*Forage Res.*, **45** (4) : pp. 258-263 (2020) **http://forageresearch.in**

# STUDY OF *PER SE* PERFORMANCE AND HETEROSIS FOR FORAGE YIELD AND ITS ATTRIBUTING TRAITS IN SORGHUM [*SORGHUM BICOLOR* (L.) MOENCH]

**D. P. RATHOD[1], R. A. GAMI[2*], R. M. CHAUHAN[3], K. G. KUGASHIYA[4] AND R. N. PATEL[5]**

[1]Department of Genetics and Plant Breeding, S. D. Agricultural University, Sardarkrushinagar (Gujarat)
[2]Sorghum Research Station, S. D. Agricultural University, Deesa-385 535 (Gujarat)
[3&4] Department of Seed Technology, S. D. Agricultural University, Sardarkrushinagar (Gujarat)
[5]Potato Research Station, S. D. Agricultural University, Deesa-385 535 (Gujarat)
**(e-mail : ramangami@gmail.com)*

**(Received : 29 February 2020; Accepted : 16 March 2020)**

## SUMMARY

The present investigation was carried out to study *per se* performance and magnitude of heterosis in sorghum [*Sorghum bicolor* (L.) Moench]. The 27 hybrids were generated by L × T fashion during early summer, 2018 at Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa using three females (2219A, 296A and 7A) as a line and nine males (DS 105, DS 173, DS 155, DS 137, DS 167, DS 176, DS 149, DS 156 and DS 161) as a tester. The resultant 27 hybrids along with 12 parents and two standard checks (GJ 39 and CSH 30) were evaluated in randomized block design with three replications at Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa during *kharif*, 2018. Perusal of *per se* performance of parents and their hybrids for different traits evinced that 296A among the females, DS 155 among the males and 7A × DS 156, 296A × DS 173 and 296A × DS 161 among the hybrids exhibited higher mean performance for green fodder yield per plant and some of the yield contributing traits. For earliness, female 2219A, male DS 173 and hybrid 2219A × DS 137 were found superior as they exhibited lower values for days to flowering. Looking to the grain yield per plant, 7A among the females, DS 155 among the males and 296A × DS 137 among the hybrids recorded more grain yield per plant. Significant heterosis over better parent and best standard check (GJ 39 and CSH 30) was observed in many hybrids for various traits. The hybrid 296A × DS 173 manifested significant and positive heterosis over better parent (82.20 %), standard check GJ 39 (52.45 %) and CSH 30 (13.45 %), while hybrids 7A × DS 173, 2219A × DS 155 and 296A × DS 137 evinced significant and positive heterosis over better parent and standard check GJ 39 for the green fodder yield while in case of grain yield, the hybrid 296A × DS 137, 7A × DS 161 and 7A × DS 149 exhibited significant and desirable heterosis over better parent (92.21, 3.95 and 31.05 %), standard check GJ 39 (30.84, 27.83 and 19.78 %) and CSH 30 (14.02 and 11.40 %), respectively.

**Keywords :** *Per se* performance, heterobeltiosis, standard heterosis, yield

Sorghum [*Sorghum bicolor* (L.) Moench] with chromosome number (2n = 2x = 20) belongs to Poaceae family, about 25 per cent the genome size of maize or sugarcane. Its centre of origin is Ethiopia (Reddy *et al.*, 2009). It is an often cross pollinated crop, having average six per cent natural cross pollination. Photo synthetically, it is the most efficient $C_4$ plant with very high biomass production potential. Its small genome (750 Mb) makes sorghum an attractive model for functional genomics of $C_4$ grasses. It is the fifth most important world cereal crop after wheat, rice, maize and barley. Sorghum is one of the most important staple food and fodder crops in parts of the semi-arid tropics of the world and cultivated in areas considered to be too dry and hot for other cereals, because of its tolerance to drought and heat stress. In the light of rapidly increasing human population and expansion of agriculture into marginal lands, the importance of sorghum will increase in the future (House, 1995). Due to its versatile use, drought hardiness, stability of yield and adaptability over wide range of climates, sorghum has maintained its importance and dependability. Therefore, improvement of this crop will have a great impact on the socio-economic status of the people living in drought areas. The heterosis study helps to exploit the genetic variability in the crops. Recognition of a potential hybrid combination through magnitude and direction of heterotic behaviour is of paramount importance. Knowledge on the magnitude of heterosis

for various characters is essential to locate better combinations to exploit them through heterosis breeding. Over dominance is attributed towards heterobeltiosis, while commercial superiority of the hybrid may be assessed by evaluating with a standard commercial check.

