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Partitioning of Chemical Constituents in the Leaf and Stover of Sorghum Grown in a Saline Soil

H.A. Esechie* and F.R. Miller#

**College of Agriculture, Sultan Qaboos University, P.O.Box 34 Al-Khod 123, Muscat, Sultanate of Oman, and #Department of Soil and Crop Sciences, Texas A & M University, College Station, TX 77843, U.S.A.*

خلاصة : أجريت دراسات حقلية ومعملية في عامي ١٩٩٠و ١٩٩١لتحديد التركيز الكلي للكاربوهيدرات غير البنائية والبروتين الخام والسليلوز والنصف سليلوز والليقنين ومستخلص الأثير مجزأة في أوراق وسيقان الذرة الرفيعة المزروعة في تربة ملحية (ت ك ١١,٨ دس م -١). وقد استخدمت في هذه التجارب ثلاثة وعشرون صنفاً من الذرة الرفيعة منها ١٠ عينات مؤنثة و٦ مذكرة و٧ عينات علف. ووجد أن تركيز الكاربوهيدرات غير البنائية قد وزعت بانتظام على أجزاء الأوراق والسيقان، وكان تركيز السليلوز والليقنين أكثر بصورة معنوية في السيقان منها في الأوراق، بينما احتوت الأوراق على كميات أكبر من النصف سليلوز ومستخلص الأثير عنها في السيقان . وبالرغم من ذلك - واعتماداً على الكاربوهيدرات غير البنائية لدى بعض أنواع الذرة قابلية التخمير الميثانولي - فإن الحاجة المنافسة كعلف للحيوانات جديرة بالاعتبار.

ABSTRACT: Field and laboratory studies were conducted in 1990 and 1991 to determine the concentrations of total nonstructural carbohydrates (TNC), crude protein, cellulose, hemicellulose, lignin and ether extract partitioned in the leaf and stover of sorghum grown in a saline soil (EC = 11.8 dSm^{-1}). Twenty three sorghum cultivars comprising 10 female lines, 6 male lines and 7 forage lines were used. TNC was uniformly distributed in the leaf and stover portions. Significantly higher concentrations of cellulose and lignin were partitioned to the stover portions than the leaf, but the leaf contained larger amounts of hemicellulose and ether extract than the stover. Although, based on TNC contents, some of the sorghum types have a potential for methanogenesis, the competing demand as animal feed also needs to be considered.

Apart from its livestock feed value, sorghum is also known to be good for fermentation to methanol or ethanol. To maximize vegetative biomass yield, it is usual to remove the entire aboveground part, a practice which, over time, can result in declining soil productivity. Powell et al. (1991) found that stover carbohydrates are mainly contained in the lower-third of sorghum stalk fraction and consequently proposed a management system for returning the upper stover portions to the soil, while removing the remaining portion for alternative uses. This practice would be appropriate in a desert climate such as the Batinah Coast region of Oman where wind erosion is common, due to very sparse vegetative cover. However, apart from its aridity, the soils in Batinah Coast region have salinity problems caused primarily by ocean spray and ocean water intrusion.

There is little or no information on the partitioning of chemical constituents in the leaf and stover of sorghum growing in a saline soil. The objective of this study was to determine the partitioning of carbohydrates, crude protein, lignin and ether extract in the leaf and stover portions of several cultivars of sorghum growing in a saline soil. Such information, apart from providing a better understanding of the forage value of the crop, will be useful in evaluating the feasibility of the previously proposed management practice of returning part of the stover to the soil, while keeping the other parts for alternative uses.

Materials and Methods

Twenty three sorghum cultivars comprising 10 female grain types, 6 male grains types and 7 male forage types obtained from the Texas A & M University Agricultural Experiment Station were used for this study. Cultivars 1-10 are grain lines (females), while cultivars 11-17 and 18-23 are grain lines (males) and forage lines (males), respectively. They have been selected because of their good tropical adaptation.The cultivars were planted at the Sultan Qaboos University Agricultural Experiment Station, Muscat (23°37' N and 58°38' E) near the Batinah Coast of Oman in 1990 and 1991. The soil had a pH of c. 7.8 and salinity level

* Corresponding Author.

of c. 11.8 dS/m. The relatively high salinity was due to a high Na concentration in the soil.

