Changes in Chemical Composition of Sorghum as Influenced by Growth Stage and Cultivar

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ABSTRACT : To determine the effect of different growth stages and cultivars on the chemical composition of sorghum plant and its morphological fractions, samples of whole plant, leaf and stem of J.S-263, J.S-88 and Hegari cultivars, harvested at various growth stages were drawn for analysis. All the samples were analysed for their dry matter contents and various cell wall components such as NDF, ADF, hemicellulose, cellulose, lignin, cutin and silica. Significant increase in DM contents of whole sorghum plant, leaf and stem was observed with advancing stage of growth. The highest DM content was recorded in leaf fraction of the plant. All the cell wall constituents increased significantly in whole sorghum plant, leaf and stem as the plant matured. The maximum NDF, ADF, cellulose and lignin contents were observed in stem fraction, followed by whole plant. However, the hemicellulose, cutin and silica contents were higher in leaf fraction of the plant. The cultivars were found to have some effect on the chemical composition of whole plant, leaf and stem fractions. The results indicated that plant maturity had a much greater effect on the chemical composition of sorghum plant, whereas it was little affected by cultivars. *(Asian-Aust. J. Anim. Sci. 2001. Vol 14, No. 7 : 935-940)*

Key Words : Cell Wall Components, Growth Stages, Morphological Fractions, Sorghum Cultivars

INTRODUCTION

In Pakistan, large ruminants such as buffaloes and cattle are traditionally raised on farm grown fodders and crop residues. Green fodders provide adequate amount of protein, carbohydrates and minerals. Value of green fodders depends upon the nutrient concentration in the fodder as well as fodder intake by the animal. The nutrients are utilized for body maintenance and various productive functions depending upon the efficiency with which the animal converts these nutrients into animal products.

In general, the quality of forage and fibrous feedstuffs varies a great deal due to a number of factors such as species, stage of growth, soil condition, fertilizer application, availability of water and climatic conditions. As the plants mature, they generally tend to decline in nutritive value. Such changes are due to altered chemical composition involving lignification and decreased proportion of leaves to stem (Van Soest, 1987).

The major fodder crops used in the Pakistan during winter include berseem, lucerne, oats, barley and mustard, while during summer these comprised maize, sorghum and millet. These crops cover from 16 to 19 % of total cropped area in Pakistan (Bhatti and Khan, 1996). Sorghum (*Sorghum bicolor*) is a widely grown summer fodder. It is grown both on irrigated and rainfed areas in the country. It needs relatively high temperature for maximum yield and mean summer temperature of 27 to 30°C is regarded as ideal (Leonard and Martin, 1963). The fodder is quite palatable and extensively fed to all classes of livestock. Among the sorghum varieties, J.S–263, and Hegari are sweet in taste and are liked by animals. These varieties are grown for fodder as well as for grain production. In the rainfed areas of the country, the crop is extensively used for conversion into hay (Hanjra et al., 1995).

The tropical forages on average are higher in lignin contents than those of the temperate regions. Animal production in tropical countries is handicapped by the low quality of the forage (Van Soest, 1987). The information on chemical composition of local sorghum cultivars is scanty, especially the changes occurring in chemical composition of different fractions of the plant with advancing growth stages. Keeping this in view, the present study was undertaken to determine the changes in chemical composition of different cultivars and morphological fractions of sorghum fodder at various growth stages.

MATERIALS AND METHODS

The experiment was conducted on three approved sorghum cultivars namely J.S-263, J.S-88 and Hegari. All sorghum cultivars were sown in April, 1992 in experimental fields of the University of Agriculture, Faisalabad. The fodder samples were harvested up to July, 1992. The procedure used for fodder cultivation, harvesting and sampling is given below:

Agronomic practices

The sorghum cultivars were sown in three replicates using randomized complete block design. Plot size was 5 m×8 m and row spacing 30 cm. The experimental fields were fertilized by farm yard manure before soil preparation. Five irrigations of canal water were given during the experimental period.

