

Stockpiling strategies for BRS Paiaguás (*Urochloa brizantha*) in the Atlantic Forest region of Minas Gerais state

Estratégias de diferimento da BRS Paiaguás (*Urochloa Brizantha*) na região de Mata Atlântica de Minas Gerais

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Highlights

Paiaguás grass has high potential for use under stockpiling management.

The stockpiling date and residual heights have little influence on nutritive value.

Early stockpiling and low residue promote greater dry matter accumulation of forage.

Abstract

Forage planning is essential to overcome the seasonality of forage production, and pasture stockpiling is one of the available strategies. The cultivar BRS Paiaguás (*Urochloa brizantha*) has been considered to have the best drought tolerance among cultivars of this species. The objective of this study was to evaluate the effects of three stockpiling dates and three pasture stubble heights (SHs) on the yield and quality of stockpiled BRS Paiaguás forage. The experiment was conducted at the Embrapa Dairy Cattle Experimental Field using 3 × 2 m plots arranged in a randomized block design with three replicates in a factorial arrangement over two years of evaluation. Three stockpiling dates were evaluated: March 15 (early), March 30 (intermediate), and April 15 (late). For each stockpiling date, three pasture SHs at the beginning of the stockpiling period were evaluated (10, 20, and 30 cm). The stockpiling period was 70 days for all treatments. The interaction between SH and stockpiling date affected only the percentage of stems in the forage dry weight, whereas the studied factors had no effect on *in vitro* dry matter digestibility (663.1 g kg⁻¹) or crude protein (67.9 g kg⁻¹). Stubble height influenced the structure and dry matter yield of the BRS Paiaguás pasture. The 10 cm SH resulted in the greatest forage dry weight after 70 days (3,800 kg ha⁻¹ above the SH), but also in higher percentages of stems and neutral detergent fiber. The 30 cm SH resulted in a better leaf-to-stem ratio. Early stockpiling resulted in greater ground

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cover and green weight (3,800 kg ha⁻¹ vs. 3,012 and 2,468 kg ha⁻¹), whereas late stockpiling (April 15) increased the percentage of senescent forage by 13.5 percentage points compared with the average of the other stockpiling dates. The results indicate that a 20 cm SH combined with early or intermediate stockpiling provides the best balance between productivity and quality.

Key words: Forage mass. Morphological composition. Nutritive value. Stockpiling time. Stubble height.

Resumo

O planejamento forrageiro é fundamental para superar a estacionalidade da produção de forragem, sendo o diferimento da pastagem uma das estratégias disponíveis. A cultivar BRS Paiaguás de *Urochloa brizantha* tem sido considerada a de melhor tolerância a seca dentro da espécie. O objetivo deste trabalho foi avaliar o efeito de três datas e três alturas de rebaixamento do pasto sobre a produção e a qualidade da forragem da BRS Paiaguás diferida. O experimento foi realizado no Campo Experimental da Embrapa Gado de Leite, utilizando parcelas de 3x2 metros em delineamento de blocos casualizados com três repetições num esquema fatorial, durante dois anos de avaliação. Foram avaliadas três datas de diferimento sendo, 15 de março (precoce), 30 de março (intermediário) e 15 de abril (tardio). Em cada data de diferimento foram avaliadas três alturas de resíduo para o início do diferimento (10, 20 e 30 cm). O período de diferimento de todos os tratamentos foi de 70 dias. A interação altura de resíduo x data de diferimento afetou apenas a porcentagem da massa seca de colmo na massa de forragem, porém não houve efeito dos fatores estudados sobre a DIVMS (663,1 g kg⁻¹) e PB (67,9 g kg⁻¹). A altura de resíduo influenciou a estrutura e a produção de forragem da pastagem de BRS Paiaguás. O resíduo de 10 cm produziu maior massa de forragem após os 70 dias (3.800 kg ha⁻¹ de massa de matéria seca acima do resíduo), porém com maior porcentagem massa seca de colmo e FDN. Já o resíduo de 30 cm apresentou melhor relação folha-colmo. O diferimento precoce resultou em dossel mais alto e mais massa de matéria seca verde (3.800 kg ha⁻¹ contra 3.012 e 2.468 kg ha⁻¹), enquanto o diferimento tardio (15/04) elevou a porcentagem de massa seca de forragem senescente em 13,5 pontos percentuais em comparação a média dos demais. Os resultados indicam que resíduos de 20 cm com diferimento precoce/intermediário oferecem o melhor equilíbrio entre produtividade e qualidade.

Palavras-chave: Altura de resíduo. Época de diferimento. Composição morfológica. Massa de forragem. Valor nutritivo.

Introduction

Brazil has a favorable climate, extensive pasture areas, and a diversity of forage species and cultivars and, in recent decades, has shown substantial advances in pasture management. All these characteristics place the national livestock industry at an advantage over those of

other countries. However, the seasonality of forage production, mainly caused by drought and low temperatures in much of the country, remains one of the main limitations to livestock production in Brazil (Pedreira & Silva, 2022). Among the forage planning strategies for the dry period, pasture stockpiling is one of the most widely used (M. E. R. Santos et al., 2022). Fonseca et al. (2014) and M. E. R.

