Genetic Variability in the Fodder Yield, Chemical Composition and Disappearance of Nutrients in Brown Midrib and White Midrib Sorghum Genotypes

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ABSTRACT : Samples of eleven brown midrib (ICSU 96031, ICSU 93046, ICSU 96082, ICSU 96078, ICSU 96075, ICSU 95101, ICSU 96034, ICSU 96063, ICSU 45116, ICSA 93-3 and ICSA 3845 X 3816) and nine white midrib genotypes (ICSU 96050, ICSU 96030, ISU 95082, SSG 59-3, FSHI 93-1, FSHI 2219A X 3211, HC 171, ICSA 93-2 and ICSA 93-1) based on their phenotypic appearance were collected at 50 per cent flowering from the sorghum germplasm grown at Research farm of IGFRI, Jhansi. These genotypes were evaluated with respect to crude protein, fiber composition, in-sacco dry matter, OM, cell wall components disappearance/digestibility besides the fodder yield, total phenolic and availability index values. Brown midrib genotypes were lower ($p<0.05$) in NDF, ADF, cellulose and acid detergent lignin concentration than white midrib genotypes. Mean NDF, ADF, cellulose and lignin contents were 69.4, 42.1, 35.4 and 5.7% in brown mid rib vis-a vis 75.8, 47.5, 39.6 and 7.3% in white mid rib genotypes. Non-significant ($p>0.05$) differences were observed in dry matter, crude protein and organic matter contents between brown midrib and white midrib genotypes. Phenolic contents were significantly ($p<0.05$) lower in browm mid rib (0.2) than white mid rib (0.3%) sorghum. Brown midrib genotypes exhibited significantly ($p<0.05$) higher in-sacco DM, OM and CP disappearance than normal (white midrib) genotypes. The mean degradability of DM, OM and CP was 64.1, 62.6 and 79.6% in brown mid rib and 53.1, 54.0 and 76.6% in white mid rib genotypes, respectively. There were no significant ($p>0.05$) differences between genotypes in extent of fiber fraction degradability though in-sacco NDF and ADF degradability was more by 5 and 4 units, respectively in brown midrib genotypes vis-a-vis white midrib genotypes. Average fodder yield (green and dry g/plant) and availability index (%) values were significantly ($p<0.05$) higher for brown midrib (474.2, 129.8 and 80.4) genotypes than white midrib (375.0, 104.8 and 69.2) genotypes. Lignin contents had significant negative correlation with DM, OM, NDF and ADF degradability. The results of the study revealed that brown midrib genotypes are superior not only with regard to chemical entities and disappearance of DM and fiber fractions but also better in respect of fodder yield and availability index values. Thus, brown midrib sorghum strains may be useful in increasing digestibility, intake, feed efficiency and animal performance. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 9 : 1303-1308)***

Key Words : Brown Mid Rib, Genotype, Nutrient Disappearance, Lignin

INTRODUCTION

Among the cultivated forages, sorghum is the most important crop for summer and July-October months. Sorghum is grown exclusively for fodder over 2.6 m ha in Northern India, which constitute 60 to 70 % of green fodder supply in July-October and sizeable in November-March as hay. Nitrogen content together with the contents of the cell wall is the most important factor to the voluntary consumption by ruminants (Van Soest, 1994) as they are the indicators of forage quality. Proportion of lignin in the cell wall appears to be the major factor limiting the availability of cell wall polysaccharides to ruminal degradation (Morrison, 1979; Van Soest, 1981). Inverse relationship between lignin contents and cell wall digestion is well established (Casler, 1987). Lignin forms covalent complexes with cell wall carbohydrates, which are probably associated with the hemi-cellulose fraction of cell wall matrix (Neilson and Richards, 1982). Brown midrib mutants have been identified in corn and chemically induced in sorghum (Porter et al., 1978). Brown midrib mutants have been shown to produce a reduced and chemically altered lignin content when compared to their normal (white mid rib) counter parts (Cherney et al., 1986). Enhanced dry matter intake has been recorded in early (Block et al., 1981) and mid to late lactation (Stallings et al., 1982) dairy cows fed brown mid rib (bm3) corn silage. Oba and Allen (1999) observed a 9% increase in dry matter intake and a 7% increase in milk yield in dairy cows fed brown mid rib corn silage over those fed isogeneic normal corn silage. These workers further reported a negative relationship between difference in NDF digestibility and difference in dry matter intake for brown mid rib and normal corn silage for lactating dairy cows. Feeding of brown mid rib corn silage to beef steers increased dry matter intake and improved DM and fiber digestibility but did not improve the daily gain compared with normal silage (Tjardes et al., 2000). This shows that sorghum genotypes with brown mid rib character holds a significant promise in improving the live stock productivity. In the present study

