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The effect of defoliation interval and height on growth and herbage quality of kikuyu grass (*Pennisetum clandestinum*)

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Abstract

A plot study, undertaken on the subtropical north coast of New South Wales, Australia, assessed the effect of defoliation interval (equivalent to time taken to regrow 2, 4, or 6 leaves/tiller) and height (3, 6 or 12 cm) on growth and herbage quality of 'common' kikuyu (*Pennisetum clandestinum*). The pasture had been established for more than 10 years on a red Krasnozem soil. Rainfall and daily temperature during the experimental period were near long-term average except for below average rainfall in March and April.

In summer, leaf DM yield was maximised (5225 ± 886 [mean ±s.e.] kg/ha DM) under the most intense defoliation treatment (2 leaves/tiller to 3 cm height) with the lowest yields (1722 ± 231 kg/ha) under the most lax defoliation treatment (6 leaves/tiller to 12 cm height). The proportion of stem and dead material increased significantly with defoliation interval (360, 1448 and 1956 kg/ha for 2, 4 and 6 leaves/tiller, respectively) but not with defoliation height.

In contrast, in autumn-winter, plots defoliated at an interval of 4 or 6 leaves/tiller to 3 or 6 cm gave similar leaf DM yields (3771 ± 220 kg/ha) which were significantly higher than for plots defoliated more frequently (2436 ± 220 kg/ha). At all defoliation intervals, defoliation to 12 cm gave the lowest leaf DM yields.

In spring, leaf yields of plots defoliated at 3 or 6 cm (3084 ± 302 kg/ha) was significantly higher than for plots cut to 12 cm height (1734 ± 181 kg/ha) with no effect of defoliation interval.

The concentration of water-soluble carbohydrate, starch, neutral detergent fibre, metabolisable energy (ME), nitrogen (N), calcium and phosphorus in kikuyu herbage in summer, autumn-winter and spring were, respectively: 4.2, 3.7 and 5.7%; 5.9, 4.1 and NA%; 56, 52 and 43%; 8.2, 9.3 and 9.1 MJ/kg; 2.85, 2.83 and 2.32%; 0.25, 0.34 and 0.26%; and 0.33, 0.27 and 0.26%.

Defoliation height influenced NSC concentration (8.4, 9.5 and 10.6% for 3, 6 and 12 cm, respectively), while defoliation interval affected both the ME and N (9.1, 8.8 and 8.6 MJ/kg and 2.8, 2.6 and 2.1% for 2, 4 and 6 leaves/tiller, respectively) concentration.

Although this study was a plot experiment over only one year, the changes in nutritive value with regrowth interval and the inability of dairy cows to graze below 6 cm height support the recommendation that dairy cattle should graze kikuyu pastures to 6 cm stubble height at 3–4 leaves/tiller interval in spring and summer, and to the same height but at 5–6 leaves/tiller in autumn-winter.

Introduction

Recent studies by Reeves *et al.* (1996) indicate that the optimal time to graze kikuyu grass (*Pennisetum clandestinum*), in terms of forage quality for milking cows, is when $4^1/_2$ new leaves/tiller have appeared. After the kikuyu plant has reached this stage of regrowth, organic matter digestibility (OMD) and crude protein (CP) concentration of forage above 5 cm stubble height begin to fall. This is associated with a gradual decline in the proportion of leaf and a commensurate increase in stem, and particularly, dead material. An additional management

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strategy for improving the quality of forage available to grazing dairy cows is the removal, either mechanically or with stock of lower priority, uneaten stem and dead material post-grazing (Drummond *et al*. 1976). Although this practice may optimise forage quality, growth rate would be expected to be lower than with less frequent and intense grazing (Whitney 1974; Kemp 1976; Rethman and de Witt 1988). In perennial ryegrass (*Lolium perenne*), a defoliation interval of less than the time taken to fully expand 2 new leaves per tiller reduces regrowth (Fulkerson and Slack 1995) because insufficient time is allowed to replenish carbohydrate reserves (Donaghy and Fulkerson 1998). Thus, it is unclear whether the beneficial effects of more frequent and intense grazing on forage quality outweigh an anticipated reduction in growth rate of kikuyu.

