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# HETEROSIS AND INBREEDING DEPRESSION IN FORAGE SORGHUM [*SORGHUM BICOLOR* (L.) MOENCH]

**SUNEETA PANDEY* AND P. K. SHROTRIA[1]**

Department of Plant Breeding and Genetics,
JNKVV, Jabalpur
*(e-mail : suneetaalmora@gmail.com)
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**ABSTRACT**

The present investigation in forage sorghum {*Sorghum bicolor* (L.) Moench} was carried out to study the magnitude of heterosis and inbreeding depression in fifty four crosses ($F_1$s) and their $F_2$s made by crossing nine sudan grass pollinators with six cytoplasmic male sterile lines in a line x tester mating design. Observations were recorded on yield and quality traits *viz*. plant height, stem diameter, number of leaves per plant, leaf length, leaf width, number of basal tillers, shootfly infestation, total soluble solids, HCN content, protein percent, green and dry fodder yield. Variable magnitude of three type of heterosis (better parent, mid parent and standard) were observed for different cross combinations for all the traits. Based on *per se* performance and heterotic response for green and dry fodder yield, two best crosses identified were ICSA-271 x UTMC-523 and ICSA-271 x 700R. Response of inbreeding depression was significant in positive direction for most of the characters except leaf width, number of basal tillers, total soluble solids, HCN content and protein percent.

**Key words :** *Sorghum bicolor*, heterosis, inbreeding depression, green fodder yield, dry fodder yield

Sorghum is a food, feed, fodder and fuel crop in different parts of the world and has achieved a special significance after wheat, rice and maize among cereals. In India fodder sorghum is an important *Kharif* crop that is highly palatable and digestible as far as its nutritional quality is concern. For improving the genetic architecture of crop through breeding efforts, utilization of heterosis is very important for maximizing the yield in sorghum. To attain good fodder yields and to exploit the fodder yield heterosis, development of forage sorghum multicut hybrids is an important area of research in which much work is being done. In forage sorghum, the extent of heterosis has been observed up to 300 per cent for green fodder, 273 per cent for dry fodder and for quality traits in the range of -81 to 43 per cent, (Lodhi *et al*., 1987). The present investigation has been undertaken to study the heterosis in $F_1$ over better parent (BP), mid parent (MP) and standard check (SD) and inbreeding depression in $F_2$ segregating generations for fodder yield and its related characters.

## MATERIALS AND METHODS

The study was conducted at the Instructional Dairy Farm of the G.B. Pant University of Agriculture and Technology, Pantnagar (U.S. Nagar), India. The experimental materials consisted fifty four $F_1$ crosses developed through lines ´ tester mating design involving six diverse *Sorghum bicolor* type CMS lines (female) and nine *Sorghum sudanense/ Sorghum bicolor* type forage sorghum pollinators (male) and the corresponding 54 $F_2$ populations obtained after selfing of $F_1$s. The experimental material consisting of 124 treatments (54 $F_1$s + 54 $F_2$s + 15 parents + 1 check- CSH-20MF) was planted on April 27, 2007 in Randomized Block Design with three replications. Each of the 124 treatments was accommodated in plot of 3.75 $m^2$ size (5R x 3m x 0.25m). To obtain the data on pooled analysis over year/ season the same field experiment was also planted during 2008-2009 on April 28, 2008. Ten and thirty competitive plants during both the years (2007 and 2008), were randomly taken, from each treatment/ genotype in each replication for recording observations from $F_1$s and $F_2$s respectively. Observations were recorded for plant height (cm), stem diameter (cm), number of leaves per plant, leaf length (cm), leaf width (cm), number of basal tillers, shootfly

[1]Department of Genetics and Plant Breeding, G.B. Pant Univ. Agri. & Tech. Pantnagar-263145

infestation (dead heart %), total soluble solids (T.S.S.%), HCN content (ppm), protein percent, green and dry fodder yield (Kg/plot). The means of different characters for the purpose of statistical analysis were calculated on the basis of the individual data recorded for each character, in each replication separately, for each cross. Heterosis was worked out utilizing the overall mean of each hybrid for each trait. Relative heterosis was estimated as per cent deviation of the $F_1$ from its mid-parental value (MP). Hetero-beltiosis was estimated as per cent increase or decrease of $F_1$ over better parent (BP). Standard heterosis for each character was expressed as per cent increase or decrease of $F_1$ value over the standard hybrid (SD). The significance of heterosis was tested against't' value from 't' table of Fisher and Yates (1963) at error degree of freedom of ANOVA table at 5% or 1% levels of probability. The inbreeding depression (ID) between two generations i.e. $F_1$ and $F_2$ was calculated as the deviation of the mean performance from its previous generation mean. The significance of inbreeding depression was tested by the critical difference (CD) values at 5% or 1% probability level respectively.

