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Research Paper

Seasonal herbage accumulation, plant-part composition and nutritive value of signal grass (*Urochloa decumbens*) pastures under simulated continuous stocking

Acumulación estacional de forraje, composición morfológica y valor nutritivo de Urochloa decumbens *bajo pastoreo continuo simulado*

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Abstract

In order to optimize the regrowth and harvest of signal grass (*Urochloa decumbens*) cv. Basilisk pastures it is necessary to establish more precise grazing management guidelines. The objective of this study was to evaluate herbage accumulation, plant-part composition and nutritive value of signal grass managed under contrasting levels of steady-state canopy heights. Treatments included 3 canopy height targets, i.e. 10 (S-short), 17.5 (M-medium) and 25 cm (T-tall), in a completely randomized design with 4 replications. Experimental units were 144-m^2 plots which were grazed by groups of steers for short periods in an endeavor to keep canopy heights at the 3 desired targets. On average, herbage accumulation rate (HAR) in T pastures was greater than in M and S pastures, including the dry-wet season transition period in spring (September–November). The S pastures had higher crude protein and lower acid detergent fiber concentrations than M and T pastures, especially in the first half of the calendar year. However, in vitro organic matter digestibility was similar for all treatments (612 g/kg). As S and M pastures had lower HARs than T pastures in the spring, it appears advantageous to maintain the signal grass canopy at ~25 cm in order to ensure quick regrowth with the return of the wet season. However, longer-term studies are needed with recording of animal performance before these initial findings can be promoted widely.

Keywords: Crude protein, digestibility, grazing management, light interception, pasture height, tropical pastures.

Resumen

Para optimizar la producción de pasturas de *Urochloa* spp. es necesario establecer pautas de manejo del pastoreo más precisas. En Brotas, Estado de São Paulo, Brasil, se evaluaron la acumulación de forraje, la morfología de planta y el valor nutritivo de *Urochloa decumbens* cv. Basilisk en función de diferentes alturas de planta. Los tratamientos incluyeron 3 alturas del pasto: 10 cm (S - baja), 17.5 cm (M - mediana) y 25 cm (T - alta), en un diseño completamente al azar con 4 repeticiones en parcelas de 144 m^2 que fueron utilizadas por grupos de novillos durante períodos cortos con el fin de mantener las alturas de planta de acuerdo con los tratamientos. En promedio, la tasa de acumulación de forraje (TAF) en las pasturas del tratamiento T fue mayor que en las pasturas en los tratamientos M y S, incluyendo el período de transición de estación seca a lluviosa en la primavera (septiembre–noviembre). Las pasturas en el tratamiento S presentaron mayores concentraciones de proteína cruda y menores concentraciones de fibra detergente ácido que las pasturas en M y T, especialmente en el primer semestre del año calendario. Sin embargo, la digestibilidad in vitro de la materia orgánica fue similar para todos los tratamientos (612 g/kg). Las pasturas en los tratamientos S y M presentaron

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TAF más bajas en la primavera que las pasturas en T, lo que sugiere que mantener una altura de pastura de ~25 cm sobre el nivel del suelo permite un rápido crecimiento al comienzo de la época de lluvias. Sin embargo, se necesitan estudios de producción animal a largo plazo antes de que estos resultados iniciales puedan promoverse en forma amplia.

Palabras clave: Altura de pastura, digestibilidad, intercepción de luz, manejo de pastoreo, pastos tropicales, proteína cruda.

Introduction

Signal grass [*Urochloa decumbens* (Stapf) R.D. Webster, syn. *Brachiaria decumbens* Stapf] cv. Basilisk is a decumbent perennial tropical grass, that despite being susceptible to spittlebug (*Deois* spp. and *Zulia* spp.) is widely used in forage-livestock systems in central Brazil, owing to its great tolerance to acidic and infertile soils (Rao et al. 1996). With the increasing competition for land associated with expansion of cropping areas, i.e. maize (*Zea mays*), soybean (*Glycine max*) and sugarcane (*Saccharum officinarum*), pastures must be more productive and sustainable; improvement of grazing management is required to achieve this objective.

Plant growth and harvest efficiency in grazed pastures are closely related to canopy structure (Bircham and Hodgson 1983). The presence of photosynthetically active leaves supports fast regrowth, eventually followed by stem elongation, a process triggered by the complete or near-complete interception of light by the forage canopy (maximum leaf area index, LAI) (Korte et al. 1982). For tropical grasses, excessive elongation of stem has a negative effect on pasture utilization (Hodgson and Silva 2002) due to increasing proportion of rejected patches and plant lodging. Grazing management, based on the maintenance of specific canopy structure by controlling LAI, canopy height or herbage mass, may avoid excessive stem growth and allow more predictable levels of herbage accumulation and animal performance (Silva et al. 2013). In addition, plant-part composition is an important variable for cattle nutrition, as animals can select a higher quality diet from a leafy pasture than from one with lower leaf proportion. Canopy height ranges recommended for grazing management are associated with the canopy architecture, as well as the plant-part (leaf, stem and dead material) accumulation dynamics under grazing. For example, keeping canopy height of Marandu palisade grass (*Urochloa brizantha*) at 10 cm by heavy grazing intensity negatively affected herbage accumulation (Silva et al. 2013). For signal grass pastures, optimum canopy height seems to be around 15–25 cm under continuous stocking (Santos et al. 2013), with a pre-grazing target under rotational stocking of 18–30 cm (Pedreira et al. 2017).

Although some research-based recommendations regarding defoliation strategies for signal grass are available (Braga et al. 2009; Santos et al. 2010; Portela et al. 2011; Pedreira et al. 2017), a better comprehension of the effects of year-round grazing at steady-state (constant) canopy heights is still necessary rather than just average wet-season estimates. Forage growth in central Brazil is markedly seasonal, concentrated in the warm, wet months (November–April), and overgrazing during the dry season is common due to limited forage accumulation during this period. This raises the question of how canopy structure in the dry season affects plant regrowth at the onset of the following wet season. The objective of this study was to evaluate herbage accumulation, plant-part composition (leaf blade, stem and dead material) and nutritive value on a monthly basis in signal grass pastures managed under various steady-state canopy heights mimicking continuous stocking management.

Materials and Methods

Experimental site

The research was carried out at APTA (Agência Paulista de Tecnologia dos Agronegócios) in Brotas, State of São Paulo, Brazil (21°59′ S, 47°26′ W; 650 masl). The climate at the site is a subtropical Cwa, according to the Köppen-Geiger classification (Peel et al. 2007). The experimental area was a 25-years-old pasture of signal grass cv. Basilisk. The soil at the site is a Quartzipsamment with 9% clay, 33% fine sand, 57% coarse sand and 1% silt. Chemical analysis in the 0–20 cm layer showed 5 mg P/dm^3 (P_{resin}), 3 mmol$_c$ Ca/dm^3, 3 mmol$_c$ Mg/dm^3, 2 mmol$_c$ K/dm^3, 42 mmol$_c$ H+Al/dm^3, 22 g OM/dm^3, 16% base saturation and pH$_{(CaCl2)}$ 4.2. Rainfall data were recorded by the Department of Environment of the City of Brotas, and the maximum and minimum monthly average temperatures were recorded at a weather station 45 km from the experimental site (Figure 1).

