One size does not fit all – matching grazing strategies with plant growth stages

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Abstract: *A glasshouse study was conducted to quantify the nutritive value of four tropical grasses at four growth stages. The grasses were digit grass (*Digitaria eriantha*) cv. Premier, Makarikari grass (*Panicum coloratum *var.* makarikariense*) cv. Bambatsi, Rhodes grass (*Chloris gayana*) cv. Katambora and panic grass (*Megathyrsus maximus*) cv. Gatton and the growth stages were 2-leaf, 4-leaf, 6-leaf and stem elongation. Makarikari grass developed the fastest and digit grass the slowest (38 and 52 days to stem elongation, respectively). Rhodes grass had the highest biomass at stem elongation. Nutritive value was highest at the earliest growth stage, declining as the tillers matured. Leaf per tiller number was used as a potential plant-based indicator of optimum time of grazing. The optimum growth stage for grazing and potentially fodder conservation was 4-leaf for Rhodes grass and digit grass. The optimum growth stage for Makarikari grass and panic grass was the 6-leaf growth stage. With field testing, this information could be a useful tool for producers to optimise pasture and stock production.*

Key words: metabolisable energy, crude protein, acid detergent fibre, neutral detergent fibre, silage, Bambatsi panic

Introduction

The technique of using leaf number per tiller as a plant-based indicator to determine the optimum time for grazing was first described by Fulkerson and Slack (1994). They used it for irrigated perennial ryegrass (*Lolium perenne* L.) pastures. The advantage of leaf number is that it is a generic and readily identifiable trait (Fulkerson and Donaghy 2001). This technique has been extended to other temperate grass species used in the dairy industry such as cocksfoot (*Dactylis glomerata* L.; Rawnsley *et al.* 2002; Turner *et al.* 2006a) and prairie grass (*Bromus willdenowii* Kunth; Turner *et al.* 2006a,b). The technique has also been applied to two tropical grasses commonly used in dairy pastures including: kikuyu (*Pennisetum clandestinum* Hochst. ex Chiov; Reeves and Fulkerson 1996; Reeves *et al.* 1996; Fulkerson *et al.* 1999) and Rhodes grass (*Chloris gayana* Kunth; Pembleton *et al.* 2009). This plant-based indicator has been promoted within the dairy industry as a tool for producers to use to determine the optimum time for grazing.

Leaf number has been used to determine the optimum time for grazing and could also be applied to dryland pastures. Tropical grasses are favoured pastures in the summer dominant rainfall zone because of their high productivity and persistence (Boschma *et al.* 2015, 2017). However, they are commonly underutilised (Boschma *et al.* 2014; Harris *et al.* 2014). This particularly occurs following periods of significant summer rainfall when growth rates are highest. This issue is complex and many factors need to be considered. Factors include paddock size, stock availability and highly variable production (e.g. Wilson and Minson 1980; Boschma *et al.* 2014; Harris *et al.* 2014). However, there is a lack of knowledge of the interaction between growth stages and nutritive value of tropical grass species that are commonly grown in dryland pastures. This information could also be useful to understand the optimum time to cut tropical grass pastures for fodder conservation. The aim of this study was to quantify tiller development and the associated nutritive value of a number of tropical perennial grasses used in dryland tropical grass pastures.

Materials and methods

An experiment was conducted between November 2012 and May 2013 in a temperature-controlled glasshouse at the University of New England, Armidale (30.487°S, 151.637°E), Australia. The glasshouse was initially set at 25/20°C day (0600–1800 hr)/night (1800–0600 hr) and increased to 28/22°C day/night on 19 February 2013 for the balance of experiment.

In November 2012, 10 seeds of four tropical grass species were sown into pots (20 cm diameter, 20 cm deep) filled with a potting mixture of sand and peat (2:1 ratio). The grasses were digit grass (*Digitaria eriantha* Steud.) cv. Premier, Makarikari grass (*Panicum coloratum* L. var. *makarikariense*) cv. Bambatsi, Rhodes grass (*Chloris gayana* Kunth) cv. Katambora, and panic grass (*Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs) cv. Gatton. The pots were free draining and watered manually twice a day until emergence, then twice daily using an automatic irrigation system for the remainder of the experiment. Plants were thinned to 4 plants/pot on 30 November 2012 and further thinned to 2 plants/pot on 7 January 2013. All pots were fertilised with urea (46% N at 72.5 kg/ha), potassium phosphate (52% K, 34% P at 75 kg/ha) and potassium sulphate (41% K, 18% S at 34 kg/ha) on 8 January 2013. Urea (124 kg N/ha) was applied weekly from 1 April 2013 and further applications of the same rates of potassium phosphate and potassium sulphate as previously were applied on 1 April and 20 May 2013. The plants in pots were cut to about 5 cm on 18 January 2013.

