Utilising leaf number as an indicator for defoliation to restrict stem growth in rhodes grass (*Chloris gayana*) cv. Callide

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Abstract

A plot experiment examined the yield response of a nitrogen-fertilised rhodes grass (*Chloris gayana*) sward to defoliation using the production of a set number of leaves after the last defoliation as the indication for defoliation harvesting. Two factors, defoliation frequency and nitrogen fertiliser rate, were imposed on the rain-grown sward in south-east Queensland over 2 defoliation cycles. Defoliations occurred when an average of 2, 4, 6 and 8 leaves were produced on tillers, and the rates of nitrogen fertiliser were 150 and 300 kg/ha N.

Total and leaf yields of rhodes grass were unaffected by defoliation frequency (P>0.05). Stem yield increased only once 4 leaves had been regrown; hence, leaf:stem ratio was highest at the 2- and 4-leaf defoliation intervals. This response was most pronounced when coupled with the higher rate of nitrogen fertiliser. The results suggest leaf number per tiller can be used as an indication of time to harvest rhodes grass pastures to limit the production of stem and increase the leaf:stem ratio. Further studies are required to examine this principle under grazing.

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Introduction

In the tropics and subtropics, it is difficult to maintain milk production from cows grazing tropical pastures over summer and autumn as the quality of tropical grass deteriorates rapidly, limiting the production of grazing animals (Cowan *et al.* 1993; Ehrlich *et al.* 2003a). This problem of low forage quality is exacerbated by the high daytime temperatures experienced during the summer, which limit dry matter intake by animals during the day (Thurbon *et al.* 1971). To attain maximum milk production from pastures in this environment, pasture managers must ensure that the forage consumed by cows is of the highest quality possible.

The 2 sward components, leaf and stem, of tropical grasses are of considerably different quality. Quality of leaf is much higher and animals grazing a tropical pasture sward actively select leaf (Cowan *et al.* 1993). Stem, being of lower quality, can reduce intake and physically restrict grazing animals' access to the higher quality leaf.

There have been a number of attempts to manage tropical pasture swards to maximise the production of leaf, while limiting stem production (Ehrlich *et al.* 2003a; 2003b). While the use of nitrogen fertiliser increases dry matter yield, it does not lead to an increase in leaf:stem ratio (Cowan *et al.* 1995). Topping tropical pastures after grazing reduces stem production, but the economics of the practice are marginal (Ehrlich *et al.* 2003a). Altering grazing intervals has been shown to have no effect on milk production of cows (Ehrlich *et al.* 2003a) or liveweight gains of heifers (Williams *et al.* 2002). However, in these investigations, grazing intervals were at set times. As such, they took no account of the plant physiological processes that lead to the production of stem and influence the leaf:stem ratio.

The rate of production of rhodes grass (*Chloris gayana*) leaf tends to be constant with time, while stem growth starts slowly and increases with time (Ehrlich *et al.* 2003a). This suggests that there may be a physiological trigger, which leads to the increased production of stem material in tropical pastures. If defoliation intervals are based on plant physiological parameters, animals might maximise consumption of quality leaf and reduce the intake of stem, thus increasing the quality of the forage consumed.

Fulkerson and Slack (1994) suggested using leaf number as a simple plant-based indicator for a flag time for grazing temperate pastures. Defoliating ryegrass (*Lolium* spp.) swards when tillers produced an average of 3 new leaves can improve yield and pasture persistence, while defoliating after this leads to a drop in quality and yield wastage through an increase in dead material (Fulkerson and Slack 1994) as older leaves senesce. Similar results were achieved at 4 new leaves/tiller for cocksfoot (*Dactylis glomerata*) pastures (Turner *et al.* 2006). In both species, shorter grazing intervals were found to deplete the plants' reserves of storage carbohydrates, which led to retarded regrowth and reduced yield (Fulkerson and Slack 1994; Turner *et al.* 2006).