A randomized complete block design with four replications of single row plots and thinned to 83000 plants/ha was used. Inter-row and intra-row spacings were 60 cm and 20 cm, respectively, and with 20m long rows, there were ca. 100 plants per row.Sprinkler irrigation was applied daily or as needed to avoid moisture stress. The electrical conductivity (EC) of the irrigation water was determined every 2 days with a conductivity meter (Jenway Model PCM 3, Felstead, Essex). The Ec values were in the range of 4.7 to 8.6 dS/m. Weed control was accomplished by applying 3 kg a.i./ha of atrazine [6-chloro -N- ethyl -N- (1-methylethyl) -1,3,5- triazine -2,4- diamine] 1 day after planting.

Four plants were randomly selected from each row when the kernels had attained physiological maturity, cut at the soil surface and bulked to form a sample. Blades and sheaths were stripped from each plant and bulked, while the stems were divided into three equal parts (upper, middle and basal portions). The panicles, including the preduncle were discarded. All sections were dried at 100°C for 1hr and subsequently at 70°C for 72 hrs. They were then ground in a sample mill (Cyclotec 1093, Hoganas, Sweden) to pass a 1 mm screen. Previously described methods were used for the determination of total nonstructural carbohydrates (TNC) (Smith, 1969). Crude protein (N x 6.25), crude fibre (CF) and ether extract were determined according to AOAC (1975), while neutral detergent fibre (NDF) followed the procedure described by Goering and Van Soest, (1970). Acid detergent fibre (ADF) was determined gravimetrically following the method described in Technical Bulletin No. 27 of the Ministry of Agriculture, Fisheries and Food, London (Anonymous, 1973). One gram sample was boiled with sulphuric acid solution of cetyltrimethylammonium bromide (CTAB) under controlled conditions. The CTAB dissolved nearly all the nitrogenous constituents and the acid hydrolysed the starch, leaving the acid detergent fibre as an insoluble matter.

Following the report of Singh et al. (1987), hemicellulose was estimated as neutral detergent fibre minus acid detergent fibre (NDF-ADF), while lignin was the difference between acid detergent fibre and crude fibre concentration (ADF-CF). Cellulose was represented by crude fibre.

All data were subjected to an analysis of variance and means for the two years were separated by LSD ($P<0.05$).

Results and Discussion

TOTAL NONSTRUCTURAL CARBOHYDRATES: Leaf TNC varied greatly among the different entries (Table 1). Among the females, ATx623 with TNC concentration of 72.3 g kg-1 was the highest. The highest leaf TNC contents in the males and forage lines (males) were 69.3 and 71.6 g kg^{-1} in Dorado and RAR2002, respectively. Averaged over entries, there were no significant differences in the TNC concentrations in the leaf (LF), upper stem portion (USP), middle stem portion (MSP) and basal stem portion (BSP), respectively in the females and forages (Table 2), but TNC concentration in the males was generally lower in the leaf than in the other plant parts.

This is contrary to the results of McBee and Miller (1990) who worked with sorghum cultivars, some of which are included in the current study. However, if alcohol yields are directly proportional to the sugar contents of the biomass as was shown by Smith et al. (1987), then some of the cultivars, notably BTx630, ATx631, CS3541 and Hegari with TNC ≥ 75g kg^{-1} in the MSP show some promise. While further research will be needed to confirm this, the competing demand as animal feed needs to be considered.

TABLE 1

Mean TNC, CP, ADF, NDF, CF, EE, hemicellulose and lignin in the leaf of sorghum[*].

