Seasonal Patterns of Herbage Accumulation Dynamics in Marandu Palisadegrass Subjected to Intensities of Continuous Stocking Management

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Seasonal patterns of herbage accumulation dynamics in marandu palisadegrass subjected to intensities of continuous stocking management

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Key words: *Brachiaria brizantha*; grassland ecophysiology; forage production; tissue flow; warm-season grasses; abiotic stress.

Abstract

It is relatively well reported in the literature that pastures can have similar forage net accumulation when managed with contrasting structures. However, we hypothesized that the patterns of forage accumulation dynamics of pastures managed at different canopy heights is dependent on environmental conditions. The experimental treatments were four canopy heights (10, 20, 30, and 40 cm), allocated to experimental units according to a randomized complete block design with four replicates and evaluated throughout four contrasting environmental seasons (Summer, Autumn, Winter-Early Spring, and Late Spring). Under favourable growing conditions greater forage accumulation was observed in pastures maintained taller; on the contrary, under more stressful conditions, net forage accumulation rate reduced as canopy height increased. Such patterns of responses were related to compensations between tiller population density and tissue flows during summer and late spring and the reduced capacity of taller canopies to compensate lower population with greater growth rates during autumn and winter-early spring. Pastures subjected to intensities of continuous stocking management change their patterns of forage growth as they transitioned from favourable to more abiotic stressful conditions suggesting that warm-season perennial grasses demand seasonal adjustments in grazing heights in order to maximize herbage production.

Introduction

It is relatively well reported in the literature that pastures can have similar forage net accumulation when managed with contrasting structures (e.g., forage mass, leaf area index [LAI], and canopy height; Bircham and Hodgson, 1983; Parsons et al., 1988; Sbrissia et al., 2018). This variation is due to a "homeostatic" mechanism that operates in the plant population, which is capable of maximizing forage production with different structures by adjusting the size and number of tillers (Bircham and Hodgson, 1983; Matthew et al., 1995). Thus, taller canopies maintain fewer larger tillers that have greater growth rates compared to shorter canopies, which maximize their production through a greater number of smaller tillers (Berone et al., 2007; Sbrissia et al., 2018).

According to Lemaire and Chapman (1996), the formation and expansion of plant tissues determine their morphogenesis, which is responsible for the shape of plants in space and, consequently, for the structure of the pasture canopy. According to the same authors, the dynamics of the processes involved in morphogenesis depend on environmental conditions (e.g., temperature, water, and nutrients). In this sense, in situations where plants are subjected to some level of stress (for definition of stress, please see Grime, 1977) the rates of morphogenetic processes and pasture's tillering dynamics are reduced (Assuero and Tognetti, 2010; Sbrissia et al., 2010; Barbosa et al., 2011). Thus, it is reasonable to suppose that in pastures formed with more exploitative species or maintained at a specific/optimum LAI, losses in net forage production due to stress would be greater. This is because, in such scenarios, plant demand for necessary resources to maintain plant population (Duchini et al., 2018) and photosynthetic apparatus (Parsons and Penning, 1988) is greater, such that the more stressful the conditions under which the population is subjected the less will be its ability to express its maximum growth potential.

Against that background, marandu palisadegrass , cultivated in an area with a long-term history of variable resource availability, was managed under continuous stocking at four canopy heights (10, 20, 30, and 40 cm) during four seasons of the year to test the central hypothesis that the growth pattern of pastures managed under continuous stocking at different canopy heights is dependent on environmental conditions. In this sense, under favorable environmental conditions to growth, taller pastures (i.e., greater canopy heights, herbage mass, and LAI) maximize yield potential by optimizing resource use and under stressful conditions shorter pastures can sustain greater yields by maintaining greater tiller population density.

Methods and Study Site

A year-round experiment (from January 8th 2002 to December 17th 2002) was conducted at "Luiz de Queiroz" College of Agriculture, University of São Paulo (USP-ESALQ), Piracicaba, SP, Brazil (22°42'S, 47°37'W and 550 m a.s.l.), on a well-established marandu palisadegrass pasture(*Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf. cv Marandu). According to the Köppen climate classification, the local climate is humid sub-tropical with dry winters and hot summers (Cwa; Alvares et al., 2013). Weather data are presented in Table 1. Treatments corresponded to four grazing heights (10, 20, 30, and 40 cm) maintained through continuous stocking and variable stocking rate by cattle. These were allocated to experimental units (1200-m^2 plots) according to a randomized complete block design with four blocks. Grazing heights were monitored on undisturbed plants twice a week (3 and 4 day-intervals) on 20 points per plot using a thin acetate sheet and ruler. Average grazing heights were allowed to vary 10% around the target, with animals being added or removed from plots when grazing height was close to the upper or lower end of the range, respectively.

