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# HETEROSIS FOR FODDER YIELD AND QUALITY TRAITS IN FORAGE SORGHUM

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## SUMMARY

A field experiment was couducted during summer-kharif, 2013 at Sorghum Research Station, Deesa to study the heterosis for fodder yield and quality traits in forage sorghum. Analysis of variance in individual environment as well as on pooled basis revealed highly significant differences among genotypes, parents and hybrids for all the traits. The heterosis was evident for green fodder yield per plant and other important yield contributing traits from the significance of mean squares due to parents vs. hybrids in individual as well as pooled over environments for almost all the traits. Significance of mean squares due to genotypes x environments, parents x environments and hybrids x environments for most of the traits indicated that genotypes, parents and hybrids performed differently in different environments. The analysis also revealed highly significant differences for mean squares due to parents vs. hybrids x environments for all the traits except brix per cent, HCN content and crude protein content. The magnitude of heterosis was high for green fodder yield per plant, dry fodder yield per plant, brix per cent and leaf : stem ratio, medium for plant height, stem diameter, number of leaves per plant, leaf length, leaf width, shoot fly dead heart per centage and HCN content and low for days to flowering and crude protein content. The best five hybrids on the basis of standard heterosis were 27A x SRF 317 (39.79 %), 14A x SRF 332 (38.76 %), 104A x SPV 2113 (35.77 %), 9A x SPV 2113 (34.81 %) and 14A x SRF 335 (29.26 %) for green fodder yield per plant. These hybrids also exhibited high heterosis for one or two of its contributing traits, thereby these top hybrids can be exploited commercially for fodder yield after testing in wide range of environments.

**Key Words :** Heterosis, genotypes x environments interaction, heterobeltiosis, standard heterosis

The commercial application of heterosis is an outstanding application of the principles of genetics in the field of plant breeding. The phenomenon of heterosis has attracted the attention of earlier plant breeders mainly through conspicuous effects noted in economic characters of several crop plants, notably grain yield in maize. The concept of heterosis which refers to the superiority of hybrid over the better parent. In present days, concept of heterosis is the expression of "joint action of favorable genes and interaction among allelic, non-allelic and mitochondrial genes brought together from the parents to the heterozygotes." Heterosis has been successfully exploited in many cross pollinated crops like maize, bajra, sorghum, castor and many other crops. In sorghum development of Kafir-milo cytoplasmic genetic male sterility system opened new vistas in sorghum improvement.

The heterosis breeding in forage sorghum had limited application either due to practical difficulties for want of easy method of emasculation and hybrid seed in sufficient quantity. However, information gathered on the nature and magnitude of heterosis would now be helpful in identifying superior cross combination for the development of hybrids and also can be exploited to get better transgressive segregants. Spectacular progress has been made through the exploitation of hybrid vigour in grain sorghum; the situation is less encouraging in forage sorghum. The limited number of forage sorghum hybrid had been notified and release for commercial cultivation (GFSH 1, PCH 106, PCH 109 and CSH 20MF and CSH 24MF). In the present study, heterosis over better parent (heterobeltiosis) and over standard check (standard heterosis) was therefore studied.

## MATERIALS AND METHODS

The experimental material comprised of 82

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genotypes including fertile counter parts of four male sterile lines (9A, AKMS14A, 27A and 104A), 15 males (SRF 317, SRF 321, SRF 323, SRF 327, SRF 328, SRF 330, SRF 331, SRF 332, SRF 334, SRF 335, SRF 336, SRF 337,CSV 15, SPV 1616 and SPV 2113), 60 hybrids and three checks *viz.*, GFS 4, GFS 5 and CSV 21F, were grown in a randomized block design replicated thrice during summer-*kharif*, 2013 at Sorghum Research Station, S. D. Agricultural University, Deesa, Gujarat. The individual environments were created by sowing in two seasons *i.e.*, summer and *kharif* and each season having two different date of sowing with two different dose of fertilizers (Early sowing + 80 : 40 : 00, Late sowing + 100 : 50 : 00) . Each genotype was represented by a single row plot of 4.0 metre length. The inter row and intra row distance was 30 cm and 7.5 to 10 cm, respectively. All the recommended agronomical practices and plant protection measures were followed as and when required to harvest a good crop. Observations were recorded on thirteen characters viz., days to flowering, plant height (cm), number of leaves per plant, stem diameter (cm), leaf length (cm), leaf width (cm), leaf : stem ratio, green fodder yield per plant (g), dry fodder yield per plant (g), shoot fly dead heart percentage, brix (%), HCN content (ppm) and crude protein (%). Five competitive plants were randomly selected and tagged from each plot of entry for recording observations and average value per plant was computed. The character days to flowering and maturity were recorded on plot basis. Heterosis was estimated as per the standard procedure using mean values for various characters over replications. The heterosis of individual location (environment) does not give real picture about the heterotic values of hybrids as it also includes the effect of hybrids x environments interaction. Hence, the mean values over replications over environments for different traits were used for the estimation of pooled heterosis over mid-parent, better parent and standard check. For the characters like days to flowering, stem diameter, shoot fly dead heart percentage and HCN content low scoring parent was considered as better parent for the estimation of heterobeltiosis. Whereas, high scoring parent was considered as a better parent for the rest of the traits.