Treatments, experimental design and grazing management

Treatments included 3 canopy height targets, 10 (S-short), 17.5 (M-medium) and 25 cm (T-tall), set in a completely randomized design with 4 replications. On 24 October

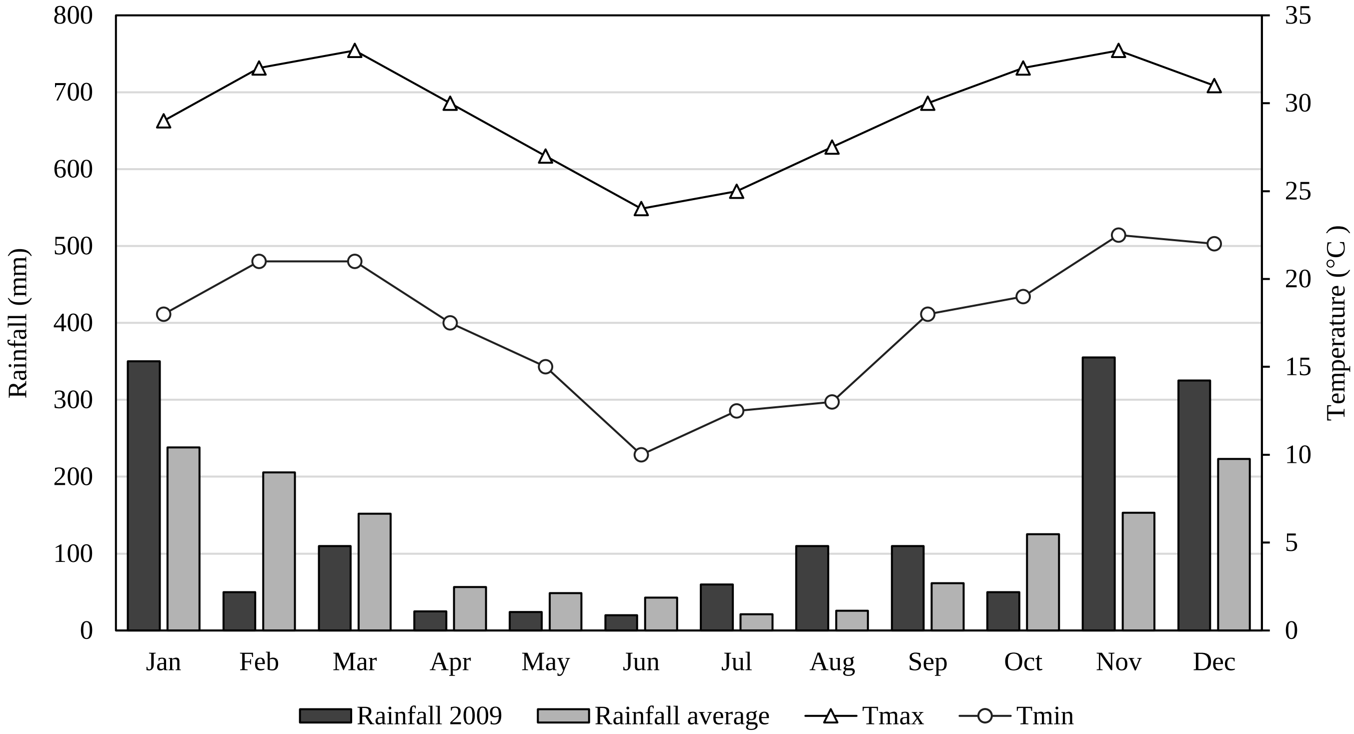

Figure 1. Monthly rainfall and temperatures during the experimental period (2009) and average long-term rainfall (1983–2006).

2008, the experimental area was mechanically clipped to reduce the canopy height to approximately 5 cm. In November 2008, dolomitic lime (0.98 t/ha) and single superphosphate (44 kg P/ha) were surface-applied to increase the base saturation to 40% and soil P to >15 mg/dm (P_{resin}), respectively. The area was divided by electric fence into 12 experimental plots measuring 144 m^2 (12 × 12 m) each. The experimental period was January 2009–January 2010. Mob stocking was used to impose defoliation on the experimental plots according to their respective treatments. Two crossbred steers, with mean live weight of 650 kg were used to graze each plot at each grazing event, always after overnight fast for solids. Defoliation mimicked continuous stocking, with animals assigned to pastures whenever canopy height was approximately 10% above target height. During the wet season, animals grazed pastures approximately once a week, while during the dry season the period between grazing events was 1–2 weeks. As paddocks were small, grazing events lasted for only 15 min to 2 h, and steers grazed non-experimental pastures when they were not grazing treatment pastures. Aiming not to decrease the height of pastures by more than 10% below the target, several visual observations and measurements of canopy height were made during grazing. Ammonium sulfate and potassium chloride were used to provide a total of 250 kg N + 210 kg K/ha during the course of the experiment. Fertilizers were split-applied in equal amounts on 24 December 2008, 7 February 2009, 10 March 2009, 4 May 2009 and 24 September 2009.

Measurements

Canopy height and herbage mass (HM) were evaluated using a rising plate meter (RPM). Periodic calibrations were necessary to correlate the RPM reading with canopy height and HM. The calibrations were made 6 times during the experimental period by selecting 2 sites (0.30 m^2) per plot, representing the extremes of height, i.e. the tallest and the shortest canopy areas. To measure canopy height a light-transparent acetate sheet (21 × 30 × 0.02 cm) was placed on top of the canopy and an RPM reading was taken. Herbage inside the quadrat (0.30 m^2) was then clipped at soil level (double sampling). The samples were dried in a forced-air oven for 72 h at 60 °C to estimate HM on a dry matter basis. Linear regression curves were established to estimate canopy height and HM as a function of the RPM readings. RPM readings were taken every 5 days in the wet season, and every 7 days in the dry season at 42 sites per plot in a systematic way following a grid-like pattern. All HM values were expressed on a dry matter basis and estimated from the RPM calibration derived from the double sampling sites. Light interception (LI) was evaluated monthly (except August) with an LAI-2000 canopy analyser (Li-COR, Lincoln, NE, USA) at 20 sites per plot, with a single reading above the canopy for every 5 readings near the base of the canopy.

