Changes in nutrient composition of kikuyu foggage as winter progressed

E. Rautenbach[1,2], J.B.J. van Ryssen[1#] and W.A. van Niekerk[1]
[1] Department of Animal & Wildlife Sciences, University of Pretoria, Pretoria 0002, South Africa
[2]

Abstract

Samples of kikuyu foggage (standing hay) were collected in northern KwaZulu-Natal from five adjoining paddocks to measure the changes in nutrient composition of the foggage as winter progressed. Leaves and stems were separated. The first samples collected on the 18th of May contained green to dry material at a ratio of 3 : 1 and that was reduced to practically no green material in July. Although the proportion of leaf decreased from 64.6% to 56.8% as winter progressed, differences were not significant. Crude protein (CP) levels and effective dry matter degradation decreased significantly with time while neutral and acid detergent fibre levels increased. The calcium (Ca) and phosphorus (P) concentrations in the leaves decreased significantly between the first collection and later collections, while these changes were less pronounced in the stems. At all stages the stems contained significantly lower concentrations of Ca than the leaves, while P concentrations between leaves and stems did not differ. Consequently, the Ca : P ratios in the leaves varied between 2.08 and 1.60 and that of the stems between 0.74 and 1.10. These results suggest that the significantly lower Ca levels in kikuyu stems compared to leaves could make a significant contribution to the variation in Ca : P ratios reported for kikuyu. The concentrations of the other elements measured did not differ between the leaves and stems. Concentrations of CP, potassium, magnesium, copper and selenium in the kikuyu foggage decreased rapidly from the first collection that contained a relatively high proportion of green material to later collections when the foggage was dry.

Keywords: Standing hay, *Pennisetum clandestinum*, leaf : stem ratio, calcium : phosphorus ratio, minerals
[#] Corresponding author. E-mail: jvryssen@up.ac.za
[2] Present address: P.O. Box 44, Ingogo 2944, South Africa

Introduction

Foggaging is defined as the practice of allowing herbage to accumulate on a pasture during the growing season, and it is then utilized by grazing animals during the dormant season (Gertenbach, 1998). The term foggage (also called standing hay) is usually associated with cultivated pastures. Kikuyu (*Pennisetum clandestinum*, Hochst) is a perennial summer growing pasture in the high rainfall regions of South Africa (Dickenson, 1976). It is essentially a grazing grass and for all practical purposes its potential as hay can be ignored due to its thick stems and high moisture content that make drying difficult (Dickenson, 1976). Under dryland conditions it is predominantly a summer pasture but investigations demonstrated that it can be utilized as foggage in winter (Rethman & Gouws, 1973; Rethman & De Witt, 1991; Barnes & Dempsey, 1993; Gertenbach, 1998; De Villiers *et al*., 2002).

The nutrient composition and nutritive value of kikuyu foggage have been reported in a number of investigations (Rethman & Gouws, 1973; Barnes & Dempsey, 1993; De Villiers *et al*., 2002). It is evident from these studies that quite a number of factors could affect the nutritive value of foggage, and are mostly related to the management of the pasture and climatic conditions during the growing season. However, conditions during the dormant season, i.e. the foggage stage, could affect the quality of the foggage, and would include precipitation and severity of climatic conditions during the winter. Factors such as leaching out of nutrients, loss of leaf material, for example, could contribute to changes in the composition of foggage as winter progressed. The objective of the present investigation was to establish to what extent changes in nutrient content occur in kikuyu foggage as the winter progressed.

Materials & Methods

The experiment was conducted at the Eversly Research Station (Dundee, KwaZulu-Natal) (28°12' S, 30°10' E). The mean annual rainfall is 790 mm and precipitation is mainly between October and March.