## MATERIALS AND METHODS

The present investigation was carried out to study *per se* performance and magnitude of heterosis in sorghum [*Sorghum bicolor* (L.) Moench]. The 27 hybrids were generated by L × T fashion during early summer, 2018 at Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa using three females (2219A, 296A and 7A) as a line and nine males (DS 105, DS 173, DS 155, DS 137, DS 167, DS 176, DS 149, DS 156 and DS 161) as a tester. The resultant 27 hybrids along with 12 parents and two standard checks (GJ 39 and CSH 30) were evaluated in randomized block design with three replications at Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa during *kharif*, 2018. Data were recorded on five competitive plants selected randomly for plant height (cm), number of leaf per plant (No), stem girth (mm), leaf length (cm), leaf width (cm), leaf : stem ratio, grain yield per plant (g), green fodder yield per plant (g), dry fodder yield per plant (g), leaf area per plant ($cm^2$) and protein content (%), where as data for days to flowering was recorded based on plot basis. 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 Snedecor and Cochran (1967) and reviewed by Panse and Sukhatme (1985). Heterosis was estimated as per cent increase or decrease in the mean value of $F_1$ hybrid over better parent *i.e.*, heterobeltiosis (Fonesca and Patterson, 1968) and over standard check *i.e.*, standard heterosis (Meredith and Bridge, 1972) for each characters.

## RESULTS AND DISCUSSION

The analysis of variance for all the characters under study is presented in Table 1. The result revealed that significant differences among the parents for all the traits except number of leaf per plant. This

TABLE 1
Analysis of variance showing mean sum of squares for various traits in sorghum

| Sources of variation | d. f. | Days to flowering | Plant height (cm) | No. of leaf/ plant | Stem girth (mm) | Leaf length (cm) | Leaf width (cm) |
|---|---|---|---|---|---|---|---|
| Replications | 2 | 41.88* | 24.65 | 10.32* | 5.45 | 59.27 | 5.01 |
| Genotypes | 40 | 185.73** | 4600.38** | 5.41** | 10.74** | 355.40 | 5.24** |
| Parents | 11 | 139.79** | 9440.80** | 3.59 | 11.34* | 827.25** | 4.96** |
| Lines | 2 | 289.78** | 210.06** | 0.88 | 32.64** | 65.09 | 3.91 |
| Testers | 8 | 9.25 | 3467.68** | 1.63 | 7.09 | 507.28** | 4.55* |
| Lines vs. Testers | 1 | 884.08** | 75687.26** | 24.65** | 2.77 | 4911.30** | 10.35* |
| Parents vs. Hybrids | 1 | 3017.38** | 38259.09** | 19.04** | 7.05 | 228.25** | 0.13 |
| Hybrids | 26 | 94.72** | 1541.81** | 4.76** | 10.63* | 185.08** | 4.71** |
| Error | 80 | 13.26 | 220.17 | 2.35 | 5.32 | 32.89 | 1.89 |

| Sources of variation | d. f. | Leaf : Stem ratio | Grain yield/ plant (g) | Green fodder yield/plant (g) | Dry fodder yield/plant (g) | Leaf area ($cm^2$) | Protein content (%) |
|---|---|---|---|---|---|---|---|
| Replications | 2 | 0.00 | 0.73 | 51.42 | 429.66 | 43078.49 | 0.03 |
| Genotypes | 40 | 0.03** | 1315.62** | 19514.23** | 9004.92** | 2782321.29** | 4.26** |
| Parents | 11 | 0.01** | 1655.61** | 32329.88** | 18801.69** | 3261488.38** | 3.96** |
| Lines | 2 | 0.02 | 516.98** | 9822.56** | 295.37 | 1339703.11** | 2.19** |
| Testers | 8 | 0.00** | 1963.00** | 13026.41** | 13198.97** | 1915889.17** | 4.89** |
| Lines vs. Testers | 1 | 0.03** | 1473.71** | 231772.32** | 100636.04** | 17869852.56** | 0.01 |
| Parents vs. Hybrids | 1 | 0.03** | 269.66** | 3144.33** | 16.05 | 8381564.80** | 1.28** |
| Hybrids | 26 | 0.04** | 1178.16** | 15457.30** | 3620.19** | 1703061.78** | 4.65** |
| Error | 80 | 0.01 | 17.88 | 313.34 | 201.18 | 91594.68 | 0.15 |

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

indicated the presence of adequate amount of variability in the parents (lines and testers) for all the traits except number of leaf per plant. Mean sum of squares due to lines were significant for all the traits except number of leaf per plant, leaf length, leaf width, leaf : stem ratio and dry fodder yields per plant. Mean sum of squares due to testers were significant for all the traits except days to flowering, number of leaf per plant and stem girth. Further, mean sum of squares due to hybrids were significant for all the traits. Mean sum of squares due to parents *vs*. hybrids were significant for days to flowering, plant height, number of leaf per plant, leaf length, leaf : stem ratio, grain yield per plant, green fodder yield per plant, leaf area and protein content which indicated the presence of enormous heterosis for these traits. Mean sum of squares due to lines *vs.* testers were significant for all the characters except stem girth and protein content.