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Harvesting / sampling

The first fodder sample was obtained two weeks after germination of seeds. The subsequent samples were harvested up to 14th week at different stages of plant maturity. For random sampling ten or more sites were selected and the aerial parts of the plants were clipped and saved in plastic bags (Harris, 1970). The leaf portion (blade+sheath) of plant was separated manually from the stem. All the samples were then saved in plastic bags for further analysis.

Sample preparation

The whole plant, leaf and stem fractions of sorghum fodder were run through a fodder cutter and cut into 2 to 3 cm pieces. After cutting the fodder was mixed and representative samples were drawn. The dry matter contents of fodders were determined by using the method of AOAC (1990). Fodder samples were dried in hot air oven at 60°C to a constant weight. Dried samples were ground in a laboratory mill and passed through 4mm screen. Sub - samples were drawn and further ground to pass through 1mm screen (Harris, 1970; Van Soest and Robertson, 1985). Dried fodder samples from three replicates were mixed to make one composite sample. These samples were analyzed in duplicate.

Samples of whole sorghum plant and its leaf and stem fractions were analyzed for cell wall constituents such as neutral detergent fibre (NDF), acid detergent fiber (ADF), hemicellulose, cellulose, lignin, cutin and silica. For the determination of NDF, the method of Van Soest and Wine (1967) was used. ADF and silica were estimated according to Van Soest (1963), whereas hemicellulose contents of the fodders were worked out by difference between NDF and ADF. Cellulose, permanganate lignin and cutin contents were determined using the method of Van Soest and Robertson (1985). In this procedure the sample was first digested with neutral detergent and then acid detergent and the residue after these extractions was further digested by 72% H_2SO_4. The loss in weight was estimated as cellulose. The remaining residue was then oxidised by potassium permanganate solution to separate plant cuticle which was resistant to $KMnO_4$

The loss in weight was taken as permanganate lignin and the residue was cutin and ash.

Statistical analysis

Statistical analysis of the data was carried out by using analysis of variance technique (ANOVA-2). Treatment means were compared by Duncan's new multiple range test (Steel and Torrie, 1984).

RESULTS AND DISCUSSION

Table 1 shows the values for dry matter (DM) contents and different structural components such as NDF, ADF, hemicellulose, cellulose, lignin, cutin and silica of whole sorghum plant and its morphological fractions at various growth stages.

Dry matter contents and cell wall constituents of different cultivars of sorghum fodder have been presented in table 2.

Dry matter

Dry matter contents of whole sorghum plant, leaf and stem increased significantly ($p<0.01$) with advancing stage of maturity. Results showed that DM contents were the maximum in leaf fraction, ranging from 18.28±0.29 to 41.84±0.95% followed by whole sorghum plant (13.45±0.27 to 37.35 ±1.52%). However, the minimum dry matter was recorded in stem fraction (10.05±0.19 to 33.66±0.96%). It could have been due to increased photosynthetic activity of the plant which led to higher biomass production in leaves (Azim et al., 1989).

Further the dry matter, soluble carbohydrates and total phenolic contents were also higher in leaves than in stems of various sorghum cultivars (Alhassan et al., 1987). In another study, Ashrif et al. (1995a) reported an increase in dry matter content of four sorghum varieties at different cutting heights. The values reported by them were comparable with those obtained in the present study. The changes in dry matter contents due to cultivars were found to be non - significant in whole sorghum plant and its leaf fraction. However, significant differences were observed in case of stem fraction. J.S-88 cultivar had significantly lower DM content, whereas it was almost similar in J.S-263 and Hegari cultivars. As J.S-88 is a late variety and its flowering stage did not appear till 14th week of age. Although there was an increase in dry matter contents of stem as the plant advanced in age but at a slower rate than those of J.S - 263 and Hegari cultivars.