Table 1 Average monthly rainfall, minimum and maximum temperatures, and radiation throughout the experimental period in Piracicaba, SP, Brazil.

Month	Rainfall (mm)	Minimum (ºC)	Maximum (ºC)	Radiation (cal cm^{-2} d)
		2001		
November	152.4	18.7	30.7	466.0
December	204.2	18.7	29.2	427.0
		2002		
January	320.2	19.3	29.8	409.9
February	187.9	18.8	29.0	404.1
March	272.4	19.5	32.0	462.0
April	27.2	17.6	31.8	393.0
May	112.4	14.5	26.9	298.0
June	0.0	12.6	27.9	307.4
July	23.4	10.2	25.2	267.0
August	79.6	14.3	28.9	316.8
September	45.6	13.6	27.5	340.0
October	49.4	18.8	33.8	430.7
November	176.4	18.8	30.6	432.2
December	164.7	19.7	31.1	460.7

Rates of forage gross accumulation (Gross FAR, kg DM ha^{-1} d), senescence (SR, kg DM ha^{-1} d), and forage net accumulation (Net FAR, kg DM ha^{-1} d) were estimated in marked tillers by using tissue flow technique (Davies, 1993). To this end, a set of three 2-m transects containing 30 tillers was selected every month per plot in areas considered to represent the average canopy condition (based on visual assessment of height and mass). These transects were identified at their extremities with 20-cm height wooden stakes and the tillers were tagged every 20 cm at their base with coloured plastic rings. The tillers were assessed at different intervals depending on climatic/growth conditions (3-6 days between January-April, 9-10 days between May-October, and 7 days between November-December). It was necessary to convert both elongation and senescence rates calculated in centimetres per tiller (cm $tiller^{-1}$ day) to kilogram per hectare (kg DM ha^{-1}). Thus, all marked tillers were collected on the last day of each evaluation period, separated into plant-part components (leaves, stems, and senescent material), measured, dried at 60°C for 48 hours, and weighted to calculate specific weights (g cm^{-1}). The tiller population density (TPD) was determined by counting tillers within 0.25 m^2 (1.0 x 0.25 m) metallic frames placed in three representative areas per plot (based on visual assessment of canopy height and forage mass). From these data, Gross FAR, SR, and Net FAR were calculated as follows:

$$\text{Gross FAR} = [(\text{LER} \times \text{swLB}) + (\text{SER} \times \text{swS})] \times \text{TPD} \times 10$$

$$\text{SR} = [(\text{LSR} \times (\text{swLB} - \text{swSM})] \times \text{TPD} \times 10$$

$$\text{Net FAR} = \{[(\text{LER} \times \text{swLB}) + (\text{SER} \times \text{swS})] - [\text{LSR} \times (\text{swLB} - \text{swSM})]\} \times \text{TPD} \times 10$$

where swLB, swS, and swSM are the specific weight (g cm^{-1}) of leaf blades, stems, and senescent material, respectively; and 10 is a unit conversion factor from grams DM per square meter to kilograms DM per hectare.

Data were collected monthly, but results were pooled into seasons of the year (summer: January to March; autumn: April to June; winter/early spring: July to October and late spring: November and December). Seasons were defined in such a way that patterns of herbage accumulation were similar within and contrasting among seasons. Analysis of variance was carried out on the grouped data using the Mixed Procedure of SAS® (SAS Inst., Cary, NC, USA) and the restricted maximum likelihood (REML) method. Data were analyzed as repeated measures. The model used considered canopy height, blocks, and season of the year as variation sources. The choice of the variance-covariance matrix was made using the Akaike Information Criterion (AIC) (Wolfinger, 1993). The SLICE command was used in cases of significant interactions and, when appropriate, means were calculated using the 'LSMEANS' statement and comparisons made using the Student test at $P < 0.10$.

Results

There was a season × canopy height interaction for senescence (P=0.0964), gross (P=0.0099), and net (P<0.0001) forage accumulation rates. Overall, during summer and late spring, greater rates of forage accumulation (gross and net) and senescence were observed in pastures maintained at 30 and 40 cm (Figure 1). These observations were more pronounced during summer since, in late spring, senescence rates presented a positive linear increment with canopy heights, reducing forage net accumulation to a greater extent in pastures maintained at 30 and 40 cm. Conversely, during autumn and winter-early spring, similar rates of forage gross accumulation were observed, leading to a decrease in forage net accumulation rate as management canopy height increased because of greater senescence rates.