The *per se* performance of parents and hybrids for yields and their traits is presented in Table 2 *evinced* that none of the parents (*i.e.,* females or males) show consistent good performance for all the traits. The female 296A was top ranking for plant height (cm), leaf length (cm), leaf width (cm), green fodder yield per plant (g), dry fodder yield per plant (g), leaf area ($cm^2$) and leaf : stem ratio. The female 2219A showed better *per se* performance for earliness, stem girth and protein content. The female 7A was found better for number of leaf per plant and grain yield per plant (g).

In case of male parents, DS 149 was found superior for plant height (cm) and stem girth (mm). Parent DS 161 was found better for number of leaf per plant and dry fodder yield per plant. Parent DS 137 showed better *per se* performance for leaf length (cm), leaf width (cm) and protein content (%). DS 167 was top ranking for leaf : stem ratio and leaf area. The male DS 173 tooks minimum days for flowering. The male DS 155 and DS 156 were better for grain yield per plant and green fodder yield per plant, respectively.

In case of hybrids none of the hybrids was exhibited superior *per se* performance for all the traits. The hybrids 7A × DS 149, 296A × DS 155, 7A × DS 161, 296A × DS 137, 7A × DS 156 and 296A × DS 167 was found better for leaf length (cm), leaf width (cm), leaf : stem ratio, grain yield per plant (g), green fodder yield per plant (g) and protein content (%). The hybrid 296A × DS 173 was exhibited its superiority for leaf area ($cm^2$) and protein content. The cross 2219A × DS 137 tooks minimum day for flowering. The hybrid 296A × DS 161 show better *per se* performance for plant height (cm). 2219A × DS 176 was superior for number of leaf per plant. Minimum stem girth (mm) was recorded by 2219A × DS 105.

In practical plant breeding, the heterosis measured over better parent and popular cultivar is more realistic and is of more practical importance. Hence in present study the heterosis was measured over better parent and standard checks *i.e.,* GJ 39 and CSH 30. In present study, 7 hybrids registered significant and positive heterobeltiosis, while the 9 and 2 hybrids superior over standard check GJ 39 and CSH 30 for green fodder yield per plant (g), respectively. The wide range of heterosis over better parent and standard check was recorded *i.e.*, -53.95 to -87.20 per cent (heterobeltiosis), -39.29 to 52.57 per cent over GJ 39 and -54.84 to 13.53 per cent over CSH 30. The hybrid 296A × DS 173 manifested significant and positive heterosis over better parent (82.20 %), standard check GJ 39 (52.45 %) and CSH 30 (13.45 %), while hybrids 7A × DS 173, 2219A × DS 155 and 296A × DS 137 evinced significant and positive heterosis over better parent (Fig. 1) and standard check GJ 39 (Table 3). The low to high estimates of heterobeltiosis and standard heterosis for green fodder yield per plant also reported by Prakash *et al.* (2010), Patel *et al*. (2018) and Parmar *et al.* (2019). In case of grain yield per plant total hybrids six, four and two hybrids exhibited significant and positive heterosis over better parent, standard check GJ 39 and standard check CSH 30, respectively. The wide spectrum of heterosis over better parent and standard check was recorded *i.e.*, -59.23 to 92.21 per cent (heterobeltiosis), -57.13 to 30.84 per cent over GJ 39 and -62.64 to 14.02 per cent over CSH 30. The hybrid 296A × DS 137, 7A × DS 161 and 7A × DS 149 exhibited significant and desirable heterosis over better parent (92.21, 3.95 and 31.05 %), standard check GJ 39 (30.84, 27.83 and 19.78 %) and CSH 30 (14.02 % and 11.40 %), respectively. The above result also reported by Jadhav and Deshmukh (2017), Dingare *et al.* (2017) and Chikuta *et al.* (2017) for grain yield/plant.

A comparative study of best heterotic hybrid, 296A × DS 173,7A × DS 173 and 2219A × DS 155 for green fodder yield per plant and 296A × DS 137, 7A × DS 161 and 7A × DS 149 for grain yield per plant manifested significant positive heterosis over both better parent and standard check. This hybrids also exhibited significant and positive heterosis over better parent or combination of standard check for various component traits *viz.,* days to flowering, plant height, number of leaf per plant, stem girth, leaf length, leaf: stem ratio and dry fodder yield per plant (Table 4).