Cultivars	TNC	CP	ADF	NDF	CF	EE	Hemi cellulose	Lignin
	g kg^{-1}							
ATx630	48.8	84.5	216.5	590.8	170.3	6.63	374.3	46.3
BTx630	71.1	93.5	203.3	600.3	167.3	3.25	397.0	36.0
ATx631	68.3	77.5	219.5	584.5	163.8	4.88	365.0	55.7
BTx631	57.4	81.5	185.5	487.8	152.5	4.33	302.3	33.0
A_2Tx632	56.5	94.0	197.0	523.5	169.8	3.33	326.5	27.2
B_2Tx632	59.4	92.3	214.5	537.5	162.5	7.15	323.0	52.0
ATx629	67.2	67.5	186.8	550.8	152.5	6.80	364.0	34.3
BTx629	71.1	55.0	206.8	485.8	164.8	3.18	279.0	42.0
ATx623	72.3	47.8	182.5	485.5	152.0	3.60	303.0	30.5
BTx623	52.1	76.8	170.0	472.8	141.0	4.35	302.8	29.0
RTx430	59.5	90.5	180.0	522.5	141.5	5.13	342.5	38.5
RTx432	35.0	74.3	175.5	563.0	142.8	6.40	387.5	32.7
RTx434	49.2	85.0	166.4	504.5	143.5	3.90	338.1	23.3
CS3541	63.8	65.8	175.3	504.5	151.5	4.63	329.2	23.8
Dorado	69.3	81.5	185.0	544.5	143.5	4.65	359.5	41.5
Sureno	51.6	77.0	182.3	482.5	141.8	4.23	300.2	40.5
Greenleaf Sudangrass	56.5	53.3	216.0	524.0	157.0	4.85	308.0	59.0
Lahoma Sudangrass	52.4	48.5	204.3	545.8	152.3	6.25	241.5	52.8
RAR2002	71.6	52.3	177.8	493.0	141.3	3.85	317.5	36.5
Rio	51.3	64.5	184.5	564.5	145.8	4.10	380.0	38.7
Hegari	69.4	53.0	201.8	563.3	152.5	4.85	361.5	49.3
Grassl (MN1500)	58.7	38.8	164.0	450.3	143.5	3.20	286.3	20.5
Hoti	65.7	45.8	177.0	465.0	144.3	2.20	287.2	33.6
LSD (0.05)	13.1	17.7	23.1	61.2	15.2	1.92	52.2	19.6

[*]Average of 1990 and 1991 data
TNC = Total Nonstructural Carbohydrates
CP = Crude Protein
ADF = Acid Detergent Fibre
NDF = Neutral Detergent Fibre
CF (Crude Fibre) = Cellulose
EE = Ether Extract
NDF - ADF = Hemicellulose
ADF - CF = Lignin

TABLE 2

Hemicellulose, lignin and ether extract partitioning in three sorghum groupings averaged over entries.

Sorghum grouping	Plant Part*	Hemicellulose	Lignin	Ether Extract
		g kg^{-1}		
Grain lines (females)	LF	333.7	38.6	4.75
	USP	171.1	74.7	3.37
	MSP	174.2	74.8	3.75
	BSP	170.9	78.7	3.44
	LSD (0.05)	12.6	8.3	0.62
Grain (males)	LF	337.8	33.4	4.82
	USP	193.9	54.7	3.60
	MSP	184.8	53.4	2.91
	BSP	188.4	59.7	3.41
	LSD (0.05)	14.2	9.4	0.50
Forage lines (males)	LF	325.7	41.4	4.18
	USP	157.9	58.1	3.00
	MSP	167.0	66.5	3.18
	BSP	160.5	70.7	3.39
	LSD (0.05)	15.0	13.4	0.61

* LF = Leaf (leaf sheath + blade)
USP = Upper Stem Portion
MSP = Middle Stem Portion
BSP = Basal Stem Portion

TABLE 3

Total nonstructural carbohydrates (TNC), crude protein (CP) and cellulose partitioning in three sorghum groupings averaged over entries.

Sorghum grouping	Plant Part*	TNC	CP	Cellulose
		g kg^{-1}		
Grain lines (females)	LF	62.4	77.0	159.6
	USP	66.2	55.0	163.8
	MSP	66.8	55.1	161.8
	BSP	62.9	57.5	157.8
	LSD(0.05)	NS	6.3	5.5
Grain lines (males)	LF	54.7	79.0	144.1
	USP	62.1	61.3	155.4
	MSP	61.2	59.6	158.7
	BSP	61.3	60.8	151.9
	LSD(0.05)	NS	6.6	6.1
Forage lines (males)	LF	60.8	50.9	148.1
	USP	64.7	28.2	163.2
	MSP	60.9	30.9	165.8
	BSP	61.4	30.5	152.3
	LSD (0.05)	NS	4.4	6.7

*LF = Leaf (Leaf sheath and blade)
USP = Upper Stem Portion
MSP = Middle Stem Portion
BSP = Basal Stem Portion

The apparent uniformity in TNC partitioning in the different plant parts obtained in the present study could be explained from the stand point of salinity stress. Sorghum leaf blades were relatively smaller in the current investigation when compared to those growing elsewhere under stress-free environment. Therefore, even though photosynthetic activities may have proceeded normally in the leaves, the reduced size became limiting in terms of storage of sugars. Zerbi et al. (1991) have shown that the morphological adaptations of wheat to salinity include smaller plant size and reduced leaf size. Each unit increase in salinity above 6.8 dS/m reduced yield by 18% while plant height was significantly reduced at salinity level of 11.4dS/m (Francois et al., 1984).

