature of gene action governing the expression of various traits could help in predicting the effectiveness of selection.

## MATERIALS AND METHODS

The present investigation was carried out at Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa (Gujarat). The testing materials consisted nine lines (DSF-123, DSF-130, DSF-138, DSF-140, DSF-141, DSF-146, DSF-150, DSF-152, DSF-154), three testers (Malwan, CSV 21 F and GFS 5) and their 27 $F_1$ hybrids. The $F_1$ hybrids along with twelve parents (9 lines and 3 testers) and one check CSH 13 were evaluated in a Randomized Block Design with three replications during *kharif* 2016. Data were recorded on five competitive plants selected randomly for plant height (cm), number of leaves per plant, sStem diameter (cm), leaf length (cm), leaf width (cm), leaf : stem Ratio, brix (%), green fodder yield per plant (g), dry fodder yield per plant (g), leaf area ($cm^2$) and protein content (%). The protein content was estimated in per centage by protein analyzer. Whereas days to flowering was recorded on plot basis. The mean data were subjected to statistical analysis. The analysis of variance was carried out as per the procedure suggested by Sukhatme and Amble (1989) as well as combining ability variance analysis by Kempthorne (1957). The data were analyzed statistically using the software WINDOSTAT version 8.1.

## RESULTS AND DISCUSSION

The analysis of variance for combining ability by partitioning the total genetic variance into general combining ability which representing additive genetic variance and specific combining ability as a measure of non-additive genetic variance was carried out for different characters and are presented in Table 1. The mean sum of square due to lines was significant for brix (%). The mean sum of square due to testers was significant for days to flowering and protein content. The mean sum of square due to line × testers interaction was significant for all the traits except stem diameter, revealed the significant contribution of hybrids for specific combining ability variance components. The sum of mean square due to testers was larger in magnitude for day to flowering and protein content than the lines indicated greater contribution of testers to these traits. In case of lines, it was observed greater for plant height, number of leaves per plant, stem diameter, leaf length, leaf width, leaf: stem ratio, brix (%), green fodder yield per plant, dry matter yield per plant and leaf area which showed contribution of female lines to these traits more than male parents.

The $\sigma^2 gca$ / $\sigma^2 sca$ ratio was less than unity for all the traits (Table 1) suggesting the greater role of non-additive genetic variances in the inheritance of all the traits. In other word, it can interpreted that the magnitude of specific combining ability variance was higher than general combining ability variance for all the traits which indicated importance of non-additive gene effects in the inheritance of these traits. Thus, for the improvement of forage yield, its components and quality traits, heterosis breeding may be more rewarding.

The presence of predominantly large amount of non-additive gene action would be required for the maintenance of heterozygosity in the population. Preponderance of non-additive genetic variance suggested the relevance of heterosis breeding in forage sorghum. The non-additive gene action for different traits in sorghum has been reported earlier by Patel (2011), Tariq *et al.* (2012), Padmashree *et al.* (2014), Aruna *et al.*(2015) and Kumar and Chand (2015) for days to 50 per cent flowering; Bhatt and Baskheti (2011), Padmashree *et al.* (2014), Tariq *et al.* (2012), Aruna *et al.* (2015), Kumar and Chand (2015) and Kumari *et al.* (2018) for plant height; Bhatt and Baskheti (2011), Patel (2011), Abdelmula *et al.* (2014), Padmashree *et al.* (2014) and Kumar and Chand (2015)for number of leaves per plant and leaf area; Kumari *et al.* (2018) for number of leaves per plant Patel (2011), Jain and Patel (2014), Padmashree *et al.* (2014), Tariq *et al.* (2012) and Kumar and Chand (2015) for stem diameter; Parmar (1997) and Mohan *et al.* (2007) for leaf: stem ratio; Bhatt and Baskheti (2011), Tariq *et al.* (2012), Jain and Patel (2014),

TABLE 1
Analysis of variance for combining ability for different traits in forage sorghum