Winters are cold with regular frost (mean daily minimum of 2.1 °C) while the growing season is warm (mean daily maximum of 24.5 °C). The kikuyu pasture was established *ca.* 10 years before commencement of the study and has been used since then as animal grazing under dryland conditions. For the present study the pasture received 400 kg limestone ammonium nitrate (LAN) and ± 150 mm of rain after animal withdrawal at the end of January. The five paddocks used in the study were approximately five hectares each. The paddocks were strip-grazed by five groups of beef weaners involved in a different aspect of the study, using an electric fence. Herbage collection started on the 18th of May, after the first frost of the winter, and lasted until the 6th of July when the animals entered the last strips of available pasture. The steers were moved four times to fresh strips in paddocks allocated randomly to a group of steers. Before a group of weaners entered a strip in each paddock, four quadrant herbage samples were taken randomly in the strip. The sampling procedure was the hand-plucking of the foliage in a quadrant, with the height of defoliation matching as closely as possible the defoliation intensity carried out by grazing animals.

The four hand-plucked quadrants per strip were pooled and three representative samples were taken per pool. Grab sample 1 was weighed and then dried at 100 °C to determine dry matter (DM) content and was used for the *in situ* DM degradability study. In Grab sample 2 the leaves were separated from the stems at the leaf collar and both fractions were dried at 60 °C and weighed separately to determine leaf to stem ratios. Chemical analyses were performed on these samples. Grab sample 3 was separated into green and dry material and dried to determine the green to dry matter ratio.

Dry leaf and stem samples were ashed by igniting the samples in a muffle furnace at 525 °C for 8 h. Nitrogen (N) content was measured by the Kjeldahl method (AOAC, 1995; method 990.03) and crude protein (CP) was calculated as N x 6.25. The neutral detergent fibre (NDF) concentration in the samples was determined using the alpha-amylase method described by Mertens (2002), and acid detergent fibre (ADF) according to AOAC (1990; method 973.18). After wet digestion with a nitric-perchloric acid mixture, the calcium (Ca), magnesium (Mg), manganese (Mn), copper (Cu) and zinc (Zn) concentrations were measured using atomic absorption spectrophotometry, and the sodium (Na) and potassium (K) concentrations using a flame emission spectrophotometer. A combined standard was used to verify the accuracy of mineral concentrations (Na: 143.50 mmol/L, K: 3.84 mmol/L and Ca 2.50 mmol/L). The photometric method using molybdovanadate was used to measure phosphorus (P) concentration in the samples (AOAC, 1990; method 965.17). The selenium (Se) concentration was determined by hydride generation, using atomic absorption spectrophotometry according to the method described by the AOAC (2000; method 4.8.15). A peach leaf sample from the National Institute of Standards and Technology (NIST, US Department of Commerce, Gaithersburg, MD) was used as Standard Reference Material (SRM 1572) to verify the accuracy of trace mineral analyses.

The *in situ* technique as standardized by the AFRC (1992) was followed to measure the rumen degradability of DM in the samples over a period of 48 h. Rumen cannulated sheep, fed a lucerne hay diet, were used in the *in situ* study. The kikuyu foggage samples were suspended for 4, 8, 24 and 48 h in the sheep rumens, and a pre-incubated (0 h) sample was processed as the incubated samples. After incubation the bags were washed thoroughly in running water and dried at 60 °C. A lucerne hay sample with a known DM ruminal disappearance (internal laboratory standard) was included with each batch of incubations. The DM disappearance percentages (indicative of the herbage degradation kinetics) with time were fitted, using the iterative least squares method in a nonlinear procedure (NLIN), to an exponential equation (Ørskov & McDonald, 1979):

$$p = a+b\,[1 - \exp^{-ct}]$$

where:

- p = the percentage herbage DM degraded after time t (h);
- a = washing losses, soluble or rapidly degradable DM fraction. This value is the intercept of the degradation curve at time 0 h;
- b = the insoluble but potentially fermentable DM fraction which will degrade with time;
- c = the fractional rate constant, indicating the degradation rate (/h) of the b fraction.

Effective degradation (ED) = a + bc/(c + k)

k = outflow rate (0.03).

Foggage samples from each strip in a particular camp and on each sampling date were treated as replications. Procedure GLM (General Linear Modelling) in SAS (2001) with repeated measures was used to determine whether concentrations of individual nutrients or nutrient ratios in foggage varied significantly during the winter months. Significant differences were quoted at the P <0.05 level. An analysis of variance with the GLM model (SAS, 2001) was used to determine the significance between different period and plant part effects. Means and standard deviations (s.d.) were calculated. Significance of differences (5%) between means was determined by the Fischer's Protected Test (Samuels, 1989).

