Yield and nutritive value of tropical grasses grown without fertiliser treatment in semi-arid tropics

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Abstract

Five grasses (*Sorghum bicolor* cv. PNR 841, *Pennisetum purpureum* cvv. Napier SDPP 19 and Bana, *Chloris gayana* cvv. Giant Rhodes and *Cynodon nlemfluensis* cvv. Star-grass No. 2) were grown in experimental plots (6 m x 6 m) on four soil types in Gokwe South District, Zimbabwe. The soil types were sandy, sandy loam, sandy clay loam and clay. The first three soil types are regosols formed on Kalahari sands and the clay soil is black vertisol derived from basalt. The forages were grown without fertiliser treatment from 1995 to 1998. Forage yield was significantly affected ($P < 0.001$) by the type of soil. In terms of digestible organic matter yield, the grasses were ranked in descending order as Bana, Napier, *Sorghum bicolor*, *Chloris gayana* and *Cynodon nlemfluensis* on the sandy, sandy loam and sandy clay loam soils. On the clay soil, the descending order of the grasses in terms of dry matter yield was *Sorghum bicolor*, Bana, Napier, *Chloris gayana* and *Cynodon nlemfluensis*. These results indicate that in this District, Napier and Bana grass were the most suitable for most soils other than clays with average yields of 5.9 and 6.4 t/ha respectively. *Sorghum bicolor* was the best on clay soils with a yield of 8.9 t/ha. The results show that grasses often grown in the high rainfall areas can still be grown in this District.

Key words: grass, nutritive value, tropics, yield

Introduction

A number of constraints to improved milk production on smallholder farms in Zimbabwe have been identified. Among the constraints, low food base and poor feeding systems are the major limiting factors (Sibanda, 1986). The feeding of cattle in the smallholder sector in Zimbabwe is based mostly on natural pastures and crop residues, which are generally low in nutritive value and are unable to support the higher nutrient requirements of the productive dairy cows in the smallholder sector.

Fodder production has to be improved in the smallholder sector in order to provide low cost nutrition for dairy cows by producing more and better quality forages on-farm. Because pastures can provide an affordable source of nutrients, dairy farmers must maximise the proportion of pasture forage in the total diet of cows (Murtagh and Moore, 1987). The farmer must also satisfy the nutrient requirements of the cows at all times without producing unwanted surplus of forage.

Smallholder farmers in Zimbabwe have introduced fodder crops into their farming systems to address the feed shortage, particularly in the dry season. These efforts are being hampered by, amongst other things, a dearth of farm-generated information required for use in fodder production planning. The performance of most of the fodder crops in smallholder farming areas is largely unknown because most studies have been done at research stations in the high rainfall areas of Zimbabwe. The objective of this study was to determine the most productive grass species for the soils in the District among *Sorghum bicolor*, *Cynodon nlemfluensis*, *Chloris gayana* and *Pennisetum purpureum* and to determine seasonal differences between growing seasons.

Materials and methods

Soils and Climate

The Gokwe South District is located in the Midlands province of Zimbabwe and is characterized by two agro-ecological zones. The southern area lies mainly in Natural Region III while the northern area lies in Natural Region IV. Rainfall ranges between 650 and 800 mm in the southern part, declining to between 450 and 650 mm in the north. Temperatures in the district range from a minimum of around 16°C to a maximum

Table 1 Chemical characteristics of four soil types in Gokwe South District, Zimbabwe

	Soil texture							
	Clays		Sandy clay loams		Loamy sands		Sandy soil	
Characteristic	Mean	sd[1]	Mean	sd	Mean	sd	Mean	sd
pH	6.0	0.44	5.8	0.46	6.0	0.67	5.3	0.47
Cation exchange capacity (cmol/kg)	35.9	5.25	19.3	3.17	13.1	2.27	3.3	0.89
Nitrogen (mg/kg)	7.0	1.83	12.7	2.80	4.3	1.20	6.0	2.10
Phosphorus (mg/kg)	0.2	0.01	1.3	0.20	0.9	0.08	0.9	0.09
Exchangeable Potassium (cmol/kg)	0.5	0.10	0.5	0.06	0.5	0.10	0.2	0.02

[1]Standard deviation of the mean

of 32°C. The district is predominantly a Kalahari sand escarpment, but soils to the northwest are basaltic and shallower. Vegetation types range between Tree Savanna and Tree Bush Savanna. The rainfall and temperature data for the 1995 to 1998 rainy seasons are shown in Table 1.