Crude protein

A significantly higher crude protein concentration was found in the leaves than the other plant parts (Table 3). There were no significant differences in USP, MSP and BSP leaf crude protein concentrations in all the three sorghum groupings. Genotype A_2Tx632 had the largest leaf crude protein concentration of 94.0 g kg^{-1} among the female lines (Table 1). The largest leaf crude protein concentrations of 90.5 g kg^{-1} was found in RTx430 among the male lines.

Generally, leaf crude protein concentrations were relatively low, especially in the forage lines with a range of 38.8 - 64.5 g kg^{-1}. The forage lines also had lower crude protein concentrations partitioned to their USP, MSP and BSP, compared to the other two groupings.

The level of crude protein below which nitrogen is the first limiting factor in the tropical grasses is about 7% on DM basis (Minson and Milford, 1967). Crude protein partitioning in the three sorghum groupings suggested that sufficiently high amounts were in the leaf portion of the female and male lines but, surprisingly not in the forage lines. Crude protein partitioned to the other plant parts was less than the limit recommended in livestock feed by Minson and Milford (1967). Therefore, the stover of most of the sorghum lines in this study do not seem promising with respect to their crude protein concentration. However, this should be beneficial in terms of TNC removal, since high crude protein level interferes with TNC determination (Smith,1969).

Cellulose

Cellulose, determined as crude fibre, differed significantly in the leaves among entries (Table 1). Significant differences were evident in cellulose concentrations in the USP, MSP and BSP (Table 3). In the male and forage lines, significantly higher cellulose concentrations were partitioned to the MSP and BSP than the leaf. Although the USP had the highest cellulose concentration partitioned to it and the BSP had the least in the female lines, the differences were not statistically significant. Among the females, ATx630 had the largest leaf cellulose content of 170.3 g kg^{-1}, while the corresponding high values in the male and forage lines were 151.5 and 157.0 g kg^{-1}, for CS3541 and Greenleaf sudangrass, respectively. USP cellulose content was highest in BTx631 among the females with 184.5 g kg^{-1} while BTx629 had the largest cellulose

concentration partitioned to the MSP within this grouping. Among the males, USP cellulose concentration was in the range of 144.1 to 164.5 g kg^{-1} (Table 4) while MSP cellulose concentration ranged from 155.0 to 163.5 g kg^{-1} (Table 5). Sureno had the largest cellulose concentration partitioned to the BSM among this grouping. In the forage lines,USP cellulose ranged from 145.5 to 173.5 g kg^{-1}, with RAR 2002 having the largest concentration (Table 4). Hoti had 184.3 g kg^{-1} of cellulose partitioned to the MSP (Table 5), which was the highest in all plant parts within the three sorghum groupings. Also Grassl (MN1500) with MSP cellulose content of 143.8 g kg^{-1} was the least in all plant parts within the three groupings. Cellulose concentration was lower in the leaf portion than the stover parts but the reverse was true for hemicellulose and ether extract. These results agree with those reported earlier (McBee and Miller, 1982; 1990). Stallcup et al. (1964) have also reported that cellulose concentration was higher in the stem than the leaf. Apparently, the additional strength required by stems for standing may partially explain these results.