Results & Discussion

The ratio of green to dry material changed significantly as winter progressed, with minimal green material left in July (Table 1). It must be accepted that the proportion of green material will depend on the stage at which utilization of the foggage started, and that the grass was obviously not completely dormant when the study commenced. Barnes & Demsey (1993) started their investigation on kikuyu foggage at Ermelo in Mpumalanga Province when the grass was "frost-killed". However, they pointed out that partially green kikuyu foggage would be present in kikuyu foggage grown in relatively warm winter climates, and suggested that "moderately green" kikuyu foggage should be of a higher quality than frost-killed grass.

Although the percentage of leaf material decreased with time, differences were not significant, probably because of wide variations within periods (Table 1). In their investigation Barnes & Demsey (1993) recorded 72 to 89% leaf material in kikuyu foggage compared to the 56 to 65% in the present study. However, throughout the growing season up until mid-autumn Köster *et al*. (1992) measured 62.5 to 67.1% leaf material in green kikuyu collected prior to grazing. A lower percentage leaves, as observed in the present study, could be the result of a longer growth/rest period for foggage accumulation following fertilization and exclusion of the animals. Gertenbach (1998) pointed out that an earlier closing date would result in more DM but foggage of a lower quality. In the context of the present study, changes in leaf to stem ratios would be of significance if the nutrient composition of leaves differs substantially from that of stems.

Table 1 Ratios of green : dry material and percent leaf material (± s.d.) of kikuyu foggage as winter progressed (dry matter basis)

	n	Days in winter			
		1*	17	37	55*
Green : Dry ratio	5	$3.0^{a} \pm 0.57$	$1.1^{b} \pm 0.69$	$0.2^{c} \pm 0.83$	$0.04^{d} \pm 0.46$
Leaf material (%)	5	64.6 ± 1.83	57.8 ± 8.74	58.4 ± 11.45	56.8 ± 13.8

n = number of samples/period, each consisting of a pooled sample/paddock.
[a,b,c,d,] Means within rows with different superscripts differ significantly at P < 0.05.
* First day - 18 May; Last day – 6 July.

Van Soest (1994) stated that, in general, stems of mature forages are of a lower nutritive value than the leaves. However, this depends on the function of these structures in a particular plant species. In grasses the leaves have an important structural function through the lignified midrib. Consequently, with age grass leaves tend to decline in quality, though not as rapidly as their stems (Van Soest, 1994). In the case of the kikuyu foggage analysed in the present study, CP concentrations declined as winter advanced while NDF and ADF levels increased (Table 2), but tended to stabilize after 37 days. The CP concentration of kikuyu foggage decreased with time to reach levels of <60 g/kg DM. Other studies reported CP concentrations of between 74.5 to 75.5 g/kg DM in kikuyu foggage sampled between July and September at Cedara in the Mistbelt of KwaZulu-Natal (De Villiers *et al*., 2002). Barnes & Demsey (1993) and De Villiers *et al*. (2002) recorded higher protein levels in kikuyu foggage samples selected by oesophageal fistulated animals than hand-clipped samples. This does imply that the selected material, probably leaves, had a higher CP content than the whole plant. On green kikuyu Köster *et al*. (1992) measured that cattle selected significantly more leaf than stem material. However, at a high grazing intensity as practiced in the present study, where all forage material was consumed, selection would probably be limited.