## RESULTS AND DISCUSSION

Variable magnitude of three types of heterosis *viz*., relative, better parent and standard heterosis as exhibited by different cross combinations for all the characters indicated the presence of different degree of divergence in the parental material for all the characters. The range of hetero-beltiosis, mid parent heterosis and economic heterosis varied from one character to another (Table 1). Maximum number of positive significant crosses for all three types of heterosis was reported for dry fodder yield (42, 51 and 52 for hetero-beltiosis, mid parent heterosis and economic heterosis, respectively), followed by leaf length, green fodder yield, number of basal tillers and leaf width.

For commercial exploitation of heterosis for fodder yield, two crosses *viz.*, ICSA-271 x UTMC-523 and ICSA-271 x 700R were identified as the best cross combinations as they showed significant heterosis in desirable direction over the better parent, mid parent and standard check, for important component traits besides green and dry fodder yield (during both the years and also in pooled analysis). This indicated the presence of non additive gene action for fodder yield and its components. On the basis of pooled analysis six crosses were identified as best for green and dry fodder yield and component characters. (Table 2).

Among the different characters studied, the extent of heterosis for character green fodder yield ranged from –18.03 to 56.87 (better parent), -5.30 to 84.43

TABLE 1
The range of heterosis and number of crosses showing significant heterosis for 12 Characters in pooled analysis

| Characters | Range of hetero-beltiosis | Range of mid parent heterosis | Range of economics herterosis | No. of crosses showing significant heterosis (Pooled) | | |
|---|---|---|---|---|---|---|
| | | | | Hetero-beltiosis | Mid parent heterosis | Economic heterosis |
| Plant height | –18.43 to 22.33 | 9.05 to 31.07 | –7.98 to 26.16 | 8 | 31 | 29 |
| Stem diameter | -42.34 to 7.78 | –26.51 to 12.14 | –13.94 to 12.20 | - | 1 | 1 |
| Number of leaves per plant | –8.62 to 13.72 | -5.64 to 14.26 | –5.95 to 12.69 | 8 | 30 | 23 |
| Leaf length | –2.33 to 23.35 | 0.38 to 25.37 | –7.82 to 15.97 | 36 | 50 | 25 |
| Leaf width | –26.72 to 23.73 | -14.78 to 31.22 | 2.38 to 42.19 | 17 | 33 | 45 |
| Number of basal tillers | –23.53 to 88.89 | 0.00 to 100.00 | –15.52 to –68.97 | 17 | 36 | 16 |
| Total soluble solids | –52.79 to 43.85 | –47.02 to 47.43 | –42.17 to 103.47 | 4 | 6 | 17 |
| Shootfly infestation (DH %) | –65.48 to -1.94 | –58.27 to 7.42 | –49.88 to 50.87 | 47 | 41 | 13 |
| HCN content | –86.87 to 0.77 | –83.71 to 34.42 | –76.28 to 112.84 | 52 | 40 | 20 |
| Green fodder yield | –18.03 to 56.87 | -5.30 to 84.43 | –17.31 to 36.25 | 25 | 48 | 17 |
| Dry fodder yield | –23.36 to 118.99 | -5.78 to 179.48 | –5.35 to 170.54 | 42 | 51 | 52 |
| Protein (%) | –33.97 to 23.66 | 27.20 to 31.70 | –36.84 to 4.45 | 8 | 11 | - |