TABLE 4

Mean TNC, CP, ADF, NDF, CF, EE, hemicellulose and lignin in the upper stalk portion (USP) of sorghum.*

Cultivars	TNC	CP	ADF	NDF	CF	EE	Hemi cellulose	Lignin
	g kg^{-1}							
ATx630	63.9	55.5	262.0	464.0	163.0	5.4	262.0	99.0
BTx630	77.1	65.3	258.0	419.0	183.0	2.0	161.5	74.5
ATx631	79.5	49.5	208.0	346.0	162.0	3.6	138.3	46.0
BTx631	60.0	63.3	235.0	426.0	185.0	3.0	191.0	50.0
A_2Tx632	54.0	73.0	262.0	442.0	161.0	2.1	179.2	101.0
B_2Tx632	64.4	71.5	235.0	413.0	155.0	5.8	177.5	80.5
ATx629	74.5	51.3	242.0	424.0	164.0	4.4	182.0	78.3
BTx629	62.9	40.5	244.0	392.0	160.0	2.2	148.0	84.0
ATx623	81.0	27.8	227.0	398.0	154.0	2.4	171.0	73.0
BTx623	45.1	52.5	212.0	372.0	151.0	2.8	160.3	60.7
RTx430	62.0	78.8	211.0	408.0	160.0	3.4	197.3	51.0
RTx432	44.4	53.8	210.0	435.0	153.0	5.4	225.3	56.7
RTx434	55.6	65.3	193.0	383.0	144.0	2.4	188.0	49.3
CS3541	82.3	46.8	218.0	401.0	155.0	3.5	182.5	63.5
Dorado	78.0	61.5	224.0	425.0	157.0	3.7	201.8	67.0
Sureno	49.3	61.5	205.0	372.0	165.0	3.2	166.5	40.5
Greenleaf Sudangrass	59.3	35.8	237.0	402.0	172.0	3.7	165.0	65.0
Lahoma Sudangrass	59.3	26.3	251.0	431.0	165.0	5.2	180.5	86.8
RAR2002	69.4	34.5	223.0	360.0	174.0	2.6	137.3	49.5
Rio	58.3	45.5	226.0	426.0	164.0	2.8	200.3	62.0
Hegari	79.0	25.8	253.0	424.0	170.0	3.4	171.3	82.8
Grassl (MN1500)	55.6	11.8	170.0	290.0	146.0	2.1	120.0	24.0
Hoti	72.3	17.8	191.0	322.0	154.0	1.2	131.5	36.8
LSD (0.05)	16.5	17.8	30.6	57.5	37.6	1.7	37.6	29.2

*Average of 1990 and 1991 data
TNC = Total Nonstructural Carbohydrates
CP = Crude Protein
ADF = Acid Detergent Fibre
NDF = Neutral Detergent Fibre
CF (Crude Fibre) = Cellulose
EE = Ether Extract
NDF - ADF = Hemicellulose
ADF - CF = Lignin

TABLE 5

Mean TNC, CP, ADF, NDF, CF, EE, hemicellulose and lignin in the middle stalk portion (MSP) of sorghum.*

Cultivars	TNC	CP	ADF	NDF	CF	EE	Hemi cellulose	Lignin
	g kg^{-1}							
ATx630	50.3	54.7	258.2	453.0	164.8	5.3	194.7	92.5
BTx630	80.1	67.5	253.8	424.5	153.8	2.7	170.7	100.0
ATx631	77.9	48.5	216.5	372.5	153.3	3.7	156.0	63.8
BTx631	65.6	63.2	232.0	427.5	165.3	3.5	195.5	66.8
A_2Tx632	57.9	69.8	254.0	423.2	170.8	2.4	159.3	83.2
B_2Tx632	62.2	73.2	244.3	423.8	163.0	6.6	179.5	81.2
ATx629	73.0	53.0	243.7	433.0	164.3	4.3	189.2	79.5
BTx629	71.8	37.8	245.7	404.0	173.5	3.1	158.2	72.3
ATx623	78.2	35.7	213.5	373.2	154.8	2.5	159.8	58.7
BTx623	50.8	48.5	204.2	373.5	154.8	3.5	169.2	49.8
RTx430	50.5	73.0	219.0	406.2	155.8	3.5	187.3	63.3
RTx432	48.6	56.2	204.0	403.5	155.0	3.4	199.5	49.0
RTx434	65.6	64.5	185.0	364.2	163.0	2.3	179.3	22.0
CS3541	76.9	40.0	225.5	404.8	163.5	2.1	179.3	62.0
Dorado	71.0	64.5	226.0	424.8	152.5	3.5	198.8	73.5
Sureno	54.6	60.8	213.0	377.8	162.5	2.6	164.5	50.8
Greenleaf Sudangrass	53.1	36.5	235.2	420.2	172.5	4.2	185.5	63.2
Lahoma Sudangrass	66.6	28.2	264.5	422.5	154.8	4.4	158.0	109.8
RAR2002	71.6	40.2	220.5	386.0	167.3	2.3	165.5	53.2
Rio	55.4	34.8	235.0	429.0	162.8	3.7	194.0	72.2
Hegari	75.7	25.0	253.8	417.0	175.5	3.2	163.2	78.3
Grassl (MN1500)	55.4	30.8	174.0	324.8	143.8	1.6	150.8	30.2
Hoti	48.4	21.2	242.8	395.2	184.3	2.8	152.5	58.5
LSD (0.05)	15.4	15.7	31.2	41.7	17.3	1.6	25.2	31.2