TABLE 2
Mean performance of parent and hybrids for various traits in sorghum

| S. No. | Parents/Crosses | Days to flowering | Plant height (cm) | No. of leaf/ plant | Stem girth (mm) | Leaf length (cm) | Leaf width (cm) | Leaf : stem ratio | Grain yield/ plant | Green fodder yield/ plant (g) | Dry fodder yield/ plant (g) | Leaf area ($cm^2$) | Protein content (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lines** | | | | | | | | | | | | | |
| 1 | 2219A | 63.00 | 90.93 | 8.27 | 10.96 | 40.17 | 5.13 | 0.27 | 36.72 | 88.64 | 34.32 | 2546.88 | 7.26 |
| 2 | 296A | 81.67 | 105.45 | 9.13 | 17.54 | 49.05 | 7.40 | 0.32 | 53.08 | 193.62 | 54.01 | 3087.01 | 5.58 |
| 3 | 7A | 67.00 | 105.40 | 9.27 | 13.84 | 47.05 | 6.52 | 0.31 | 62.68 | 101.67 | 41.97 | 1758.22 | 6.66 |
| Mean : | | 70.56 | 100.60 | 8.89 | 14.11 | 45.43 | 6.35 | 0.30 | 50.82 | 127.98 | 43.43 | 2464.04 | 6.50 |
| **Testers** | | | | | | | | | | | | | |
| 1 | DS105 | 83.00 | 225.28 | 11.53 | 12.74 | 63.78 | 7.52 | 0.23 | 76.03 | 275.33 | 197.33 | 3545.60 | 6.83 |
| 2 | DS 173 | 79.00 | 179.21 | 10.00 | 11.76 | 47.09 | 7.20 | 0.23 | 80.48 | 216.00 | 100.99 | 3360.31 | 6.18 |
| 3 | DS 155 | 83.67 | 174.67 | 10.67 | 14.14 | 72.92 | 8.24 | 0.22 | 103.03 | 275.01 | 107.90 | 3114.58 | 4.36 |
| 4 | DS 137 | 79.67 | 206.91 | 10.60 | 14.23 | 89.39 | 10.43 | 0.18 | 38.35 | 252.28 | 130.32 | 3511.87 | 8.66 |
| 5 | DS 167 | 80.67 | 176.51 | 10.87 | 13.59 | 65.35 | 7.68 | 0.28 | 50.21 | 295.98 | 127.65 | 5278.99 | 4.87 |
| 6 | DS 176 | 83.33 | 219.49 | 10.80 | 13.25 | 79.45 | 6.80 | 0.23 | 36.13 | 339.99 | 156.69 | 5186.78 | 7.02 |
| 7 | DS 149 | 82.33 | 258.35 | 9.60 | 10.87 | 82.19 | 7.65 | 0.27 | 71.26 | 370.66 | 143.29 | 4057.00 | 6.54 |
| 8 | DS 156 | 83.33 | 167.94 | 11.07 | 15.92 | 83.84 | 6.47 | 0.26 | 39.01 | 408.98 | 215.30 | 4703.21 | 7.26 |
| 9 | DS 161 | 83.00 | 250.01 | 12.07 | 14.73 | 67.60 | 6.32 | 0.20 | 95.89 | 385.28 | 310.36 | 4061.71 | 6.81 |
| Mean : | | 82.00 | 206.49 | 10.80 | 13.47 | 72.40 | 7.59 | 0.23 | 65.60 | 313.28 | 165.54 | 4091.11 | 6.50 |
| **Crosses** | | | | | | | | | | | | | |
| 1 | 2219A × DS105 | 63.33 | 198.13 | 10.53 | 10.23 | 69.63 | 6.33 | 0.18 | 34.64 | 213.30 | 105.31 | 1972.66 | 7.00 |
| 2 | 2219A × DS173 | 60.67 | 202.69 | 11.20 | 10.49 | 66.49 | 3.92 | 0.17 | 54.90 | 326.15 | 158.01 | 2113.10 | 7.09 |
| 3 | 2219A × DS155 | 63.33 | 215.63 | 10.73 | 13.67 | 68.70 | 6.08 | 0.18 | 42.00 | 378.55 | 176.34 | 4160.15 | 8.31 |
| 4 | 2219A × DS137 | 59.67 | 213.33 | 8.60 | 10.53 | 62.40 | 4.72 | 0.14 | 64.54 | 235.66 | 105.29 | 2462.26 | 7.76 |
| 5 | 2219A × DS167 | 63.33 | 205.99 | 10.33 | 11.80 | 69.79 | 6.79 | 0.22 | 37.19 | 242.31 | 110.68 | 2745.89 | 7.92 |
| 6 | 2219A × DS176 | 61.00 | 243.79 | 13.87 | 13.72 | 69.88 | 6.71 | 0.22 | 63.27 | 161.02 | 87.64 | 3214.68 | 6.63 |
| 7 | 2219A × DS149 | 62.33 | 219.37 | 9.53 | 11.68 | 69.08 | 6.83 | 0.15 | 64.40 | 322.65 | 152.03 | 3534.69 | 6.14 |
| 8 | 2219A × DS156 | 63.67 | 197.49 | 12.53 | 11.85 | 68.49 | 7.07 | 0.17 | 46.44 | 270.13 | 124.99 | 2784.33 | 7.63 |
| 9 | 2219A × DS161 | 64.33 | 209.35 | 13.47 | 12.36 | 66.73 | 7.05 | 0.15 | 56.52 | 187.54 | 94.29 | 2765.24 | 7.80 |