The aim of this study was to determine the seasonal effect of varying defoliation interval and height on growth and herbage quality of kikuyu grass pasture.

Materials and methods

The study was conducted over a 12-month experimental period (January–December 1997), at Wollongbar Agricultural Institute (28°S) on the north coast of New South Wales, Australia. Plots were laid out on a 'common' kikuyu grass pasture established for more than 10 years on a red Krasnozem soil (pH [$CaCl_2$] 5.1, P [Colwell method using bicarbonate extraction] 60 ppm; K 0.35 meq/100 g soil).

At the start of the experimental period, 250 kg superphosphate and 100 kg/ha muriate of potash was applied, followed by 100 kg/ha urea at monthly intervals in summer and autumn and twice in spring to give a total N application of 322 kg.

The monthly rainfall and monthly mean daily maximum and minimum ambient temperatures during the experimental period and long-term means are shown in Figure 1.

Experimental design

The area was mown to 5 cm height on January 10, 1997. Treatments were then imposed with plots defoliated, when 2, 4, or 6 new leaves/tiller had appeared, to 3, 6 or 12 cm stubble height. The actual defoliation interval varied from 6 days for the 2-leaf treatment in February–March to 48 days for the 6-leaf treatment in June–July.

The 2 m × 2 m treatment plots were laid out in a completely randomised block design with 3 replicates to give a total of 27 plots. At each defoliation, the entire plot was harvested with a rotary mower. A subsample of herbage was dried in a forced-draught oven at 80°C for 24 h in order to determine dry matter (DM) yield. When the *initial* defoliation treatment was imposed on the 3 cm height treatment, only the yield above 5 cm height was recorded. The forage between 5 and 3 cm was predominantly stem and therefore its inclusion in total yield would give an *overestimate* of the forage potentially available to stock.

At one defoliation in each season (summer = January 15–April 3; autumn-winter = April 4–September 11; spring = September 12–November 25), two 30 cm × 6 cm quadrats of grass, selected at random from each plot, were cut to treatment height using hand-held shears. The samples were sorted into leaf, stem and dead material for determination of DM component yield and for chemical analysis.

At one defoliation in April, one 30 cm × 6 cm quadrat was selected at random from each plot, cut to ground level and the number of tillers/unit area counted.

Chemical analysis

The OMD of forage was determined *in vitro* by the method of Ayres (1991) using ruminal fluid from cattle fed on lucerne hay. Metabolisable energy (ME) was calculated from OMD according to SCA (1990) using the relationship: ME (MJ/kg DM) = −1.8 + 0.16 OMD(%).

N, P and K were determined (John 1970; AOAC 1990) using a micro-colorimetric method on a Kjeldahl digest (Havilah *et al*. 1977). Calcium (Ca) was determined using a wet ashing procedure and atomic absorption (Johnson and Ulrich 1959). The CP concentration in pasture was estimated from N % × 6.25. Water soluble carbohydrates (WSC) and starch were determined by extraction of plant material at room temperature for 1 h using 0.2% benzoic acid-water solution. The hydrolisation of the WSCs to invert sugar was undertaken by adding 1 M HCl, heating to 90°C and dialysing the sugar into an alkaline stream of potassium ferricyanide. The reaction was measured using an auto-analyser