TABLE 2
Heterotic response of six best crosses for green, dry fodder yield and component characters in pooled analysis

| Crosses | Characters | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Plant Height | | | Number of leaves/plant | | | Leaf length | | |
| | BP | MP | SD | BP | MP | SD | BP | MP | SD |
| ICSA 467 x PC 5 | -0.12 | 1.33 | -2.18 | 11.20** | 12.32** | 7.22* | 14.10** | 20.32** | 13.27** |
| 993100A x HC 260 | 16.86** | 31.07** | 26.16** | 3.15 | 8.72** | 11.51** | 9.31** | 13.42** | -0.72 |
| ICSA 271 x UTMC 523 | 1.36 | 16.80** | 18.57** | 2.89 | 4.01 | 5.44 | 1.51 | ‘12.24** | 0.96 |
| SP 55609A x PC5 | 8.87* | 13.04** | 6.62 | 6.72* | 11.50** | 10.32** | 9.06** | 19.77** | 8.27** |
| SP55609A x PC 6 | 2.71 | 8.73** | 4.77 | -4.44 | 3.25 | -1.21 | 8.42** | 17.75** | 5.03 |
| $11A_2$ x HC 260 | -8.61* | 6.38 | -1.34 | 5.03 | 6.41* | 1.89 | 10.72** | 19.23** | 8.81** |

*Contd.*

Table 2. contd.

| Crosses | Characters | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Leaf width | | | Number of basal tillers | | | Green fodder yield | | | Dry fodder yield | | |
| | BP | MP | SD | BP | MP | SD | BP | MP | SD | BP | MP | SD |
| ICSA 467 x PC 5 | -2.34 | 17.90** | 42.19** | 36.36* | 42.86** | 15.21 | 31.10** | 32.96** | 17.92** | 99.16** | 108.0** | 126.6** |
| 993100A x HC 260 | -11.59** | -1.14 | 17.50** | 55.56** | 55.56** | 7.53 | 12.80** | 55.56** | 7.53 | 23.84** | 24.7** | 52.4** |
| ICSA 271 x UTMC 523 | 13.52** | 14.84** | 20.21** | 63.64** | 63.64** | 38.25** | 56.87** | 84.43** | 36.25** | 65.17** | 104.3** | 107.4** |
| SP 55609A x PC5 | 23.73** | 30.16** | 18.31** | 18.75 | 46.15** | 45.93** | 27.06** | 46.15** | 45.93** | 48.20** | 64.9** | 54.3** |
| SP55609A x PC 6 | 11.36* | 16.84** | 5.89 | 29.41** | 33.33** | 68.97** | 24.35** | 33.33** | 68.97** | 29.33** | 50.6** | 49.7** |
| $11A_2$ x HC 260 | 9.98* | 15.75** | 28.04** | 88.89** | 88.89** | 30.57* | 15.96** | 67.58** | 8.14** | 52.46** | 119.7** | 87.6** |

(mid parent) and –17.31 to 36.25 per cent (standard parent), respectively. For green fodder yield maximum better parent heterosis was recorded in the cross ICSA-271 x UTMC-523 (56.87), followed by ICSA-276 x UPMC 512 (36.63) and ICSA-467 x PC 5 (31.10). For dry fodder yield maximum positive heterobeltiosis was observed in the cross ICSA-276 x UPMC-512 (118.99) followed by ICSA-467 x PC-5 (99.16) and 993100A x UPMC 8 (74.24). These crosses were also superior in *per se* performance. (Table 3)

Heterosis for end product *i.e.* fodder yield is being manifested as the cumulative effect of heterosis for component traits (Shull, 1914). The elaborative study of six crosses revealed this fact as most of the crosses that exhibited positive and significant heterosis for yield also showed it for most of the component characters (Table 2). The findings of the present investigation are consistent with the earlier reports of Ravindrababu *et al*., 2002, Smilovenko, 2002, Deshpande *et al*., 2003, Grewal *et al*., 2003 and Agrawal and Shrotria, 2005, Sharma and Sharma 2006, Bhatt, 2008 .

For shoofly infestation, measured through recording per cent dead heart counts (at 25-30 days after showing) where negative heterosis is desirable, occurrence of forty eight crosses showing negative heterosis over better parent based on pooled analysis, suggested preponderance of non-additive gene action and role of over dominance for shootfly resistance in sorghum.