For the tropical grass, kikuyu (*Pennisetum clandestinum*), Reeves *et al.* (1996) found an increase in the amount of stem and dead material and a steep reduction in the leaf:stem ratio after tillers achieved an average of 4.5 leaves. These authors concluded that a grazing interval allowing growth of 4.5 leaves was the appropriate defoliation frequency for optimising forage quality for lactating dairy cattle. This paper investigates whether these strategies can be developed for another tropical grass, viz. rhodes grass.

Materials and methods

Site

The experiment was conducted at Mutdapilly Research Station (27°45′S, 152°40′E; elevation 40 m) in south-east Queensland over the 2004–2005 summer period from November to April. The stand of rhodes grass (*Chloris gayana* cv. Callide) had been established in the 1993–1994 summer. The soil was a black vertosol, with a soil analysis of 215 mg/kg P (Colwell extraction), 1.3 cmole/kg of potassium (K) and a pH of 6.4 (H_20) in the top 100 mm.

Experimental design and treatments

In the first week of November 2004, the site was mown to 75 mm and the cut material removed. In the first week of December, twenty-four 2 m × 2 m plots were laid out in a 6 by 4 layout. Plots were defoliated and the dry matter yields (4-weeks growth) used as a covariate and for blocking.

The experiment was laid out as a randomised block design with 2 factors: nitrogen fertiliser rate (2 levels) and cutting frequency (4 levels) and 3 replications. Nitrogen fertiliser was applied at 150 or 300 kg/ha N as urea in 3 equal applications (second week of December, second week of January and third week of February). Four cutting frequencies, based on leaf number, were implemented with plots defoliated when an average of 2, 4, 6 or 8 leaves appeared on tillers within the respective plots. Half-way through the experiment cattle broke into the site and grazed all treatments. This occurred immediately after the plots defoliated at 2, 4 and 8 leaves had been harvested (*i.e.*, the end of the first cycle), so some (although minimal) yield loss occurred in the plots with 6-leaf defoliation frequency factor. The entire site was mown off and the second cycle of defoliation commenced.

Measurements

The leaf numbers on 10 tillers in each plot were recorded weekly following the method used by Fulkerson and Slack (1994). Fractions of leaves were estimated based on leaf length relative to a fully expanded leaf. Plots were harvested when the required number of leaves per tiller was reached for that harvest treatment.

Prior to harvesting, a 400 mm × 400 mm quadrat was placed in a fixed position in each plot and defoliated to 75 mm with hand shears. The cut material was weighed, before being hand-separated into rhodes grass leaf, rhodes grass stem, other grasses and broadleaf species. This hand-separated material was dried at 60°C for 48 h and then weighed. Weights were used to determine the dry matter concentration and the sward composition of each plot. Once the sample from the quadrat was taken, the entire plot was defoliated to 75 mm using a rotary mower with a rear-mounted catcher. The cut material was gathered in the catcher and weighed.

The leaf and stem components from the dried hand-separated material for each plot from both defoliation cycles were combined and ground through a 1 mm screen. The ground material was then digested using the standard Kjeldahl procedure. Crude protein was determined by multiplying the nitrogen concentration by 6.25.

Statistical analysis

The yield and sward composition data were analysed as a split-plot model. Defoliation frequency and nitrogen fertiliser rate were the 2 main plot factors and defoliation cycles were the subplots. Total grass yields, and leaf and stem yields were transformed using the natural logarithm. Forage crude protein concentration was analysed as a randomised block design with 2 factors as samples were combined from both defoliation cycles. Fisher's least significant difference (LSD) at the 5% level was used to identify significant differences between factors and treatments. All statistical analysis was undertaken using GenStat (Payne *et al.* 2007).

Rainfall and air temperature

Rainfall (Figure 1) was below average during the latter half of the experimental period. The majority of rain fell in the first 2 months of the experiment, while there was comparatively little in the final 2 months. Average monthly maximum and minimum air temperatures increased through summer, peaking in February (33°C max, 19°C min) before decreasing into autumn (data not presented).