Table 2 Crude protein, neutral detergent fibre (NDF) and acid detergent fibre (ADF) concentrations (g/kg dry matter) in kikuyu foggage as winter progressed (n = 5)

Nutrient	Plant* section	Days in winter			
		1**	17	37	55**
Crude protein	Leaf	119 ^{a} ± 21.0	75 ^{b} ± 18.6	67 ^{b} ± 15.1	60 ^{b} ± 10.4
	Stem	105 ^{a} ± 18.7	68 ^{b} ± 32.1	64 ^{b} ± 22.0	55 ^{b} ± 9.4
	Leaf + stem	115 ^{a} ± 19.5	73 ^{b} ± 24.7	66 ^{b} ± 17.5	58 ^{b} ± 10.5
NDF	Leaf	756 ^{a} ± 29.0	806 ^{b} ± 18.5	854 ^{c} ± 25.0	821 ^{c} ± 13.8
	Stem	745 ^{a} ± 28.7	782 ^{ac} ± 47.1	825 ^{b} ± 60.4	825 ^{b} ± 37.3
	Leaf + stem	752 ^{a} ±19.4	794 ^{bc} ± 31.9	840 ^{b} ± 34.3	826 ^{bd} ± 25.7
ADF	Leaf	361 ^{a} ± 11.0	397 ^{ab} ± 22.6	418 ^{b} ± 30.7	417 ^{b} ± 14.1
	Stem	351 ^{a} ± 17.2	400 ^{b} ± 62.4	403 ^{b} ± 53.6	419 ^{b} ± 26.1
	Leaf + stem	357 ^{a} ± 10.7	397 ^{b} ± 31.0	409 ^{b} ± 36.9	420 ^{b} ± 18.3

n = number of samples/period, each consisting of a pooled sample/paddock.
^{a,b,c} Within rows, means with different superscripts differ significantly at $P < 0.05$.
* Nutrient concentrations between leaves and stems per collection did not differ significantly ($P > 0.05$).
** First day - 18 May; Last day – 6 July.

At each stage of collection the NDF and ADF concentrations did not differ between the stems and leaves. At the later stages of the present study the NDF and ADF levels of the foggage corresponded very well with levels in foggage reported by De Villiers *et al*. (2002).

Dry matter degradability of kikuyu foggage in the rumen decreased as winter progressed, significantly between the May and June collection, but with little changes from June to July (Table 3).

Table 3 *In situ* ruminal dry matter degradation characteristics of kikuyu foggage (whole plant) as winter progressed, incubated in the rumens of sheep fed lucerne hay (n = 5)

Days in winter	Degradation parameters				
	a	b	c	a+b	ED
1	17.7 ^{m} ± 1.43	48.1 ± 6.1	0.048 ± 0.010	66 ± 5.8	44 ^{m} ± 1.7
17	12.1 ^{n} ± 1.28	46.6 ± 5.5	0.040 ± 0.009	59 ± 5.2	38 ^{n} ± 1.5
37	10.2 ^{n} ± 1.28	44.4 ± 5.5	0.043 ± 0.009	55 ± 5.2	35 ^{n} ± 1.5
55	11.1 ^{n} ± 1.28	43.9 ± 5.5	0.037 ± 0.009	55 ± 5.2	32 ^{n} ± 1.5

n = number of samples/period, each consisting of a pooled sample/paddock.
a – soluble fraction (%); b – insoluble, fermentable fraction (%); c – degradation rate constant/h of fraction b;
a+b - extent of degradation (%); ED – effective degradability (%) at k = 0.03.
^{m,n} Within columns, means with different superscripts differ significantly at $P < 0.05$.

Calcium concentrations in the kikuyu foggage were lower than requirements for growing animals while at the onset of the study P levels were marginally deficient but decreased to insufficient levels with time (NRC, 1996). This suggests that grazing animals would benefit from the supplementation of Ca and P on the kikuyu foggage. However, considering the low CP levels in the kikuyu foggage, Ca and P might not necessarily be the first limiting nutrients in kikuyu foggage (Van Niekerk & Jacobs, 1985), suggesting that the supplementation of only Ca and P would not necessarily deliver a response in the performance of animals.

Furthermore, Ca concentrations in the kikuyu leaves in the present study were higher ($P < 0.05$) than in the stems, while P concentrations between leaves and stems of the same plants did not differ significantly. Consequently, the Ca : P ratio in leaves varied between 2.2 to 1.6 : 1, while all the stem samples contained more P than Ca, ranging from 0.7 to 0.96. Collecting results from a large number of studies, Minson (1990) reported that the leaves of grasses, in general, contain a higher concentration of Ca than the stems. In the example of green kikuyu reported by Minson (1990) the leaves contained more than double the concentration of Ca than the stems.