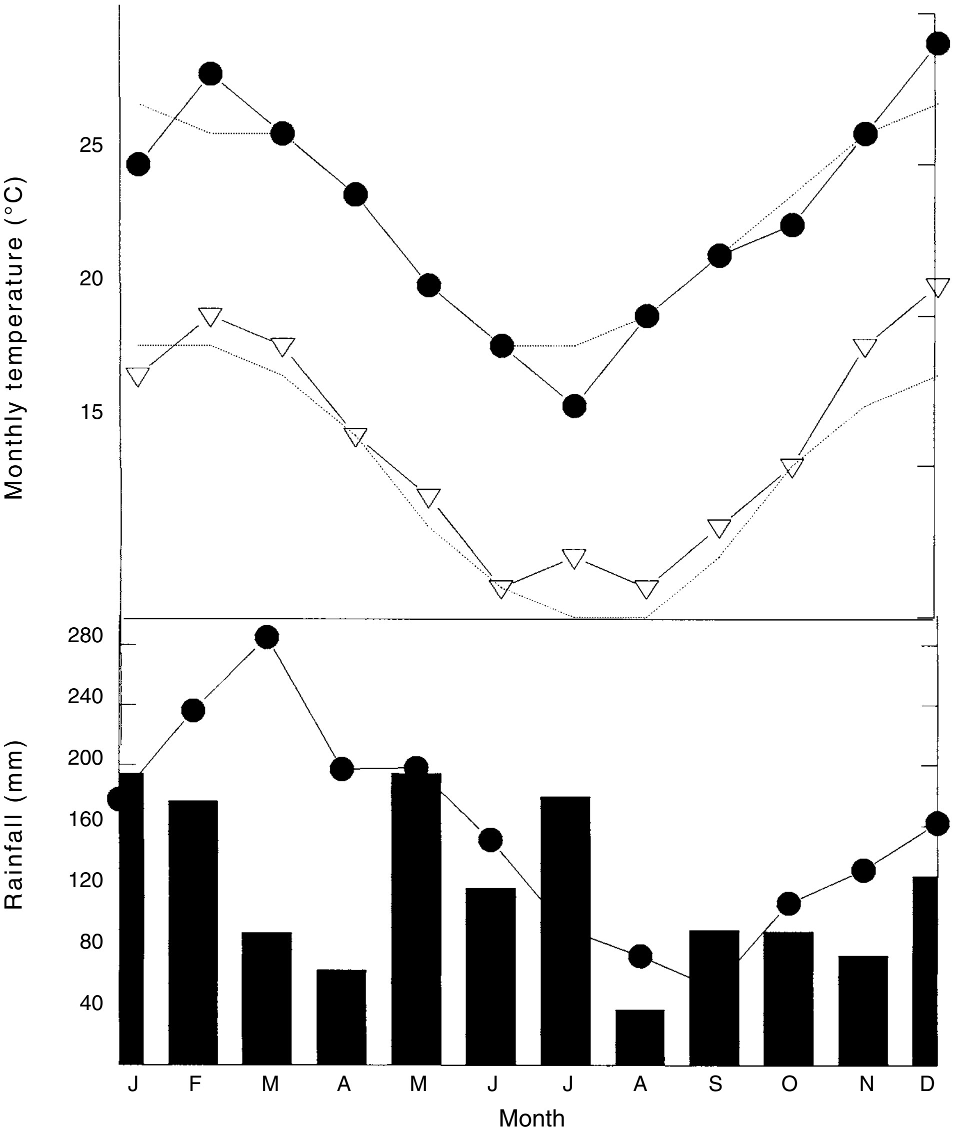

Figure 1. Monthly rainfall (■) (mm) and mean monthly daily maximum (-●-) and minimum (-,-) temperatures (°C) at Wollongbar in 1997, and long-term mean rainfall (-●-) (mm) and maximum and minimum temperatures (----).

(420 nm) (Smith 1969). Neutral detergent fibre (NDF) was determined using the method of van Soest and Wine (1967) without adjustment for protein content.

Statistical analysis

The data were analysed by the General Linear Model in Minitab (Ryan *et al.*1985) with differences between means being tested by least significant difference.

Results

Annual DM yields

At each defoliation interval, the highest annual green (leaf plus stem) DM yields were obtained when defoliation was most severe (to 3 cm height) although at intervals of 4 and 6 leaves/tiller, yields at 3 and 6 cm were not significantly different (see Table 1).

Table 1. Annual yield of total live leaf and stem and dead material for plots defoliated at 2, 4 or 6 leaves/tiller to 3, 6 or 12 cm stubble height.