| 10 | 296A × DS105 | 69.00 | 222.60 | 11.40 | 11.85 | 71.99 | 8.95 | 0.25 | 56.22 | 360.30 | 161.16 | 2858.37 | 7.25 |
| 11 | 296A × DS173 | 71.00 | 221.41 | 12.93 | 15.84 | 70.11 | 7.69 | 0.18 | 83.42 | 404.34 | 199.55 | 4704.09 | 8.42 |
| 12 | 296A × DS155 | 77.00 | 247.07 | 11.20 | 14.27 | 77.44 | 9.43 | 0.23 | 87.44 | 267.53 | 161.50 | 2925.49 | 7.28 |
| 13 | 296A × DS137 | 76.00 | 219.86 | 12.70 | 14.69 | 77.81 | 7.31 | 0.16 | 102.02 | 341.61 | 174.09 | 3540.80 | 5.36 |
| 14 | 296A × DS167 | 79.33 | 242.67 | 11.20 | 12.23 | 66.03 | 7.89 | 0.18 | 55.33 | 242.41 | 154.98 | 3070.57 | 8.67 |
| 15 | 296A × DS176 | 75.33 | 238.97 | 11.67 | 12.27 | 75.35 | 7.07 | 0.15 | 65.02 | 251.00 | 126.53 | 3616.51 | 7.55 |
| 16 | 296A × DS149 | 72.67 | 245.01 | 10.47 | 10.66 | 69.31 | 8.71 | 0.23 | 43.57 | 170.68 | 78.85 | 2664.49 | 4.49 |
| 17 | 296A × DS156 | 68.67 | 234.33 | 9.80 | 12.95 | 77.76 | 7.36 | 0.19 | 48.02 | 226.23 | 121.67 | 2663.56 | 5.96 |
| 18 | 296A × DS161 | 74.33 | 251.58 | 11.60 | 13.08 | 67.29 | 8.76 | 0.16 | 40.54 | 379.99 | 166.31 | 4423.48 | 6.78 |
| 19 | 7A × DS105 | 65.33 | 230.06 | 11.53 | 11.30 | 61.40 | 7.03 | 0.27 | 33.43 | 240.67 | 102.43 | 2548.38 | 4.76 |
| 20 | 7A × DS173 | 68.00 | 210.83 | 11.93 | 15.67 | 72.08 | 7.40 | 0.19 | 56.04 | 367.83 | 195.67 | 3664.77 | 6.30 |
| 21 | 7A × DS155 | 68.67 | 233.80 | 10.33 | 14.48 | 63.19 | 7.59 | 0.16 | 71.05 | 245.98 | 106.09 | 4140.70 | 5.15 |
| 22 | 7A × DS137 | 68.00 | 224.23 | 10.80 | 13.33 | 74.92 | 8.64 | 0.26 | 38.48 | 308.23 | 154.84 | 3032.55 | 8.33 |
| 23 | 7A × DS167 | 68.67 | 218.40 | 11.93 | 16.82 | 59.37 | 7.97 | 0.11 | 41.40 | 256.95 | 120.63 | 3033.97 | 5.52 |
| 24 | 7A × DS176 | 78.00 | 206.31 | 10.60 | 13.67 | 72.88 | 7.99 | 0.22 | 59.20 | 257.57 | 122.68 | 2570.83 | 5.75 |
| 25 | 7A × DS149 | 66.00 | 217.93 | 11.73 | 16.26 | 79.23 | 8.97 | 0.33 | 93.39 | 260.63 | 115.00 | 4034.06 | 4.92 |
| 26 | 7A × DS156 | 66.00 | 211.36 | 10.73 | 15.71 | 68.32 | 8.09 | 0.17 | 44.52 | 404.65 | 166.28 | 2994.32 | 5.33 |
| 27 | 7A × DS161 | 66.00 | 136.04 | 8.93 | 12.27 | 38.79 | 6.20 | 0.75 | 99.67 | 187.09 | 80.82 | 1579.75 | 7.59 |
| | Mean : | 68.14 | 219.19 | 11.20 | 13.10 | 68.68 | 7.35 | 0.21 | 58.62 | 278.18 | 134.21 | 3104.43 | 6.73 |
| **Check** | | | | | | | | | | | | | |
| 1 | GJ 39 | 82.00 | 232.07 | 7.53 | 17.88 | 71.73 | 8.07 | 0.15 | 77.97 | 265.23 | 82.68 | 3598.51 | 6.74 |
| 2 | CSH 30 | 77.33 | 207.20 | 11.27 | 20.51 | 71.03 | 10.59 | 0.36 | 89.47 | 356.41 | 265.68 | 6061.17 | 7.92 |
| | General mean : | 71.92 | 207.75 | 10.85 | 14.97 | 67.93 | 7.43 | 0.23 | 60.80 | 276.49 | 136.39 | 3358.33 | 6.69 |
| | S. Em± | 2.10 | 8.57 | 0.88 | 1.37 | 3.31 | 0.79 | 0.02 | 2.44 | 10.22 | 8.19 | 174.73 | 0.22 |
| C. D. (P=0.05) | | 5.92 | 24.11 | 2.49 | 3.86 | 9.32 | 2.23 | 0.05 | 6.87 | 28.76 | 23.05 | 491.76 | 0.63 |
| C. V. (%) | | 5.06 | 7.14 | 14.12 | 17.53 | 8.44 | 18.50 | 13.21 | 6.95 | 6.40 | 10.40 | 9.01 | 5.79 |
| Range | | 59.67 to 87.67 | 90.93 to 251.58 | 7.53 to 13.87 | 10.23 to 20.51 | 38.79 to 89.39 | 3.92 to 10.43 | 0.11 to 0.75 | 33.43 to 103.03 | 88.64 to 408.98 | 34.32 to 310.36 | 1579.75 to 6061.17 | 4.36 to 8.67 |