Cell wall components

NDF : A significant ($p<0.01$) increase in NDF content in whole sorghum plant and its morphological fractions was observed with advancing plant age/stage of growth. The concentration of NDF (42.44±0.23 to 73.77±1.28%) was higher in stem than that in whole plant (40.73±0.13 to 69.76±0.83%), whereas lower (38.51±0.19 to 66.16± 0.22%) values were recorded in leaf fraction. Chauhan (1983) reported an increasing trend of NDF in hybrid napier and found as 67.02, 73.50, 75.59 and 77.71 % when harvested at 45, 75, 105 and 120 cm height, respectively.

Table 1. Chemical composition (%) of whole sorghum plant and its morphological fractions at different stages of growth (mean±S E)

Chemical composition	Growth stages (age in weeks)				
	Seedling (2nd week)	Early growth (6th week)	Flowering (9th week)	Milk/dough (12th week)	Mature (14th week)
Whole plant					
DM	13.45^{c} ±0.27	15.66^{c} ±0. 45	22.76^{b}±1.18	34.08^{a} ±1.02	37.35^{a} ±1.52
NDF	40.37^{c}±0.13	53.09^{d} ±0.12	60.54^{c} ±0.46	65.49^{b} ±0.35	69.76^{a} ±0.83
ADF	25.34^{d}±0.15	34.89^{c}±0.22	39.29^{b}±0.65	41.18^{ab}±0.36	43.35^{a}±0.54
Hemicellulose	15.03^{d}±0.14	18.10^{c}±0.17	21.69^{b}±0.38	24.31^{ab} ±0.17	26.25^{a}±0.28
Cellulose	21.41^{d}±0.17	28.27^{c}±0.15	30.70^{b}±0.43	27.61^{b} ±0.06	28.75^{a}±0.17
Permanganate lignin	2.46^{d}±0.10	4.10^{c} ±0.04	5.08^{b} ±0.14	5.44^{a} ±0.13	5.69^{a} ±0.11
Cutin	0.39^{e} ±0.09	0.86^{d} ±0.02	1.17^{c} ±0.03	1.37^{b} ±0.02	1.60^{a} ±0.04
Silica	1.07^{d} ±0.02	1.83^{c} ±0.09	2.34^{b} ±0.08	2.50^{b} ±0.08	2.62^{a} ±0.08
Leaf					
DM	18.28^{c} ±0.29	22.65^{c} ±0.43	29.29^{b} ±0.90	41.18^{a} ±1.11	41.84^{a} ±0.95
NDF	38.51^{e} ±0.19	48.87^{d} ±0.26	58.57^{c} ±0.29	61.97^{b} ±0.34	66.16^{a} ±0.52
ADF	21.16^{d} ±0.19	27.41^{c} ±0.09	32.98^{b} ±0.15	34.89^{ab} ±0.37	37.34^{a} ±0.71
Hemicellulose	17.73^{e} ±0.17	21.46^{d} ±0.20	25.59^{c} ±0.16	27.21^{b} ±0.25	28.66^{a} ±0.13
Cellulose	17.61^{d} ±0.13	20.95^{c} ± 0.01	25.03^{b} ±0.21	26.12^{b} ±0.16	27.82^{a} ±0.47
Permanganate lignin	2.14^{d} ±0.05	3.33^{c} ±0.04	4.19^{ab} ±0.19	4.19^{ab} ±0.12	5.07^{a} ±0.18
Cutin	0.42^{d} ±0.01	0.76^{c} ±0.03	1.27^{bc} ± 0.04	1.35^{b} ±0.02	1.67^{a} ±0.05
Silica	1.55^{d} ±0.03	1.82^{c} ±0.04	2.52^{b} ±0.04	2.76$^{a\,b}$ ±0.02	2.77^{a} ±0.09
Stem					
DM	10.05^{c} ±0.19	10.77^{c} ±0.18	18.65^{b} ±0.57	31.69^{a} ±0.95	33.66^{a} ±0.96
NDF	42.44^{e} ±0.23	56.59^{d} ±0.56	64.56^{c} ±0.61	68.33^{b} ±0.71	73.77^{a} ±1.28
ADF	27.35^{d} ±0.24	39.33^{c} ±0.68	43.45^{b} ±0.64	44.87^{b} ±0.56	47.90^{a} ±0.51
Hemicellulose	14.47^{e} ±0.24	16.98^{d} ±0.32	21.03^{c} ±0.31	23.46^{b} ±0.28	25.87^{a} ±0.24
Cellulose	23.13^{d} ±0.23	31.36^{c} ±0.59	33.99^{b} ±0.45	34.89^{b} ±0.45	36.44^{a} ±0.29
Permanganate lignin	3.49^{d} ±0.06	5.45^{c} ±0.06	6.31^{b} ±0.14	6.76^{b} ±0.04	7.49^{a} ±0.93
Cutin	0.35^{d} ±0.02	0.77^{c} ±0.01	1.14^{b} ±0.01	1.23^{b} ±0.02	1.46^{a} ±0.07
Silica	0.78^{d} ±0.03	1.63^{c} ±0.04	2.10^{b} ±0.05	2.39^{a} ±0.06	2.51^{a} ±0.07