Table 4 Macro-mineral element composition (g/kg dry matter ± s.d.) and calcium : phosphorus ratio in kikuyu foggage as winter progressed (n = 5)

Nutrient	Plant section	Days in winter			
		1**	17	37	55**
Calcium	Leaf*	4.4 ^{a} ± 0.47	3.2 ^{b} ± 0.65	3.6 ^{b} ± 0.62	3.6 ^{b} ± 0.33
	Stem*	2.1 ± 0.61	2.4 ± 0.89	1.9 ± 0.22	2.0 ± 0.33
	Leaf + Stem	3.6 ^{a} ± 0.47	2.9 ^{b} ± 0.64	2.9 ^{b} ± 0.50	2.9 ^{b} ± 0.28
Phosphorus	Leaf	2.6 ^{a} ± 0.56	2.2 ± 0.68	2.0 ^{b} ± 0.74	2.0 ^{b} ± 0.73
	Stem	3.2 ^{a} ± 0.84	2.6 ± 1.05	2.2 ^{b} ± 0.87	2.7 ± 0.91
	Leaf + Stem	2.8 ^{a} ± 0.63	2.4 ^{ab} ± 0.78	2.1 ^{b} ± 0.77	2.3 ^{b} ± 0.71
Ca : P ratio	Leaf*	1.79 ± 0.59	1.60 ± 0.66	2.08 ± 1.02	1.96 ± 0.59
	Stem*	0.74 ± 0.37	1.10 ± 0.75	0.96 ± 0.41	0.81 ± 0.30
	Leaf + Stem	1.37 ± 0.49	1.31 ± 0.67	1.61 ± 0.87	1.35 ± 0.30
Magnesium	Leaf	2.6 ± 0.52	2.5 ± 0.24	2.2 ± 0.52	2.1 ± 0.18
	Stem	3.5 ^{a} ± 1.81	2.8 ^{ab} ± 0.69	2.4 ^{b} ± 0.60	2.3 ^{b} ± 0.36
	Leaf + Stem	2.9 ^{a} ± 0.68	2.6 ^{ab} ± 0.21	2.3 ^{b} ± 0.49	2.2 ^{b} ± 0.19
Potassium	Leaf	18.8 ^{a} ± 4.0	13.0 ^{c} ± 3.9	10.4 ^{cb} ± 4.3	8.1 ^{b} ± 3.0
	Stem	25.7 ^{a} ± 7.3	13.7 ^{b} ± 8.4	13.9 ^{b} ± 6.2	13.7 ^{b} ± 6.4
	Leaf + Stem	21.2 ^{a} ± 4.6	13.7 ^{b} ± 5.8	12.1 ^{b} ± 5.1	10.1 ^{b} ± 3.9
Sodium	Leaf	0.17 ± 0.09	0.21 ± 0.13	0.15 ± 0.06	0.17 ± 0.09
	Stem	0.28 ± 0.15	0.37 ± 0.40	0.46 ± 0.55	0.17 ± 0.09
	Leaf + Stem	0.21 ± 0.11	0.29 ± 0.18	0.24 ± 0.18	0.17 ± 0.09

n = number of samples/period, each consisting of a pooled sample/paddock.
^{a,b,c} Within rows, means with different superscripts differ significantly at $P < 0.05$.
* At all stages in winter the Ca concentration and the Ca : P ratios in the leaves were higher ($P < 0.05$) than in the stems.
** First day - 18 May; Last day – 6 July.
Leaf + stem – calculated by proportional addition.

Although differences were not significant in the present study, at all stages of sampling, the leaves contained lower concentrations of P than the stems. Minson (1990) reported a green kikuyu sample containing 2.6 g P/kg DM in the leaves and 3.1 g P/kg DM in the stems.