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Table 1. Chemical composition of brown midrib and white midrib sorghum genotypes

Genotypes	DM	OM	CP	NDF	ADF	Hemicellulose	Cellulose	Lignin	Phenolics
Brown midrib									
ICSU 96031	19.9	92.1	10.1	72.3	44.9	27.4	37.7	6.0	0.15
ICSU 93046	20.5	93.2	9.6	67.7	42.7	25.0	36.2	5.9	0.29
ICSU 96082	17.5	88.8	10.5	66.6	39.4	27.1	35.5	5.1	0.21
ICSU 96078	17.9	91.5	11.1	68.3	42.3	26.0	35.4	6.3	0.21
ICSU 96075	19.5	92.8	11.2	65.3	38.6	26.6	33.1	5.1	0.26
ICSU 95101	18.7	92.0	12.0	67.4	40.3	27.0	33.7	5.9	0.23
ICSU 96034	16.9	91.8	10.7	70.2	44.0	26.2	37.7	5.0	0.15
ICSU 96063	15.6	95.2	9.4	69.1	43.5	25.6	36.8	5.9	0.37
ICSU 45116	16.5	92.5	11.3	72.9	42.1	30.8	34.8	6.1	0.14
ICSA 93-3	22.3	91.8	12.8	75.4	43.4	32.0	35.9	5.9	0.13
ICSA 3845 X 3816	16.0	94.0	10.0	68.5	41.5	27.0	34.6	5.6	0.14
Mean	18.3	92.3	10.8	69.4	42.1	27.3	35.4	5.7	0.20
White midrib									
ICSU 96050	22.8	93.6	10.9	76.9	45.8	31.0	38.2	6.7	0.44
ICSU 960.30	15.0	90.0	10.5	75.8	47.2	28.5	37.4	7.8	0.24
ISU 95082	18.9	94.9	10.3	73.4	44.0	29.4	36.4	6.8	0.34
SSG 59-3	26.1	93.7	8.5	80.7	53.1	27.6	42.9	9.2	0.23
FSHI 93-1	18.0	93.5	8.5	75.7	47.7	28.0	40.3	6.4	0.29
FSHI 2219A X 3211	16.9	92.5	11.2	73.4	46.1	27.2	37.3	7.3	0.22
HC 171	14.4	90.1	13.3	72.4	44.3	28.1	36.8	5.6	0.29
ICSA 93-2	24.6	92.6	9.2	79.3	50.8	28.5	41.4	8.3	0.25
ICSA 93-1	20.6	91.7	9.9	74.8	48.9	25.8	40.1	7.8	0.37
Mean	19.7	92.5	10.2	75.8	47.5	28.2	39.6	7.3	0.30
p<0.05	NS	NS	NS	*	*	NS	*	*	*
SEM	0.88	0.51	0.40	0.91	0.76	0.56	0.60	0.24	0.02

SEM; Standard error of mean, * Significant at $p<0.05$.

an attempt was made to screen the sorghum genotypes from its germplasm, having browm mid rib character for their fodder yield, chemical constituents and in-sacco nutrient degradation besides the availability index value.

MATERIALS AND METHODS

On the basis of visual appearance (phenotypic appearance) samples of eleven brown midrib (ICSU 96031, ICSU 93046, ICSU 96082, ICSU 96078, ICSU 96075, ICSU 95101, ICSU 96034, ICSU 96063, ICSU 45116, ICSA 93-3 and ICSA 3845 X 3816) and nine white midrib (ICSU 96050, ICSU 96030, ISU 95082, SSG 59-3, FSHI 93-1, FSHI 2219A X 3211, HC 171, ICSA 93-2 and ICSA 93-1) genotypes were collected from the germplasm grown under uniform agronomic and soil condition at Central Research Farm of Indian Grassland and Fodder Research Institute, Jhansi, India. Plants of brown mid rib genotypes were identified by the characteristic pigmentation present in the mid rib of the leaves. Pigmentation was also visible on the stem and pith of plants. Three plants of each genotype were collected at 50 per cent flowering stage. Plants were chopped and weighed for green fodder yield and these samples were initially dried under shade followed by drying in hot air oven at 60-70°C. Dried samples were ground to pass through 2 mm sieve using Willay mill. These samples were sequentially analyzed for NDF, ADF, cellulose and acid detergent lignin using the procedure of Goering and Van Soest (1970). Cellulose was determined as weight loss of ADF upon extraction with 72% sulphuric acid. Hemicellulose was calculated as the difference between NDF and ADF. Dry matter, crude protein and organic matter contents were estimated as per the method of AOAC (1992). The phenolic acids were determined as per cent tannic acid equivalent using Prussian blue method.