| Parents | d. f. | Days to flowering | Plant height (cm) | No. of leaves/ plant | Stem diameter (cm) | Leaf length (cm) | Leaf width (cm) | Leaf : stem ratio | Brix (%) | Green fodder yield/ plant (g) | Dry matter yield/ plant (g) | Leaf area (cm) | Protein content (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Replications | 2 | 3.20 | 654.65 | 1.04 | 0.004 | 6.66 | 0.03 | 0.001 | 0.26 | 358.39 | 133.18 | 179064.79 | 0.01 |
| Females (Lines) | 8 | 46.99 | 1573.14 | 4.97 | 0.010 | 621.86 | 7.86 | 0.012 | 40.55* | 19408.79 | 5536.11 | 2918708.22 | 1.05 |
| Males (Testers) | 2 | 141.38* | 50.17 | 0.001 | 0.002 | 80.48 | 0.14 | 0.004 | 0.74 | 547.17 | 52.27 | 56757.58 | 2.63 * |
| Females × Males | 16 | 35.29** | 2246.36** | 7.72** | 0.010 | 560.43** | 9.25** | 0.006** | 12.05** | 19858.89** | 2589.47** | 3197868.67** | 0.56** |
| Error | 52 | 4.61 | 355.23 | 0.70 | 0.007 | 42.17 | 0.03 | 0.001 | 0.27 | 357.51 | 51.75 | 65330.56 | 0.07 |
| **Components of Variance** | | | | | | | | | | | | | |
| $\sigma^2$ Females | | 4.79 | 141.52 | 0.49 | 0.001 | 63.85 | 0.87 | 0.001 | 4.48* | 2111.03 | 610.55 | 318239.99 | 0.11 |
| $\sigma^2$ Males | | 5.09* | -9.23 | -0.02 | -0.001 | 1.23 | 0.003 | 0.000 | 0.02 | 5.10 | 0.41 | 81.83 | 0.09* |
| $\sigma^2$ gca | | 5.02** | 28.46 | 0.11 | 0.000 | 16.89 | 0.22 | 0.001* | 1.13* | 531.58 | 152.94 | 79621.37 | 0.10** |
| $\sigma^2$ sca | | 10.47** | 648.97** | 2.40** | 0.002* | 171.08** | 3.07** | 0.002** | 3.93** | 6483.11** | 849.42** | 1047773.47** | 0.16** |
| $\sigma^2$gca/$\sigma^2$sca | | 0.48 | 0.04 | 0.05 | 0.025 | 0.10 | 0.07 | 0.241 | 0.29 | 0.08 | 0.18 | 0.08 | 0.61 |

*, **Significant at 5 per cent and 1 per cent levels of significance, respectively.

TABLE 2A
The estimates of general combining ability (gca) effects of the parents for various characters in forage sorghum

| Parents | Days to flowering | | Plant height (cm) | | No. of leaves/ plant | | Stem diameter (cm) | | Leaf length (cm) | | Leaf width (cm) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lines** | | | | | | | | | | | | |
| DSF-123 | 1.14 | A | 11.06 | A | 0.88** | G | 0.01 | A | 4.40 | A | 0.30** | G |
| DSF-130 | -1.64* | G | -9.03 | A | -1.01** | P | 0.02 | A | -1.46 | A | 0.24** | G |
| DSF-138 | 0.91 | A | 9.95 | A | 0.84** | G | 0.06* | P | 0.35 | A | 0.81** | G |
| DSF-140 | 1.14 | A | -1.89 | A | 0.08 | A | -0.05 * | G | -1.94 | A | -0.22** | P |
| DSF-141 | 2.58** | P | -2.16 | A | -0.01 | A | -0.01 | A | 4.28 | A | 0.04 | A |
| DSF-146 | -4.75** | G | 19.15** | G | 0.77** | G | 0.01 | A | 13.04** | G | 1.24** | G |
| DSF-150 | -0.98 | A | 0.48 | A | -0.31 | A | 0.01 | A | 1.63 | A | -0.09 | A |
| DSF-152 | -0.64 | A | -0.74 | A | -0.14 | A | -0.01 | A | -2.08 | A | -0.19* | P |
| DSF-154 | 2.25** | P | -26.83** | P | -1.10** | P | -0.04 | A | -18.22** | P | -2.13** | P |
| S. Em± | 0.66 | | 5.77 | | 0.24 | | 0.02 | | 2.29 | | 0.07 | |
| **Testers** | | | | | | | | | | | | |
| Malwan | 2.47** | P | 1.51 | A | 0.00 | A | -0.002 | A | -0.58 | A | -0.08 | A |
| CSV 21F | -0.42 | A | -1.13 | A | - 0.01 | A | -0.01 | A | 1.94 | A | 0.03 | A |
| GFS 5 | -2.05** | G | -0.38 | A | -0.01 | A | 0.01 | A | 1.36 | A | 0.05 | A |
| S. Em± | 0.38 | | 3.33 | | 0.14 | | 0.01 | | 1.32 | | 0.04 | |

*, **Significant at 5 per cent and 1 per cent levels of significance, respectively.
G=Parent having significant gca effect in desired direction
P=Parent having significant gca effect in undesired direction
A=Parent having either positive or negative but non-significant gca effect.