Defoliation		DM yield			
Interval (leaves/tiller)	Height (cm)	Leaf	Stem	Total live material	Total dead material
		(kg/ha)			
2	3	11284	850	12134	372
	6	8707	831	9538	350
	12	6623	1016	7639	292
4	3	11080	1324	12404	1620
	6	10399	1521	11920	1659
	12	7001	1459	8460	1175
6	3	9977	2122	12099	1822
	6	9336	2502	11838	2708
	12	6258	1580	7838	1940
LSD (P=0.05)		1404	495	1284	456

Stem represented 9.5, 13.1 and 20.0% of DM yield for the 2, 4 and 6 leaves/tiller regrowth interval treatments, respectively. Defoliation height had no significant effect (P>0.05) on stem DM except at 6 leaves/tiller where significantly less stem was harvested from plots cut to 12 cm height than from plots defoliated at the lower heights.

Seasonal DM yields

The seasonal component DM yields are shown in Figure 2.

Over the summer period, there was no significant effect of defoliation treatment on total herbage harvested with a mean (± s.e.) of 4478 ± 154 kg/ha DM. However, there was a substantial effect of defoliation treatment on component yield. Leaf yield for the most severe defoliation treatment (at 2 leaves/tiller to 3 cm height) was significantly greater (P<0.001) than that for all other treatments. Although the most severe defoliation treatment tended to have the lowest stem DM, this was not significant. No dead matter was harvested from any plots defoliated at 2 leaves/tiller whereas this component comprised 26% and 30% of total DM on plots cut at 4 and 6 leaves/tiller, respectively.

In contrast to summer, in autumn-winter, defoliation at 6 leaves/tiller to 3 cm height gave the highest leaf DM yield although this was not significantly different from plots defoliated to 6 cm height at the same interval nor from plots defoliated to 3 cm height at 4 leaves/tiller. The DM yield of stem was not significantly different in plots defoliated at 4 or 6 leaves/tiller but these yields were significantly (P<0.001) higher than for plots defoliated at 2 leaves/tiller (767 *vs* 396 kg/ha).

In spring, total DM yields of leaf plus stem were similar at all defoliation intervals, but yields of plots defoliated to 12 cm were significantly (P<0.001) lower than for other defoliation heights irrespective of defoliation interval.

There was no significant effect of defoliation treatment on tiller density.

Changes in nutrient levels

As there was no significant interaction between defoliation treatment and season on nutrient concentrations in kikuyu, the responses to the 2 variables will be reported separately.

Seasonal changes. NSC (WSC plus starch) levels were affected significantly by season with autumn-winter < summer (P<0.05) < spring (P<0.05) (Table 2). In contrast, NDF followed a

Table 2. Concentration of NDF, starch, water-soluble carbohydrate, N, Ca and P and the ratio of Ca:P and ME in kikuyu herbage harvested in summer, autumn-winter and spring.

	Carbohydrate (% DM)			ME	N	Mineral (% DM)			
Season	NDF	Starch	WSC	(MJ/kg DM)	(% DM)	K	Ca	P	Ca:P
Summer	56	5.9	4.2	8.15	2.85	2.92	0.25	0.33	0.76
Autumn-winter	52	4.1	3.7	9.30	2.83	2.63	0.34	0.27	1.26
Spring	43	NA[1]	5.7	9.06	2.32	1.69	0.26	0.26	1.00
LSD (P = 0.05)	2.1	0.84	0.82	0.15	0.21	0.14	0.03	0.02	NA

[1] Not available.