Different superscripts on means in the same row show significant ($p< 0.01$) differences.

NDF concentration was also reported to differ significantly ($p<0.05$) between plant parts, leaf blades, leaf sheaths and stem in orchardgrass (Grabber et al., 1991). In another study

Rakkiyappan and Krishnamoorthy (1982) observed a higher percentage of cell wall components in the stem than leaf. The findings of present study are comparable with those of above reported work. Leaf and stem fractions of the plant showed significant effects on NDF contents due to cultivars, whereas in case of whole plant the differences were non-significant. Significantly lower NDF contents were observed in J.S-88 cultivar. The reason probably could be that J.S-88 was a late cultivar and its flowering stage did not appear till 14th week of age. Ashrif et al. (1995b) reported a higher NDF content in sorghum variety No. 94.

ADF : Significant changes in ADF were seen in whole plant, leaf and stem of sorghum fodder with advancing stage of maturity. It was observed that ADF contents of stem ranged from 27.35±0.24 to 47.90±0.51%, being higher than that of whole plant (25.34±0.15 to 43.35±0.54%). However, the leaf fraction of the plant had minimum values which ranged from 21.16±0.19 to 37.34±0.71%). Reid et al. (1979) reported that cell wall constituents (CWC) and ADF increased in a linear fashion with increased maturation of 24 grasses and legumes. ADF increased in whole plant and stem samples of old world blue stem grasses during the 10 weeks sampling period. Consequent to advancing maturity, the changes in ADF were less marked in leaves than in stem (Dabo et al., 1988). Some cultivar differences were also observed with respect to ADF content of whole sorghum plant and its stem fraction. J.S-88 cultivar had significantly lower ADF contents in both fractions. This may be due to the seasonal effects. Because of being a late variety, the flowering stage in J.S-88 did not appear till 14th week of age. Seven sorghum cultivars differed significantly in chemical composition (Fulpagare et al., 1985). Results of above reported work support the findings of present study.

Hemicellulose : A significant increase in hemicellulose content of sorghum and its morphological fractions was observed with advancing stages of growth. Hemicellulose

Table 2. Chemical composition (%) of various cutivars of sorghum fodder and its morphological fractions (mean ± SE)