Participating farmers

In 1995, there were 69 smallholder farmers who were producing milk in the District. Some of the farmers were growing pasture grasses on a small scale. The soils in the District comprise of four major textural classes: sand (Kalahari sands derived from granite), loamy sands, sandy clay loams, and clays (black vertisols). The farms were stratified into four blocks on the basis of the type of soil on each farm. The participating farms were then selected randomly within each soil type. Twelve of the participating farms were on the Kalahari sands, and six farms on each of the other three soil types.

Soil analysis

Five soil samples were randomly taken from the pasture on each of the 30 selected farms. The soil samples were taken using a soil auger to a depth of 15-cm. The five samples from each field were then mixed, and a sub-sample placed into a polythene bag. The samples were air-dried for four days before laboratory analysis. The samples were analysed for pH, cation exchange capacity, total N, and exchangeable P and K. Exchangeable K was analysed by ammonium acetate extraction and flame photometer determination (Page, Miller and Keeney, 1982). Available P was determined by the Bray and Kurtz method (1945). Total N was determined by the Kjeldahl method (Bremner, 1960) and pH was determined by the Schofield and Taylor method (1955). Cation exchange capacity was determined by the ammonium acetate method (Page *et al.*, 1982). Rainfall data for the three years for the growing seasons from 1995 to 1998 were recorded at a central point and are given in Table 2.

Forages

Five pasture grasses which were already being grown by farmers on a small scale were evaluated. These were: *Sorghum bicolor* cvv. PNR 841, *Cynodon nlemfluensis*, cvv. Star-grass No. 2, *Chloris gayana*

Table 2 Rainfall and temperature data for the rainy seasons of 1995 - 1998 for Gokwe South District, Zimbabwe

	Rainfall (mm)				Temperature (°C)					
					1995 - 1996		1996 – 1997		1997 – 1998	
Month	1995-1996	1996- 1997	1997- 1998	1972-1994 avg.	Min	Max	Min	Max	Min	Max
October	24	9	26	29	21	32	19	32	17	30
November	152	168	131	82	19	30	19	30	19	30
December	154	92	181	164	18	27	18	28	19	30
January	333	354	328	175	18	26	18	26	19	27
February	252	208	150	159	18	27	17	26	19	29
March	34	150	67	86	17	27	18	27	18	29
April	1	87	2	31	14	26	15	26	16	28
Mean	-	-	-	-	18	28	18	28	18	29
Total	950	1 067	884	-	-	-	-	-	-	-

cvv. Giant Rhodes and two cvv. of *Pennisetum purpureum* (Napier SDPP 19 and Bana grass).

Experimental design and management of experimental plots

The experiment was carried out over three years from December 1995 to March 1998. The 30 selected farms were grouped into four blocks according to the soil types. Each of the selected forages was grown on each farm in experimental plots measuring 6 m x 6 m. Shortages of available land meant that duplicate plots were established on five farms on the sandy soils, three farms on the sandy clay loams, four farms on loamy sands and two farms on the vertisols. On the remaining farms, sites were selected and plots arranged in an attempt to minimise variation due to factors such as fertility gradients.

The land allocated for the plots on each farm was first ploughed by an ox-drawn mouldboard plough and then harrowed to a fine tilth. The experimental plots were made in duplicate. The plots were 1 m apart and a path of 2 m was left from the borders of each field. The five species were randomly allocated to the plots.