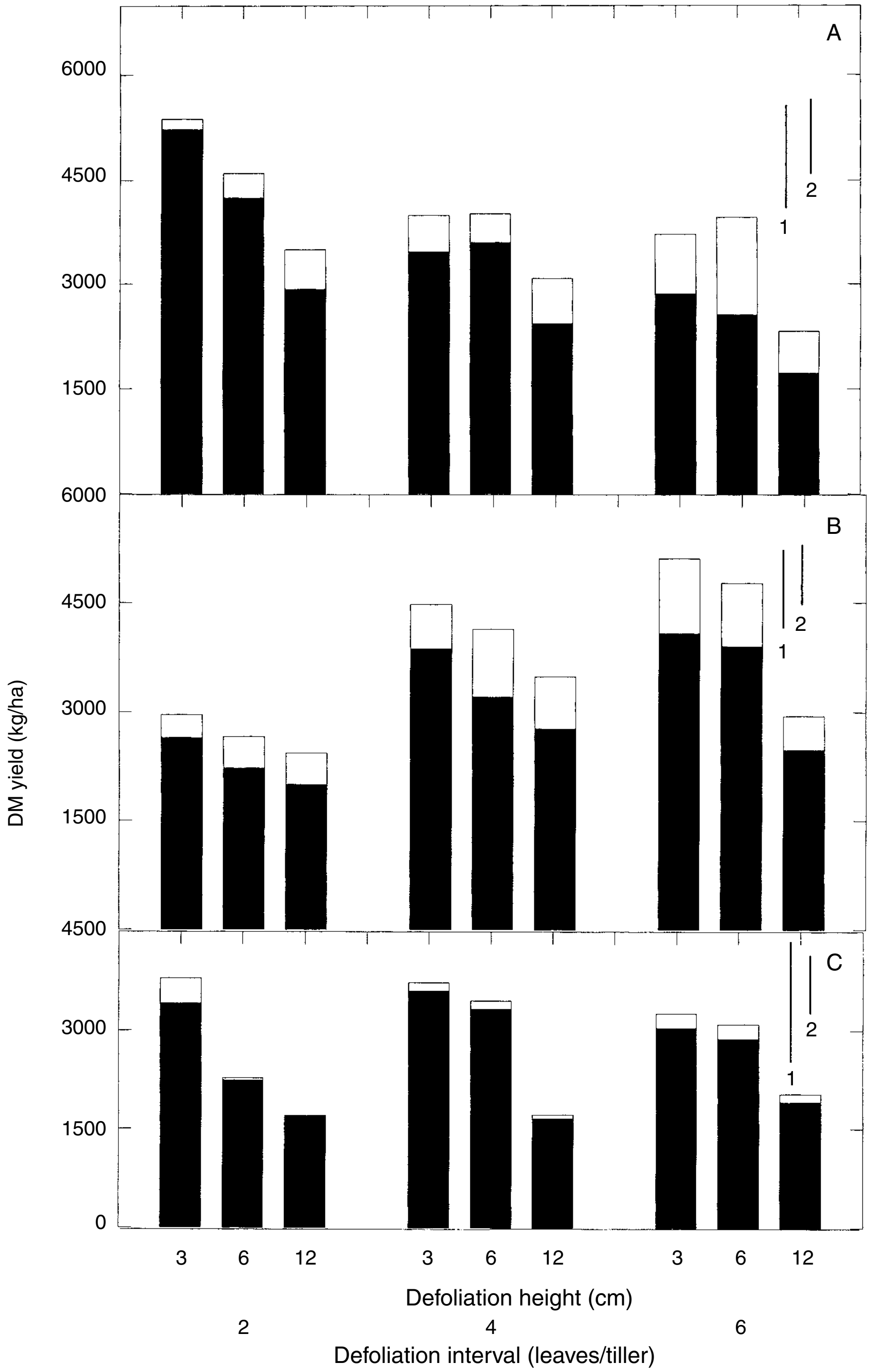

Figure 2. DM yield (kg/ha) of leaf (■) and stem (u) over summer (A), autumn-winter (B) and spring (C) of plots cut to 3, 6 or 12 cm stubble height and at the 2, 4 or 6 leaves/tiller stage of regrowth. LSD values (P=0.05) for comparing means within season are shown as vertical bars and designated as 1 for leaf and 2 for stem.

different pattern with spring < autumn-winter < summer (P<0.05).