For in-sacco digestion of DM and other nutrients, 5 g sample in triplicate was placed in nylon bags (10×20 cm^2) of 25-30 mesh sizes. Bags were then suspended in the rumen of fistulated cattle (Hariana) for a period of 48 h, as described by Mehrez and Orskov (1977). These fistulated animals were being maintained on wheat straw-concentrate diet at the Institute Livestock Research Farm. Bags were retrieved after stipulated period of incubation and washed under tap water till clear. Loss of sample weight was calculated as the digestibility of DM. Organic matter, CP, NDF, ADF contents were also estimated in the residue samples left after incubation for determining the in sacco digestion of these nutrients. For green fodder and dry matter yield estimation three plants of each genotype were weighed immediately after harvesting and later after drying in oven to constant weight, respectively. The availability index values of genotypes were determined following the

Table 2. In-sacco nutrients disappearance of brown midrib and white midrib sorghum genotypes

Genotypes	DM	OM	CP	NDF	ADF	Hemicellulose
Brown midrib						
ICSU 96031	63.5	62.6	81.5	51.8	47.6	63.4
ICSU 93046,	60.6	59.6	78.3	48.2	45.0	53.8
ICSU 96082,	66.3	64.6	79.2	57.0	49.8	56.3
ICSU 96078,	61.7	60.3	83.2	50.0	47.8	53.5
ICSU 96075	70.2	68.5	81.9	59.7	58.2	62.6
ICSU 95101,	67.3	66.2	82.3	55.9	52.9	61.1
ICSU 96034,	64.8	62.4	83.2	54.7	53.2	57.3
ICSU 96063,	57.3	54.6	69.7	41.9	39.2	45.0
ICSU 45116,	58.8	56.7	77.1	49.5	44.3	57.0
ICSA 93-3	67.7	66.9	82.7	63.0	59.8	67.0
ICSA 3845 X 3816	66.8	65.9	76.9	55.5	51.9	59.7
Mean	64.1	62.6	79.6	53.4	50.0	57.9
White midrib						
ICSU 96050	57.2	56.2	72.2	51.7	48.1	57.9
ICSU 960.30	50.6	43.5	69.6	40.0	36.8	44.4
ISU 95082	53.9	54.2	69.8	49.8	46.4	53.4
SSG 59-3	44.5	43.5	63.4	41.3	38.7	45.1
FSHI 93-1	61.7	62.3	71.5	53.9	50.2	59.9
FSHI 2219A X 3211	58.1	57.6	77.0	50.0	48.4	51.8
HC 171	60.5	60.0	81.2	53.6	52.2	55.8
ICSA 93-2	52.4	51.8	67.1	48.1	48.5	46.0
ICSA 93-1	56.7	56.9	72.6	44.2	47.9	52.4
Mean	55.1	54.0	76.6	48.1	46.1	52.6
p<0.05	*	*	*	NS	NS	NS
SEM	1.02	1.09	0.87	1.10	1.36	1.31

SEM; Standard error of mean. * Significant at $p<0.05$.

method of Van Soest and Moore (1965) taking lignin and neutral detergent soluble into account. The data generated subjected to suitable statistical analysis using fisher's discriminent function analysis (Snedecor and Cochran, 1994).

RESULTS AND DISCUSSION

Chemical composition

Average contents of dry matter, organic matter and crude protein did not vary significantly ($p>0.05$) between the brown midrib and white midrib genotypes of sorghum (Table 1). Crude protein contents varied from 8.5 to 13.3% amongst the tested sorghum genotypes. However mean CP contents were 10.0 and 10.29% in brown and white mid rib genotypes, respectively. Brown midrib genotypes were lower ($p<0.05$) than white midrib genotypes in fiber fractions (NDF, ADF, cellulose) concentration. Average concentration of these nutrients was 68.58, 41.54 and 34.61 in brown and 75.8, 47.5 and 39.6% in white mid rib genotypes, respectively. Brown midrib genotypes (5.7) were significantly ($p<0.05$) lower in acid detergent lignin (ADL) contents than white midrib genotypes (7.3%). Average cellulose contents were 4.2 units lower in brown midrib (35.4) than white midrib (39.6%) genotypes. Dry matter accumulation was comparable between brown midrib (18.4) and white midrib (19.7%) genotypes. However Tjardes et al. (2000) observed 5.4 units more dry matter accumulation in brown mid rib than normal genotypes. Brown midrib genotypes recorded to be 22% lower in lignin than white midrib sorghum strains. This reduction is comparable to the results reported for brown midrib sorghum×Sudan grass hybrids (Cherney et al., 1986). Kuc and Nelson (1964) and Gee et al. (1968) were the first to show that brown midrib corn plants contained less lignin than normal plants. Brown midrib genotypes were lower by 5 units in NDF and ADF and cellulose concentrations than white midrib strains. Similar variations in ADF and cellulose contents between chemically induced brown midrib mutants and normal genotypes have been reported earlier (Porter et al., 1978; Fritz et al., 1981). Cell wall contents (NDF, ADF and ADL) were lower in brown mid rib (39.5, 22.4 and 1.7) than isogeneic normal (44.0, 29.3 and 3.6%) corn hybrids (Tjardes et al., 2000). Phenolic contents were significantly lower in brown mid rib (0.2) than white mid rib (0.3) genotypes. Fritz et al. (1990) had reported lower p-coumaric acid concentration and a p-coumaric to ferulic acid ratio than normal genotypes.