The experiment commenced on 1 April 2013. We used a split-plot design with species as the main plot and growth stage harvest times as subplots, with three replicates. Growth stage harvest times were based on the number of emerged leaves produced per tiller: 2-leaf, 4-leaf, 6-leaf and stem elongation (presence of a node on the stem). Twelve pots of each species were selected and plants cut to 5 cm above the soil surface (except for panic grass, which was cut just below the first node which varied in height for each tiller). In total the experiment comprised 48 pots and concluded 27 May 2013.

Tillers of each species were inspected daily and the number of emerged leaves counted to determine if they were ready to harvest based on the average number of leaves per tiller. When the majority of inspected tillers of all plants of a species within a treatment had reached the designated leaf stage, the date was recorded and all replicates of that species and treatment were harvested (i.e. three pots). Plants in each pot were cut to 5 cm and the harvested material dried at 60°C for 48 hours. The dried samples were weighed (g/pot) then ground through a 2 mm sieve and stored in airtight plastic containers. The samples were analysed for neutral detergent fibre (NDF, %), acid detergent fibre (ADF, %), crude protein (CP, %), and metabolisable energy (MJ/kg DM). Herbage samples from replicates of the 2- and 4-leaf growth stages were too small for analysis and the three replicates were bulked.

Biomass data were analysed by analysis of variance using RStudio, version 0.97.551 (RStudio Inc. 2009–2012). Replicate samples for the 2 and 4-leaf growth stage samples were combined so analyses could not be conducted, therefore means are presented for these treatments.

Results

The average number of days for each species to progress through the growth stages to stem elongation varied, as did the rate that they accumulated biomass (Table 1). Makarikari grass tillers developed the fastest, reaching stem elongation in 38 days. Significant biomass accumulation occurred in the last 14 days when the tiller growth stage progressed from 6-leaf to stem elongation ($P < 0.05$). Digit grass tillers were the slowest to develop (52 days). Also, digit grass had significant biomass accumulation through each growth stage then plateauing from 6-leaf to stem elongation. Panic grass also plateaued from 6-leaf to stem elongation. The tiller development of Rhodes grass was intermediate to Makarikari and digit grass taking an average of 43 days to reach stem elongation. The biomass of Rhodes grass increased significantly at each growth stage from 4-leaf to stem elongation, achieving the highest biomass of the grasses at stem elongation ($P < 0.05$) (Table 1).

Crude protein concentration was highly responsive to tiller development, being highest at the 2-leaf growth stage. However crude protein declined as the tillers developed to be lowest at stem elongation (Fig. 1). Rhodes grass showed the greatest changes, declining sharply from 32 to 23% between the 2- and 4-leaf growth stages and further to 16.5% at stem elongation. In contrast, Makarikari grass had the smallest decline (27 to 17%) which was almost evenly distributed across the four growth stages observed. All grasses had similar crude protein levels at stem elongation. Metabolisable energy also declined with tiller development, but the changes were not as large. Most grasses had an average of 11.0 MJ/kg DM at the 2-leaf growth stage and declined to 7.9 MJ/kg DM at stem elongation (Fig. 1). Panic grass was the exception; it had the highest metabolisable energy at the 2-leaf growth stage and declined to a similar level as the other grasses at stem elongation. Acid detergent fibre and NDF concentration of all grasses tended to be lowest at the 2-leaf growth stage and increased as the tillers developed to stem elongation (Fig. 1).

Discussion

It is well reported that as grasses mature, herbage production increases while both digestibility and crude protein content decline (e.g. Wilson 1976; Wilson and Minson 1980; Pembleton *et al.* 2009). These changes result in selective grazing (Wilson and Minson 1980) and a decline in voluntary intake (Minson *et al.* 1993). This inverse relationship between herbage production and its nutritive value means that the optimum time to graze is a compromise of the two. Grazing management techniques based on growth stage to determine the optimum time of grazing can assist optimising livestock production by maximising nutritive value without compromising biomass production and pasture persistence. Field studies have determined the optimal time to graze kikuyu pasture is at the 4.5-leaf stage (Reeves and Fulkerson 1996; Reeves *et al.* 1996) which is a compromise between forage quantity and nutritive value. In kikuyu at growth stages later than 4.5 leaves/tiller, digestibility and crude protein levels declined associated with a declining leaf-stem ratio, and increasing dead material due to leaf senescence (Fulkerson *et al.* 1999). Similarly, for Rhodes grass (cv. Callide), the proportion of stem in the herbage increased when 4 leaves/tiller were present. The crude protein of the leaf fraction also decreased

Table 1. Average time (number of days regrowth), acid detergent fibre (%) and neutral detergent fibre (%) of tropical grasses at 2-leaf, 4-leaf, 6-leaf and stem elongation (SE) growth stages.