ME values in kikuyu in summer were much lower than in other seasons (P<0.05). N levels in harvested material were similar in summer and autumn-winter but significantly (P<0.05) lower in spring (2.85, 2.83 *vs* 2.32%).

Calcium concentration was highest in autumn-winter and P levels were highest in summer with the lowest Ca:P ratio in summer.

Potassium concentrations declined progressively from summer through autumn-winter with lowest values in spring (P<0.001).

Effects of defoliation treatments. Defoliation interval did not affect leaf WSC concentration (P<0.05) but there was a significant effect (P<0.01) of height of cutting (Table 3). Both starch and WSC concentrations were different (P<0.05) at the extreme defoliation height treatments (3 *vs* 12 cm).

Table 3. Concentration of non-structural carbohydrate (starch and water-soluble carbohydrate) in kikuyu in summer at various defoliation heights.

Defoliation height	Starch	WSC
(cm)	(% DM)	
3	4.5	3.9
6	5.0	4.5
12	5.5	5.1
LSD (P=0.05)	0.84	0.82

ME and NDF levels were not affected by cutting height (P>0.05) but were affected by defoliation interval (see Table 4), ME values declining as defoliation interval increased with the reverse effect for NDF.

Table 4. Concentration of NDF and ME in kikuyu at various defoliation intervals.

Defoliation interval	NDF	ME
(leaves/tiller)	(% DM)	(MJ/kg DM)
2	49	9.1
4	52	8.8
6	50	8.6
LSD (P=0.05)	2.1	0.2

N concentration declined with increasing defoliation interval but differences were significant (P<0.01) only between extreme intervals (2.69, 2.59 and 2.47% for 2, 4 and 6 leaves/tiller, respectively).

Of the three minerals analysed, only Ca concentration of kikuyu changed with defoliation interval rising from 0.22 ± 0.01 (mean ± s.e.) % at 4 leaves/tiller to 0.26 ± 0.008% at 6 leaves/tiller.

Discussion

In this study, annual yields of leaf DM harvested were maximised with the most severe defoliation treatment, *viz.* a defoliation interval equivalent to 2 leaves/ tiller and cutting to 3 cm stubble height. However, in autumn-winter, a more lax defoliation treatment (6 leaves/tiller interval and 12 cm stubble height) gave the highest leaf yields. The shortest leaf appearance interval (time, in days, taken for 1 leaf to fully extend) in summer was approximately 3 days, giving a defoliation interval of 6–7 days for the 2 leaves/tiller treatment whereas the longest defoliation interval was in autumn-winter when it took about 48 days for 6 leaves/tiller to extend. In contrast to these results, previous studies have found a positive relationship between total yield and defoliation interval. For example, Kemp (1976) found that DM yield increased from 14.6 t/ha to 21.6 t/ha as defoliation interval increased from 21 to 63 days, when 1270 kg N/ha/year was applied. Similarly, Colman (1966) reported a reduction in DM yield of 25–54% as defoliation interval was reduced from 84 days to 14 days. In Hawaii, Whitney (1974) reported a 3- to 4-fold increase in kikuyu yield if grazing interval was increased from 14 days to 70 days.

The contrasting results may be due to the fact that, in previous studies, regrowth times examined started beyond our longest intervals, particularly in summer, and more importantly, only total DM yield, and not yield of leaf, was considered. Total annual DM yield in our study did increase slightly with increasing defoliation interval. However, total DM yield is not a meaningful criterion to use in comparing performance of C_4 grasses. Animal production from grasses like kikuyu is limited by forage quality rather than yield, with quality being related to leaf:stem ratio (Reeves *et al.* 1996). In the study by Whitney (1974), cellulose concentration rose by 4.5 percentage units and CP dropped from 14.1% to 8.6% as grazing interval increased from 14 days to 70 days. Similar changes in nutrient status as regrowth time increased were obtained when kikuyu yields were determined in pure swards at Wollongbar (Reeves *et al*. 1996) and as a component in mixed swards in New Zealand (Goold 1979) and South Africa (Rethman and de Witt 1988). Kemp (1976), commenting on his study, concluded that kikuyu grazed at a 70-d interval would not have been 'well utilised'. After reviewing the literature, Mears (1970) concluded that frequent and hard grazing is likely to maximise animal production from kikuyu.