Chloris gayana, *Sorghum bicolor* and *Cynodon nlemfluensis* were planted between 3 and 10 December 1995. The *Pennisetums* were planted between 20 and 23 December 1995 when there was adequate soil moisture for successful establishment from root stalks. Following the most common practice in the district, all the forages were planted without fertiliser.

Chloris gayana and *Sorghum bicolor* were sown at a rate of 4 and 7 kg/ha, with inter-row spacing of 0.75 and 1 m, respectively (Skerman and Riveros, 1990). The seeds were placed by hand in furrows 1 cm deep and lightly covered with soil. For vegetatively propagated grasses, the rows in each plot were 1 m apart. The *Pennisetum* root stalks were planted at 0.75 m apart along these rows (Anindo and Porter, 1986), and stem cuttings of *Cynodon nlemfluensis* were planted 1 m apart. The seedling establishment of *Chloris gayana* and *Sorghum bicolor* in the first season (1995/96) were assessed by quadrat counts.

The management of experimental plots, which included seedbed preparation, planting, weeding and harvesting was done jointly with the farmers and the local extension staff. Hand weeding was done when necessary. During the remainder of the year the plots were left open to grazing until the onset of the rains.

Harvesting
All the flowering forages were harvested *post-anthesis* at the mid-full bloom stage (physiological maturity) to maximise dry matter yield. The *Pennisetums* were harvested when they reached a height of 1.5 m (Anindo and Porter, 1986) by chopping with machetes. Two central rows in each plot of *Sorghum bicolor* and the *Pennisetums* were harvested to leave stubble of 15 cm (Williams, Burt and Strickland, 1985). All the other forages were harvested from quadrats measuring 1 m x 1 m, and two central quadrats (1 m x 1 m) from each plot were cut. *Chloris gayana* and *Cynodon nlemfluensis* were harvested to a stubble height of about 10 cm (Williams *et al.*, 1985). Any re-growths from the harvested portions were cut at six-week intervals. After the harvest from the rows and quadrats, the remainder of the herbage in the plot was harvested. All the plots on three farms (one farm each on sandy, sandy clay loam, and clay soil) were destroyed by animals. There were 27 samples for each grass species.

The harvested forage from the rows and quadrats was immediately weighed and chopped using machetes into pieces of about 5 cm in length and 1kg fresh samples were taken from each plot. Duplicate samples were mixed and a one-kilogram sample was taken and air-dried indoors for five days before laboratory analysis.

Sample preparation for analysis
The air-dried samples were weighed. Half of each sample was dried in a forced draught oven at 105°C for 24 hours for dry matter yield determination. The second halves to be used for chemical analysis were dried at 60°C in a forced-draught oven for 48 hours. The samples dried at 60°C were each ground in a Wiley mill sieved through a 2 mm screen, and stored in plastic sample bottles.

Chemical analysis
The ash content of the samples was determined by igniting a sub-sample in a muffle furnace at 550°C for 8 hours. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to the Goering and van Soest method (1970). The acid detergent insoluble nitrogen (ADIN) content was determined on the ADF samples. Crude protein and ADIN were analysed by the Kjeldahl method (Association of Official Analytical Chemists, 1990). Calcium and phosphorus were determined from the ash solutions by an Unicam 701 ICP spectrophotometer (Unicam, 1992).

In-vitro studies
It was assumed that the digestible organic matter (DOM) content did not vary between farms for a given soil type. Therefore, the forage samples were bulked by mixing 5 g samples for each species in each year according to soil type to give a total of 12 samples (4 soil types x 3 years) for each forage species for the first cut and re-growth where applicable. The digestible organic matter was measured *in-vitro* by the Tilley and Terry method (1963). The DOM data calculated from the pooled DOM samples were used with the yield data from individual plots to calculate the DOM yield.