	Time (days)				Acid detergent fibre (%)				Neutral detergent fibre (%)			
Grass species	2-leaf	4-leaf	6-leaf	SE	2-leaf	4-leaf	6-leaf	SE	2-leaf	4-leaf	6-leaf	SE
Makarikari grass	5	13	24	38	28	27	30	34	61	61	59	67
Rhodes grass	5	19	24	43	29	35	37	40	56	67	68	72
Panic grass	7	17	30	40	21	26	35	37	47	61	63	73
Digit grass	5	21	34	52	33	35	35	38	68	70	67	71

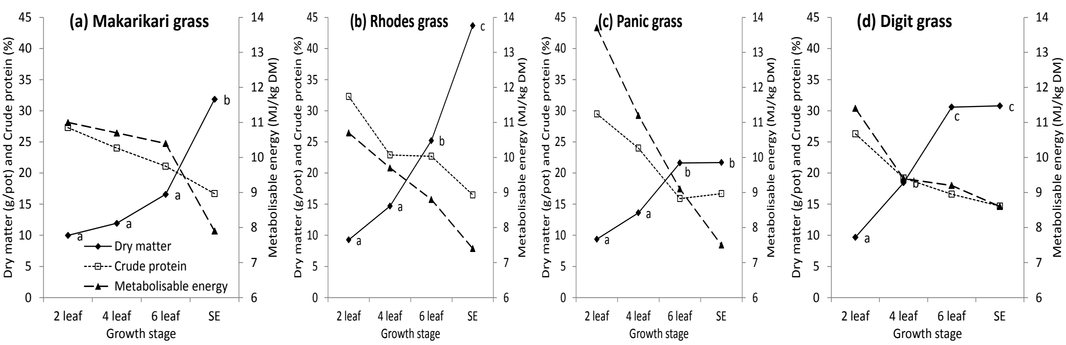

Figure 1. Biomass (dry matter, g/pot), crude protein (%) and metabolisable energy (MJ/kg DM) content of (a) Makarikari grass, (b) Rhodes grass, (c) panic grass and (d) digit grass at different growth stages. Biomass production values marked with the same letter within a grass species are similar (P = 0.05).

as the tiller matured. The greatest decline was observed between the 4- and 6-leaf harvest stages (Pembleton *et al.* 2009).

The principle of matching good nutritive value, primarily metabolisable energy, with good biomass can be applied to the grasses in this study. For good animal production, the grasses would need to be grazed at the 4-leaf (Rhodes grass and digit grass) or 6-leaf growth stage (Makarikari grass and panic grass) to achieve minimum metabolisable energy of 10 MJ/kg DM. Delaying grazing until the average tiller development was at stem elongation would result in metabolisable energy values <7.5 MJ ME/kg DM. This lower level is only suitable for maintenance. This 4- to 6-leaf growth stage target for grazing is consistent with previous studies (Reeves and Fulkerson 1996; Reeves *et al.* 1996; Pembleton *et al.* 2009). These growth stages are also relevant for fodder conservation. Tropical grasses can produce silage of medium forage value (i.e. metabolisable energy of 9–10 MJ/kg DM) (Kaiser *et al.* 2004). Extensive research has been conducted on silage production of kikuyu and is summarised in the Topfodder Successful Silage manual (Kaiser *et al.* 2004).

High rates of N were applied to this experiment and were reflected in the high crude protein values. This response in crude protein to increasing N application is well reported (Pembleton *et al.* 2009; Boschma *et al.* 2017), along with a positive, although small response in metabolisable energy. In a field study, average crude protein of tropical grasses (digit grass and Rhodes grass) fertilised with 300 kg N/ha increased by 12 percentage-units (11 to 23%) compared to the unfertilised grasses. Metabolisable energy also increased significantly, but only from 8.0 to 9.5 MJ/kg DM (Boschma *et al.* 2017).

Many actively growing fertilised tropical grasses will flower within six weeks of grazing/cutting in the field in northern inland NSW (S Boschma pers. comm.). This is a shorter timeframe than the regrowth of the grasses in this study. This delayed development could be due to a combination of rapidly shortening day length in April–May and cloudy days at the time of the experiment.