## RESULTS AND DISCUSSION

The statistical analysis of the data on the characters studied for 82 genotypes (comprising of 4 females, 15 males and their 60 hybrids and 3 checks) revealed significant differences among genotypes, checks, check vs. parents, parent, parents vs. hybrids and hybrids for all the characters under study in individual as well as pooled over the environments.

Significant heterotic variation for one or more characters studied under the present investigation. The degree of heterosis varied from cross to cross for all the 13 characters. Considerable high heterosis in certain crosses and low in other crosses revealed that nature of gene action varied with the genetic architecture of parent. The range of relative heterosis, heterobeltiosis and standard heterosis for different characters revealed that high heterosis was observed for green fodder yield per plant, dry fodder yield per plant, brix per cent and leaf : stem ratio, while, medium level heterosis was recorded in plant height, stem diameter, number of leaves per plant, leaf length, leaf width, shoot fly dead heart percentage and HCN content (Table 1). Low value of heterosis was found for days to flowering and crude protein content. The high heterosis for green and dry fodder yield per plant was explained on the basis of gene effects involved. The non-additive gene effects observed in combining ability analysis for green and dry fodder yield per plant and its components favored the magnitude of heterosis in this study. Thus, the chance of obtaining superior hybrid combinations increases with increase in genetic distance between the male sterile line and restorers (Madhusudhan, 2002).

There was large variation for heterobeltiosis and standard heterosis showed by most of the hybrids for earliness. The variation for days to flowering was observed due to genotype, temperature and photoperiod. The hybrid 9A x SRF 321 and 9A x SRF 337 reflected maximum heterobeltiosis and standard heterosis respectively in desirable direction for earliness. The earliness in hybrids may be due to their high rate of growth and early vigour. This is because the meristems of hybrid become larger and develop at faster rate than parents in shorter period. The results were in agreement with the findings of Bhatt (2008), Akabari *et al.* (2012) and Jain and Patel (2016) for relative heterosis, heterobeltiosis and standard heterosis, while Singh and Shrotria (2008) and Jain and Patel (2014) reported similar results only for relative heterosis.

In present study tallness was dominant over

TABLE 1

Number of hybrid(s) showing significant positive and negative heterosis and range of relative heterosis, heterobeltiosis and standard heterosis in individual and pooled over the environments for thirteen characters in forage sorghum