Results

Yield

Overall pasture growth during the first cycle was considerably greater ($P<0.05$) than during the second. The smallest difference in yield between the cycles was for the 6-leaf defoliation treatment and the largest difference in the 8-leaf defoliation treatment (Figure 2). The first experimental cycle yielded an average 1700 kg/ha DM more rhodes grass and 1100 kg/ha DM more leaf than the second experimental cycle.

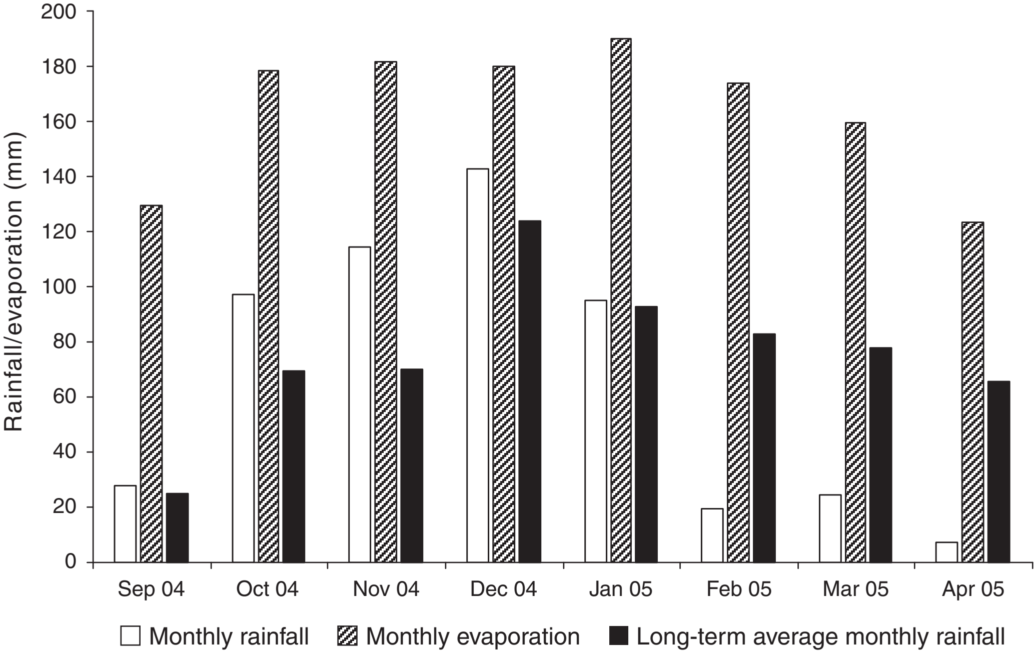

Figure 1. Rainfall, evaporation and the long-term (23 years) average rainfall at Mutdapilly Research Station for each month during the study.