Regarding quality characters, *viz,* total soluble solids and protein per cent, where positive estimates of heterosis are desired, considerable amount of positive heterobeltiosis, relative heterosis and standard heterosis was observed as earlier reported by Shaug and Lo, 1995, Carlos *et al*., 1998 and Shaug *et al*., 2000.

One of the characteristics of heterosis is that

TABLE 3
Crosses showing high and positive estimates of heterosis and inbreeding depression

| Crosses | Characters | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Green fodder yield | | | | Dry fodder yield | | | |
| | Heterosis (H) | | | Inbreeding depression (ID) | Heterosis | | | Inbreeding depression (ID) |
| | BP | MP | SD | | BP | MP | SD | |
| ICSA 467 X PC 5 | 31.10** | 32.96** | 17.92** | 18.60** | 99.16** | 107.99** | 126.55** | 26.67** |
| ICSA 467 X UPMC 512 | 11.74** | 16.16** | 8.79* | 27.50** | 50.69** | 56.90** | 86.16** | 34.50** |
| ICSA 276 X UPMC 512 | 36.63** | 78.14** | 33.02** | 27.78** | 118.99** | 179.48** | 170.54** | 37.88** |
| 993100 A X UPMC 532 | 17.32** | 24.05** | 15.91** | 20.16** | 42.49** | 46.58** | 83.16** | 13.23** |
| 993100A X UPMC 8 | 23.66** | 27.62** | 16.12** | 23.84** | 74.24** | 75.76** | 115.19** | 39.25** |
| ICSA 271 X UTMC 523 | 56.87** | 84.43** | 36.25** | 28.50** | 65.17** | 104.33** | 107.35** | 11.52** |
| ICSA 271 X UPMC 532 | 14.99** | 42.28** | 13.60** | 19.68** | 50.34** | 87.66** | 93.26** | 27.58** |
| ICSA 271 X 700R | 21.03** | 56.70** | 35.32** | 24.65** | 29.25** | 76.20** | 114.23** | 18.71** |
| 11A2 X HC 260 | 15.96** | 67.58** | 8.14* | 35.64** | 52.46** | 119.73** | 87.55** | 53.92** |

*, **Significant at 5% at 1% probability, respectively.
H=Relative heterosis, ID=Inbreeding depression, P=Pooled over years.

the increase in vigor is confined to $F_1$ generation. There is considerable depression from $F_1$ to $F_2$ and latter generations. Shull, 1914 reported that high inbreeding depression is the reflection of higher heterosis in cross-pollinated crop like maize.

It may be seen from the present study that the hybrid combinations, which showed higher estimates of heterosis for green and dry fodder yield in general found to show substantial inbreeding depression in $F_2$ for green and dry fodder yield (Table 3).The magnitude of inbreeding depression varied from -2.25 % to 46.91% and -4.77 to 53.92%, respectively. High inbreeding depression for green and dry fodder yields in forage sorghum have also been reported by Carlos *et al.*, 1998 and Agrawal and Shrotria, 2005.

Besides positive estimates of inbreeding depression for most of the traits in most of the crosses, negative and significant estimates of inbreeding depression have also been observed for characters viz. leaf width, number of basal tillers, total soluble solids, HCN content and protein percentage in few crosses. Out of 54 crosses, one cross for protein content, two crosses for leaf width, nine crosses for T.S.S %, and twenty each for HCN content and number of basal tillers (based on pooled analysis) showed negative and significant estimates of inbreeding depression. The occurrence of negative inbreeding depression may be attributed to the presence of transgressive segregants in the $F_2$ population. The formation of new gene combinations as result of segregation might lead to increased expression of the traits in the $F_2$ population for these traits. For the characters showing significant and negative inbreeding depression, these lies the scope for selection of desirable plants in $F_2$ population for improvement of these traits where low expression is desirable.

For lesser shootfly infestation, the most heterotic cross on the basis of *per se* performance was ICSA-276 x UPMC-8 followed by 993100A x PC-6, 993100A x UTMC-523 and ICSA-271 x PC-5. These crosses also showed positive magnitude of inbreeding depression which showed the role of non-additive genetic components and presence of over-dominance for shootfly resistance as earlier been reported by Nimbalkar and Bapat, 1991.

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