Santos et al. (2022) described how pasture stockpiling can extend the grazing period. However, some factors must be considered, such as the choice of the species or cultivar to be used, pasture height at the beginning of stockpiling, and the duration of the stockpiling period, among others. Regarding the characteristics of forage species used for stockpiling, desirable traits include short stature, thin stems, good growth during the transition from the rainy to the dry season, and little flowering during the stockpiling period to minimize negative effects on forage structure and nutritive value (M. E. R. Santos et al., 2022).

Among the main species used for stockpiling tropical pastures is *Urochloa brizantha*. Within this species, cultivar BRS Paiaguás is characterized by good drought tolerance and a high proportion of leaves in the produced forage (Valle et al., 2013). Although these characteristics make it suitable for stockpiling, few studies have evaluated BRS Paiaguás under this management strategy. M. E. R. Santos et al. (2021) evaluated four cultivars of *U. brizantha* (BRS Paiaguás, Marandu, BRS Xaraés, and BRS Piatã) under a 90-day stockpiling period in the Cerrado region of Minas Gerais. BRS Paiaguás grass stood out because of its high percentage of vegetative tillers and high forage production, ranking second only to Xaraés grass.

The stockpiling strategy directly influences forage accumulation and its nutritive value. The timing and duration of stockpiling influence pasture structure and nutritive value (Silva et al., 2021; Fernandes et al., 2022), whereas climatic conditions at the end of the rainy season and the

beginning of the dry season can determine the capacity for biomass accumulation. To obtain a forage canopy with a better structure, it is recommended to stagger stockpiling among different pasture areas to maintain better structure and nutritive value of the accumulated forage (Nogueira et al., 2020), as well as to extend pasture use during the dry season. However, the progression of the dry season may result in reduced biomass production, and adjustments in stocking rate or expansion of the stockpiled area may be necessary to ensure adequate animal performance. On the other hand, the SH at the beginning of stockpiling can also influence forage structure, accumulation, and nutritive value (Veloso et al., 2021). Moderate to high SHs generally allow for greater forage accumulation and maintain or improve nutritive value, whereas very low heights can reduce forage production and decrease nutritive quality (Nogueira et al., 2020; Borges et al., 2023).

Studies aimed at establishing stockpiling strategies, especially for new forage cultivars such as BRS Paiaguás, are essential to maximize the use of their agronomic characteristics and enhance animal performance during the dry season. The hypothesis of this study is that the production and quality of stockpiled BRS Paiaguás forage are influenced by both stockpiling time, corresponding to the end of the rainy season and the beginning of the dry season, and SH at the beginning of the stockpiling period. The objective was to evaluate the effects of three stockpiling dates and three SHs on the yield and quality of stockpiled BRS Paiaguás forage.

Material and Methods

Experimental site

The experiment was conducted at the José Henrique Bruschi Experimental Field of Embrapa Dairy Cattle, located in Coronel Pacheco, Minas Gerais, Brazil, in the Atlantic Forest biome (21°33'22" S, 43°06'14" W, and 410 m above sea level). The soil of the experimental area is classified as a dystic Red-Yellow Latosol with a clayey texture (M. E. R. Santos et al., 2018).

Before the experiment was established, the soil presented the following characteristics in the 0-20 cm layer: pH in water, 5.3; P (Mehlich-1), 0.96 cmolc dm⁻³; K, 25.0 cmolc dm⁻³; Na, 24.2 cmolc dm⁻³; Mg, 0.93 cmolc dm⁻³; Al, 0.1 cmolc dm⁻³; H+Al, 4.62 cmolc dm⁻³; sum of bases, 3.99 cmolc dm⁻³; t, 4.09 cmolc dm⁻³; cation-exchange-capacity at 7.0 pH, 8.61 cmolc dm⁻³; base saturation, 46.3%; and Al saturation, 2.4%. The experimental plots, measuring 3 × 2 m, were established in a BRS Paiaguás grass (*Urochloa brizantha*) pasture established in 2017. Temperature and precipitation conditions during the experimental period are described in Figure 1.