Statistical analysis
The data were analysed by multiple linear regression using the General Linear Models procedure of the Statistical Analysis Systems (SAS) package (1990). The following factors were fitted: year, soil, farm within soil, grass and the interactions soil type x species and year x species. The other interactions were shown to be insignificant in the preliminary analysis of the data and were omitted in the final analysis. The effects of farm within soil were included as blocking. Farm effects within soil type were used as the error term for testing the effects of the soil type. Results are presented as least squares means.

Results

Establishment and persistence
The *Pennisetums* and *Cynodon nlemfluensis,* which were vegetatively propagated established successfully in the first season and persisted throughout the experiment on all the four soil types. Seedling establishment was estimated at 90 and 70 per cent for *Sorghum bicolor* and *Chloris gayana*, respectively, on the sandy soils, sandy clay loams and loamy sands. Lower establishment rates for the two grasses were observed on the black clays and were 70 and 60 percent for *Sorghum bicolor* and *Chloris gayana*, respectively. *Chloris gayana* had about 95 per cent plot cover by the end of the first season due to the establishment of rooted tillers. Plot covers for the stoloniferous *Cynodon nlemfluensis* and *Chloris gayana* were almost 100 per cent in the second and third seasons. *Sorghum bicolor* plots were re-seeded every season because of poor persistence.

Fodder yield
Sorghum bicolor and the *Pennisetums* reached the required harvesting stage (full bloom) within 90 days in the middle of the rainy season. This allowed for re-growth under moist conditions, allowing second harvests after six weeks of re-growth. Second harvests were not possible with *Chloris gayana* and *Cynodon nlemfluensis* because these attained the required harvesting stage (full bloom) late in the season, after

Table 3 Influence of soil type on the digestible organic matter yield of five grass species grown without manure or fertiliser on four soil types in Gokwe South District, Zimbabwe (tonnes/hectare)

		Grass type					
Soil type	n[4]	***Sorghum bicolor***	*Pennisetum purpureum* (Napier)	*Pennisetum purpureum* (Bana)	*Cynodon nlemfluensis*	***Chloris gayana***	SEM[5]
First cuts							
Sandy soils	30	2.6^{a1}	4.0^{b1}	4.3^{c1}	1.5^{c}	2.9^{e1}	0.1
Loamy sands	18	3.2^{a2}	3.7^{b13}	3.8^{b2}	2.0^{c}	3.5^{ab2}	0.2
Sandy clay loams	15	2.3^{a1}	3.0^{b2}	3.0^{b3}	1.4^{c}	2.9^{b1}	0.2
Black clays	15	6.3^{a3}	3.4^{b32}	3.6^{b2}	1.8^{c}	3.6^{b3}	0.2
Second cuts							
Sandy soils	30	0.6^{a1}	2.8^{b1}	2.9^{b1}	-	-	0.1
Loamy sands	18	0.6^{a1}	3.0^{b1}	3.4^{b2}	-	-	0.2
Sandy clay loams	15	0.6^{a1}	1.3^{b2}	1.9^{c3}	-	-	0.2
Black clays	15	2.6^{a2}	2.1^{b3}	2.5^{a1}	-	-	0.2

[a,b,c,d]Means in the same row with different superscripts are significantly different ($P < 0.05$)
[1,2,3]Means in the same column with different superscripts are significantly different ($P < 0.05$)
[4]Number of samples
[5]Standard error of mean
- Not applicable

about 150 days of growth, allowing little time for re-growth under moist conditions.

Sorghum bicolor and the *Pennisetums* were harvested on two occasions in each season because the growth of the aftermath, six weeks after the first harvest, was substantial, and *Chloris gayana* and *Cynodon nlemfluensis* were harvested only once in each season. Therefore, the digestible organic matter yields are given separately for the first, second cuts (where applicable).