*Average of 1990 and 1991 data
TNC = Total Nonstructural Carbohydrates
CP = Crude Protein
ADF = Acid Detergent Fibre
NDF = Neutral Detergent Fibre
CF (Crude Fibre) = Cellulose
EE = Ether Extract
NDF - ADF = Hemicellulose
ADF - CF = Lignin

Hemicellulose

Hemicellulose, estimated as NDF-ADF, was significantly higher in the leaf portion than any of the other hemicellulose content of 397 g kg^{-1}, had more of this constituent partitioned to the leaf than any of the other lines in this grouping. Similarly, more hemicellulose was partitioned to the leaves of RTx432 and Hoti among male and forages lines, respectively (Table 1). The partitioning of hemicellulose to the USP had ATx630 with 262 g kg^{-1} as the highest among the females. The leading lines in this category for the male and forage lines were RTx432 and Rio, respectively (Table 4). Hemicellulose partitioned to the MSP was in the range of 156.0 to 194.7 g kg^{-1} in the females, 164.5 to 199.5 g kg^{-1} in the males and 150.8 to 194-0 g kg^{-1} in the male forages (Table 5). BTx631, with BSP hemicellulose concentration of 210.3 g kg^{-1}, was significantly higher than any of the other lines in the female lines. Among the males and forage lines, the largest BSP hemicellulose partitioning were found in RTx432 and Rio, respectively (Table 6).

TABLE 6

***Mean TNC, CP, ADF, NDF, CF, EE, hemicellulose and lignin in the basal portion (BSP) of sorghum*.**

Cultivars	TNC	CP	ADF	NDF	CF	EE	Hemi cellulose	Lignin
	g kg^{-1}							
Atx630	48.3	54.3	267.5	454.0	173.8	5.45	186.5	93.7
BTx630	73.2	73.3	255.5	412.8	165.0	2.23	157.0	90.5
ATx631	76.5	48.8	215.5	375.8	152.3	3.33	160.3	63.2
BTx631	56.1	63.2	233.5	443.8	162.8	2.53	210.3	70.7
A_2Tx632	56.0	75.5	255.5	429.3	161.5	1.80	173.8	94.2
B_2Tx632	63.6	72.5	243.0	413.3	145.3	5.85	170.3	97.7
ATx629	73.3	53.0	240.0	434.3	162.5	3.70	194.3	77.5
BTx629	64.8	36.8	243.5	395.0	154.5	3.00	151.5	89.0
ATx623	71.4	43.3	208.5	382.8	151.5	3.88	174.3	57.0
BTx623	46.1	53.8	202.3	330.5	148.5	2.68	128.2	53.8
RTx430	52.5	77.2	219.0	403.8	156.5	3.40	184.8	62.5
RTx432	44.7	55.3	205.0	432.0	149.8	2.85	227.0	55.2
RTx434	57.9	66.0	184.5	366.5	141.3	3.28	182.0	43.2
CS3541	77.9	38.0	224.8	396.0	151.8	3.45	171.2	73.0
Dorado	72.7	64.5	224.3	425.5	155.8	4.83	201.2	68.5
Sureno	62.1	63.5	211.5	375.5	156.8	2.70	164.0	54.7
Greenleaf Sudangrass	60.4	37.8	244.3	414.3	145.8	3.70	170.0	98.5
Lahoma Sudangrass	58.9	25.8	262.3	415.0	155.5	5.20	152.7	106.5
RAR2002	57.4	34.5	231.3	386.5	163.8	2.80	155.2	67.5
Rio	56.1	35.5	235.3	437.8	157.8	3.70	202.5	77.5
Hegari	76.3	27.0	251.5	418.5	163.8	3.20	167.0	87.7
Grassl (MN1500)	60.2	24.8	186.3	323.3	146.3	3.53	137.0	40.0
Hoti	60.2	28.5	150.3	289.5	133.5	2.63	139.2	16.8
LSD (0.05)	14.1	16.3	38.1	56.4	17.1	1.56	35.0	33.2