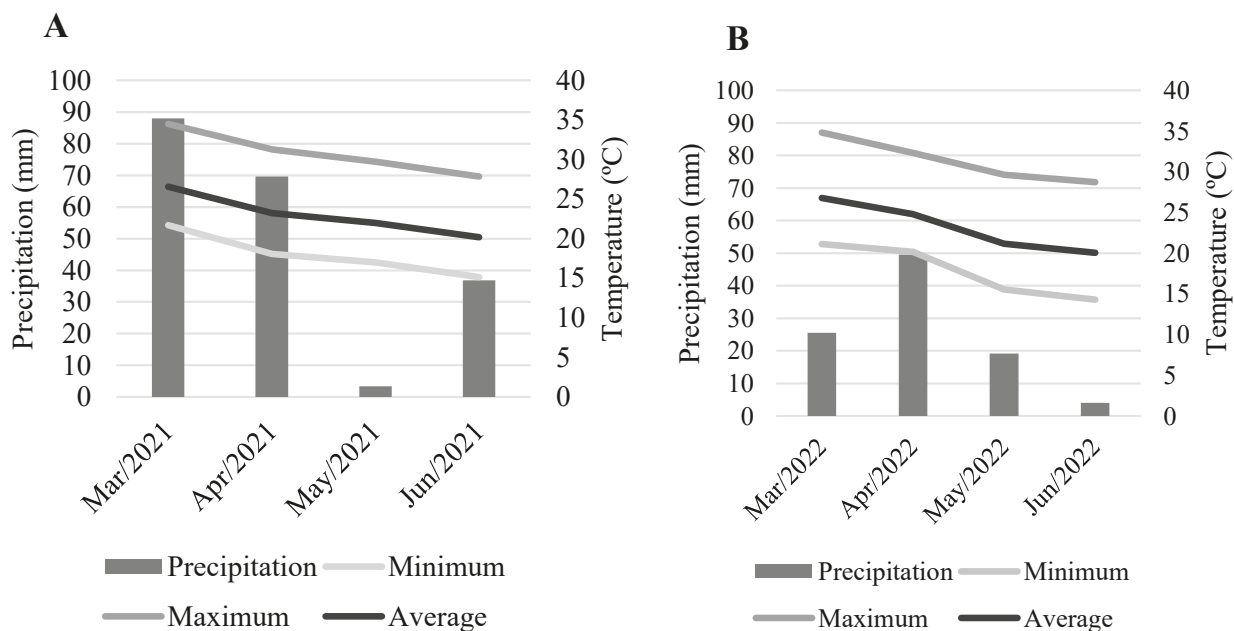


Figure 1. Accumulated monthly precipitation (columns) and average, maximum and minimum monthly temperature (lines) from March to June 2021(A) and March to June 2022 (B).

Treatments and experimental design

The trial was conducted in a 3×3 factorial arrangement with three replicates per treatment in a randomized block design. The factors studied were three stockpiling dates (March 15, early; March 30, intermediate; and April 15, late) and three SHs (10, 20, and 30 cm). The experiment was evaluated over two years, from March to June in 2021 and 2022.

Management of the experimental area

Since its establishment, the pasture had been managed under rotational grazing with crossbred cows during the rainy seasons of 2018–2019 and 2019–2020. During the dry period of 2020 and the rainy season of 2020–2021, the area was managed more extensively, with occasional grazing by dry cows and heifers to reduce canopy height.

On February 12, 2021, 30 days before the first stockpiling date, all plots were uniformly cut to a height of 25 cm above the soil surface using an electric brush cutter. Fertilizer was applied at the beginning of the stockpiling period at a rate equivalent to 40 kg ha⁻¹ of N, 40 kg ha⁻¹ of K₂O, and 10 kg ha⁻¹ of P₂O₅, using a 20-05-20 N-P-K formulation. The stockpiling period was 70 days for all treatments, resulting in harvests on May 25 (early), June 8 (intermediate), and June 22 (late). The stockpiling and harvest dates were maintained in both years of evaluation.

Variables evaluated

At harvest, canopy height was measured in centimeters using a graduated

ruler at three points per plot. Subsequently, forage was harvested using a 0.5 × 0.5 m quadrat, with two distinct cuts: one above the SH and another below it. The forage harvested above the SH was used to assess canopy structural composition, including leaf blades, stems + sheaths, and senescent forage, as this fraction represents the material effectively available to animals under grazing or for harvest after the stockpiling period. The portion below the SH was excluded from the structural analysis because it corresponded to the residue remaining from previous grazing events or the pre-established cutting height and, therefore, was not representative of the forage accumulated during the stockpiling period.

The forage harvested below the SH was specifically used to quantify the live and dead forage dry weight present in the residual canopy, allowing the accumulation of senescent material to be estimated. The collected samples were placed in plastic bags and transported to the laboratory for weighing and separation into their component fractions. All samples were dried in a forced-air oven at 55 °C for 72 h to determine dry matter content. Total forage dry weight was estimated based on the biomass harvested at the end of the stockpiling period (70 days). The forage dry matter accumulation rate was calculated by dividing the dry mass of forage above the SH by the interval between the beginning of stockpiling and harvest (70 days).

The leaf chlorophyll index (SPAD) was estimated only during the first year using indirect readings obtained with a portable Soil Plant Analysis Development (SPAD) meter, model SPAD-502 (Konica Minolta, Japan). Measurements were performed

at harvest on three tillers per plot, and the fully expanded penultimate leaf of each tiller was selected for measurement. The mean of the three readings was considered representative of the experimental unit.

The percentage of stems was determined from the stem + sheath fraction manually separated from the biomass harvested above the SH. It was calculated as the ratio of stem dry weight to the total dry weight of the forage above the SH, multiplied by 100. The same procedure was used to estimate the percentages of senescent forage below and above the SH, leaves, and green forage. The leaf-to-stem ratio was calculated as the ratio of the dry weight of the leaf blade fraction to that of the stem + sheath fraction obtained from the biomass harvested above the SH.

The nutritive value of the forage was characterized during both years of evaluation. For this purpose, samples harvested above the SH were collected from each experimental unit. After collection, the samples were dried in a forced-air oven at 55 °C, ground in a mill fitted with a 1-mm sieve, and analyzed for dry matter content in an oven at 105 °C. Crude protein (CP), neutral detergent fiber (NDF), and *in vitro* dry matter digestibility (IVDMD) were determined at the Animal Nutrition Laboratory of Embrapa Dairy Cattle according to the methodologies described by Detmann et al. (2012).