| Heterosis | Relative heterosis | | | | | Heterobeltiosis | | | | | Standard heterosis | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $E_1$ | $E_2$ | $E_3$ | $E_4$ | Pooled | $E_1$ | $E_2$ | $E_3$ | $E_4$ | Pooled | $E_1$ | $E_2$ | $E_3$ | $E_4$ | Pooled |
| **Days to flowering** | | | | | | | | | | | | | | | |
| Significant positive | 12 | 23 | 30 | 35 | 32 | 28 | 34 | 43 | 42 | 42 | 12 | 15 | 20 | 32 | 19 |
| Significant negative | 32 | 26 | 13 | 12 | 23 | 21 | 16 | 6 | 6 | 13 | 41 | 36 | 30 | 8 | 33 |
| Range | -19.48 | -32.10 | -17.94 | -9.33 | -12.76 | -13.33 | -29.49 | -9.86 | -8.11 | -11.92 | -26.34 | -28.44 | -19.56 | -10.96 | -17.04 |
| | to | to | to | to | to | to | to | to | to | to | to | to | to | to | to |
| | 10.52 | 31.33 | 35.33 | 31.23 | 22.59 | 25.29 | 50.33 | 50.00 | 33.33 | 25.65 | 9.82 | 15.59 | 12.00 | 15.99 | 10.96 |
| **Plant height (cm)** | | | | | | | | | | | | | | | |
| Significant positive | 57 | 59 | 54 | 59 | 59 | 37 | 37 | 35 | 39 | 48 | 18 | 39 | 26 | 48 | 47 |
| Significant negative | 1 | 1 | 2 | 1 | 1 | 2 | 4 | 11 | 7 | 4 | 33 | 3 | 13 | 1 | 2 |
| Range | -30.99 | -42.21 | -56.45 | -39.34 | -43.33 | -41.04 | -51.28 | -60.99 | -47.24 | -51.54 | -49.06 | -54.77 | -60.99 | -52.03 | -54.41 |
| | to | to | to | to | to | to | to | to | to | to | to | to | to | to | to |
| | 111.58 | 97.43 | 75.68 | 82.21 | 76.84 | 105.90 | 76.91 | 61.48 | 59.45 | 55.80 | 25.16 | 27.71 | 27.80 | 45.22 | 27.03 |
| **Number of leaves per plant** | | | | | | | | | | | | | | | |
| Significant positive | 7 | 21 | 19 | 35 | 29 | 3 | 8 | 12 | 23 | 26 | 5 | 0 | 19 | 9 | 2 |
| Significant negative | 14 | 13 | 4 | 1 | 5 | 24 | 24 | 13 | 7 | 19 | 23 | 55 | 3 | 10 | 32 |
| Range | -49.38 | -26.30 | -28.20 | -10.30 | -8.21 | -56.15 | -28.64 | -30.82 | -21.43 | -15.40 | -42.73 | -41.48 | -18.53 | -19.95 | -14.26 |
| | to | to | to | to | to | to | to | to | to | to | to | to | to | to | to |
| | 28.83 | 43.13 | 42.33 | 51.06 | 26.49 | 22.91 | 26.67 | 28.94 | 48.38 | 20.06 | 25.66 | 1.48 | 29.23 | 21.98 | 7.87 |
| **Stem diameter (cm)** | | | | | | | | | | | | | | | |
| Significant positive | 7 | 18 | 23 | 18 | 14 | 28 | 26 | 32 | 28 | 35 | 44 | 47 | 21 | 30 | 56 |
| Significant negative | 35 | 6 | 2 | 10 | 9 | 8 | 0 | 1 | 2 | 2 | 0 | 1 | 1 | 0 | 0 |
| Range | -39.80 | -22.80 | -28.07 | -22.66 | -15.60 | -28.57 | -11.88 | -24.07 | -17.83 | -9.51 | -0.48 | -23.69 | -22.64 | -6.88 | 2.87 |
| | to | to | to | to | to | to | to | to | to | to | to | to | to | to | to |
| | 21.15 | 46.62 | 38.49 | 42.58 | 24.40 | 105.57 | 97.79 | 48.15 | 56.60 | 61.94 | 69.36 | 82.18 | 32.08 | 42.83 | 41.39 |
| **Leaf length (cm)** | | | | | | | | | | | | | | | |
| Significant positive | 23 | 36 | 26 | 17 | 38 | 9 | 16 | 11 | 3 | 15 | 0 | 0 | 0 | 0 | 0 |
| Significant negative | 6 | 2 | 5 | 3 | 0 | 12 | 5 | 12 | 10 | 13 | 50 | 60 | 47 | 40 | 60 |
| Range | -21.74 | -14.43 | -16.00 | -17.67 | -3.54 | -28.94 | -33.40 | -21.58 | -20.55 | -16.02 | -37.32 | -47.02 | -37.59 | -32.54 | -27.94 |
| | to | to | to | to | to | to | to | to | to | to | to | to | to | to | to |
| | 33.61 | 39.79 | 25.24 | 31.09 | 23.11 | 23.03 | 35.57 | 20.54 | 20.00 | 22.78 | 5.64 | -9.98 | 3.08 | 2.38 | -5.17 |
| **Leaf width (cm)** | | | | | | | | | | | | | | | |
| Significant positive | 31 | 33 | 5 | 20 | 31 | 21 | 14 | 0 | 13 | 15 | 17 | 0 | 5 | 34 | 9 |
| Significant negative | 6 | 9 | 24 | 5 | 5 | 11 | 14 | 37 | 15 | 15 | 12 | 45 | 9 | 0 | 15 |
| Range | -28.79 | -42.64 | -20.49 | -18.37 | -11.33 | -34.98 | -44.08 | -30.51 | -32.30 | -15.57 | -30.14 | -38.59 | -21.67 | -7.85 | -14.78 |
| | to | to | to | to | to | to | to | to | to | to | to | to | to | to | to |
| | 43.18 | 44.51 | 27.38 | 35.94 | 25.00 | 33.96 | 40.38 | 7.51 | 25.59 | 14.71 | 27.68 | 5.07 | 18.79 | 32.97 | 13.84 |
| **Leaf : stem ratio** | | | | | | | | | | | | | | | |
| Significant positive | 4 | 5 | 8 | 9 | 2 | 2 | 2 | 5 | 3 | 1 | 21 | 1 | 0 | 7 | 2 |