Herbage accumulation rate (HAR) was estimated at 3 sites per plot which were protected from grazing using cylindrical exclusion cages (0.9 m diameter × 1.5 m in height) in 21-day cycles on average. Herbage accumulation inside the cages was estimated from RPM readings inside and outside the cages, and cages were repositioned at new sites in each plot for the following accumulation cycle. Herbage accumulation rate was estimated by the difference, as follows: HAR = ($HM_{last\ day}$ - $HM_{first\ day}$)/d, where $HM_{last\ day}$ = herbage mass inside the cages on the last day of exclusion, $HM_{first\ day}$ = herbage mass on the pasture on the first day of exclusion and d = number of days of the accumulation cycle. Tiller population density was measured every month at 3 random 0.2 × 0.5 m sites per plot inside a metal frame. Tillers were classified as basal, aerial or reproductive, allowing for the calculation of their participation on each evaluation date. Tillers were considered basal when originated from basal tissue buds, and aerial when originated from axillary buds of the main tiller. Tillers with visible inflorescence were classified as reproductive.

Forage samples were clipped monthly, except in August and September, at 3 sites per plot inside a 0.3 m^2 quadrat at soil level to evaluate plant-part composition. Sites that had been previously sampled were avoided in subsequent samplings. A subsample (~0.25 kg) was taken from each sample and separated into green leaf blades, green stems (true stems plus leaf sheaths) and dead material. Dead material was visually defined as senescent leaves and stems with >50% area of yellow or dry tissue. The samples were dried in a forced-air oven for 72 h at 60 °C to calculate the proportion of each plant-part component on a dry matter basis and then the amount of each based on HM estimates.

Forage nutritive value was estimated from hand-plucked samples taken monthly, except in September. The samples were collected from the top of the canopy after observation of the grazing behavior of the animals, and then dried in a forced-air oven for 72 h at 55 °C. They were then ground in a Wiley mill to pass a 1 mm screen and taken to the laboratory for chemical analyses. Ash concentration was determined by incineration at 600 °C. Crude protein (CP) concentration was calculated as N × 6.25, with N concentration determined using the Micro Kjeldahl method (AOAC 1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) concentrations were determined according to Van Soest et al. (1991). In vitro organic matter digestibility (IVOMD) was estimated according to the two-stage procedure of Tilley and Terry (1963) modified by Moore and Mott (1974).

Statistical analysis

Data were analyzed using the MIXED procedure of SAS (Littell et al. 2006) using an auto-regressive first order covariance model. Canopy height, period and their interactions were considered fixed effects, and period was analyzed as a repeated measure (Littell et al. 2006). Treatment means were estimated using LS means and compared using the probability of the difference (PDIFF) by t-test (5%). Rising plate meter calibration curves were analyzed for their need for sorting by date or canopy height treatments using the covariance analysis of PROC GLM in SAS (SAS Institute 2002).

Results

Canopy height and herbage mass

The calibration curves between RPM and canopy height did not differ across treatments and dates of calibration (P>0.05). Consequently, canopy height was monitored with RPM readings using a single calibration curve (Figure 2). For HM prediction there was no effect of treatment (P>0.05), but there was an effect of calibration date (P<0.05), so results for HM (including HAR estimates) used 2 calibration curves covering 2 periods (January–February and March–December) (Figure 2). The response was positive and linear, and models were adjusted satisfactorily, both for canopy height (R^2 = 0.96) and HM, for the first 2 calibration dates (R^2 = 0.88) and for the last 4 dates (R^2 = 0.92). Monitoring canopy height throughout the year revealed some variation around the target heights, especially for M and T treatments (Figure 3). Canopy heights of S pastures were maintained near the target of 10 cm throughout the year, whereas M and T pastures tended to exceed the target heights (17.5 and 25 cm, respectively) during the months of greater plant growth such as January–March and November–December. The opposite happened during the dry season (May–September), when canopy height decreased to 20–25 cm in T pastures.

There was a height × month interaction effect on HM (P = 0.0024), although T canopies always had greater HM throughout the experimental period (2,590–4,010 kg/ha) than M (1,810–3,040 kg/ha) and S pastures (1,070–1,660 kg/ha) with smaller differences between M and T pastures (~700 kg/ha) in the dry season (May–September) (Figure 4A), similar to canopy height variation. Leaf mass also showed a height × month interaction (P<0.0001). Early in the year (January–April), leaf mass followed the order T>M>S pastures (Figure 4B) but there was no canopy height effect between May and October (P>0.05), followed by a greater leaf mass on M pastures, especially