Statistical analyses

For all variables except SPAD, statistical analyses were performed using the mean values obtained over the two experimental years. The analyses were conducted using the ExpDes.pt package

in R software, considering a 3 × 3 factorial arrangement in a randomized block design with three replicates. The sources of variation included stockpiling date, SH, and the interaction between these factors.

The statistical model was:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \omega_k + e_{ijk}$$

where Y_{ijk} is the observed value for the combination of stockpiling date i and SH j in block k ; μ is the overall mean of the experimental units for the variable under study; α_i is the effect of stockpiling date i ; β_j is the effect of SH j ; $(\alpha\beta)_{ij}$ is the effect of the interaction between stockpiling date i and SH j ; ω_k is the effect of block k ; and e_{ijk} is the random error associated with the observation.

All statistical analyses were performed at a significance level of 5%. The normality of the variables was assessed using the Shapiro-Wilk test at the 5% significance level. When appropriate, treatment means were compared using Tukey's test at the 5% significance level.

Results

Morphological composition, forage weight, and SPAD index

The influence of SH ($p < 0.05$) was observed for most of the variables analyzed (Table 1). Canopy height was greater with the 30 cm SH than with the heights of 10 and 20 cm, which did not differ from each other ($p = 0.0005$). The leaf-to-stem ratio was also higher with the 30 cm SH, followed by 20 cm, while the 10 cm height had the lowest value ($p = 0.0133$), indicating a higher proportion of leaves in the stockpiled forage with higher SHs.

Table 1

Morphological and productive traits of cultivar BRS Paiaguás harvested after 70 days of stockpiling with different heights according to the stubble height before stockpiling

Variable	----- Stubble height -----			P-value	CV (%)	SEM
	10 cm	20 cm	30 cm			
Canopy height (cm)	48.16 b	49.71 b	55.68 a	0.0005	6.49	2.82
Leaf-to-stem ratio	2.11 b	2.83 ab	3.02 a	0.0133	22.69	0.17
Total forage dry weight above SH (kg ha ⁻¹)	3,800 a	3,012 ab	2,467 b	0.0194	28.79	227.68
Green forage dry weight above SH (kg ha ⁻¹)	3,099 a	2,437 ab	2,078 b	0.0106	24.74	199.68
Rate of forage dry matter accumulation above SH (kg ha ⁻¹ day ⁻¹)	43.64 a	34.34 ab	29.29 b	0.0108	24.74	2.81
Green forage dry weight below SH (kg ha ⁻¹)	2,235 b	3,713 a	4,735 a	0.0005	29.54	285.11
Dead forage dry weight below SH (%)	73.81 a	68.96 ab	61.54 b	0.0263	12.68	2.21

Means followed by the same letter do not differ from each other by Tukey's test at 5% probability. SH - stubble height, CV - coefficient of variation, SEM - standard error of the mean.

Management with a 10 cm SH resulted in greater forage dry weight above the SH than with 20 and 30 cm heights, with the 30 cm SH showing the lowest forage weight and the 20 cm SH an intermediate value ($p = 0.0194$). A similar pattern was observed for green forage (leaf and stem) dry weight above the SH, with the 10 cm SH resulting in greater values than the 30 cm SH ($p = 0.0106$). Likewise, the dry matter accumulation rate above the SH was higher when a 10 cm SH was adopted than when a 30 cm SH was adopted ($p = 0.0108$).

In contrast, below the SH, green forage weight was higher when 30 and 20 cm SHs were adopted than when the lowest SH was used ($p = 0.0005$). The percentage of senescent forage below the SH increased as SH decreased, and a higher percentage of senescent forage was observed with the 10

cm SH ($p = 0.0263$). On the other hand, the percentage of senescent forage above the SH was not affected by SH ($p > 0.05$). The overall average percentage of senescent forage was 18.4%.

Stockpiling date influenced canopy height ($p = 0.001$), leaf-to-stem ratio ($p = 0.017$), percentage of stem dry weight ($p = 0.001$), percentage of senescent forage dry weight ($p = 0.001$), green forage dry weight above the SH ($p = 0.005$), and the rate of forage dry matter accumulation above the SH ($p = 0.005$) (Table 2). On the other hand, total forage dry weight above the SH (mean of 3,093 kg ha⁻¹), total green forage dry weight below the SH (mean of 3,561 kg ha⁻¹), and percentage of senescent forage dry weight below the SH (mean of 68.1%) were not influenced by stockpiling date ($p > 0.05$).

Table 2

Morphological and productive traits of cultivar BRS Paiguás according to the stockpiling date

Variable	Stockpiling date*			P-value	SEM	CV (%)
	Early	Intermediate	Late			
Canopy height (cm)	63.3 a	57.3 b	33.0 c	0.0001	6.49	2.82
Stem dry weight above SH (%)	2.3 b	2.5 ab	3.2 a	0.0179	22.69	0.17
Dead forage dry weight (%)	12.2 b	15.6 b	27.6 a	0.0007	38.22	1.91
Green forage dry weight above SH (kg ha ⁻¹)	2,940 a	2,787 a	1,887b	0.0054	24.74	199.68
Rate of forage dry weight accumulation above SH (kg ha ⁻¹ day ⁻¹)	41.4 a	39.3 a	26.6 b	0.0053	2.36	2.81

*Early = 03/15; intermediate = 03/30; late = 04/15.