## CONCLUSION

The analysis of variance revealed that significant differences among the parents for most of the traits. The female 296A was top ranking for plant height (cm), leaf length (cm), leaf width (cm), green fodder yield per plant (g), dry fodder yield per plant (g), leaf area ($cm^2$) and leaf: stem ratio. In case of male parents, DS 149 was found superior for plant height (cm) and stem girth (mm). The hybrid 296A ×

TABLE 3
Number of hybrids having significant heterotic effect in sorghum

| Characters | Over better parent | | | | Over standard check (GJ 39) | | | | Over standard check (CSH 30) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | +ve | -ve | Total | Range | +ve | -ve | Total | Range | +ve | -ve | Total | Range |
| Days to flowering | 1 | 6 | 7 | -15.92 to 16.42 | 0 | 24 | 24 | -27.24 to -3.25 | 0 | 20 | 20 | -22.84 to 2.59 |
| Plant height | 11 | 5 | 16 | -45.59 to 39.53 | 0 | 6 | 6 | -41.38 to 8.41 | 8 | 1 | 9 | -34.34 to 21.42 |
| No. of leaves/plant | 2 | 1 | 3 | -25.97 to 29.33 | 23 | 0 | 23 | 14.16 to 84.07 | 1 | 1 | 2 | -23.67 to 23.08 |
| Stem girth (mm) | 3 | 0 | 3 | -11.34 to 49.65 | 0 | 19 | 19 | -42.76 to -5.91 | 0 | 26 | 26 | -50.12 to -18.01 |
| Leaf length | 3 | 10 | 13 | -42.62 to 53.06 | 0 | 3 | 3 | -45.93 to 10.45 | 0 | 3 | 3 | -45.39 to 11.54 |
| Leaf width (cm) | 0 | 3 | 3 | -45.56 to 24.13 | 0 | 2 | 2 | -51.40 to 16.94 | 0 | 21 | 21 | -62.97 to -10.89 |
| Leaf : stem ratio | 1 | 23 | 24 | -65.96 to 139.36 | 10 | 0 | 10 | -30.43 to 389.13 | 1 | 25 | 26 | -70.37 to 108.33 |
| Grain yield/plant (g) | 6 | 15 | 21 | -59.23 to 92.21 | 4 | 21 | 25 | -57.13 to 30.84 | 2 | 22 | 24 | -62.64 to 14.02 |
| Green fodder yield/plant | 7 | 16 | 22 | -53.95 to 87.20 | 9 | 7 | 16 | -39.29 to 52.57 | 2 | 20 | 22 | -54.82 to 13.53 |
| Dry fodder yield/plant (g) | 8 | 15 | 23 | -73.96 to 97.59 | 19 | 0 | 19 | -4.64 to 141.35 | 0 | 27 | 27 | -70.32 to -24.89 |
| Leaf area/plant ($cm^2$) | 3 | 18 | 21 | -61.11 to 39.99 | 4 | 17 | 21 | -56.10 to 30.72 | 0 | 27 | 27 | -73.94 to -22.39 |
| Protein content | 6 | 11 | 17 | -38.08 to 55.41 | 10 | 9 | 19 | -33.42 to 28.52 | 1 | 17 | 18 | -43.33 to 9.38 |