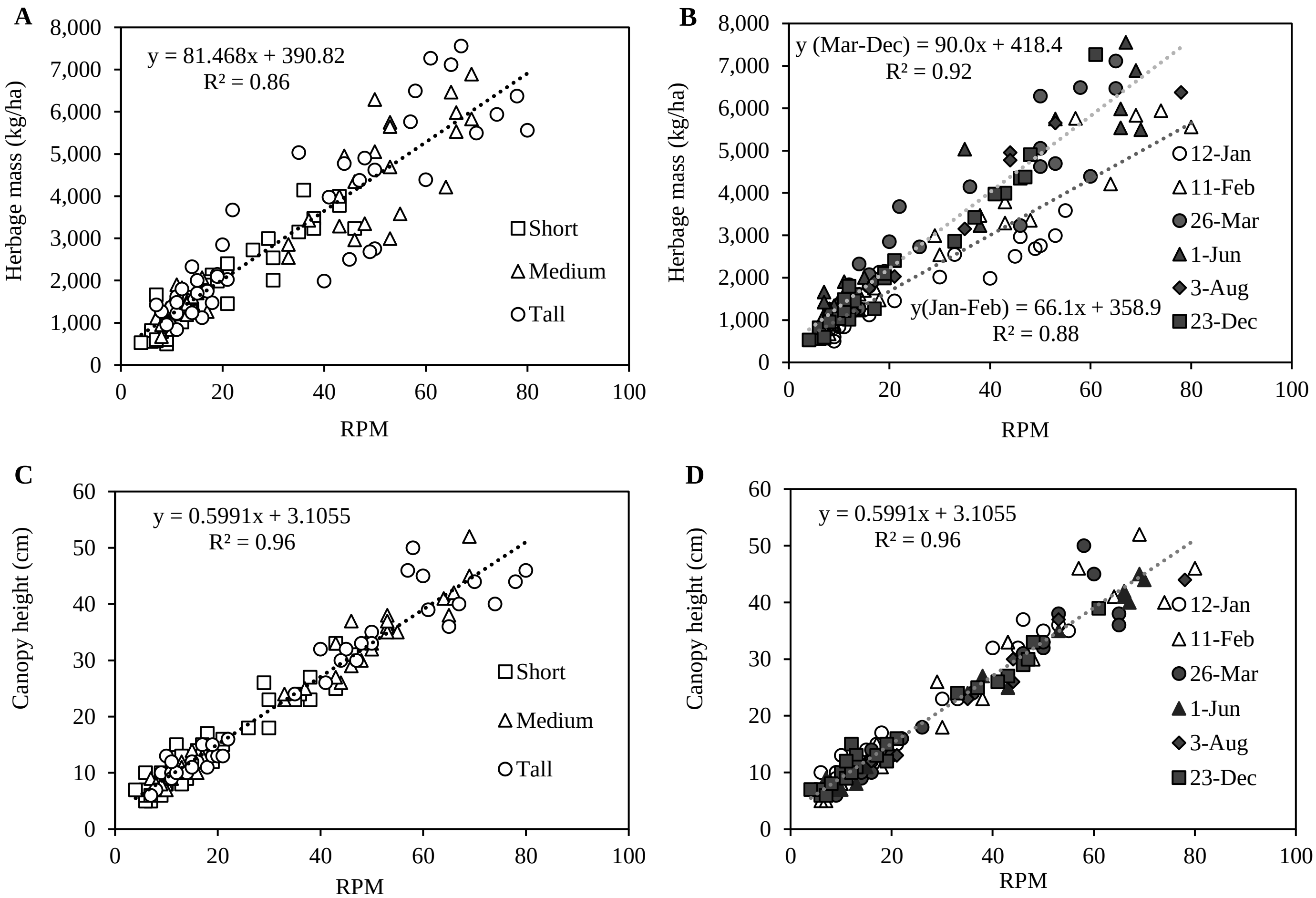

Figure 2. Prediction of herbage mass and canopy height as a function of rising plate meter (RPM) readings considering the effects of treatment (A and C) and date of calibration (B and D) in signal grass (*Urochloa decumbens*) cv. Basilisk pastures at 3 canopy heights in Brotas, SP, Brazil.

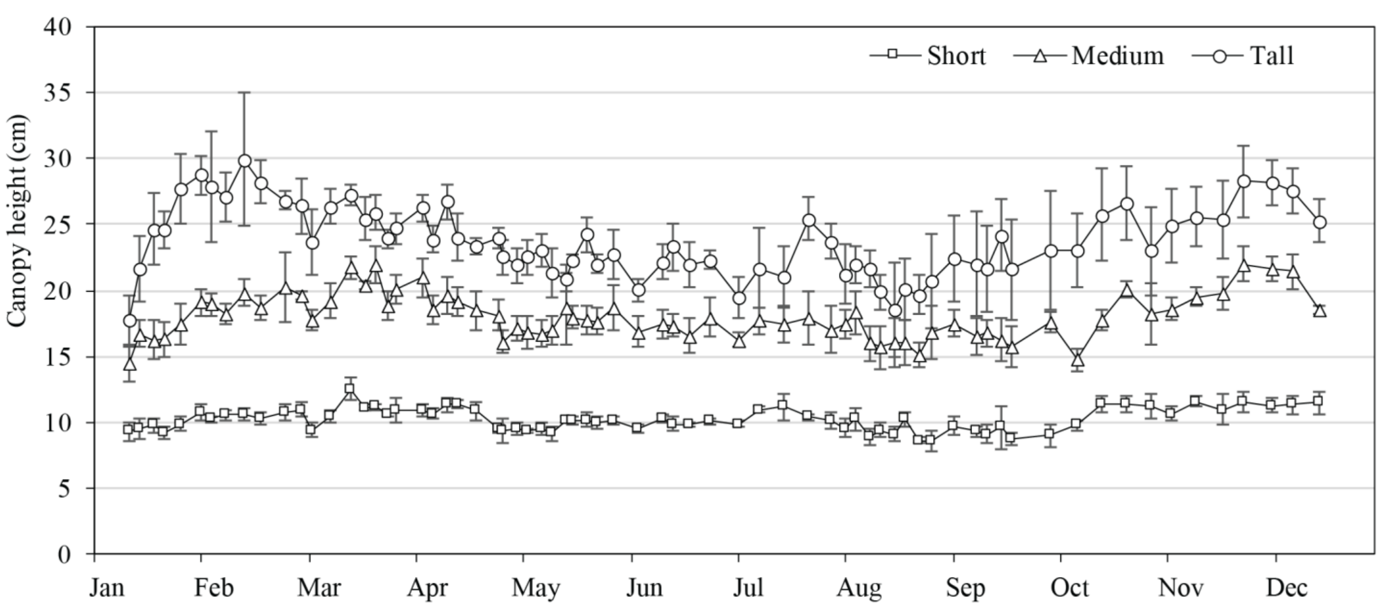

Figure 3. Actual canopy heights in signal grass (*Urochloa decumbens*) cv. Basilisk pastures while aiming at 3 target canopy heights (10 – short, 17.5 – medium and 25 – tall cm) in Brotas, SP, Brazil. Bars correspond to ± standard deviation.