| Significant negative | 55 | 52 | 40 | 42 | 57 | 57 | 57 | 46 | 52 | 59 | 23 | 55 | 60 | 44 | 57 |
| Range | -65.91 | -62.79 | -55.56 | -55.93 | -55.88 | -71.15 | -69.81 | -61.70 | -58.06 | -62.50 | -45.45 | -67.50 | -62.16 | -45.45 | -54.84 |
| | 12.57 | 94.29 | 68.42 | 66.67 | 26.67 | 56.10 | 38.46 | 45.45 | 42.86 | 5.56 | 190.91 | 70.00 | -8.11 | 36.36 | 22.58 |
| **Green fodder yield per plant (g)** | | | | | | | | | | | | | | | |
| Significant positive | 39 | 54 | 45 | 45 | 56 | 27 | 49 | 37 | 31 | 45 | 21 | 17 | 38 | 32 | 34 |
| Significant negative | 11 | 3 | 6 | 6 | 3 | 19 | 6 | 13 | 18 | 6 | 28 | 31 | 6 | 7 | 12 |
| Range | -68.27 | -62.70 | -78.76 | -38.31 | -60.35 | -72.81 | -68.04 | -80.61 | -44.91 | -62.54 | -69.00 | -76.19 | -76.97 | -41.62 | -65.74 |
| | to | to | to | to | to | to | to | to | to | to | to | to | to | to | to |
| | 162.32 | 146.37 | 175.35 | 262.20 | 137.15 | 148.96 | 142.31 | 140.34 | 241.58 | 96.87 | 99.04 | 57.16 | 109.59 | 73.39 | 39.79 |
| **Dry fodder yield per plant (g)** | | | | | | | | | | | | | | | |
| Significant positive | 35 | 44 | 40 | 42 | 48 | 25 | 35 | 33 | 27 | 34 | 11 | 6 | 30 | 21 | 9 |
| Significant negative | 12 | 3 | 11 | 9 | 5 | 18 | 14 | 19 | 23 | 20 | 42 | 49 | 18 | 27 | 39 |
| Range | -74.37 | -68.14 | -81.36 | -39.97 | -66.20 | -78.73 | -71.80 | -83.68 | -50.08 | -69.29 | -78.94 | -67.12 | -82.98 | -57.21 | -75.54 |
| | to | to | to | to | to | to | to | to | to | to | to | to | to | to | to |
| | 118.98 | 158.95 | 134.94 | 265.20 | 108.40 | 100.88 | 118.92 | 117.27 | 181.74 | 98.12 | 38.25 | 43.51 | 71.82 | 48.07 | 24.10 |
| **Shoot fly dead heart percentage** | | | | | | | | | | | | | | | |
| Significant positive | 30 | 17 | 29 | 19 | 31 | 34 | 35 | 36 | 38 | 46 | 37 | 45 | 40 | 52 | 57 |
| Significant negative | 7 | 18 | 13 | 21 | 15 | 4 | 4 | 7 | 5 | 7 | 1 | 0 | 1 | 0 | 0 |
| Range | -52.15 | -60.35 | -32.94 | -46.99 | -36.41 | -46.52 | -54.48 | -30.32 | -39.37 | -35.32 | -34.41 | -17.94 | -14.90 | -10.79 | -5.98 |
| | to | to | to | to | to | to | to | to | to | to | to | to | to | to | to |
| | 198.71 | 109.15 | 112.80 | 62.86 | 96.95 | 250.00 | 173.97 | 120.75 | 86.00 | 106.70 | 262.06 | 129.57 | 118.22 | 95.88 | 97.96 |
| **Brix (%)** | | | | | | | | | | | | | | | |
| Significant positive | 28 | 32 | 30 | 31 | 38 | 10 | 24 | 23 | 21 | 27 | 8 | 29 | 9 | 10 | 13 |
| Significant negative | 11 | 21 | 10 | 6 | 10 | 6 | 28 | 14 | 16 | 33 | 29 | 21 | 34 | 23 | 32 |
| Range | -22.18 | -49.28 | -21.38 | -24.478 | -24.53 | -32.94 | -57.02 | -31.39 | -32.40 | -32.51 | -32.60 | -47.16 | -39.05 | -28.51 | -28.49 |
| | to | to | to | to | to | to | to | to | to | to | to | to | to | to | to |
| | 96.66 | 138.40 | 80.08 | 87.98 | 91.59 | 93.48 | 132.81 | 64.65 | 73.73 | 76.99 | 85.42 | 74.78 | 58.38 | 66.80 | 70.12 |
| **HCN (ppm)** | | | | | | | | | | | | | | | |
| Significant positive | 34 | 32 | 36 | 36 | 37 | 42 | 41 | 46 | 44 | 46 | 0 | 0 | 0 | 1 | 0 |
| Significant negative | 9 | 9 | 12 | 12 | 14 | 3 | 1 | 3 | 4 | 4 | 59 | 57 | 57 | 57 | 58 |
| Range | -32.08 | -32.85 | -31.05 | -29.91 | -31.49 | -29.11 | -30.63 | -30.03 | -27.56 | -29.34 | -46.46 | -46.14 | -44.80 | -44.17 | -45.41 |
| | to | to | to | to | to | to | to | to | to | to | to | to | to | to | to |
| | 49.54 | 50.12 | 44.42 | 45.92 | 47.21 | 72.87 | 67.19 | 68.09 | 62.11 | 64.61 | -2.20 | 0.74 | -1.60 | 7.00 | -1.14 |
| **Crude protein (%)** | | | | | | | | | | | | | | | |
| Significant positive | 18 | 13 | 18 | 28 | 29 | 4 | 1 | 3 | 13 | 10 | 0 | 0 | 0 | 2 | 1 |
| Significant negative | 16 | 11 | 14 | 18 | 19 | 23 | 16 | 25 | 26 | 27 | 33 | 14 | 34 | 31 | 36 |
| Range | -27.82 | -26.25 | -28.53 | -27.19 | -27.47 | -34.87 | -33.85 | -34.30 | -33.80 | -34.26 | -32.92 | -26.53 | -31.84 | -29.54 | -30.25 |
| | to | to | to | to | to | to | to | to | to | to | to | to | to | to | to |
| | 15.74 | 18.12 | 17.77 | 23.96 | 14.98 | 13.89 | 15.71 | 13.28 | 20.63 | 14.98 | 0.93 | 8.06 | 2.50 | 7.07 | 4.41 |