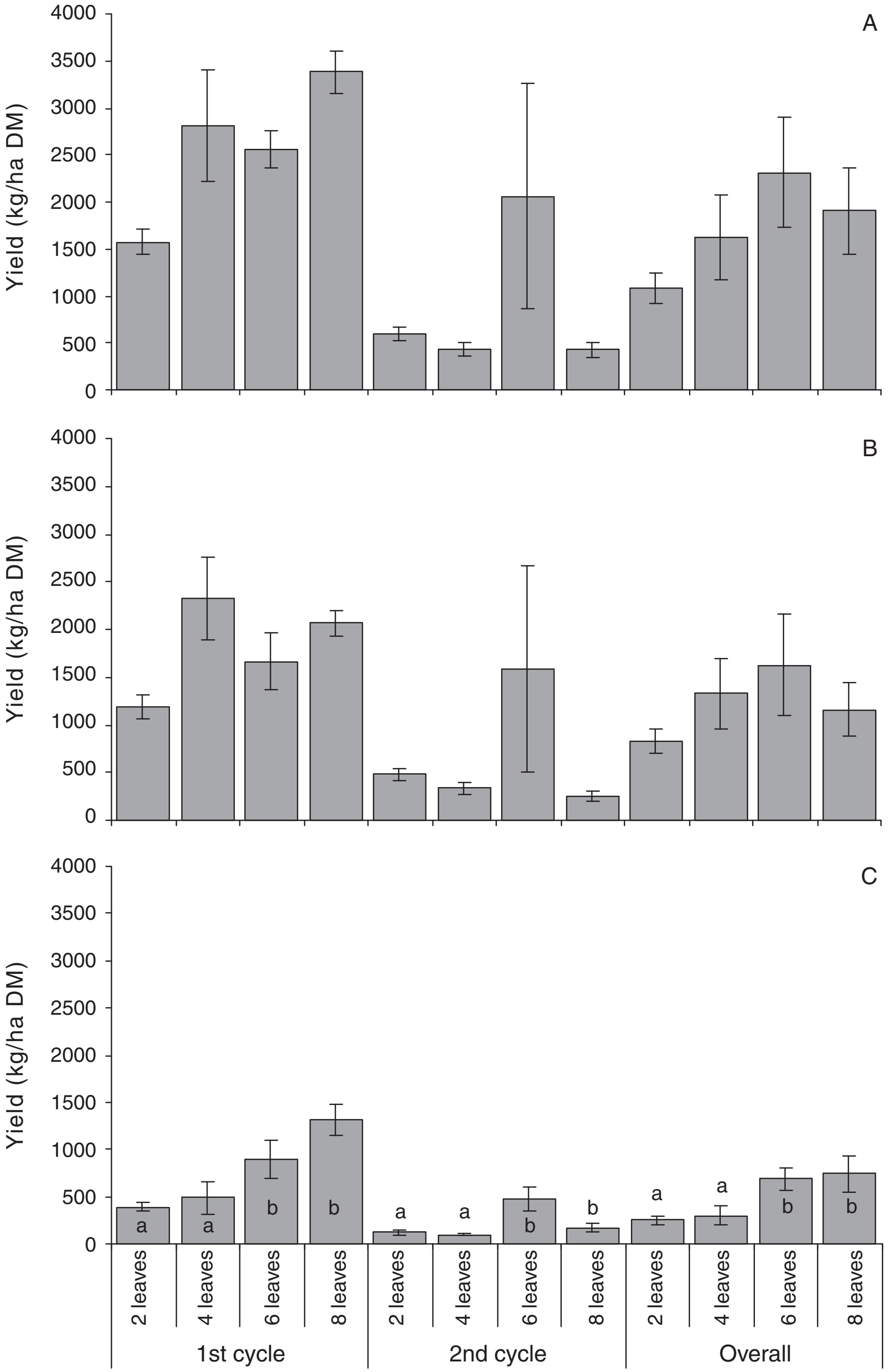

Figure 2. Total (A), leaf (B) and stem (C) yield of rhodes grass for each defoliation frequency within each cycle and the overall average. Columns with different letters within the same cycle are significantly different ($P<0.05$). Error bars represent the standard error of the mean.

Neither nitrogen fertiliser nor defoliation interval affected total rhodes grass yield or leaf yield when analysed across both cycles. However, defoliation frequency affected stem yield, with the 2- and 4-leaf frequencies producing less ($P<0.01$) stem than the 6- and 8-leaf frequencies (Figure 2). The increase in stem yield occurred between the 4- and 6-leaf defoliation frequencies in both defoliation cycles (Figure 2). Nitrogen fertiliser had no effect ($P>0.05$) on the production of stem. There was a large degree of variation in stem yield of the 6-leaf defoliation treatments in the second cycle, which was reflected in the total rhodes grass yield of these treatments.