Miles *et al*. (1995) pointed out that kikuyu is a most unusual forage in that it often contains more P than Ca. In green kikuyu from different locations in the KwaZulu-Natal Midlands they measured Ca : P ratios of between 0.74 and 1.01. However, in kikuyu from the Eastern Cape Miles *et al*. (2000) reported a mean Ca : P ratio of 1.30. Jumba *et al.* (1995) reported a Ca concentration in kikuyu collected at the dry season "at the hay stage" in Kenya of 1.38 g/kg DM and a P concentration of 1.59 g/kg DM. When calculating combined Ca and P concentrations in the leaves and stems of the kikuyu foggage in the present investigation, the Ca : P ratio ranged from 1.3 to 1.6. Although factors such as differences in soil type, soil acidity and fertilizer application could have been responsible for the differences between the Ca : P ratios in the KwaZulu-Natal Midlands and the present study in Northern KwaZulu-Natal, time of the year could have contributed to these differences (Awad *et al*., 1979). Miles *et al*. (1995) found that the Ca : P ratios in the green kikuyu were much narrower in spring and autumn than in midsummer. Fulkerson *et al*. (1998) reported that for kikuyu in subtropical Australia the level of P fell significantly as the grass became dormant, while the Ca level rose. They measured Ca : P ratios of 1.2 : 1 in summer and 2.3 : 1 in the seventh to the tenth month when the pasture was largely dormant.

Judged from the present study where Ca levels in the kikuyu stems were much lower than in the leaves, the proportion of leaf to stem ratio should contribute substantially in acquiring a positive or negative Ca : P ratio in kikuyu herbage.

As is often the case with cultivated pastures (Miles *et al*., 1995), the K levels of the kikuyu foggage in this study were higher than animal requirements (NRC, 1996), though the levels were lower than the concentrations reported by Miles *et al*. (1995; 2000) for green kikuyu herbage. The Mg levels were low, with the potential to induce Mg deficiencies in grazing ruminants. However, considering the low production potential of livestock on kikuyu foggage and the absence of other factors inducing grass tetanus, such as high N levels in the grass and specific climatic conditions (Awad *et al*., 1979), it is unlikely that hypomagnesaemia would be a problem.

The lack of Na in kikuyu, a natrophobic plant that accumulates its sodium in the roots and not the leaves, requires correction in the diet. A Na deficiency will probably be aggravated in the animal by the high K levels in the grass.

Table 5 Trace element composition (mg/kg dry matter) in kikuyu foggage as winter progressed (n = 5)

Nutrient	Plant* section	Days in winter			
		1**	17	37	55**
Zinc	Leaf	175 ± 23.5	171 ± 64.1	144 ± 58.5	176 ± 40.8
	Stem	176 ± 23.8	171 ± 63.7	125 ± 35.3	176 ± 40.5
Manganese	Leaf	232 ± 196.9	138 ± 61.2	135 ± 45.9	107 ± 487
	Stem	234 ± 198.7	139 ± 61.0	134 ± 46.6	108 ± 48.4
Copper	Leaf	$11.3^{a} \pm 0.08$	$8.1^{ab} \pm 3.18$	$7.1^{b} \pm 2.56$	$6.9^{b} \pm 2.50$
	Stem	$11.4^{a} \pm 0.09$	$8.2^{b} \pm 3.21$	$7.1^{b} \pm 2.54$	$6.9^{b} \pm 2.55$
Selenium	Leaf	$0.036^{a} \pm 0.012$	$0.021^{b} \pm 0.006$	$0.026^{ab} \pm 0.008$	$0.023^{b} \pm 0.005$
	Stem	$0.037^{a} \pm 0.012$	$0.021^{b} \pm 0.007$	$0.029^{ab} \pm 0.010$	$0.023^{b} \pm 0.005$

n = number of samples/period, each consisting of pooled sample/paddock.
[a,b] Within rows, means with different superscripts differ significantly at $P < 0.05$.
* Element concentrations between leaves and stems per collection did not differ significantly ($P > 0.05$).
** First day - 18 May; Last day – 6 July.