*Average of 1990 and 1991 data
TNC = Total Nonstructural Carbohydrates
CP = Crude Protein
ADF = Acid Detergent Fibre
NDF = Neutral Detergent Fibre
CF (Crude Fibre) = Cellulose
EE = Ether Extract
NDF - ADF = Hemicellulose
ADF - CF = Lignin

Forage structural carbohydrates are not completely digestible and the main factor limiting extent of digestion is lignin. Assuming, however, that cellulose and hemicellulose are fermentable or digestible (McBee et al., 1987), quite a good number of the sorghum lines used in this study appear to have a potential for conversion to methane or ethanol. The relatively high hemicellulose concentration, especially in the leaf portion, should be an added advantage to methanogenesis. However, this may be disadvantageous to utilization of carbohydrates and their calorific value as had been shown in millet by Southgate (1973).

Lignin

Significantly lower amounts of lignin were partitioned to the leaves than any of the other plant parts (Table 2). The BSP had the largest lignin concentration though not significantly different from the USP or MSP. Leaf lignin concentrations were generally low, ranging from 27.2 to 55.7 g kg^{-1} in the female lines, 23.3 to 41.5 g kg^{-1} in the male lines and 20.5 to 59.0 g kg^{-1} in the forages lines (Table 1). More lignin was partitioned to the USP than the leaf, with A_2Tx632 accumulating 101.0 g kg^{-1}, Dorado 47.1 g kg^{-1} and Lahoma sudangrass 86.3 g kg^{-1} in the females, males and forages, respectively (Table 4). In the MSP, lignin partitioning ranged from 49.8 to 100.0 g kg^{-1} in the females, 22.0 to 73.5 g kg^{-1} in the male lines and 30.2 to 109.8 g kg^{-1} in the forages.

Higher lignin concentrations are generally known to be detrimental to the rate of cell wall digestion. Consequently, the relatively higher lignin concentrations in the BSP, USP and MSP suggested that they do not hold as much promise as the leaf as animal feed. The concentration of lignin has been shown to influence in vitro digestibility in smooth bromegrass (Caster et al.,1987) and sorghum biomass (Cherney et al., 1986). However, lignin like cellulose, gives added strength to the culm and may reduce the incidence of stalk breakage.

Ether Extract

Like hemicellulose, significantly higher concentrations of ether extract were partitioned to the leaf than the other plant portions (Table 2). Generally, ether extract concentrations were relatively low in all the plant portions, ranging from 2.20 to 6.80 g kg^{-1} in the leaf (Table 1), 1.25 to 5.78 g kg^{-1} in the USP (Table 4), 1.63 to 6.60 g kg^{-1} in the MSP (Table 5) and 1.80 to 5.85 g kg^{-1} in the BSP (Table 6).

Ether extract, which is a measure of the lipid concentration, is readily hydrolysed in the rumen of ruminant animals to free fatty acids which has bactericidal action. Therefore, while ether extract is a good source of energy for ruminants, the bactericidal action of free fatty acids may be detrimental to fibre digestion if ether extract concentration is ≥ 5% (John Chesworth, personal communication). Ether extract concentrations were less than 5% in all the sorghum cultivars included in this study and are, therefore, within safe limits.

Conclusion

While the potential for methanogenesis was apparent in several of the sorghum lines, in view of the relatively high carbohydrate contents, the competing demand as animal feed should be considered. Uniformity in the distribution of TNC and the higher concentration of hemicellulose in the leaf than the stover portions suggested that the management system proposed by Powell et al. (1991) in which the upper stover portions are returned to the soil while removing the remaining portion for alternative uses, is not appropriate for sorghum growing in a saline soil.

However, if the ability of sorghum to accumulate carbohydrates and lignin is heritable under salinity stress, then progress could be made toward the development of strains for biomass production as well as for animal feed through a selective and judicious breeding program.

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