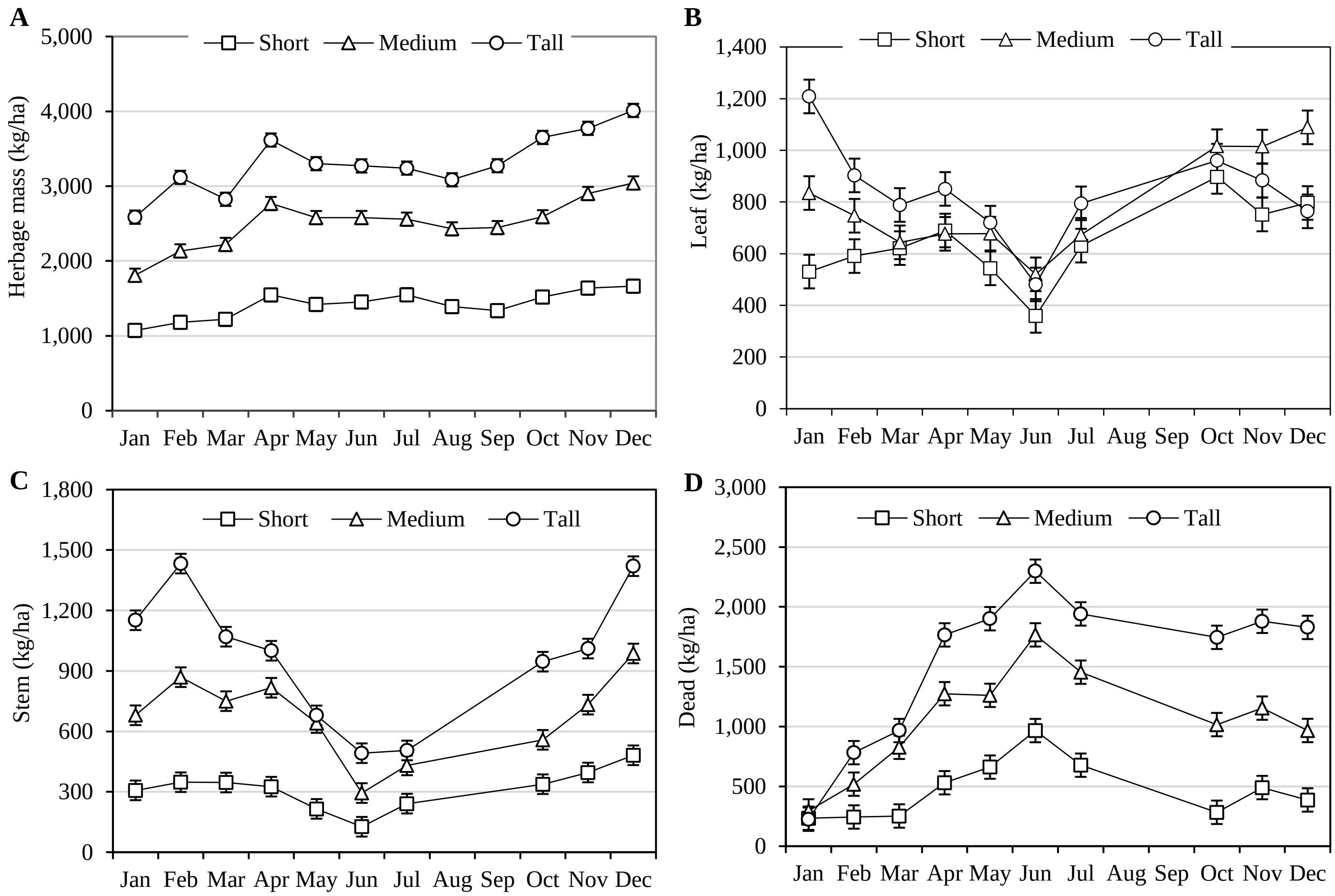

Figure 4. A) Herbage mass; B) leaf; C) stem; and D) dead material in signal grass (*Urochloa decumbens*) cv. Basilisk pastures maintained at 3 canopy heights in Brotas, SP, Brazil. Bars correspond to ± standard error of mean.

in December. A height × month interaction effect on stem mass ($P<0.0001$) was also observed. Tall pastures had the greatest stem mass, followed by M and S pastures (Figure 4C), with stem mass being greatest during January–April and October–December, especially in T and M pastures, but displaying much less variation in S pastures over the course of the year. Dead material mass displayed a height × month interaction ($P<0.0001$) but was greater in T pastures, followed by M and S pastures (Figure 4D). Mass of dead material increased during the first half of the year peaking in June, regardless of canopy height.

Herbage accumulation rate

Overall, HAR mirrored rainfall and temperature levels being high initially before dropping to near zero in May–June (Periods 4 and 5), then increasing to peak in December (Period 10) (Figure 5). Herbage accumulation rate was affected by a height × period interaction ($P = 0.0005$). In general, T pastures had greater HAR than M and S pastures, the advantage being most evident in Periods 2 and 3 (February–April) and Periods 8, 9 and 10 (September–December). During the dry season (May–August; Periods 4–7), there was no difference among treatments ($P>0.05$).

Tiller population density and light interception

Time of year was the only factor affecting total tiller population density ($P<0.0001$), and the increase in tiller numbers in February and March was largely an increase in aerial tillers (Figure 6). Aerial tiller numbers were affected by a height × month interaction ($P<0.0045$) as S pastures had fewer aerial tillers only in February and March (440 and 145 tillers/m^2, respectively) than M and T pastures (626 and 317 tillers/m^2, respectively). There were effects of month ($P<0.0001$) and height ($P = 0.0474$) on basal tiller population density as M pastures had more than T pastures (1,340 vs. 1,250 tillers/m^2, respectively). Reproductive tiller numbers displayed a height × month interaction ($P<0.0001$) and were present mainly between

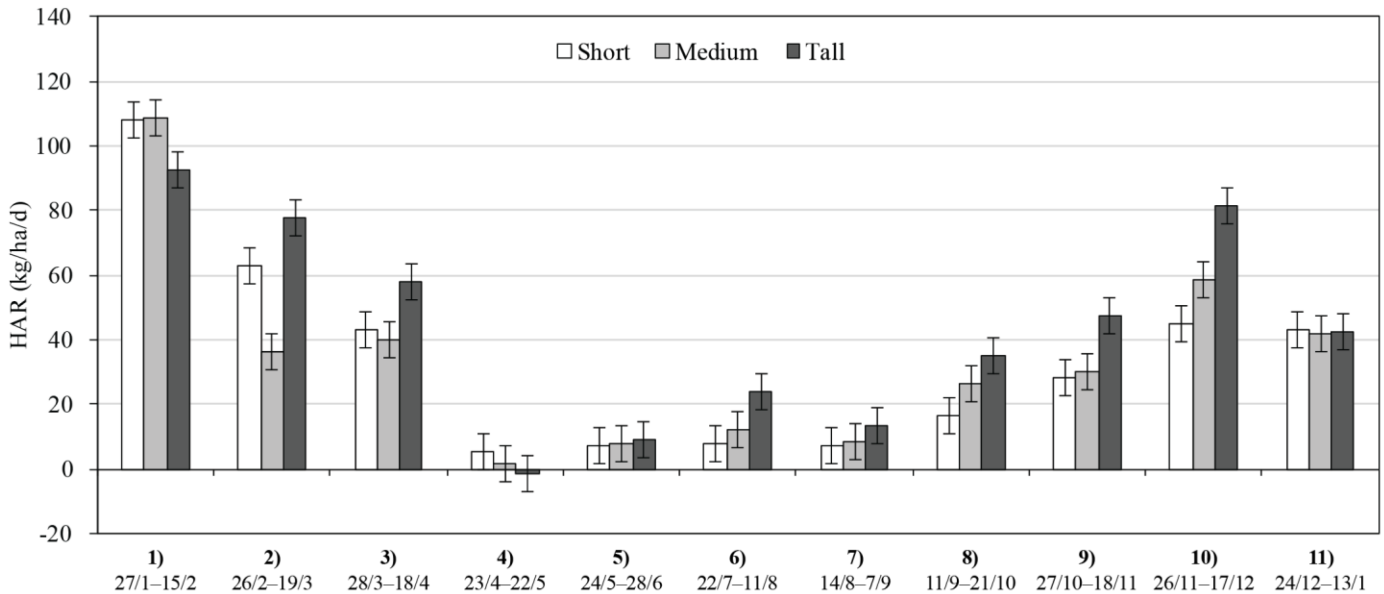

Figure 5. Daily herbage accumulation rates (HAR) during Periods 1–11 in signal grass (*Urochloa decumbens*) cv. Basilisk pastures maintained at 3 canopy heights in Brotas, SP, Brazil. Bars correspond to ± standard error of mean.