In none of the trace elements analysed did concentrations differ between leaves and stems. Minson (1990) reported that Cu content in the leaves of temperate grasses was on average 35% higher than in the stem fraction. However, in the one tropical grass, *Laplap purpureus* he reported, there was no difference between the fractions. Minson (1990) reported lower Zn levels in the stems of grasses than in the leaves, but found that Mn levels did not follow any specific trend. However, the Zn and Mn levels reported by Minson (1990) were much lower than the concentrations observed in the present study. Minson (1990) reported Zn concentrations ranging from 12 to 42 mg/kg DM and Mn in a similar range, though the one kikuyu result he reported contained 96 mg Zn/kg DM. Since the plant material was not washed in the present study, it is uncertain to what extent dust could have contaminated the samples and affected the concentrations of Zn and Mn in them.

In terms of animal requirements the kikuyu foggage in this study contained adequate to high concentrations of Zn and Mn (NRC, 1996). The foggage could be marginally deficient in Cu (NRC, 1996). However, Blamey (1972) reported that the soils in the Dundee region contain very low concentrations of molybdenum. The absence of an interaction with Mo could result in an improved bioavailability of Cu in the foggage at Dundee, to reach an adequate level for livestock. The Se concentration of the foggage in this study was below 0.037 mg/kg DM, and decreased ($P < 0.05$) as winter progressed. Under grazing conditions in New Zealand, Grace & Clark (1991) recommended 0.05 mg/kg DM as the minimum requirement for Se in feed, while the NRC (1996) suggested about 0.1 mg Se/kg DM as an adequate level. These results support the assumption by Van Ryssen (2001) that northern KwaZulu-Natal is a Se deficient region. Considering that Cu and Se have antioxidant functions in the body, supplementation of these elements would probably be beneficial irrespective of whether other nutrients have higher nutritional priorities (Cronjé *et al*., 2006).

Conclusions

The CP, P, K, Cu and Se concentrations and DM degradability of kikuyu foggage decreased rapidly from the first collection that contained a high proportion of green material to later collections when the foggage contained little green material. This confirms Barnes & Demsey's (1993) suggestion that "moderately green" kikuyu foggage should be of a higher quality than frost-killed grass. At later stages in the winter the concentrations of these nutrients were lower than the nutrient requirements of beef cattle, suggesting that these nutrients would have to be supplemented to beef cattle grazing the kikuyu foggage.

Acknowledgements

The authors thank W.M. O'Donovan and the staff at Eversly Research Station for the willing manner in which they assisted in the execution of the trail, M.J. van der Linde and R.J. Coertze for assistance with statistical matters and statistical analysis, and the FRD (GUN 2046855) and the University of Pretoria for financial support.

References

AFRC, 1992. Nutritive requirements of ruminants: Protein. Report 9, Nutr. Abstr. Rev. (Series B). 62, 787-835.

AOAC, 1990. Association of Official Analytical Chemists. Official Methods of Analysis. 15th ed. A.O.A.C. Arlington, Virginia, USA.

AOAC, 1995. Association of Official Analytical Chemists. Official Methods of Analysis. 16th ed. A.O.A.C. Arlington, Virginia, USA.

AOAC, 2000. Association of Official Analytical Chemists. Official Methods of Analysis. 17th ed. A.O.A.C. Arlington, Virginia, USA. pp. 48-49.

Awad, A.S., Edwards, D.G. & Huett, D.O., 1979. Seasonal changes in chemical composition of heavily fertilized kikuyu pasture and their potential effects on the mineral nutrition of grazing cattle. Aust. J. Exp. Agric. Anim. Husb. 19, 183-191.

Barnes, D.L. & Dempsey, C.P., 1993. Grazing trials with sheep on kikuyu (*Pennisetum clandestinum* Chiov.) foggage in the eastern Transvaal highveld. Afr. J. Range For. Sci. 10, 66-71.

Blamey, F.P.C., 1972. Seedling response of maize (*Zea mays* L.) cultivars to seed-applied sodium molybdate. Crop Prod. 1, 43-46.