First cuts
The mean digestible organic matter yields (DOMY) of the first cuts are given in Table 3. There were significant effects ($P < 0.001$) due to soil, species type and season on DOMY of the first cuts. The adjustment of the data for farm effects within soil types was significant ($P < 0.001$) for the measured parameters of the first cuts. There was a significant season x species interaction effect on DOMY ($P < 0.01$); proportionally more yield was obtained in the second and third season for all the species, except for *Sorghum bicolor*. There was also a significant ($P < 0.001$) grass x soil interaction effect on the measured parameters; proportionally *Sorghum bicolor* produced significantly ($P < 0.05$) more green fodder, dry matter and digestible organic matter on the clays than on the other soil types. Because of the significant grass x soil type interaction, the forages were compared within each soil type. The highest DOMY for all the species were obtained for *Sorghum bicolor* on the clays (Table 3). *Cynodon nlemfluensis* produced the lowest yields on all soil types and there were no differences in its DOMY across all soil types.

Second cuts
The DOMY of the second cuts of the *Pennisetums* and *Sorghum bicolor* are shown in Table 3. There were significant effects ($P < 0.001$) due to species, soil type and season of growth. The interactions grass x season of growth, grass x soil type were also

Table 4 Variation in forage quality (g/kg dry matter) of first cuttings of five grass species grown without fertiliser or manure in Gokwe South District, Zimbabwe

	Grass type					
	Sorghum bicolor (n^1=81)	*Pennisetum purpureum* (Napier) (n=78)	Pennisetum purpureum (***Bana***) (n=78)	*Cynodon nlemfluensis* (n=78)	*Chloris gayana* (n=78)	**SEM**[2]
Organic matter	912.4^a	869.7^b	871.8^b	922.7^c	905.3^d	1.50
Crude protein	59.6^a	69.5^b	79.0^c	82.4^c	82.1^c	0.30
Neutral detergent fibre	637.0^a	654.3^b	648.4^b	678.8^c	686.2^c	2.80
Acid detergent fibre	367.7^a	368.0^a	380.7^{bc}	376.9^b	386.5^c	2.70
Acid detergent insoluble nitrogen	2.4^a	2.4^a	2.8^b	2.4^a	2.6^c	0.03
Calcium	6.1^a	3.8^b	3.7$_b$	4.9^c	5.1^d	0.10
Phosphorus	1.4^a	1.5^b	1.7^c	1.5^c	1.4^a	0.02

[a,b,c,d]Means in the same row with different superscripts are significantly different ($P < 0.05$)
[1]Number of samples
[2]Standard error of mean

significant ($P < 0.001$), following the trend observed for the first cuts. Farm effects were significant ($P < 0.01$). The *Pennisetums* produced significantly ($P < 0.05$) greater DOMY than *Sorghum bicolor* on all soil types, except on clays.

Pasture quality and mineral content
Results for the first cuts are shown in Table 4. There were significant differences ($P < 0.001$) among the grass species in the concentrations of all the chemical Constituents, but no significant effects ($P > 0.05$) due to soil type and season of growth. There were also no significant effects ($P > 0.05$) due to both interactions so only the means of the forages are given.

Chloris gayana and *Cynodon nlemfluensis* had significantly higher ($P < 0.05$) crude protein concentrations (82.4 and 82.1 g/kg DM, respectively) than the other species. *Sorghum bicolor* had the lowest ($P < 0.05$) crude protein concentration of 59.6 g/kg DM. Despite being significant ($P < 0.05$), the differences among the grass species in NDF and ADF concentrations were about 50 and 20 g/kg DM, respectively, between the highest (*Chloris gayana*) and the lowest (*Sorghum bicolor*). The *Pennisetums* had significantly higher ($P < 0.05$) ash concentrations than the other species. Calcium concentration was significantly higher ($P < 0.05$) in *Sorghum bicolor* than in the other species. The relative similarity in nutrient composition between the *Pennisetums* was notable.

The data on the forage quality and mineral content of the second cuts of *Sorghum bicolor* and the *Pennisetums* are shown in Table 5. There were no significant differences ($P > 0.05$) in quality and mineral content between the *Pennisteums*, however, *Sorghum bicolor* had significantly lower concentrations ($P < 0.05$) of CP, NDF and ADF than the *Pennisetums*. Although significant ($P < 0.05$), the differences among the grasses in ADIN, calcium and phosphorus concentrations were small in real terms and unimportant.