Means followed by the same letter do not differ from each other by Tukey's test at 5% probability. SH - stubble height, CV - coefficient of variation, SEM - standard error of the mean.

Canopy height at the end of the stockpiling period was greater with early stockpiling (03/15), with a progressive reduction on subsequent dates. Green forage dry weight above the SH was greater when early and intermediate stockpiling was performed, whereas late stockpiling resulted in lower mass production. A similar pattern was observed for the dry matter accumulation rate above the SH, with higher accumulation rates also observed when early and intermediate stockpiling was performed. The percentage of senescent forage was higher when late stockpiling was adopted than when early and intermediate stockpiling was adopted.

An interaction ($p = 0.037$) between SH and stockpiling date was observed only for the percentage of stems (Figure 2). Under early (03/15) and intermediate (03/30) stockpiling, the 10 cm SH showed a higher percentage of stems than the 20 and 30 cm SHs. Under late stockpiling (04/15), there was a reduction in the percentage of stems, and all SHs presented statistically similar values. Within each SH, there was a reduction in the percentage of stems from early to late stockpiling, which was more pronounced with the 10 cm SH than with the 30 cm SH. These results demonstrate that lower SHs and earlier stockpiling favor greater stem development.

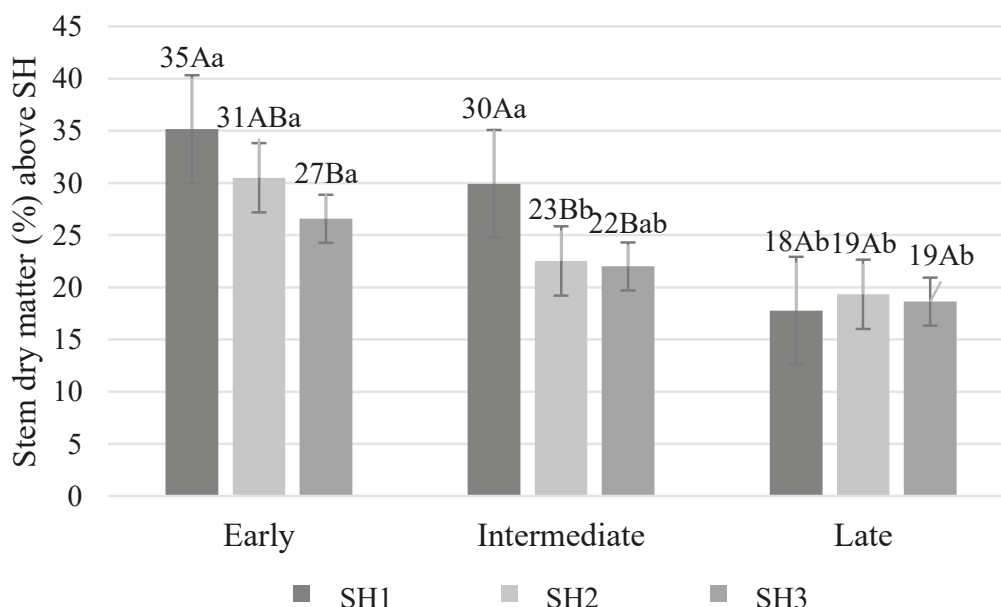


Figure 2. Interaction ($p = 0.0378$; SEM = 1.29) between stubble height (SH) and stockpiling date on the percentage of stem dry matter in BRS Paiaguás forage. Dates evaluated: March 15th (early), March 30th (intermediate), and April 15th (late); Stubble heights: 10, 20, and 30 cm.

*Uppercase letters compare stubble heights and lowercase letters compare stockpiling dates by Tukey's test at 5% probability.

The SPAD chlorophyll index, percentage of leaf dry weight, percentage of senescent forage dry weight below the SH, and total forage dry weight were not influenced by the factors studied or by the interaction between them ($p > 0.05$). The overall means were 30.9 for SPAD, 6,655 kg ha⁻¹ for total forage dry weight, 56.7% for percentage of leaf dry weight, and 68.1% for percentage of senescent forage dry weight below the SH.

Nutritive value

No interaction effect between the factors studied was observed for the nutritive value of forage harvested above the SH. However, NDF content was influenced by SH ($p = 0.0054$), with a reduction in NDF content as SH increased (Figure 3), with values of 670, 671, and 652 g kg⁻¹ for the 10, 20, and 30 cm heights, respectively. A significant difference was observed only between the 30 cm height and the other heights.