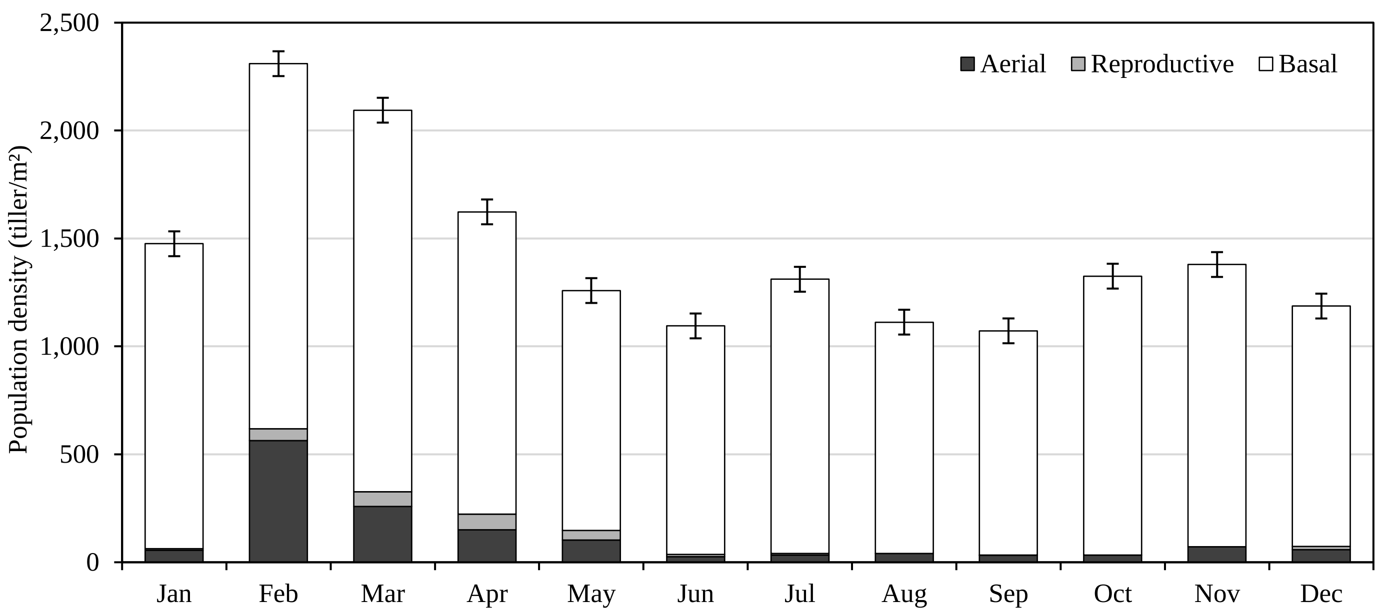

Figure 6. Population density of various tiller categories in signal grass (*Urochloa decumbens*) cv. Basilisk pastures maintained at 3 canopy heights in Brotas, SP, Brazil. Bars correspond to ± standard error of mean.

February and May, with S pastures having fewer of them in this period (38 tillers/m^2) followed by M (67 tillers/m^2) and T (74 tillers/m^2) pastures.

There was a height × month interaction effect (P<0.0001) on LI. Light interception was more variable in S pastures, peaking at 90% in June and decreasing to 50% in September (Figure 7). LI in M and T pastures was relatively stable throughout, fluctuating between 90 and 100%.

Forage nutritive value

Crude protein concentration was affected by a height × month interaction (P<0.0001). CP% in S pastures was greater than in M and T pastures in January, February, May, June and October (Figure 8A), with no differences in the other months. After peaking in October (130–170 g/kg), mean CP concentration decreased to approximately

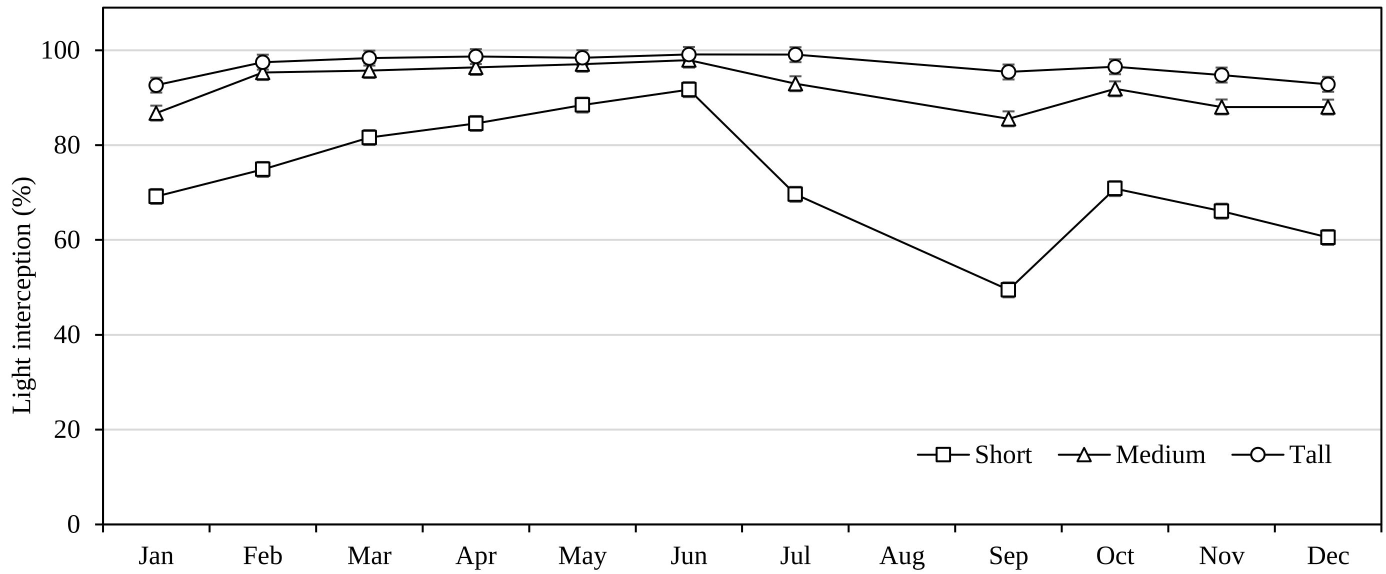

Figure 7. Light interception in signal grass (*Urochloa decumbens*) cv. Basilisk pastures maintained at 3 canopy heights in Brotas, SP, Brazil. Bars correspond to ± standard error of mean.