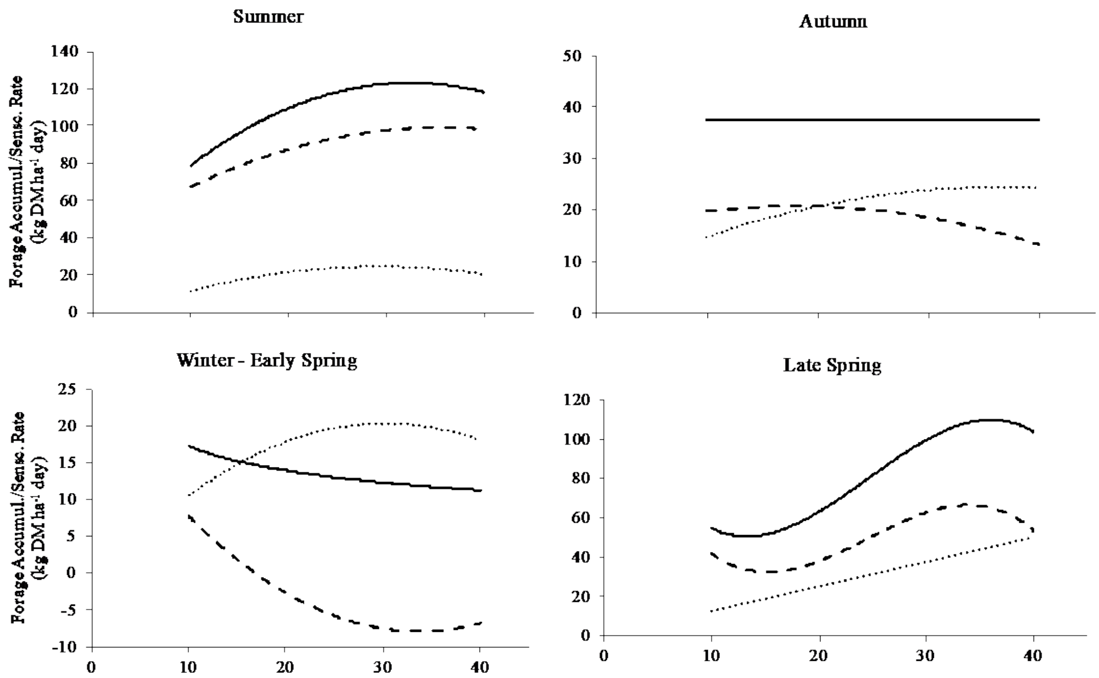

Figure 1 Forage gross (solid lines) and net accumulation rates (dashed lines) and senescence rates (dotted lines) during four periods of the year in Marandu palisade grass pastures submitted to grazing heights.

Discussion and Conclusion

Curves of forage accumulation (gross and net) and senescence showed distinct patterns among seasons (Figure 1). During summer, when environmental conditions are more favorable (Table 1) to growth of warm-season grasses, as marandu palisadegrass, growth patterns were similar to those described by Bircham and Hodgson (1983); thus, the homeostatic mechanisms (compensation between TPD and tissue flows) originally described by the authors with cool-season grasses seems to be also effective in maximizing forage production over a range of canopy heights for marandu palisadegrass. In autumn, pastures showed similar forage gross accumulation, and there was an increase in senescence rates; this indicates that both less favorable environmental conditions and lower photosynthesis capacity (by aging effects) reduced the capacity of taller canopies to compensate lower TPD with greater growth rates of individual tillers (TPD and tillers traits data can be found in Sbrissia et al., 2020). Under these conditions, maintaining large TPD becomes an important factor for maintaining greater growth rates (gross and net). This dependence was reinforced during winter-early spring since pastures managed at 10 and 20 cm had greater TPD and growth rates than those managed at

30 and 40 cm. In late spring, when water supply and temperature were becoming more favorable (Table 1), there was an increase in growth rates and the reestablishment of the pattern of homeostatic mechanisms as already described by Bircham and Hodgson (1983). Therefore, our results suggest that adequate supplies of growth factors are needed for homeostatic mechanisms and management flexibility to occur.

We conclude that the herbage accumulation dynamics in pastures subjected to intensities of continuous stocking management is linked to environmental conditions suggesting that warm-season perennial grasses demand seasonal adjustments in grazing heights in order to maximize herbage production. In this sense, the net forage accumulation rate can be maximized during the growing season (late spring and summer) by taller canopy heights. This would favor growth of individual tillers by optimizing resources acquisition and utilization. Moreover, because marandu palisadegrass prioritizes resource conservation during less favorable periods, canopy heights could be lowered by grazing. This would avoid forage losses by senescence and stimulates tiller turnover from the beginning of the upcoming growing season. However, caution is necessary since canopy heights lower than 15 cm seem to be detrimental to marandu palisadegrass persistence (Euclides et al., 2019). Therefore, maximization of forage production in marandu palisadegrass under continuous stocking can be obtained by varying canopy height throughout the year; 30-40 cm during late spring and summer and 15-20 cm during autumn, winter, and early spring.

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