Leaf:stem ratio

The leaf:stem ratio of the sward was affected by defoliation frequency ($P<0.01$), with a decrease occurring between frequencies of 4 and 6 leaves (Table 1). The effect of defoliation frequency on leaf:stem ratio changed slightly between cycles. In the first cycle, leaf:stem ratio peaked at the 4-leaf defoliation interval, while in the second cycle it was highest at the 2-leaf interval (Table 1). While there was no overall effect of nitrogen fertiliser rate, there was an interaction between nitrogen fertiliser rate and defoliation frequency. At the lower nitrogen fertiliser rate, leaf:stem ratio declined as defoliation frequency increased but differences failed to reach significance ($P>0.05$), while at the higher nitrogen fertiliser rate, leaf:stem ratio peaked at the 4-leaf defoliation frequency ($P<0.05$). There was no significant change in the effect of nitrogen fertiliser rate on leaf:stem ratio between the first and second cycles.

Table 1. Changes in leaf:stem ratio with different defoliation frequencies over the 2 cycles. Means within columns followed by different letters are significantly different ($P<0.05$).

Defoliation frequency	Cycle 1	Cycle 2	Overall
2 leaves	3.31 b	4.23 a	3.77 ab
4 leaves	6.59 a	3.25 ab	4.92 a
6 leaves	2.52 b	2.20 b	2.36 b
8 leaves	1.73 b	1.80 b	1.76 b

Table 2. Overall changes in leaf:stem ratio (averaged over harvest cycle) with different defoliation frequencies as affected by nitrogen fertiliser rate. Means within columns followed by different letters are significantly different ($P<0.05$).

Defoliation frequency	Leaf:stem ratio at 150 kg/ha N	Leaf:stem ratio at 300 kg/ha N
2 leaves	3.99	3.55 b
4 leaves	3.38	6.46 a
6 leaves	2.86	1.85 bc
8 leaves	2.32	1.21 c

Forage crude protein concentration

Leaf crude protein concentration decreased as the leaf aged, but increased as the rate of nitrogen fertiliser increased ($P<0.01$; Table 3). Leaf crude protein concentration significantly decreased ($P<0.05$) from the 2- to 4- and 4- to 8-leaf defoliation frequencies.

The response of stem crude protein concentration to defoliation interval and nitrogen fertiliser was similar to that of leaf. Overall, forage crude protein concentration showed the greatest decrease between the 4- and 6-leaf defoliation intervals (Table 3), and increased as nitrogen fertiliser rates were lifted from 150 to 300 kg/ha N.

Table 3. The impact of nitrogen fertiliser rate and defoliation interval on leaf, stem and overall forage crude protein concentrations. Means within columns and factors followed by different letters are significantly different ($P<0.05$).

	Leaf	Stem	Overall
	Defoliation frequency		
		(%)	
2 leaves	12.55 a	8.68 a	11.65 a
4 leaves	10.66 b	7.14 b	10.10 b
6 leaves	9.23 bc	5.74 bc	7.67 c
8 leaves	8.09 c	5.66 c	7.12 c
	Nitrogen fertiliser rate		
150 kg/ha N	9.20 a	6.23 a	8.33 a
300 kg/ha N	11.06 b	7.38 b	9.94 b

Discussion

These results highlight the difficulty in balancing yield and quality when designing grazing strategies for tropical tussock grasses. While extending the interval between grazing produced a doubling of dry matter yield, pasture quality declined through a disproportionate increase in stem yield with a decline in leaf:stem ratio. Ehrlich *et al.* (2003a) found that rhodes grass leaf yield increased linearly with time since the last grazing but that stem yield increased exponentially over the same period. Results from our study confirm this finding with a marked increase in stem growth after the 4-leaf stage. Yields from the plots at the 6-leaf defoliation frequency might have been higher if cattle had not broken into the experiment. However, at the time this occurred, low rainfall was severely restricting pasture growth so yield loss was minimal.

The dramatic increase in leaf:stem ratio in the 4-leaf defoliation treatments in the first cycle was due to comparatively faster leaf growth rates than stem growth rates in the early stages of regrowth. There was not enough time between defoliations in the 2-leaf defoliation treatments for the high leaf:stem ratio to develop. Ehrlich *et al.* (2003a) constantly observed faster growth rates of leaf compared with stem within the first 21 days of regrowth in irrigated rhodes grass. Low water availability might have prevented this response from developing in the second regrowth cycle of our rain-grown experiment.