TABLE 4
Comparative study of heterotic crosses in sorghum for green fodder yield per plant, grain yield per plant with other components

| S. No. | Hybrids | Heterosis over | | | | Useful and significant heterobeltiosis/ standard heterosis for components |
|---|---|---|---|---|---|---|
| | | Better parent | | Standard parent | | |
| | | | | GJ 39 | CSH 30 | |
| **Green fodder yield/plant with other component traits** | | | | | | |
| 1 | 296A × DS 173 | 82.20** | (404.34) | 52.45** | 13.45** | DF, PH, NLP, SG, NLP, LL, DFY, LAP, PC |
| 2 | 7A × DS173 | 70.30** | (367.83) | 38.68** | - | DF, PH, NLP, SG, LL, DFY |
| 3 | 2219A × DS155 | 37.65** | (378.55) | 42.72** | - | DF, PH, NLP, SG, DFY, LAP, PC |
| 4 | 296A × DS 137 | 35.41** | (341.61) | 28.79** | - | DF, NLP, SG, GYP, GFY, DFY |
| **Grain yield/plant with other component traits** | | | | | | |
| 1 | 296A × DS 137 | 92.21** | (102.02) | 30.84** | 14.02** | DF, NLP, SG, GFY, DFY |
| 2 | 7A × DS 161 | 3.95** | (99.67) | 27.83** | 11.40** | DF, SG, LL, LSR, DFY, PC |
| 3 | 7A × DS 149 | 31.05** | (93.39) | 19.78** | - | DF, NLP, GF, SG, LSR, DFY |

Figure in the parentheses indicated mean performance. *P≤0.05, **P≤0.01.

| | | | | | |
|---|---|---|---|---|---|
| DF | : | Days to flowering | PH | : | Plant height (cm) |
| NLP | : | Number of leaf per plant | LL | : | leaf length (cm) |
| SG | : | Stem girth (mm) | LSR | : | Leaf : stem ratio |
| GYP | : | Grain yield per plant (g) | DFY | : | Dry fodder yield per plant (g) |
| GFY | : | Green fodder yield per plant (g) | LAP | : | Leaf area per plant ($cm^2$) |
| PC | : | Protein content (%) | | | |

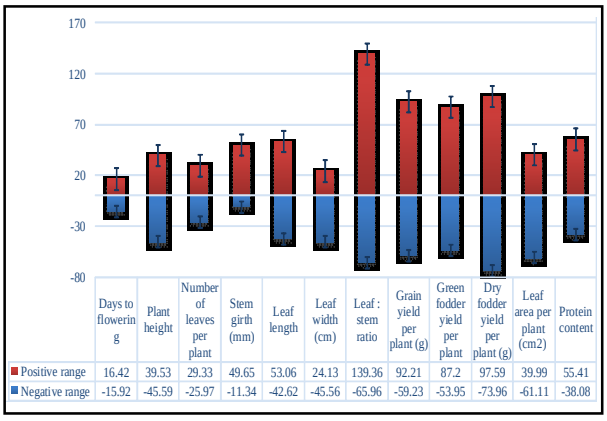


Fig. 1. Range of Heterosis over better parent in sorghum.

DS 173 manifested significant and positive heterosis over better parent (82.20 %), standard check GJ 39 (52.45 %) and CSH 30 (13.45 %), while hybrids 7A × DS 173, 2219A × DS 155 and 296A × DS 137 evinced significant and positive heterosis over better parent.

## REFERENCES

Chikuta, S., T. Odong, F. Kabi and P. Rubaihayo, 2017 : Combining ability and heterosis of selected grain and forage dual purpose sorghum genotypes. *J. Agric. Sci.* **9** : 122-30.

Dingar, R., P. K. Shotria, R. Bhanjan and P. K. Pandey, 2017

TABLE 5
Top three ranking parents with respect to per se performance and heterosis over better parent and standard check (GJ 39 and CSH 30) in sorghum