dwarfness similar trend was observed in the highest heterobeltiotic and standard heterotic hybrid 27A x SRF 337 and 9A x SRF 334, respectively. The research workers viz.,Akabari et al. (2012), Jain and Patel (2014) and Jain and Patel (2016) had also observed taller hybrids compared to their respective parents. Paroda (1975) reported that leafiness is the most important trait not only from the point of view of dry matter production, but it is positively associated with quality attributes like digestibility and crude protein content also.

For number of leaves per plant, the hybrids 14A x SRF 332 and 14A x SRF 335 exhibited the highest magnitude of positive and significant heterobeltiosis and standard heterosis, respectively. In general, no consistent difference in number of leaves per plant between parents and their hybrids was found in most of the cases. However, some crosses 9A x SRF 331, 104A x SRF 337, 14A x SRF 337 and 27A x SRF 337 had manifested heterobeltiosis for this trait. Here, one of the parents in hybrids possessed poor *per se* performance. For stem diameter only, two crosses *viz.*, 104A x SRF 336 and 9A x SPV 1616 manifested significant heterosis over thinner parent in desirable direction with very narrow range. Characters leaf length and leaf width constitutes leaf area. The high values of these characters result into high individual leaf area and ultimately result into high biomass and leaf : stem ratio. The hybrid 27A x SRF 331, 104A x SRF 334, 104A x SRF 330 and 14A x SRF 330 reflected high heterobeltiosis for leaf length. Whereas, hybrids 14A x SRF 330, 14A x SRF 337, 27A x SRF 327 and 104A x SPV 2113 had manifested high heterobeltiosis and standard heterosis for leaf width.. As like number of leaves per plant, the high leaf : stem ratio have positive correlation with digestibility and quality of fodder. The considerable amount of heterobeltiosis and standard heterosis was exhibited by 9A x SPV 1616. The positive heterotic effects observed in the present investigation were in accordance with the findings of Parmar and Tikka (2005), Jain and Patel (2014).