Table 5 Variation in forage quality (g/kg dry matter) of second cuttings of three grass species grown without fertiliser or manure in Gokwe South District, Zimbabwe

	Grass type			
	Sorghum bicolor (n[1]=81)	*Pennisetum purpureum* (Napier) (n=78)	*Pennisetum purpureum* (Bana) (n=78)	SEM[2]
Organic matter	924.2[a]	875.8[b]	859.9[b]	6.10
Crude protein	63.0[a]	74.6[b]	74.9[b]	0.30
Neutral detergent fibre	585.1[a]	645.3[b]	629.1[c]	2.30
Acid detergent fibre	290.4[a]	342.0[b]	335.3[c]	2.10
Acid detergent insoluble nitrogen	1.7[a]	1.5[b]	1.4[c]	0.02
Calcium	4.3	4.2	4.3	0.10
Phosphorus	1.4[a]	1.3[b]	1.3[b]	0.02

[1]Least squares means
[a,b,c]Means in the same row with different superscripts are significantly different ($P < 0.05$)
[1]Number of samples
[2]Standard error of mean

Discussion

Establishment and persistence

The successful establishment of the grasses, which were vegetatively propagated (*Pennisetums* and *Cynodon nlemfluensis*), was due to the adequate soil moisture during planting time. The 20 mm of rainfall received between 20 and 23, December 1995 provided adequate soil moisture for the establishment of the *Pennisetums* from root stalks.

Establishment rates were higher for *Sorghum bicolor* than *Chloris gayana.* This could be due to the differences in seed viability and physical attributes of the seeds. Such differences arise because the establishment of small seeded pasture species depends on the safe transition through the following five phases: softening, imbibition, germination, seedling emergence and early seedling growth (Mckeon and Mott, 1984). These processes differ among species.

Fodder yield

The grasses evaluated in this trial were grown with the aim of optimising yield since quantity, rather than quality of fodder, is the major limiting factor in the semi-arid tropics. In addition, forage harvesting is a labour intensive activity as smallholder farmers do it by hand. Thus, single harvests after the full reproductive cycle maximise yield (Woodard and Prine, 1991), and probably, reduce the labour load on farm households.

The grass biomass yield varied significantly according to soil type, indicating the need to evaluate the grasses within each soil type. The significant soil x species interaction could be explained in terms of the exceptionally high yield of *Sorghum bicolor* on the vertisol clays. The DOMY of *Sorghum bicolor* was much greater than that of the other grasses on these soils, probably reflecting an adaptation of this species to clay soils. The significant grass x year interaction could be attributed to the increase in yield in the second and third year for all the grasses, except *Sorghum bicolor*. The increase in yield in successive years of the *Pennisetums* may be partially ascribed to an increase in plant density (Köster, Meissner, Coertze and Rethman, 1992). The *Pennisetums* were planted from root stalks and as time progressed, tufts increased in size. Similarly, the observed yield increases for *Cynodon nlemfluensis* and *Chloris gayana*, could be explained by increases in plant density with time. Seasonal effects associated with the weather are unlikely to have greatly influenced the biomass, as differences in the amount of rainfall and ambient temperatures between the seasons were small (Table 2).

The results of this study show the high performance of the *Pennisetums* compared to the other grasses grown on all soils except the vertisol clays, where *Pennisetums* were out-performed by *Sorghum bicolor*. Several workers have indicated the high-yielding capability of *Pennisetums* (Abou-Ashour, Saleh-Youssef and El-Kaschab, 1984; Woodard and Prine, 1991). It is worth noting that differences in the yield of *Pennisetums* can arise due to several factors such as frequency of harvest and genotype (Woodard and Prine, 1991), planting density (Sollenberger, Jones, Albrecht and Ruitenberg, 1990), irrigation practices (Köster *et al.*, 1992) and the amount of applied fertiliser application (Humpherys, 1991).