Chemical composition	J.S-263	J.S-88	Hegari
Whole plant			
DM	25.11±3.26	22.72 ±2.59	26.26 ±3.56
NDF	58.79±3.61	57.02 ±3.21	57.99±3.54
ADF	37.60^{a} ±2.28	35.84^{b} ±1.92	36.98^{ab}±2.19
Hemicellulose	21.19±1.38	21.18 ±1.24	20.81 ±1.40
Cellulose	29.49 ±1.55	28.65 ±1.26	29.25 ±1.41
Permanganate lignin	4.80^{a} ±0.43	4.28^{b} ±0.37	4.59^{ab} ±0.39
Cutin	1.13 ±0.14	1.03 ±0.13	1.08±0.15
Silica	2.19^{a} ±0.21	1.88^{b} ±0.16	2.14^{a} ±0.20
Leaf			
DM	30.79 ±3.42	29.25 ±2.64	31.90 ±3.51
NDF	55.4^{a} ±3.36	54.25^{b} ±3.17	54.82^{ab}±3.42
ADF	31.06 ±2.07	30.18 ±1.67	31.03 ±2.10
Hemicellulose	24.25 ±1.27	24.16 ±1.38	23.63 ±1.40
Cellulose	23.58 ±1.24	23.29 ±1.11	23.59 ±1.38
Permanganate lignin	4.08^{a} ±0.39	3.66^{ab} ±0.37	3.96^{b} ±0.43
Cutin	1.22 ±0.15	1.16 ±0.12	1.21 ±0.13
Silica	2.26 ±0.23	2.13 ±0.18	2.22 ±0.22
Stem			
DM	21.07^{ab} ±3.26	19.52^{b} ±2.59	21.93^{a} ±3.56
NDF	62.31^{a} ±3.78	59.55^{b} ±3.42	61.56^{a} ±3.58
ADF	41.51^{a} ±2.57	39.33^{b} ±2.16	41.12^{a} ±2.33
Hemicellulose	20.76 ±1.25	20.22 ±1.28	20.09 ±1.45
Cellulose	32.51^{a} ±1.73	30.88^{b} ±1.45	32.27^{a} ±1.52
Permanganate lignin	6.05 ±0.49	5.77 ±0.43	5.93 ±0.69
Cutin	1.03 ±0.14	0.93 ±0.11	1.00 ±0.14
Silica	1.98^{a}±0.22	1.75^{b}±0.18	1.92^{ab} ±0.22

Different superscripts on means in the same row show significant ($p<0.01$) differences.

concentration was higher (17.73±0.17 to 28.66±0.13 %) in leaf fraction of plant than that of whole plant (15.03±0.14 to 26.16±0.28%), whereas the stem fraction had lower hemicellulose content (14.47±0.24 to 25.87±0.24%). Average values for hemicellulose in seven sorghum cultivars were reported to be 25.19 % (Fulpagare et al., 1985). However, the values reported by them are slightly lower than those recorded in the present study. Kim and Voigtlaender (1985) studied the synthesis of cell wall constituents in various maize and sorghum cultivars. They reported that the cellulose and hemicellulose were the main cell wall constituents with cellulose accumulated mainly in stem and hemicellulose was an important component of leaves and panicles. Cultivar effects on hemicellulose contents of whole plant, leaf and stem fractions were found to be non–significant statistically. Ahsrif et al. (1995b) also observed non-significant differences among four sorghum varieties.

Cellulose : The results showed that cellulose contents of whole sorghum plant and its leaf and stem fractions were significantly ($p<0.01$) affected by advancement in growth stages. A rapid rise in cellulose concentration was recorded up to flowering stage in all plant fractions. However, a slight increase was seen at milk/dough stage. Cellulose contents of stem fraction were higher (23.13±0.23 to 36.44±0.29%) than those of whole plant (21.41±0.17 to 33.41±0.28%) and were minimum (17.61±0.13 to 27.82±0.47%) in leaf fraction. Fulpagare et al. (1985) reported that the average value for cellulose was 32.28% in seven sorghum forage varieties. Cellulose concentration differed significantly between plant parts such as leaf blade, leaf sheath and stems (Grabber et al., 1991). The results reported above are closely comparable with those obtained from the present study.

Some cultivar effects on cellulose contents were observed in case of stem fraction of the plant, however, the changes were non- significant in whole plant and leaf fractions. The stem of J.S-88 cultivar had significantly lower cellulose content than that of J.S-263. The reason being that J.S-88 was a late variety and its flowering stage did not appear till 14th week of age. It might have some effect on cellulose content of stem but not on those of whole plant and leaf. However, Ashrif et al. (1995b) reported significantly higher cellulose content in No. 94 sorghum variety.