Padmashree *et al*. (2014), Aruna *et al*. (2015), Kumar and Chand (2015) for green forage and dry matter yield per plant, while Kumari *et al*. (2018) reported for green fodder yield. Dehinwal *et al* (2017) for total soluble sugar content

On the basis of *gca* effects, among the females, DSF-123, DSF-138 and DSF-146 were good general combiners for green fodder yield per plant, number of leaves per plant, leaf width, brix %, dry matter yield per plant and leaf area. The parents DSF-130 and DSF-146 were found good general combiners for earliness. While, DSF-123, DSF-150 and DSF-152 were found good general combiners for protein content. DSF-140 was good general combiner for stem diameter. In case of males, the GFS 5 was good general combiner for days to flowering and leaf: stem ratio. The male patent Malwan showed good general combining ability for protein content (Table 2a & b). So, these males can be extensively used in breeding programme for producing better new recombinations.

Out of 27 cross combinations, seven crosses exhibited significant positive *sca* effects. The best specific cross combinations were DSF-130 × CSV 21 F, DSF-140 × GFS 5 and DSF-138 × CSV 21 F for green fodder yield per plant. These crosses were also manifested high *sca* values for its contributing traits *viz.* plant height, number of leaves per plant, leaf length, leaf width, brix %, dry matter yield per plant and leaf area. The crosses exhibiting high *sca* effects for green fodder yield per plant involved average × average or good × average combining parents (Table 3). Better performance of these hybrids for green fodder yield per plant reflected involvement of interaction of dominant and epistasis type gene action.

TABLE 2B

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

| Parents | Leaf : stem ratio | | Brix (%) | | Green fodder yileld/plant (g) | | Dry matter yileld/plant (g) | | Leaf area ($cm^2$) | | Protein content (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lines** | | | | | | | | | | | | |
| DSF-123 | 0.02** | G | 1.40** | G | 30.41** | G | 18.90** | G | 340.08** | G | 0.44** | G |
| DSF-130 | 0.08** | G | 1.30** | G | -2.45 | A | -9.75** | P | -87.82 | A | 0.09 | A |
| DSF-138 | 0.03** | G | 2.83** | G | 26.48** | G | 19.53** | G | 570.49** | G | 0.15 | A |
| DSF-140 | -0.02** | P | -2.55** | P | -1.93 | A | -8.95** | P | -253.79** | P | -0.38** | P |
| DSF-141 | -0.02** | P | -3.31** | P | -4.56 | A | 0.49 | A | -13.79 | A | -0.11 | A |
| DSF-146 | -0.03** | P | 1.22** | G | 63.18** | G | 28.07** | G | 689.65** | G | -0.66** | P |
| DSF-150 | -0.02** | P | -2.11** | P | -1.69 | A | 8.61** | G | 152.36 | A | 0.27** | G |
| DSF-152 | -0.04** | P | 0.94** | G | -1.76 | A | -0.83 | A | -148.09 | A | 0.20* | G |
| DSF-154 | -0.002 | A | 0.29 | A | -107.69** | P | -56.07** | P | -1249.09** | P | 0.01 | A |
| S. Em± | 0.01 | | 0.17 | | 6.74 | | 2.13 | | 77.85 | | 0.09 | |
| **Testers** | | | | | | | | | | | | |
| Malwan | 0.01 | A | -0.15 | A | -0.61 | A | 1.37 | A | 18.51 | A | 0.35** | G |
| CSV 21F | -0.01** | P | 0.18 | A | -4.16 | A | -1.41 | A | 33.70 | A | -0.26** | P |
| GFS 5 | 0.01* | G | -0.02 | A | 4.78 | A | -0.04 | A | -51.21 | A | -0.09 | A |
| S. Em± | 0.004 | | 0.10 | | 3.89 | | 1.24 | | 44.95 | | 0.05 | |

*, **Significant at 5 per cent and 1 per cent levels of significance, respectively
G=Parent having significant gca effect in desired direction
P=Parent having significant gca effect in undesired direction
A=Parent having either positive or negative but non-significant gca effect.

So, these crosses with high yielding potential can be exploited through only hybrid breeding programme.

## CONCLUSION

From above result it can be concluded that the magnitude of specific combining ability variance was higher than general combining ability variance for all the traits which indicated importance of non-additive gene effects in the inheritance of these traits. The parents, DSF-123, DSF-138 and DSF-146 were good general combiners for green fodder yield per plant and its contributing traits *viz*. number of leaves per plant, leaf width, brix %, dry matter yield per plant and leaf area. DSF-123, DSF-150, DSF-152 and Malwan found good general combiners for protein content. While DSF-130 × CSV 21 F, DSF-140 × GFS 5 and DSF-138 × CSV 21 F were best specific cross combination for green fodder yield per plant and other yield contributing traits. These good general combiners for yield and its contributing traits can be utilized in intensive crossing programmes and subsequently selection of transgressive segregants for desired characters in segregating generations for development of superior lines.