Cronjé, M.C., Van Ryssen, J.B.J. & Coertze, R.J., 2006. Potential benefit of trace element supplementation of sheep on a low level of nutrition. S. Afr. J. Anim. Sci. 34, 20-27.
De Villiers, J.F., Dugmore, T.J., Botha, W.A. & Wandrag, J.J., 2002. The value of kikuyu foggage for overwintering dry ewes. S. Afr. J. Anim. Sci. 32, 7-13.
Dickenson, E.B., 1976. Kikuyu (*Pennisetum clandestinum*). Publication No 56. Dec. 1976. Fertilizer Society of South Africa, Pretoria.
Fulkerson, W.J., Slack, K., Hennesy, D.W. & Hough, G.M., 1998. Nutrients in ryegrass (*Lolium* spp.), white clover (*Trifolium repens*) and kikuyu (*Pennisetum clandestinum*) pastures in relation to season and stage of regrowth in a subtropical environment. Aust. J. Exper. Agric. 38, 227-240.
Gertenbach, W.D., 1998. Beef production from kikuyu: Overwintering on kikuyu. Proc. Kikuyu Technology Day. Ed. Batholomew, P.E., KwaZulu-Natal Department of Agriculture. pp. 49-52.
Grace, N.D. & Clark, R.G., 1991. Trace element requirements, diagnosis and prevention of deficiencies in sheep and cattle. In: Physiological Aspects of Digestion and Metabolism in Ruminants. Eds Tsuda, T., Sasaki, Y. & Kawashima, R., Academic Press, NY. pp. 321-346.
Jumba, I.O., Suttle, N.F., Hunter, E.A. & Wandiga, S.O., 1995. Effects of soil origin and mineral composition and herbage species on the mineral composition of forages in the Mount Elgon region of Kenya. 1. Calcium, phosphorus, magnesium and sulphur. Trop. Grassl. 29, 40-46.
Köster, H.H., Meissner, H.H., Coertze, R.J. & Rethman, N.F.G., 1992. Voluntary intake and quality of diet selected by cattle grazing bana grass, kikuyu and forage sorghum. S. Afr. J. Anim. Sci. 22, 35-41.
Mertens, D.R., 2002. Gravimetric determination of amylase–treated neutral detergent fiber in feeds with refluxing in beakers or crucibles: collaborative study. J. AOAC Int. 85, 1217-1240.
Miles, N., De Villiers, J.F. & Dugmore, T.J., 1995. Macromineral composition of kikuyu herbage relative to the requirements of ruminants. J. S. Afr. Vet. Assoc. 66, 206-212.
Miles, N., Thurtell, L. & Riekert, S., 2000. Quality of Kikuyu herbage from pastures in the Eastern Cape coastal belt of South Africa. S. Afr. J. Anim. Sci. 30, (Suppl. 1), 85-86.
Minson, D.J., 1990. Forage in Ruminant Nutrition. Academic Press. London, UK.
NRC, 1996. Nutrient Requirements of Beef Cattle. 7th ed. National Academy of Sciences, National Research Council, Washington, D.C., USA.
Ørskov, E.R. & McDonald, I., 1979. The estimation of protein degradability in the rumen from incubation measurements weighed according to rate of passage. J. Agric. Sci., Camb. 92, 499-503.
Rethman, N.F.G. & De Witt, C.C., 1991. The value of subtropical pastures for the use as foggage on the eastern Transvaal Highveld. J. Grassl. Soc. S. Afr. 8, 19-21.
Rethman, N.F.G. & Gouws, C.I., 1973. Foggage value of kikuyu (*Pennisetum clandestinum* Hochst. ex. Chiov). Proc. Grassld. Soc. S. Afr. 8, 101-105.
Samuels, M.L., 1989. Statistics for the Life Sciences. Collier MacMillan Publishers, London.
SAS, 2001. Statistical Analysis Systems user's guide, Version 8. SAS Institute, Inc., Cary, North Carolina. USA.
Van Niekerk, B.D.H. & Jacobs, G.A., 1985. Protein, energy and phosphorus supplementation of cattle fed low-quality forage. S. Afr. J. Anim. Sci. 15, 133-136.
Van Ryssen, J.B.J., 2001. Geographical distribution of the selenium status of herbivores in South Africa: A Review. S. Afr. J. Anim. Sci. 31, 1-8.
Van Soest, P.J., 1994. Nutritional Ecology of Ruminants. O & B Books, Corvallis, Oregon, USA.