Lignin : The results revealed that the lignin contents of whole sorghum plant and its leaf and stem fractions increased significantly ($p<0.01$) with advancing stages of growth. Lignin contents of stem fraction ranged from 3.49±0.06 to 7.49±0.93%, being higher than those of whole plant (2.46±0.1 to 5.69±0.11%), whereas the leaf fraction of the plant had the lowest lignin (2.14±0.05 to 5.07±0.18%) concentration. Rapid increase in lignin content was observed up to flowering stage in all plant fractions. Thereafter, the increase was a bit slow at milk/ dough and mature stages. It was probably due to significantly lower NDF and ADF contents of J.S-88 cultivar, which might have some effect on lignin contents at later stages of growth. Morphological differences in cell wall contents were attributed to differences in the concentration and composition of their lignin and carbohydrate fractions in normal and brown midrib mutant sorghum×sudangrass hybrid (Fritz, 1989). Fulpagare et al. (1985) reported that on average lignin contents were 8.1 % in seven sorghum varieties. However, the values reported by these workers were higher than those observed in the present study. Concentration of ADL increased in whole plant and stem samples during 10 weeks sampling period for bluestem grasses. The rate and extent of increase in ADL concentration in leaves were substantially less than in whole

plant and stem parts (Dabo et al.,1988).

Some cultivar effects on lignin contents were observed in whole sorghum plant and leaf fractions. J.S-88 cultivar had significantly lower lignin contents, whereas higher lignin concentration was observed in J.S – 263 cultivar. Ashrif et al.
(1995 b) also reported higher lignin content in sorghum variety J.S-263.

Cutin : Concentration of cutin continued to increase significantly ($p<0.01$) with increasing maturity of whole sorghum plant, leaf and stem fractions. Higher cutin concentration (0.42±0.01 to 1.67±0.05%)was recorded in leaf fraction followed by whole sorghum plant (0.39±0.09 to 1.6±0.04%), whereas corresponding values were the minimum (0.35±0.02 to 1.46±0.07%) in case of stem fraction. This could be due to the loss of plant water that occurred through the leaf surface. The cuticular wax layer which covers the surface of plant organs, acts as a barrier to water movement, repelling water externally and absorbing it internally (Bain and McBean, 1967). However, the variations in cutin contents due to cultivars were found to be non- significant in all plant fractions.

Silica : The silica contents of whole plant and its morphological fractions such as leaf and stem, increased significantly ($p<0.01$) with advancing growth stages. Higher values for silica (1.55±0.03 to 2.77±0.09%) contents were seen in leaf fraction than whole plant (1.07±0.02 to 2.62±0.08%). However, the stem fraction had the lowest (0.78±0.03 to 2.51±0.07%) silica concentration. It was probably due to more deposition of silica in leaf portion of the plant. Gupta and Sagar (1987) reported that silica contents in stem were much lower than in leaf. The reason might be that whatever silica is absorbed from the soil, gets deposited in leaves. The average value for silica contents of seven sorghum varieties was reported as 5.25 % (Fulpagare et al., 1985), which was much higher than that observed in present study.

Some cultivar effects were also observed with respect to silica contents of whole sorghum plant and stem. J.S-88 cultivar had significantly lower silica contents than those of J.S-263 and Hegari cultivars. However, in case of leaf the differences were non-significant. Among the sorghum varieties higher silica contents were reported in J.S-263 (Ashrif et al., 1995b).

CONCLUSION

The following conclusions have been drawn on the basis of the present study.

1. Dry matter contents and various cell wall constituents of whole plant, leaf and stem of sorghum fodder increased with advancing age/stage of maturity.
2. Maturity of plant had much greater effect on concentration of dry matter and various fiber constituents of sorghum fodder than did cultivars.
3. Plant leaves were high in dry matter, hemicellulose, cutin and silica, whereas the stem had high NDF, ADF, cellulose and lignin contents.
4. Hegari was the best among sorghum cultivars, since this cultivar has higher DM contents and lower lignin concentration.

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