Shoot fly is a major pest on sorghum causing heavy crop damage.Therefore, negative value of

TABLE 2

Best high yielding hybrids with heterosis (%) over better parent and standard check (GFS 5), gca effects of their parents, sca effects and component traits showing standard heterosis based on pooled analysis in forage sorghum

| Hybrids | Mean green fodder yield/ plant (g) | Heterosis (%) over # | | GCA effects | | SCA effects | Significant standard heterosis for component traits in desired direction ## |
|---|---|---|---|---|---|---|---|
| | | BP | SC | Female | Male | | |
| 27A x SRF 317 | 545.42 | 32.09 | 39.79 | 5.13* | 44.59** | 77.57** | PH, BRIX, HCN |
| 14A x SRF 332 | 541.25 | 62.33 | 38.76 | 10.04** | 49.75** | 63.34** | PH, NLPP, LW, HCN |
| 104A x SPV 2113 | 529.75 | 23.51 | 35.77 | -5.13* | 67.69** | 49.07** | DF, PH, LW, DFY, BRIX, HCN |
| 9A x SPV 2113 | 526.00 | 22.63 | 34.81 | -10.04** | 67.69** | 50.23** | DF, LW, DFY, HCN |
| 14A x SRF 335 | 504.33 | 82.40 | 29.26 | 10.04** | -8.08* | 84.25** | NLPP, DFY, HCN |
| 9A x SRF 331 | 499.50 | 57.32 | 28.02 | -10.04** | 5.44 | 85.98** | DFY, HCN |
| 104A x SRF 328 | 490.42 | 38.37 | 25.69 | -5.13* | 18.42** | 59.01** | DF, PH, LW, BRIX, HCN |
| 14A x SRF 323 | 488.50 | 15.39 | 25.20 | 10.04** | 27.34** | 33.00** | PH, HCN |
| 27A x SRF 323 | 481.83 | 13.82 | 23.49 | 5.13* | 27.34** | 31.24** | DF, PH, DFY, HCN |
| 14A x SRF 330 | 480.83 | 91.38 | 23.24 | 10.04** | 0.94 | 51.73** | PH, LW, DFY, HCN |
| 14A x SPV 2113 | 474.25 | 10.57 | 21.55 | 10.04** | 67.69** | -21.60** | DF, HCN |
| 27A x SRF 334 | 472.33 | 96.87 | 21.06 | 5.13* | -2.25 | 51.32** | PH, HCN |
| 104A x SPV 1616 | 472.08 | 32.30 | 20.99 | -5.13* | -67.50** | 25.69** | DF, PH, LW, BRIX, HCN |
| 27A x SRF 327 | 471.75 | 54.67 | 20.91 | 5.13* | 8.13* | 40.37** | DF, PH, LW, BRIX, HCN |
| 9A x SRF 328 | 470.42 | 32.73 | 20.57 | -10.04** | 18.42** | 43.91** | DFY, HCN |
| GFS 5 | 390.17 | - | - | - | - | - | - |

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

# BP=Better parent and SC = Standard check;
NLPP=Number of leaves per plant;
SDHP=Shoot fly dead heart percentage;
BRIX=Brix per cent;

## PH=Plant height; DF=Days to flowering;
LW=Leaf width;
DFY=Dry fodder yield per plant;
HCN=HCN content.

heterosis is desirable for shoot fly dead heart percentage. Significant and negative heterobeltiosis was showed by 14A x SRF 332 and 27A x SRF 323, whereas, none of the hybrids reflected negative heterosis over standard check. The negative heterosis observed under the present study was in agreement with work done by Bhatt (2008).