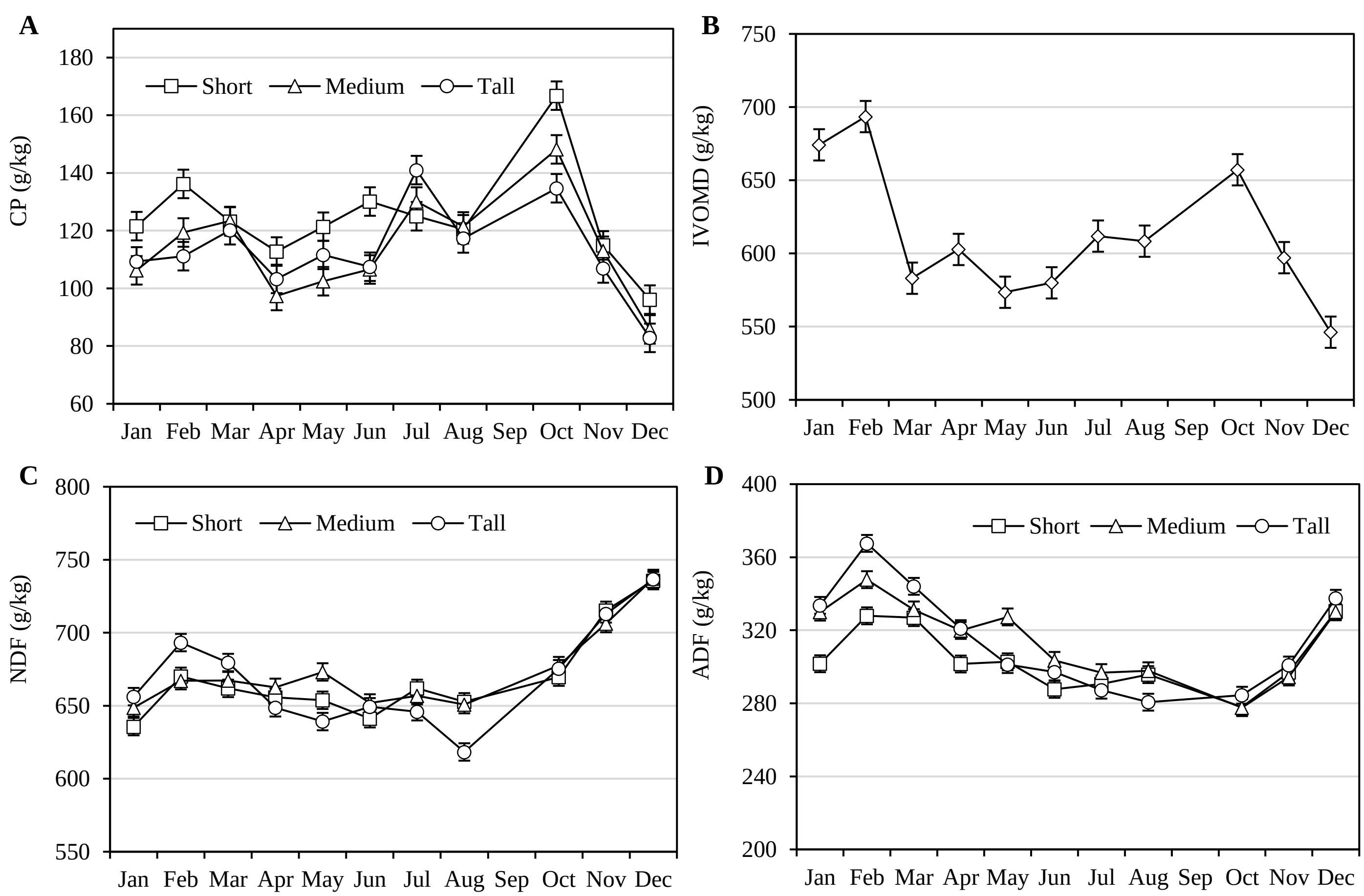

Figure 8. (A) Crude protein (CP) concentration; (B) In vitro organic matter digestibility (IVOMD); (C) Neutral detergent fiber (NDF) concentration; and (D) Acid detergent fiber (ADF) concentration of signal grass (*Urochloa decumbens*) cv. Basilisk maintained at 3 canopy heights in Brotas, SP, Brazil. Bars correspond to ± standard error of mean.

110 and 90 g/kg in November and December, respectively.

Time of year had the greatest effect on IVOMD ($P<0.0001$), which peaked in January-February and again in October, before declining sharply in November and December (Figure 8B). Both neutral detergent fiber and acid detergent fiber concentrations were affected by a height × month interaction ($P<0.0001$). Both tended to peak in February before declining slowly until August–October before increasing to December (Figures 8C and 8D).

Discussion

Steady-state canopy heights did not ensure a constant plant-part component mass within treatments throughout the year, regardless of canopy height. There was a decrease in leaf and stem mass from January to June, especially in M and T pastures, followed by an increase in dead material, even for the S pastures. This process peaked at the end of the wet season likely due to increased tissue senescence triggered by the imminent soil water deficit during this period (Figure 1). In the second half of the year, dead material mass remained relatively constant showing differences among treatments and greater senescence in T pastures, followed by M and S pastures. As expected, S pastures had less HM (leaf + stem + dead material) than M and T pastures and less stem and dead material, as also observed by Santos et al. (2010) in 4 areas of signal grass grazed at 10, 20, 30 and 40 cm canopy height during the wet season.

As expected, mean HAR varied seasonally and greater values were recorded during the warm and wet periods (January–April and September–December). During the cooler months (May–August; Periods 4–7), HAR was near zero because the daily minimum temperatures, i.e. under 15 °C (Figure 1), during this period are probably close to the threshold values that restrict the growth of C_4 species (Silva et al. 2012). The partially greater HAR in T pastures can be attributed to the additional amount of leaves, i.e. LAI, and plant reserves normally associated with the greater shoot and root plant structures (Donaghy and Fulkerson 1998). The advantage of T pastures was particularly significant in the transition between the dry and wet seasons (September–November). The positive effect of greater canopy height on HAR was similar to that reported for Xaraés palisade grass (*Urochloa brizantha*) pastures managed at 15, 30 and 45 cm (Euclides et al. 2010). On the other hand, Euclides et al. (2010) reported a negative effect of height on HAR of Marandu palisade grass, even though in both trials HAR differences were minimal for different canopy heights. This similarity is expected for a given range of canopy conditions, and sometimes the contrasting canopy heights do not result in contrasting HAR values (Bircham and Hodgson 1983). Since short canopies have small tillers with greater population density (Sbrissia and Silva 2008), the photosynthetic apparatus, i.e. leaf area index, could partially compensate. In the current study, however, differences in tiller population density were small and this compensation was not evident.

Considering the low proportion of reproductive tillers, all treatments inhibited flowering, a positive effect in terms of livestock performance considering the negative impact of reproductive tillers on stem proportion, food intake and diet quality (Benvenutti et al. 2008). Under our management system, production of reproductive tillers was concentrated between February and May, although signal grass typically concentrates its flowering between December and January at this latitude. There was a strong seasonal variation in total tiller population density, which reached a maximum of 2,300 tillers/m^2 in February and decreased to ~1,100 tillers/m^2 between June and September, although basal tiller numbers were less variable (1,000–1,700 tillers/m^2). According to Portela et al. (2011) in signal grass pastures managed under rotational stocking, there was less variation than in the current study in tiller density throughout the year and the range was 1,100–1,500 basal tillers/m^2, with pastures managed at heavier grazing intensity (5 cm post-grazing canopy height) having 10–20% more basal tillers.