Sorghum bicolor yielded well on the clay soils compared to the other grasses. However, yields recorded in this study are lower than those reported by Topps and Oliver (1993) in Zimbabwe. Such differences could derive from varying climatic and edaphic factors across the country.

Chloris gayana appears to be adapted to a wide range of soils, from the light to the heavy textured soils. This agrees with the report by Skerman and Riveros (1990). However, in this study, this species attained the required harvesting stage (full bloom) late in the season and this did not allow time for re-growth because most of the growth of *Chloris gayana* occurs fairly late in the growing season and it also seeds late (Topps and Oliver, 1993).

Cynodon nlemfluensis invariably produced the least biomass on all the soil types, and only a single cut post-anthesis was possible. The yields of *Cynodon nlemfluensis* obtained in this study are low. It is important to note that most of the values reported in literature are from experiments with fertiliser treatment. For example, Rodel and Boultwood (1971) at Henderson Research Station in Zimbabwe obtained a DMY of about 16 t/ha. However, the results of this study show the low performance of *Cynodon nlemfluensis* grown without fertiliser.

Forage quality

The nutritive value of forages is mainly determined by cell wall content and extent of lignification (van Soest, 1982). The observed differences in the cell wall content (NDF and ADF) among the species can be attributed to differences in leaf:stem ratios because leaves contain less cell wall than stems at comparable physiological stages (Norton, 1982). However, though different, it is worth noting that the differences in NDF and ADF fractions of the species are on the low side.

What is of interest is that, despite having lower values of cell wall content, *Sorghum bicolor* had the lowest CP fraction. Topps and Oliver (1993) reported a CP content range for *Sorghum bicolor* of 125 to 155 g/kg DM, which is much higher than the value obtained in this study. Pizarrol, Vera and Liseu (1984) reported a CP content of about 140 g/kg DM for *Sorghum bicolor* at about 40 to 50 days of growth, which declined to about 70 g/kg DM at 90 days of growth. Their findings are similar to the results of this study. It is also important to note that the CP content varies between leaves, stems and the panicle of the plant (Pizarrol *et al.*, 1984). Differences in the proportion of plant parts with growth and development will therefore affect the quality of the forage.

A prominent difference between the first and second cuts of the grasses is in the ADIN content. The N in the lignin present in all forages is unavailable to the animal (van Soest, 1982). It can be argued that the lower ADIN levels in the second cuts can be partially ascribed to lower lignin levels. It might be that the declining precipitation after the month of January in each of the three years did not give the chance for considerable lignification. The effects of ambient temperatures on forage quality are likely to have been minimal as this varied little between the years. High temperatures have been known to promote increased lignification (van Soest, 1982). High temperatures promote rapid metabolism and photosynthates are more rapidly converted to structural forms.

Conclusion

The results of this study show that for unfertilised conditions, the *Pennisetums* and *Chloris gayana* appear to be the 'best bet' grasses for production on the medium to light textured soils in Gokwe South District. The production of *Sorghum bicolor* on the vertisol clays is a worthwhile practice, given the high production capacity of this species on this soil type. Its disadvantage is that it has to be re-sown each year and has the lowest protein content. There is also very little difference in terms of performance and quality between the *Pennisetums*. It is also clear that *Chloris gayana* is well adapted to all the soil types found in this district. *Cynodon nlemfluensis* was notably the poorest performer.

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References

Abou-ashour, A.M., Saleh-Youssef, M. S. and El-Kaschab, S.H. 1984. Evaluation of the nutritive value of Napier grass. World Review of Animal Production XX (1):1317.

Anindo, D.O. and Porter, L.H. 1986. Milk production from Napier grass (*Pennisetum purpureum*) in a zero grazing feeding system. East African Agriculture and Forestry Journal 52:106-111.

Association of Official Analytical Chemists. 1990. Official Methods of Analysis. 15th Edition. AOAC, Arlington, VA.

Bray, R. H. and Kurtz, L.T. 1945. Determination of total, organic and available forms of phosphorus in soils. Soil Science 59:3945.