This glasshouse study has demonstrated that there is variation in tiller development and nutritive value between tropical grass species. Leaf number has potential to be used as a plant-based indicator to determine the optimum time to graze or cut pastures for hay or silage making. But one size does not fit all grazing strategies. To ensure both good metabolisable energy and biomass production Rhodes grass and digit grass pastures need to be grazed or cut when tillers are at the 4-leaf growth stage. Makarikari grass and panic grass can be cut or grazed slightly later at the 6-leaf growth stage. Field testing is required to confirm these results and assess the practicalities of harvesting short pastures.

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References

Boschma SP, Murphy SR, Harden S (2015) Herbage production and persistence of two tropical perennial grasses and forage sorghum under different fertilisation and defoliation regimes in a summer dominant rainfall environment, Australia. *Grass and Forage Science* **70**, 381–393.

Boschma SP, Murphy SR, Harris CA (2014) Managing nutrition and utilisation of tropical perennial grass pastures. In 'Proceedings of the 28th annual conference of the Grassland Society of NSW'. (Ed CA Harris). pp. 24–31. (Grassland Society of NSW Inc.: Orange)

Boschma SP, Murphy SR, Harden S (2017) Growth rate and nutritive value of sown tropical perennial grasses in a variable summer-dominant rainfall environment, Australia. *Grass and Forage Science* **72**, 234–247.

Fulkerson W, Donaghy D (2001) Plant-soluble carbohydrate reserves and senescence-key criteria for developing an effective grazing management system for ryegrass-based pastures: a review. *Animal Production Science* **41**, 261–275.

Fulkerson W, Slack K (1994). Leaf number as a criterion for determining defoliation time for *Lolium perenne*. 1. Effect of water-soluble carbohydrates and senescence. *Grass and Forage Science* **49**, 373–377.

Fulkerson W, Slack K, Havilah E (1999) The effect of defoliation interval and height on growth and herbage quality of kikuyu grass (*Pennisetum clandestinum*). *Tropical Grasslands* **33**, 138–145.

Harris CA, Boschma SP, Murphy SR, McCormick LH (2014) Tropical Perennial Grasses for Northern Inland NSW – Second Edition. (Future Farm Industries Cooperative Research Centre: Perth)

Kaiser AG, Piltz JW, Burns HM, Griffiths NW (2004) Topfodder Successful Silage 2nd Edition (Dairy Australia and NSW Department of Primary Industries: Orange)

Minson D, Cowan T, Havilah E (1993) Northern dairy feedbase 2001. 1. Summer Pasture and crops. *Tropical Grasslands* **27**, 131–149.

Pembleton K, Lowe K, Bahnisch L (2009) Utilising leaf number as an indicator for defoliation to restrict stem growth in rhodes grass (*Chloris gayana*) cv. Callide. *Tropical Grasslands* **43**, 79.

Rawnsley R, Donaghy D, Fulkerson W, Lane P (2002). Changes in the physiology and feed quality of cocksfoot (*Dactylis glomerata* L.) during regrowth. *Grass and Forage Science* **57**, 203–211.

Reeves M, Fulkerson W (1996) Establishment of an optimal grazing time of Kikuyu pastures for dairy cows. In 'Proceedings of the 8th Australian Agronomy Conference, Toowoomba, Queensland, Australia, Toowoomba. pp. 470–473.

Reeves M, Fulkerson W, Kellaway R (1996) Forage quality of kikuyu (*Pennisetum clandestinum*): the effect of time of defoliation and nitrogen fertiliser application and in comparison with perennial ryegrass (*Lolium perenne*). *Crop & Pasture Science* **47**, 1349–1359.

Turner L, Donaghy D, Lane P, Rawnsley R (2006a) Effect of defoliation management, based on leaf stage, on perennial ryegrass (*Lolium perenne* L.), prairie grass (*Bromus willdenowii* Kunth.) and cocksfoot (*Dactylis glomerata* L.) under dryland conditions. 1. Regrowth, tillering and water-soluble carbohydrate concentration. *Grass and Forage Science* **61**, 164–174.

Turner L, Donaghy D, Lane P, Rawnsley R (2006b) Effect of defoliation management, based on leaf stage, on perennial ryegrass (*Lolium perenne* L.), prairie grass (*Bromus willdenowii* Kunth.) and cocksfoot (*Dactylis glomerata* L.) under dryland conditions. 2. Nutritive value. *Grass and forage science* **61**, 175–181.

Wilson J (1976) Variation of leaf characteristics with level of insertion on a grass tiller. I. Development rate, chemical composition and dry matter digestibility. *Crop & Pasture Science* **27**, 343–354.

Wilson J, Minson D (1980). Prospects for improving the digestibility and intake of tropical grasses. *Tropical Grasslands* **14**, 253–259.