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TABLE 3
Summary of three best general combiners and best performing hybrids based on gca and sca effects, respectively for various traits in forage sorghum

| S. No. | Characters | Best General combiner | Gca value | Best performing hybrids based on *sca* effects | *Gca* effects | *Sca* value |
|---|---|---|---|---|---|---|
| 1. | Days to flowering | DSF-146 | -4.75 | DSF-152 × Malwan | A × P | -4.47 |
| | | GFS 5 | -2.05 | DSF-140 × CSV 21 F | A × A | -4.03 |
| | | DSF-130 | -1.64 | DSF-140 × GFS 5 | A × G | -3.73 |
| 2. | Plant height (cm) | DSF-146 | 19.15 | DSF-138 × CSV 21 F | A × A | 45.51 |
| | | - | | DSF-140 × GFS 5 | A × A | 32.27 |
| | | - | | DSF-123 × Malwan | A × A | 28.09 |
| 3. | Number of leaves per plant | DSF-123 | 0.88 | DSF-138 × CSV 21 F | G × A | 2.14 |
| | | DSF-138 | 0.84 | DSF-130 × Malwan | P × A | 1.98 |
| | | DSF-146 | 0.77 | DSF-130 × CSV 21 F | P × A | 1.92 |
| 4. | Stem diameter (cm) | DSF-140 | -0.05 | DSF-140 × Malwan | G × A | -0.09 |
| | | - | | - | | |
| | | - | | - | | |
| 5. | Leaf length (cm) | DSF-146 | 13.04 | DSF-138 × CSV 21 F | A × A | 17.61 |
| | | - | | DSF-140 × GFS 5 | A × A | 16.65 |
| | | - | | DSF-130 × CSV 21 F | A × A | 15.24 |
| 6. | Leaf width (cm) | DSF-146 | 1.24 | DSF-138 × CSV 21 F | G × A | 3.11 |
| | | DSF-138 | 0.81 | DSF-140 × GFS 5 | P × A | 2.24 |
| | | DSF-123 | 0.30 | DSF-130 × CSV 21 F | G × A | 1.83 |
| 7. | Leaf: stem ratio | DSF-130 | 0.08 | DSF-130 × GFS 5 | G × G | 0.08 |
| | | DSF-138 | 0.03 | DSF-141 × CSV 21 F | P × P | 0.06 |
| | | DSF-123 | 0.02 | DSF-152 × CSV 21 F | P × P | 0.03 |
| 8. | Brix % | DSF-138 | 2.83 | DSF-154 × CSV 21 F | A × A | 3.05 |
| | | DSF-123 | 1.40 | DSF-140 × GFS 5 | P × A | 2.48 |
| | | DSF-130 | 1.30 | DSF-138 × GFS 5 | G × A | 2.40 |
| 9. | Green fodder yield per plant (g) | DSF-146 | 63.18 | DSF-130 × CSV 21 F | A × A | 112.49 |
| | | DSF-123 | 30.41 | DSF-140 × GFS 5 | A × A | 111.19 |
| | | DSF-138 | 26.48 | DSF-138 × CSV 21 F | G × A | 100.31 |
| 10. | Dry matter yield per plant (g) | DSF-146 | 28.07 | DSF-130 × CSV 21 F | P × A | 51.28 |
| | | DSF-138 | 19.53 | DSF-140 × GFS 5 | P × A | 36.55 |
| | | DSF-123 | 18.90 | DSF-138 × CSV 21 F | G × A | 36.49 |
| 11. | Leaf area (cm2) | DSF-146 | 689.65 | DSF-138 × CSV 21 F | G × A | 1827.60 |
| | | DSF-138 | 570.49 | DSF-140 × GFS 5 | P × A | 1185.64 |
| | | DSF-123 | 340.08 | DSF-130 × CSV 21 F | A × A | 1123.61 |
| 12. | Protein content (%) | DSF-123 | 0.44 | DSF-146 × GFS 5 | P × A | 0.63 |
| | | Malwan | 0.35 | DSF-154 × CSV 21 F | A × P | 0.57 |
| | | DSF-150 | 0.27 | DSF-140 × Malwan | P × G | 0.53 |

G=Parent having significant gca effect in desired direction
P=Parent having significant gca effect in undesired direction
A=Parent having either positive or negative but non-significant gca effect.

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