Bremner, J.M. 1960. Determination of nitrogen in soil by the Kjeldahl method. Journal of Agricultural Science 55:1133.

Goering, H.K. and Van Soest, P. J. 1970. Forage Fibre Analysis. USDA ARS Agriculture Handbook.

Humphreys, L. R. 1991. (Ed.) Tropical pasture utilisation. Cambridge University Press, Cambridge.

Köster, H.H., Meissner, H.H., Coertze, R.J. and Rethman, N.F.G. 1992. Variation in the production and quality of Bana grass over a growing season using hand-clipped samples. South African Journal of Animal Science 22(1):31-34.

Mckeon, G..M. and Mott, J.J. 1984. Seed biology of *Stylosanthes species*. In H.M. Stale and L.A. Edye (Eds.) The Biology and Agronomy of *Stylosanthes* species. Academic Press, Sydney pp. 311332.

Murtagh, G.J. and Moore, K.G. 1987. A pasture budget for dairy farms in the Kyogle District. Tropical Grasslands 21(4):145-153.

Norton, B.W. 1982. Differences between species in forage quality. In J.B. Hacker (Ed.) Nutritional Limits to Animal Production from Pastures. C.A.B. Farnham Royal, UK.

Page A. L., Miller, R. H. and Keeney, D. R. 1982. Methods of soil analysis. Part 2: Chemical and Microbiological Properties. In A.L. Page, R.H. Miller and D.R. Keeney (Eds.) Soil Science Society of America, Inc, Madison, Wisconsin, USA.

Pizarrol, E.A., Vera, R.R. and Liseu, L.C. 1984. Growth curve and nutritive value of *Sorghum bicolor* in the tropics. Tropical Animal Production 9:175184.

Rodel, M.G.W. and Boultwood, J.N. 1971. Herbage yields of 30 grasses fertilised heavily with nitrogen. Proceedings of Grasslands Society of South Africa 6:129134.

Schofield, R.K. and Taylor, A.W. 1955. The measurement of soil pH. Soil Science Society of America Proceedings 19:164167.

Sibanda, S. 1986. The use of crop residues in livestock production systems in the communal areas of Zimbabwe. In: T.R. Preston and M.Y. Nuwanyakpa (Eds.), Proceedings of the ARNAB workshop, Alexandra, Egypt, ILCA, Addis Ababa.

Skerman, P. J. and Riveros, F. 1990. (Eds.) Tropical grasses. FAO. Rome.

Sollenberger, L.E., Jones, C.S. Jr., Albrecht, K.A. and Ruitenberg, G.H. 1990. Vegetative establishment of dwarf elephant grass. Effect of defoliation prior to planting stems. Agronomy Journal 82:274278.

Statistical Analysis Systems Institute. 1990. SAS/STAT user's guide, Version 6, Volume

1. Statistical Analysis Systems Institute Inc., Cary NC: SAS Institute Inc.

Tilley, S.M. And Terry, R.A. 1963. A two-stage technique for the in vitro digestion of forage crops. Journal of the British Grassland Society 18:104-111.

Topps, J.H. And Oliver, J. 1993. Animal foods of Central Africa. Zimbabwe Agricultural Journal. Technical Bulletin No. 2. Harare. pp. 76-105.

Unicam. 1992. User's guide. Cambridge, England.

Van Soest, P.J. 1982. (Ed.) Nutritional ecology of the ruminant. pp. 139-151. O & B Books Inc., Corvallis, OR.

Williams, R. J., Burt, L. R. and Strickland, R.W. 1985. Plant Introduction. In: N.H. Shaw and W.W. Bryan (Eds.). Tropical Pasture Research: Principles and Methods. pp 77-100. CSIRO. Brisbane, Australia.

Woodard, K.R. and Prine, G.M. 1991. Forage yield and nutritive value of elephant grass as affected by harvest frequency and genotype. Agronomy Journal 83:541546.