The character brix per cent had direct correlation with palatability. The sugar content in juice may increase microbes population in the rumen of the animal because sugar is very essential for normal growth and development of microbes. The high heterobeltiotic and standard heterotic crosses 9A x SRF 337, 14A x SRF 336 and 104A x SRF 337 involved parents with poor x good, good x average and good x good mean performance, respectively. The results were in accordance with the findings of Grewal *et al*. (2003) and Bhatt (2008). Most of the hybrids showed negative and significant standard heterosis for HCN content. The hybrid 14A x SRF 323 exhibited maximum heterobeltiosis in pooled as well as individual environments followed by 104A x SRF 323. The crosses *viz.,* 9A x SRF 337, 9A x SRF 331, 9A x SRF 336 and 27A x SRF 327 proved its superiority over standard check GFS 5 for this trait. The negative heterosis observed under the present study. These results were supported by earlier workers for heterobeltiosis and standard heterosis (Bhatt, 2008). The negative heterosis implies less amount of HCN content from such hybrids and best segregants would be identified. Nutritive quality of fodder is also important as fodder yield. Crude protein content determines the nutritive value of fodder and hence improvement in protein content is highly essential. Only one cross 104A x SRF 332 manifested standard heterosis in desirable direction. Total ten crosses had reflected heterosis over better parent. Out of the best ten heterobeltiotic hybrid 14A x SRF 336 showed superiority, in which both the parents had poor mean performance and this was in agreement with over dominance hypothesis. Similar results were also obtained by Patel *et al*. (2006), Parmar and Tikka (2005) and Bhatt (2008).

The significant and positive heterobeltiosis and standard heterosis for green and dry fodder yield per plant as well as its contributing traits were observed. In all, total 13 and 7 hybrids manifested positive heterosis over better parents and standard check for green and dry fodder yield per plant, respectively. The positive relative heterosis observed under the present investigation for green fodder yield per plant. The heterobeltiotic crosses for green fodder yield as well as for other yield and quality related parameters were 14A x SRF 332, 104A x SPV 2113 and 14A x SRF 335. All these hybrids also manifested significantly high standard heterotic effects for atleast two or more than two yield components. For dry fodder yield per plant, the trend for most heterobeltiotic effect was same but for standard heterosis slightly different, the same two hybrids *viz.*,14A x SRF 332 and 14A x SRF 335 had high green fodder and high dry fodder yield also for heterobeltiosis. The higher heterobeltiosis and standard heterosis in hybrid 9A x SRF 331 might be due to combination of all favorable genes with additive effects from poor x good performing parents, while 27A x SRF 334 for heterobeltiosis and 9A x SRF 331 for standard heterosis, having both the parents with poor x good *per se* performance. The high heterobeltiosis and standard heterosis in such crosses may be due to best *per se* performance of either of the parents individually for other yield attributes and quality parameters.

The comparative study of 15 most heterotic hybrids (Table 2) revealed that, the high heterosis in green fodder yield per plant was mostly found alongwith high heterosis in dry fodder yield per plant, number of leaves per plant, plant height and leaf width traits. These 15 hybrids were found to exhibit significant and positive sca effects so exploitaion of heterosis will be more fruitful in these crosses. Further, the performance of these hybrids seems mainly due to non additive type of gene action. Additionally, remarkable reduction in antinutritional factor HCN content was also observed in these cross. In general high standard heterosis and high mean *per se* performance of hybrids was not always related with sca effects. There was no consistency of high standard heterosis with high heterobeltiosis. As far as, the quantum of standard heterosis is concerned, more than 35 per cent standard heterosis was observed in top ranker and more than 20 per cent standard heterosis was also observed in ninth ranked hybrid. Therefore, forage sorghum breeders should give emphasis on exploiting heterosis commercially as there is sufficient amount of standard heterosis.

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