Our results indicate that grazing or mulching (slashing) post-grazing to 3 cm stubble height will not be deleterious to kikuyu growth in summer. Grazing as frequently as 2 leaves/tiller is often necessary to prevent the build-up of fungal leaf diseases which make kikuyu unpalatable and lower its quality. However, other aspects of grazing as frequently as 2 leaves/tiller need to be considered before recommending such a strategy.

Firstly, the amount of pasture *on offer* may be inadequate for dairy cows. Our results indicate that, when pasture is grazed at 2 leaves/tiller to 6 cm stubble height in summer, there would be 471 kg/ha DM *on offer* (above 5cm stubble height). At a stocking intensity of 50 cows/ha (a stocking rate of 6.25 cows/ha for an 8-day or 2 leaves/tilller grazing interval), intake per cow would be 9.4kg DM/cow/d. However, field observations with kikuyu pastures indicate that, to be adequately fed, milking cows should graze only $^2/_3$ of the feed *on offer*, thus 6.3 kg DM/cow/d would be available. If grazing was delayed until 4 leaves/tiller, there would be 762 kg/ha DM *on offer* as only half the area would be available at each grazing (the rotation length has been doubled), or only 4.7 kg DM/cow/d. Thus, increasing the grazing interval increases kikuyu pasture *on offer*, but may reduce the amount of pasture available.

Secondly, our results also support the concept of delaying defoliation beyond 2 leaves/tiller to allow the Ca level to rise and CP concentration of kikuyu to fall, but before there is a substantial fall in OMD. Although Reeves *et al.* (1996) obtained a far greater fall in OMD after $4^1/_2$ leaves/tiller than we observed, this was due to a more marked change in the proportion of leaf to stem and dead material when the sward was harvested to ground level. In our study, much of the senescing and dead matter would be expected to have fallen below defoliation height and this probably explains the relatively low yields obtained for all plots cut to 12 cm stubble height. We failed to record a significant rise in NDF over the defoliation intervals tested, whereas the NSC levels (WSC and starch) did rise significantly with defoliation height, in keeping with previous results of Reeves *et al.*(1996) and Fulkerson *et al.* (1998). This is to be expected, if it is assumed that more NSC plant reserves are used to effect regrowth at severe levels of defoliation, where most leaf is removed and ongoing carbohydrate production by photosynthesis is restricted.

The significant seasonal decline in potassium from 2.92% in summer to 1.69% in spring is in line with the general growth pattern of kikuyu grass. Fulkerson *et al.* (1998) did not obtain a significant seasonal change previously, although the mean levels of 2.9 ± 0.01% were higher and this may reflect availability of K from soil.

This study indicates there is no regrowth penalty by frequently and severely defoliating kikuyu in summer under the conditions applied. The only reasons for grazing more laxly than this would be to satisfy the animal's ability to prehend and perhaps to digest herbage of more appropriate nutrient quality. Thus, grazing could be at the 4-leaf stage, or at approximately 12-day intervals, to 5–6cm stubble height, and this is in line with previous conclusions of Reeves *et al.* (1996). However, delaying grazing from the 3 to 4-leaf stage to capture rises of 18 and 20% in Ca and Mg (Reeves *et al.* 1996), may not be worthwhile considering the relatively low cost of supplementing stock with these minerals. In the autumn-winter period, a longer defoliation interval of 6 leaves/tiller or about 30–40 days is warranted. If the object is to retard kikuyu growth in order to prevent it competing with establishing temperate grasses, then it may be appropriate to continue severe defoliation (intense and frequent) into autumn. This is recommended, for example, when establishing white clover (Fulkerson and Slack 1996) in kikuyu pastures. In spring, defoliation should be similar to summer. However, spring is the driest season and optimal defoliation is often compromised by intermittent periods of severe soil moisture deficit.

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