Nutrients degradation

In sacco DM, OM and CP disappearance were significantly ($p<0.05$) higher in brown midrib than white midrib genotypes (Table 2), while non-significant (p>0.05) differences were recorded with regard to NDF, ADF and hemicellulose degradability. On an average brown midrib genotypes revealed 9.0 units higher in sacco DM degradability compared to white midrib genotypes. Extent of CP degradation was more (p<0.05) in brown midrib (79.6) vis-a-vis white midrib (71.6%) genotypes. In sacco NDF and ADF degradability was relatively higher in brown midrib (53.4, 50.0) than white midrib (48.1, 46.1%) genotypes respectively. Higher (p<0.05) extent of NDF degradability in brown midrib than white midrib genotypes observed by Fritz et al., (1990). Significant increase in in-sacco dry matter digestibility seems to be associated with reductions in percent lignin (22%) as observed in the present study. This is consistent with results from brown midrib sorghum x Sudan grass hybrids reported by Fritz et al. (1990). Lechtenberg et al. (1974) proposed that lignification affects the extent but not the rate of fiber digestion. Further the lower phenolic contents recorded in the present study in brown mid rib genotypes may be responsible for higher cell wall digestion. Lignin of the brown midrib genotypes had lower p-coumaric acid concentration and lower p-coumaric acid: ferulic acid ratios than normal genotypes. Burritt et al. (1984) observed a significant correlation (r=-0.84) between p-coumaric acid and ferulic acid ratio and concentration of digestible dry matter in several cool season grasses and speculated that the p-coumaric acid may be more important than ferulic acid in the formation of cross linkages between lignin and cell wall polysaccharides. In brown mid rib genotypes ADF exhibited poor correlation (r=-0.10) than white mid rib (r= -0.74) genotypes with CP degradability. This shows that ADF bound CP is lower in brown mid rib than white mid rib genotypes. This may be responsible for higher CP degradability in brown mid rib than its normal counter parts. Similarly Porter et al. (1978) recorded significantly (p<0.05) higher *in vitro* dry matter digestibility in chemically induced brown midrib mutants of sorghum as compared to normal counter parts. Muller et al. (1972) reported faster *in vitro* digestion rates of DM, NDF, cellulose and hemi-cellulose for corn silage with brown mid rib-3 (bmr3) mutation. *In vivo* digestibility of DM, OM, NDF and ADF was 3.0, 2.5, 10.5 and 9.4 units more in brown mid rib corn silage than normal corn silage fed to steers *ad libitum* (Tjardes et al., 2000). Further the effects of quantity and composition of lignin on digestibility of forage plants are well documented (Allison, 1969; Jung, 1989). Brown midrib mutant corn silage when evaluated *in vitro* was found superior to normal silage on the basis of feed efficiency, average daily gain and daily DMI by sheep and cattle (Muller et al., 1971; Colenbrander et al., 1973).

Table 3. Fodder yield (g/plant) and availability index values of brown midrib and white midrib sorghum genotypes

Genotypes	GFY/plant	DFY/plant	Availability index
Brown midrib			
ICSU 96031	483	117	78.2
ICSU 93046	293	93	81.5
ICSU 96082	390	98	84.6
ICSU 96078	517	148	79.8
ICSU 96075	497	167	85.2
ICSU 95101	533	127	81.9
ICSU 96034	500	138	82.9
ICSU 96063	557	190	80.8
ICSU 45116	557	138	72.2
ICSA 93-3	320	75	75.7
ICSA 3845 X 3816	570	137	82.1
Mean	474.2	129.8	80.4
White midrib			
ICSU 96050	243	72	70.9
ICSU 960.30	523	140	67.4
ISU 95082	233	63	73.3
SSG 59-3	283	87	51.9
FSHI 93-1	253	75	73.3
FSHI 2219A X 3211	657	150	72.1
HC 171	543	137	79.4
ICSA 93-2	440	147	59.5
ICSA 93-1	200	73	68.9
Mean	375.0	104.8	69.2
SEM	42.52	11.23	1.95
Significance	*	*	*

SEM; Standard error of mean. * Significant at p<0.05.