The decline in leaf:stem ratio as the interval between defoliations increased resulted in a lower quality forge being available in the 6- and 8-leaf defoliation treatments as indicated by the lower crude protein concentration in the forage. The decrease in leaf:stem ratio at defoliation frequencies longer than the 4-leaf stage has also been observed in kikuyu (Reeves *et al.* 1996; Fulkerson *et al.* 1999) with declines in both digestibility and crude protein concentration (Reeves *et al.* 1996). While we did not measure digestibility, there is a wealth of data to show that digestibility of tropical grasses declines with age (Cowan *et al.* 1993; Minson *et al.* 1993; Ehrlich *et al.* 2003a), so a similar response in rhodes grass would be expected.

While Reeves *et al.* (1996) originally suggested defoliation at the 4.5-leaf stage for kikuyu pastures, Fulkerson *et al.* (1999) showed that the optimum interval was affected by season. In spring and summer, commencing grazing when the sward showed between 3 and 4 leaves/tiller was the most appropriate, while over autumn and winter, commencing grazing when there were between 5 and 6 leaves/tiller was recommended (Fulkerson *et al.* 1999). In our study, we did not observe a change in the optimal defoliation frequency of rhodes grass associated with the seasonal change from summer to early autumn. Altering grazing frequency in late autumn or winter is likely to have little benefit in this environment as frosts and cold temperatures will strongly limit rhodes grass growth. The appropriate defoliation interval for rhodes grass in spring might differ between cultivars. For example, Callide rhodes is known to have slower spring growth than Pioneer (Loch 1980), so that a longer grazing interval may be appropriate.

Extrapolating this method of scheduling defoliation frequency to other tropical pasture species will depend on the growth habit of the species. For erect, tussock-forming grasses (*e.g. Panicum* spp. and *Setaria* spp.), it should be applicable and provide an effective method to control leaf:stem ratio. For stoloniferous, sward-forming species (*e.g. Digitaria* spp. and *Brachiaria* spp.), the change over from leaf to stem production may not be as distinct and further research may be needed to determine the appropriate stage for grazing these species.

The overall trend of decreased yield in the second defoliation cycle can be attributed to lower temperatures, shorter daylength and the reduced rainfall received over that period. Nitrogen fertiliser had no effect on leaf yield of rhodes grass, as found by Cowan *et al.* (1995) in the same environment. While these authors found that total yield increased with increasing level of nitrogen fertiliser, this was not demonstrated in our experiment. It is generally accepted that both nitrogen status of the soil and soil moisture are the primary factors controlling growth of tropical pastures (Buchanan *et al.* 1985; Ehrlich *et al.* 2003b). In our experiment, the lack of soil moisture would have prevented the plants from making full use of the available nitrogen, leading to the poor overall response to nitrogen fertiliser. The results achieved by Cowan *et al.* (1995) came from a 6-year study and not all years showed a full response. It appears that, to gain the most out of high N fertiliser rates on tropical pastures, either rainfall must be adequate or irrigation should be supplied.

We have no satisfactory explanation for the large degree of variation in the 6-leaf defoliation frequency treatments in the second cycle, and consider it was most likely a result of artefacts within the experimental site.

Stem build-up in tropical pastures has long been recognised as one of the major factors affecting milk production of dairy cattle grazing tropical grasses (Stobbs 1971). Ehrlich *et al.* (2003a) showed that removing stem by topping tropical pastures improved milk yield per animal by 3 L/day; however, once the cost associated with topping was accounted for, there was little economic benefit in the practice for the Australian subtropical dairy industry. Grazing rhodes grass pastures when 4 leaves have regrown shows promise as a means of reducing stem build-up without the need to invest in the capital, fuel and high labour requirement for topping. Similar milk production gains to those achieved by Ehrlich *et al.* (2003a) where stem was removed could be expected from the restriction of stem growth. Further studies to determine whether the effects demonstrated in this experiment hold under grazing seem warranted.

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