Plants in T pastures were larger and probably invested more energy in maintenance respiration. Under environmental restrictions, this could result in negative HAR, as observed in Period 4 of the current study (Figure 5). This was reported by Silva et al. (2013) in palisade grass pastures grazed at >30 cm canopy height during the dry season. Santos et al. (2013) also reported negative HAR, i.e. death of plant parts was greater than the growth of new plant tissue, in signal grass pastures maintained at 25 cm canopy height in the dry season. In the current study, the onset of the wet season in spring resulted in greater HAR in T pastures (Periods 8–10; Figure 5), similar to the findings of Silva et al. (2013) at the same time of year. This greater herbage accumulation is important in forage-based systems in central Brazil because feed supply at the end of the dry season can become critically low and a rapid growth response by the pasture with the return of wet season conditions helps buffer the roughage demand on the farm. Using an alternative grazing scheme, Santos et al. (2013) temporarily lowered canopy height to 15 cm in the early dry season, which boosted HAR in the following spring compared with a pasture kept at 25 cm, in contrast with results of the current study.

There have been many studies on the effects of LI on herbage accumulation dynamics of tropical grasses, especially in rotationally stocked pastures, e.g. Pedreira et al. (2017) and Moura et al. (2017). In general, maximum canopy light interception (~95–100% LI) modifies plant-part growth, shifting the primary leaf accumulation to a less desirable stem elongation, especially in well-fertilized pastures. For this reason the 95% LI criterion has been proposed as the moment when the rest/regrowth period should be terminated in intermittent (rotational and its variations) grazing schemes (Carnevalli et al. 2006). By associating LI with canopy height it may be possible to recommend specific grazing management targets for different forage species and cultivars. However, the phenotypic plasticity of species such as signal grass can lead over time to a more prostrate plant architecture, which in turn can modify the established association between canopy LI and height (Braga et al. 2006; Pedreira et al. 2017). In the current study, LI values measured in M and T pastures were close to the ceiling (95–100%) in the first half of the year, whereas in the second half, LI approached 95% for T pastures and 90% for M pastures. These values fall within the range of canopy LIs and canopy heights observed by Pedreira et al. (2017) for signal grass pastures. The large LI values were probably related to the presence of dead leaves near the bottom of the canopy as observed by Braga et al. (2006), even for the M pastures kept at shorter canopy heights. Although T pastures displayed greater HAR than shorter pastures (M and S), the plant-part composition profile changed at the end of the experimental period (November and December) and M pastures showed more leaf than S and T pastures. At the same time, T pastures showed increasing stem mass and less leaf mass. As signal grass usually starts flowering at this time of the year, more lenient grazing could favor the development of stems as opposed to leaves. If excessive stem elongation occurs, additional effort may be needed to maintain canopy height, something we did not achieve in the current study, even in the taller canopies. The control of canopy structure is important because the presence of mature stems may lead to decreased harvest efficiency by livestock associated with rejected patches and lodging, a process that becomes more important as the intensity of use of the pasture, i.e. fertilizer application, irrigation, etc., increases.

Forage nutritive value in S pastures was greater than in M and T pastures, although no differences in IVOMD were recorded. On the other hand, higher CP concentration and lower ADF concentration, especially in the first half of the year, were recorded in S pastures. The higher grazing intensity in S pastures combined with greater defoliation frequency led to greater tissue renewal and predominance of younger plant tissues with lower proportion of cell wall components such as lignin, minimizing potential negative consequences for diet nutritive value. As observed by Hernández Garay et al. (2004) and Sollenberger and Vanzant (2011), CP% and digestibility increase with heavier grazing management as a consequence of forage utilization increase and its effect on forage maturity and leaf proportion. This greater forage nutritive value in S pastures would normally result in better animal performance. However, this might not occur, because performance depends on forage intake, also regulated by herbage allowance (Herling et al. 2011; Sollenberger and Vanzant 2011). Short canopies may be associated with smaller herbage allowance and, if taken to extreme levels, may lead to overgrazing, limiting forage intake by bite size restrictions and/or insufficient grazing time to satisfy appetite (Silva et al. 2013). At the end of the year (October–December) forage nutritive value declined, regardless of treatment. This may be associated with N fertilizer application, which in the second half of the year happened only in September, reducing grazing frequency and plant tissue renewal at the end of the experimental period, and consequently lowering overall forage nutritive value. Regardless of treatment, however, the nutritive value of signal grass can be considered satisfactory since CP concentrations in hand-plucked samples which mimicked animal selection, for example, remained above 100 g/kg for most of the year, and IVOMD above 600 g/kg, similar to levels observed by Silva et al. (2013) in palisade grass pastures grazed at 4 canopy heights (10, 20, 30 and 40 cm).

The steady-state canopy allows not only better harvest efficiency, but also results in forage of greater nutritive value compared with pastures that are managed without a canopy-based criterion (Nave et al. 2010). Conversely, adhering to a canopy condition and the intensification of harvest efficiency during the warm wet season does not allow for a build-up of forage of lower nutritive value to be consumed in the cool and dry season, when forage mass usually does not meet the livestock demand (stockpiling or deferred grazing). Producers often use lax grazing intensity in the wet season, especially in low-input forage-livestock systems in order to accomplish this. In contrast, in intensive, high-input grazing systems, such as the one represented in the current study, it may be advantageous to efficiently harvest forage of greater nutritive value, maximizing the animal output in terms of both performance, i.e. daily weight gain, milk production, etc., and pasture carrying capacity, to justify the high production costs, mainly where land is expensive. At the same time, to deal with a shortage of forage on offer during the dry season in central Brazil, feeding options such as stockpiling, protein and/or energy supplements or mixed grass-legume pastures may be required.

Despite expectations to the contrary, the short canopy management (~10 cm) in signal grass pastures was not detrimental to forage productive vigor (in terms of HAR) during the wet season. In addition, leaf mass was almost the same as in M and T pastures throughout the experimental period. However, this may not be true in the long term, especially without fertilizer application. The S and M pastures produced forage with greater nutritive value, i.e. higher CP and lower fiber concentrations, than T pastures. However, with the onset of the wet season, HAR of T pastures exceeded those of S and M pastures, suggesting an advantage in maintaining signal grass at ~25 cm in order to ensure rapid growth response in spring if pastures were continuously stocked.

The results of the present study have shown the phenotypic plasticity of signal grass under a mimicked continuous stocking condition with no clear evidence of stand decline or loss of vigor, i.e. severe reduction of yield and/or tiller density, in the S pastures. How this situation will apply under long-term grazing remains to be answered. Grazing target recommendations for optimal animal performance still need to be developed, but it is expected that keeping canopy height in signal grass pastures between 15 and 25 cm should ensure maximum animal production, as a result of quality of available forage being maintained at a high level. Testing of this hypothesis commercially and recording animal performance is warranted.

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