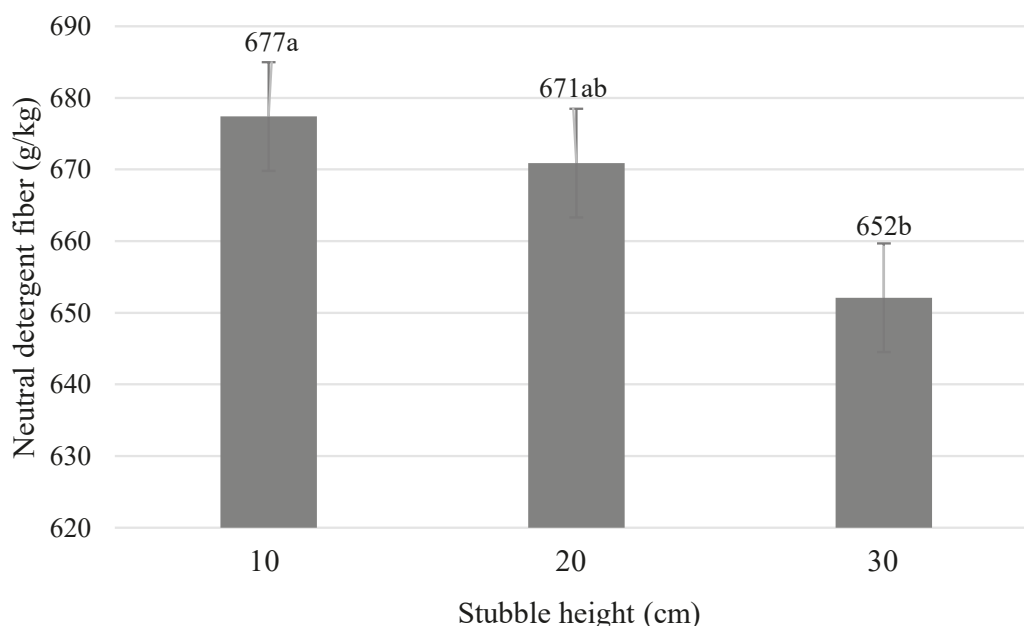


Figure 3. Neutral detergent fiber (NDF, g kg⁻¹) content of stockpiled BRS Paiaguás forage as a function of stubble height. Means followed by the same letter did not differ from each other by Tukey's test ($p < 0.05$).

In vitro dry matter digestibility and CP content were not influenced by SH, stockpiling date, or the interaction between these factors ($p > 0.05$). The overall means were 663.1 g kg⁻¹ for IVDMD and 67.9 g kg⁻¹ for CP, indicating stability of these parameters in relation to the management evaluated.

Discussion

Morphological composition, forage mass and SPAD index

SH influenced most of the variables analyzed, showing that management of the lowering height at the time of stockpiling is a determining factor for the structure, productivity, and composition of stockpiled BRS Paiaguás forage. The greater canopy height observed when the 30 cm SH was

adopted, compared with the other heights, indicates that maintaining a larger leaf area at the time of stockpiling may provide greater canopy light interception from the beginning of the stockpiling period, resulting in greater canopy elongation and vertical growth (Borges et al., 2023). This elongation is associated with greater shading at the base of the tussock and greater competition for light, which favors stem elongation of the remaining tillers as they seek greater access to light, resulting in greater canopy height in stockpiled pastures with higher SHs (Nogueira et al., 2020). Stockpiled pastures with greater canopy height are subject to a higher lodging index (M. E. R. Santos et al., 2013; Wallau et al., 2015). Wallau et al. (2015), evaluating genotypes of *Hermathria altissima* under stockpiling management, observed a higher lodging index in genotypes with

greater extended tiller heights. They also observed that increasing the stockpiling period from 8 to 12 and 16 weeks resulted in a linear increase in extended tiller height and lodging index (1.09, 1.30, and 1.43, respectively).

Although the 30 cm SH resulted in greater canopy height, it had lower total forage dry weight and lower green forage dry weight above the SH than the 10 cm SH. Although forage density was not evaluated, this result suggests differences in forage density among treatments, with greater density in the stockpiled pasture under the 10 cm SH. The more intense lowering (10 cm) may have provided greater light penetration to the base of the canopy and stimulated basal meristems, favoring the emergence of new tillers and greater biomass accumulation in the upper part of the pasture. Thus, the lower canopy height may have been compensated for by greater tiller density and biomass production (Matthew et al., 1995; Rocha et al., 2020).

The higher dry matter accumulation rate observed above this SH corroborates this hypothesis. In other words, the lower SH led to greater effective productivity, even though the resulting canopy did not reach a greater height, as observed by other authors in studies with other cultivars of the genus *Urochloa* (Nogueira et al., 2020; Rocha et al., 2020; Borges et al., 2023).

However, the higher yield under the lower SH was accompanied by changes in the structural composition of the forage. The leaf-to-stem ratio was lower at the 10 cm SH, indicating a higher proportion of stems. On the other hand, the 30 cm SH showed the highest leaf-to-stem ratio, which

is associated with forage of better nutritive value. This suggests that low SHs induce greater biomass accumulation but with a greater proportion of stems, whereas higher SHs favor a greater proportion of leaves, as also observed by M. E. R. Santos et al. (2013) and Nogueira et al. (2020). On the other hand, the percentage of senescent forage above the SH was not affected by the SHs studied ($p > 0.05$), indicating that, although changes occurred in pasture structure due to variations in the proportion of stems, the lowering strategies were effective in controlling forage senescence in the grazing stratum.