Forage yield and availability index values

Mean green and dry fodder yield (g/plant) was higher in brown midrib (474.2 and 129.8) than white midrib (375.0 and 104.8) genotypes (Table 3). Within brown mid rib genotypes, ICSA3845 X 3816, ICSU 96063 and ICSU 45116 exhibited higher green and dry fodder yield. However, the maximum forage yield was recorded in white mid rib genotype, FSHI 2219A X 3211 (657 g/plant). Comparable yield of dry matter was obtained from brown mid rib and normal corn crops (Weller et al., 1985). The organic matter digestibility and yield of digestible organic matter of the brown mid rib-3 plants were 0.06 units and 14% higher, respectively than their normal counterparts. Comparable forage yield of brown mid rib to present observations has been given earlier (Allen et al., 1997). Average availability index values were significantly higher in brown midrib (80.4) than white midrib (69.2%) genotypes of the sorghum. This suggests that lignin contents are low and cell contents are higher in brown midrib than white midrib genotypes as availability index value is the function of lignin and soluble contents of the forage crop. In brown mid rib, genotypes with higher forage yield were superior in availability index values. Highest (85.2) and lowest (51.9%) availability index values were recorded in brown mid rib ICSU 96075 and normal SSG59-3 genotypes.

Table 4. Correlation between chemical constituents and in sacco nutrients degradability of brown and white midrib genotypes

Chemical constituent	DMD	OMD	CPD	NDFD	ADFD	Hemicellulose D
Brown midrib						
DM	0.40*	0.47*	0.56*	0.51*	0.53*	0.64*
OM	-0.38*	-0.39*	-0.61*	-0.51*	-0.35*	-0.35*
CP	0.51*	0.52*	0.63*	0.70*	0.70*	0.66*
NDF	-0.23	-0.19	0.06	0.07	0.04	0.33
ADF	-0.54*	-0.50*	-0.10	-0.41*	-0.35*	-0.13
Cellulose	-0.47*	-0.47*	-0.11	-0.39*	-0.38*	-0.26
Lignin	-0.57*	-0.48*	-0.13	-0.46*	-0.44*	-0.15
Hemicellulose	0.17	0.18	0.18	0.48*	0.37*	0.58*
White midrib						
DM	-0.56*	-0.39*	-0.74*	0.24	-0.25	-0.11
OM	-0.15	0.08	-0.48*	0.23	0.07	0.27
CP	0.45*	0.33	0.85*	0.35	0.41*	0.17
NDF	-0.70*	-0.60*	-0.84*	-0.45*	-0.56*	-0.35
ADF	-0.66*	-0.54*	-0.74*	-0.58*	-0.52*	-0.47*
Cellulose	-0.46*	-0.30	-0.68*	-0.34	-0.28	-0.18
Lignin	-0.86*	-0.78*	-0.79*	-0.82*	-0.76*	-0.76*
Hemicellulose	-0.10	-0.15	-0.10	0.23	-0.07	0.17

respectively. Availability index value of normal sorghum genotypes at different stages of their maturity had been reported earlier (Singh et al., 2001)

Correlation among chemical constituents and their digestibility

In both types of genotypes CP content had significant positive correlation with DM, CP and ADF degradability (Table 4). In white mid rib genotypes lignin has more pronounce negative correlation with DM, OM and fiber fractions degradability than white mid rib genotypes. This shows that lignin had more marked effect on nutrients digestibility and thus the chemical nature of lignin in brown mid rib genotypes is altered than the normal sorghum genotypes. ADF contents exhibited more negative effect on nutrient digestion than cellulose contents in both types of genotypes, however the effects are high in case of white mid rib genotypes. Negative correlation between lignin and cell wall digestion reported by Casler (1987) supports the findings of the present study.

CONCLUSIONS

Evaluation of brown mid rib and white mid rib sorghum genotypes revealed that brown mid rib genotypes had reduced cell wall (NDF, ADF, Cellulose and lignin) and phenolic contents, more nutrients degradability, better forage yield and higher availability index values than their normal counter parts. These genotypes thus may be exploited to achieve higher livestock production as evidenced from research results.

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