| S. No. | Characters | Best performing parents | Best performing hybrids | Heterosis (%) over | | |
|---|---|---|---|---|---|---|
| | | | | BP | GJ 39 | CSH 30 |
| 1. | Days to flowering | 2219A | 2219A × DS137 | -3.17 | -25.61** | -21.12** |
| | | 7A | 2219A × DS173 | - | - | - |
| | | DS 173 | 2219A × DS176 | - | - | - |
| 2. | Plant height (cm) | DS149 | 296A × DS161 | 0.63 | 8.41 | 21.42** |
| | | DS161 | 296A × DS155 | 2.12 | -0.87 | 11.03 |
| | | DS 105 | 296A × DS149 | 11.07 | 5.05 | 17.66** |
| 3. | No. of leaf/plant | DS 161 | 2219A × DS176 | 11.60 | 78.76** | 19.53 |
| | | DS 156 | 2219A × DS161 | 28.40* | 84.07** | 23.08* |
| | | DS 105 | 296A × DS173 | - | - | - |
| 4. | Stem girth (mm) | DS 149 | 2219A × DS105 | - | - | - |
| | | 2219A | 2219A × DS173 | - | - | - |
| | | DS173 | 2219A × DS137 | - | - | - |
| 5. | Leaf length (cm) | DS 137 | 7A × DS149 | -1.29 | -6.98 | -6.05 |
| | | DS 156 | 296A × DS137 | -3.60 | 10.45 | 11.54 |
| | | DS 149 | 296A × DS156 | - | - | - |
| 6. | Leaf width (cm) | DS 137 | 296A × DS155 | - | - | - |
| | | DS 155 | 7A × DS149 | - | - | - |
| | | DS 167 | 296A × DS105 | - | - | - |
| 7. | Leaf : stem ratio | 296A | 7A × DS161 | 139.36** | 389.13** | 108.33** |
| | | 7A | 7A × DS149 | -21.18* | 45.65** | -37.96** |
| | | DS 167 | 7A × DS105 | -28.13** | 50.00** | -36.11** |
| 8. | Grain yield/plant (g) | DS 155 | 296A × DS137 | 3.95 | 27.83** | 11.40** |
| | | DS 173 | 7A × DS161 | 92.21** | 30.84** | 14.02** |
| | | DS161 | 7A × DS149 | 31.05** | 19.78** | 4.38 |
| 9. | Green fodder/plant (g) | DS 156 | 7A × DS156 | -1.37 | 43.27** | 6.61 |
| | | DS 161 | 296A × DS173 | -1.06 | 52.57** | 13.53** |
| | | DS 149 | 296A × DS161 | 37.65** | 42.72** | 6.21 |
| 10. | Dry fodder/plant (g) | DS161 | 296A × DS173 | 6.10 | 83.88** | -42.78** |
| | | DS156 | 7A × DS173 | 63.43** | 113.28** | -33.62** |
| | | DS105 | 2219A × DS155 | -46.41** | 101.15** | -37.40** |
| 11. | Leaf area (cm2) | DS167 | 296A × DS173 | 8.91 | 22.93** | -27.02** |
| | | DS176 | 296A × DS161 | 39.99** | 30.72** | -22.39** |
| | | DS156 | 2219A × DS155 | 33.57** | 15.61* | -31.36** |
| 12. | Protein (%) | DS137 | 296A × DS167 | -3.77 | 23.53** | 5.13 |
| | | DS156 | 296A × DS173 | 55.41** | 28.52** | 9.38* |
| | | 2219A | 7A × DS137 | 36.32** | 24.86** | 6.27 |

: Heterosis and inbreeding depression in sorghum. *Indo-American J. Agric. and Veterinary Sci.* **5** : 9-20.

Fonesca, S. and F. Patterson, 1968 : Hybrid vigor in a seven parent diallel crosses in common winter wheat (*Triticum aestivum* L.). *Crop Sci.* **8** : 85-88.

House, L. R., 1995 : Sorghum : one of the world's great cereals. *African J. Crop Science*, **3** : 135-142.

Jadhav, R. R. and D. T. Deshmukh, 2017 : Heterosis and combining ability studies in Sorghum [*Sorghum bicolor* (L.) Moench] over the environments. *Int. J. Current Microbiology and Applied Sci.* **6**: 3058-3064.

Meredith, W. R. and R. R. Bridge, 1972 : Heterosis and gene action in cotton. *Crop Sci.* **12** : 304-310.

Panse, V. G. and P. V. Sukhatme, 1985 : *Statistical methods for Agricultural Workers*. Indian Council of Agricultural Research (2nd Edn.), New Delhi.

Parmar, N. R., M. P. Patel, P. R. Patel and N. B. Patel, 2019 : Study of heterosis for yield and yield attributes characters in forage sorghum [*Sorghum bicolor* (L.) Moench]. *Forage Res*., **44** : 247-250.

Patel, Y. D., R. N. Patel, R. A. Gami, P. R. Patel and N. R. Parmar, 2018 : Study of *per se* performance and heterosis for yield and its attributing traits in forage sorghum [*Sorghum bicolor* (L.) Moench]. *Forage Res.*, **44** : 81-85.

Prakash, R., K. Ganesamurthy, A. Nirmalakumari and P. Nagarajan, 2010 : Heterosis for fodder yield in sorghum [*Sorghum bicolor* (L.) Moench]. *Electronic J. Plant Breeding*, **1** : 319-327.

Reddy, B. V. S., S. Ramesh, P. S. Reddy and A. A. Kumar, 2009 : Genetic enhancement for drought tolerance in sorghum. *Plant Breeding Reviews*, **31**: 189-222.

Snedecor, G. W. and W. G. Cochran, 1967 : Statistical Methods, (6th Edn.). Ames : Iowa State University Press.