Forage production above the SH was consistent with that reported by M. E. R. Santos et al. (2021), who evaluated different *Urochloa* cultivars under stockpiling and observed a forage dry matter yield of 3,376 kg ha⁻¹ for BRS Paiguás. This value was similar to those found in the present study, which ranged from 2,467 to 3,800 kg ha⁻¹.

Another relevant aspect concerns the distribution of biomass below the SH. In stockpiled pastures, this biomass fraction plays an important role in maintaining soil health, nutrient cycling, and regrowth capacity (Gouveia et al., 2017). When the pasture was managed with higher SHs (20 and 30 cm), greater accumulation of green forage dry weight and a lower proportion of senescent forage dry weight below the SH were observed. Conversely, management with a 10 cm SH resulted in lower green forage dry weight and greater accumulation of senescent forage dry weight below the SH. To some extent, this result contradicts the initial expectation, since more intense lowering would be expected to result in

greater removal of old biomass at the end of the summer and greater tissue turnover. Based on this premise, Afonso et al. (2018) observed that more intense lowering of Marandu grass in early spring resulted in a higher dry matter accumulation rate, a higher leaf-to-stem ratio, and a greater proportion of leaves in the forage produced.

Lower green forage dry weight and a higher percentage of senescent forage dry weight below the SH can affect canopy regrowth capacity because of the smaller leaf area available for light interception and photosynthesis. In addition, canopy regrowth may be slower because of the need to recruit basal meristems for the formation of new tillers and the subsequent restoration of leaf area (A. de D. Santos et al., 2020). These results indicate that managing SHs of 20 and 30 cm may favor regrowth, nutrient cycling, and, consequently, pasture longevity.

The stockpiling date influenced the structure and dynamics of forage accumulation. Canopy height decreased as stockpiling was postponed. Early stockpiling (end of the rainy season) resulted in the greatest canopy height (63.3 cm), whereas late stockpiling (beginning of the dry season) resulted in the lowest canopy height (32.98 cm). This response was expected because of the more favorable environmental conditions at the end of the rainy season, such as greater water availability and photosynthetically active radiation, which promote greater stem elongation and tillering (M. E. R. Santos et al., 2018). As the dry period progresses, water availability, light, and temperature decrease, restricting plant growth and biomass accumulation (Ochola et al., 2024). In fact, Figure 1 shows a noticeable reduction in both precipitation and minimum temperature from

May onward, with minimum temperatures falling below 15 °C. In this context, Lara (2007), in a study conducted in Piracicaba, SP, estimated the basal temperatures of the Marandu and Xaraés cultivars of *U. brizantha* at 16.3 and 16.9 °C, respectively. Andrade et al. (2014), evaluating scenarios for Marandu grass pastures under climate change, also considered 17.2 °C as the basal temperature.

Canopy height in stockpiled pastures is a factor that directly influences the animal's ability to consume forage. As the plant develops and the stems elongate in search of light, their capacity to remain vertically supported decreases, making the forage more susceptible to lodging and potentially making forage intake more difficult for grazing animals. In the present study, although the lodging index was not measured, the canopy height values indicate that excessive elongation did not occur, which may be attributed to the relatively short stockpiling period of only 70 days. Santos et al. (2009), who evaluated the structural characteristics of brachiaria grass (*Urochloa decumbens*) at different stockpiling ages, found lodging index values ranging from 1.30 at 73 days of stockpiling to 3.29 at 160 days. The authors reported that the indices observed at 73 days after the beginning of stockpiling were considered low and did not impair animal forage intake.

Furthermore, green forage dry weight above the SHs and the forage dry matter accumulation rate were higher under early and intermediate stockpiling and lower under late stockpiling. This reduction in the accumulation rate under late stockpiling reinforces that forage production capacity is directly associated with the environmental conditions prevailing during the stockpiling

period, as discussed above. According to Robles-Vega et al. (2021), stockpiled pastures under more favorable conditions at the end of the rainy season exhibit greater forage dry matter accumulation and higher growth rates because lower temperatures, reduced solar radiation, and lower water availability at the beginning of the dry season limit tiller growth and stem elongation, thereby affecting forage production. On the other hand, the percentage of stems increased under late stockpiling, suggesting that, in addition to lower forage production, there was a greater proportion of structural tissues, indicating a reduction in forage quality. The inverse relationship between stem percentage and nutritive quality is well documented (Akin, 1989; P. R. Rodrigues et al., 2023) and reinforces that the progression of the dry season favors greater tissue lignification and a lower proportion of leaves (Carrizo et al., 2021).

This pattern is consistent with the data for the percentage of senescent forage, which was also significantly higher under late stockpiling (27.6%), whereas early and intermediate stockpiling resulted in lower values (12.2% and 15.6%, respectively). Accelerated forage senescence under late stockpiling can compromise nutritive value. However, although late stockpiling resulted in a higher percentage of senescent forage, this increase was not sufficient to lead to changes in NDF, CP, or IVDMD.

Total forage dry weight above the SHs and green forage (leaf and stem) dry weight below the SHs did not differ among stockpiling dates ($p > 0.05$). Early stockpiling, initiated under favorable environmental conditions, resulted in greater canopy height, greater accumulation of green forage dry

matter, and a lower proportion of senescent forage, resulting in a pasture structure more favorable to grazing (Robles-Vega et al., 2021) and higher nutritive value. Late stockpiling, on the other hand, compromises canopy structure, reduces green forage production, and increases the proportion of stems and senescent tissues, indicating lower forage quality and utilization potential (Robles-Vega et al., 2021; Carrizo et al., 2021).

The absence of an effect of the studied factors ($p > 0.05$) on the SPAD chlorophyll index, total forage dry weight, percentage of leaf dry weight, and senescent forage dry weight below the SHs may be associated with the adaptability of the cultivar to the evaluated management conditions and environmental factors. In addition, these variables may be strongly influenced by fertilization and water availability (Domingues et al., 2021; Vêras et al., 2020). The results of this study suggest yield stability of the BRS Paiguás cultivar under different management combinations and stockpiling dates. However, although total forage dry weight did not vary among stockpiling dates, the structure of the stockpiled pasture was influenced by the interaction between stockpiling date and SH, mainly because of changes in the percentage of stems.

The higher percentage of stem dry matter under the 10 cm SH during early and intermediate stockpiling, compared with the 20 and 30 cm SHs, was not expected, since lower SHs at the beginning of stockpiling are generally associated with a lower proportion of stems in the pasture (Nogueira et al., 2020). However, M. E. R. Santos et al. (2013), seeking to identify the ideal average height of *Brachiaria* grass (*Urochloa decumbens* cv. Basilisk) at the beginning of stockpiling,

also observed high percentages of stem dry matter when a 10 cm SH was adopted and lower percentages at SHs above 15 cm. This response may be associated with the sampling methodology because, when evaluating only the forage above the SH, a lower SH tends to result in the harvest of a greater proportion of stems than higher SHs (Sales et al., 2014). In addition, the tiller size/density law described by Matthew et al. (1995) indicates that pastures maintained at lower heights tend to have a greater number of tillers. This effect, combined with a long regrowth period during stockpiling under favorable environmental conditions, may explain the observed result.

On the other hand, under late stockpiling, regardless of SH, the percentage of stem dry matter was reduced. This response may be attributed to the progression of the dry season and the reduction in photoperiod and temperature, conditions that naturally limit the growth and elongation of vegetative tissues (J. G. Rodrigues et al., 2020).

Nutritive value

Despite the absence of an interaction effect between the studied factors, SH influenced the neutral detergent fiber (NDF) content. The lower NDF content observed under the 30 cm SH was associated with the highest leaf-to-stem ratio observed for this treatment and the lowest percentage of stems, regardless of stockpiling date. This result differs from findings reported in the literature, which indicate lower NDF contents at lower SHs (Nogueira et al., 2020; Silva et al., 2019). However, this result may be associated with the sample collection methodology because, when the SH is reduced, there is

a tendency to collect a greater proportion of stems than at higher SHs, as reported by Sales et al. (2014). Thus, it is important to emphasize that the samples used to evaluate nutritive value were collected above each respective SH rather than from the entire plant close to the ground.

The higher percentage of stems observed under the lower SHs may have contributed to the increase in NDF content. Another observation supporting this hypothesis is that, although morphological composition may vary, the literature indicates that the nutritive value of forage harvested at the same stage of maturity tends to remain relatively stable (P. R. Rodrigues et al., 2023; Ongaratto et al., 2021).

In vitro dry matter digestibility and CP contents were not affected by SH, stockpiling date, or the interaction between these factors ($p > 0.05$), with overall means of 663.1 g kg^{-1} and 67.9 g kg^{-1} , respectively. These results indicate the stability of forage nutritive value in response to the management strategies evaluated. One possible explanation is the uniformity of the regrowth period. Because the stockpiling period was kept constant, differences in the proportions of stems and leaves among SHs were not sufficient to significantly alter the CP and IVDMD contents of the forage. This pattern was reported by P. R. Rodrigues et al. (2023) and Ongaratto et al. (2021), who demonstrated that, although plant structure may change, nutritive value, particularly IVDMD and CP, tends to remain relatively stable when the physiological age of the plants is similar. It is also possible that, because nutritive value was analyzed in forage harvested above the SH, part of the stem fraction consisted of pseudostems, which have nutritive characteristics more

similar to those of leaves (Castagnara et al., 2011).

The results of the present study are relevant for planning pasture management strategies aimed at balancing the distribution of forage production during the dry season with the nutritive value of BRS Paiaguás forage under stockpiling conditions.

Conclusions

The 10 cm stubble height resulted in greater forage dry matter accumulation but a lower leaf-to-stem ratio and higher NDF content, whereas the 30 cm stubble height resulted in better structural characteristics and lower NDF content.

Early stockpiling (03/15) promoted greater canopy height, greater accumulation of green forage dry matter, and a lower proportion of senescent forage, whereas late stockpiling (04/15) reduced forage dry matter yield and increased the proportion of stems and senescent forage but did not affect digestibility or crude protein content.

To balance the yield and quality of BRS Paiaguás forage under stockpiling, the use of a 20 cm stubble height is recommended. Early and intermediate stockpiling results in greater forage availability and better forage quality.

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