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Nutritional value of elephant grass in response to different harvest times in Roraima state, Brazil

Valor nutricional do capim-elefante em resposta a diferentes idades de corte no estado de Roraima, Brasil

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Highlights

Later harvesting reduced the nutritional quality of elephant grass.
Mineral matter exhibited the smallest interaction with harvest time.
The ideal grass for silage production is 55 to 65 days.

Abstract

The nutritional value of forage grasses is associated with the optimal harvest time. Forage should be harvested at a developmental stage that balances high nutritional value with ample forage production. Accordingly, this study aimed to evaluate the nutritional value of elephant grass (*Pennisetum purpureum*) harvested at different times in a forest-savannah transition region in Roraima state, Brazil. This included chemical analyses and *in situ* degradability assessments. A randomized block design was employed, evaluating five harvest times (35, 45, 55, 65, and 75 days), each with four replications. Existing forage banks were utilized. Following collection on predetermined days, samples were pre-dried for subsequent chemical analysis of dry matter (DM), mineral material (MM), organic matter (OM), ether extract (EE), crude protein (CP), and neutral detergent fiber (NDF). *In situ* degradability of DM and NDF was also assessed. Significant differences were observed in DM, MM, OM, CP, and EE ($p < 0.01$), as well as in the

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degradabilities of DM and NDF. As the harvest time of elephant grass increased, levels of CP, MM, EE, and the degradability of DM and NDF decreased, while OM, DM, and NDF contents increased.
Key words: Ruminant nutrition. Degradability. Forage. *Pennisetum purpureum.* Silage.

Resumo

O valor nutricional das gramíneas forrageiras está associado a idade de corte ideal. Nesse processo, a forrageira deve ser colhida em estádio de desenvolvimento que associe alto valor nutritivo e boa produção de forragem. Assim, o objetivo deste trabalho foi avaliar o valor nutritivo do capim-elefante (*Pennisetum purpureum*) obtido em diferentes idades de corte, sendo cultivado em região de transição floresta-savana no estado de Roraima, Brasil, incluindo análises químico-bromatológicas e da degradabilidade *in situ.* Para tanto, utilizou-se delineamento em blocos casualizado, sendo avaliado em cinco idades de corte (35, 45, 55, 65, e 75 dias), cada um com quatro repetições. Foram utilizados capineiras já estabelecidas. Após a coleta nos dias pré-determinados, as amostras foram pré-secadas para posteriores análises químico-bromatológicas de matéria seca (MS), material mineral (MM), matéria orgânica (MO), extrato etéreo (EE), proteína bruta (PB) e fibra em detergente neutro (FDN) e realizadas a degradabilidade *in situ* da MS e FDN. Observou-se diferença significativa, para MS, MM, MO, PB e EE ($p < 0,01$), assim como para as degradabilidades da MS e FDN. Quanto maior a idade de corte do capim-elefante, menor são os teores de PB, MM, EE e da degradabilidade da MS e FDN, e aumento dos teores de MO, MS e FDN.
Palavras-chave: Nutrição de ruminantes. Degradabilidade. Forragem. *Pennisetum purpureum.* Silagem.

Introduction

The primary food source for animals in Brazilian livestock farming comes from extensive pasture areas, which are the most practical and economical option for livestock farmers (Sauceda et al., 2023). However, the seasonality of pasture availability poses one of the main challenges in ruminant production. This issue stems from the prolonged periods during which pastures are unavailable, creating difficulties in managing animal feed (Bratz et al., 2019).

Among the forage crops grown in tropical and subtropical regions, elephant grass (*Pennisetum purpureum* Schum.) is distinguished by its high potential for forage accumulation, nutritional value, acceptability across various animal species, vigor, and persistence (Bratz et al., 2019; Pereira et al., 2021). Owing to these traits, producing silage from elephant grass is a primary application, offering a cost-effective alternative to other forage options (Terra et al., 2019).

Elephant grass has a high dry matter (DM) yield (Tonin et al., 2018), good climate adaptability, and high nutritional quality when harvested at optimal green mass levels (Furtado et al., 2014). Due to its perennial nature and morphological characteristics, well-established and properly managed elephant grass pastures can sustain high productivity for decades (Olivo et al., 2017).

Silage from elephant grass serves as a complementary or alternative feed option, particularly when pastures are not in optimal condition for use. It allows for the preservation of feed over extended periods as silage, or for immediate use in its natural state by harvesting and providing it directly to the animals (Martins et al., 2020). Additionally, it can be combined with other types of dietary supplements (Tonin et al., 2018; Sauceda et al., 2023).

Harvest time significantly influences the nutritional value of forage grasses. Elephant grass must be harvested at a developmental stage that balances high nutritional value with good forage production (Rosa Neto, et al., 2020). As the development stage advances towards maturity, the dry matter (DM) content tends to increase (Fluck et al., 2018), while degradability tends to decrease (Sanchês et al., 2018). Hence, identifying the optimal harvest time for elephant grass is essential to produce silage with high nutritional quality, substantial DM content, and good digestibility.

Although research on the chemical (and nutritional) composition of elephant grass is extensive, little is known about the optimal timing for its harvest (Rosa et al., 2019). The management of forage harvesting significantly affects both its production and quality (Martins et al., 2020; Silva et al., 2023). Shorter harvesting intervals typically result in lower DM production but higher nutritional values, whereas longer intervals yield higher DM production but lower nutritional quality (Souza et al., 2017; Tonin et al., 2018).

Given the increasing demand for high-quality silage, particularly in regions facing feed shortages during droughts or for enhancing feed supplementation or pasture replacement, it is crucial to conduct a thorough investigation of elephant grass. Therefore, the aim of this study is to determine the chemical characteristics of elephant grass grown in different developmental stages in the state of Roraima, Brazil.

Material and Methods

The experiment was carried out in the experimental field of the Federal Institute of Education, Science, and Technology of Roraima (IFRR), Campus Novo Paraíso (CNP), located in the municipality of Caracaraí, Roraima state, Brazil (geographical coordinates: 01°14’51.6” N and 60°28’20.4” W, altitude of 105 m asl). The climate is classified as seasonal tropical (Am) according to the Köppen classification system (Barbosa, 1997), characterized by warm and humid conditions, with annual rainfall ranging from 1600 to 2000 mm. The rainy season extends from April to September, with peak precipitation occurring between May and June (Figure 1) (Barni et al., 2022). Soil chemical analyses were performed at the Soil Laboratory on the Novo Paraíso campus, while the forage chemical analyses were conducted at the Forage Laboratory of the State University of Southwest Bahia - Juvino Oliveira Campus, in the municipality of Itapetinga, Bahia state, Brazil.

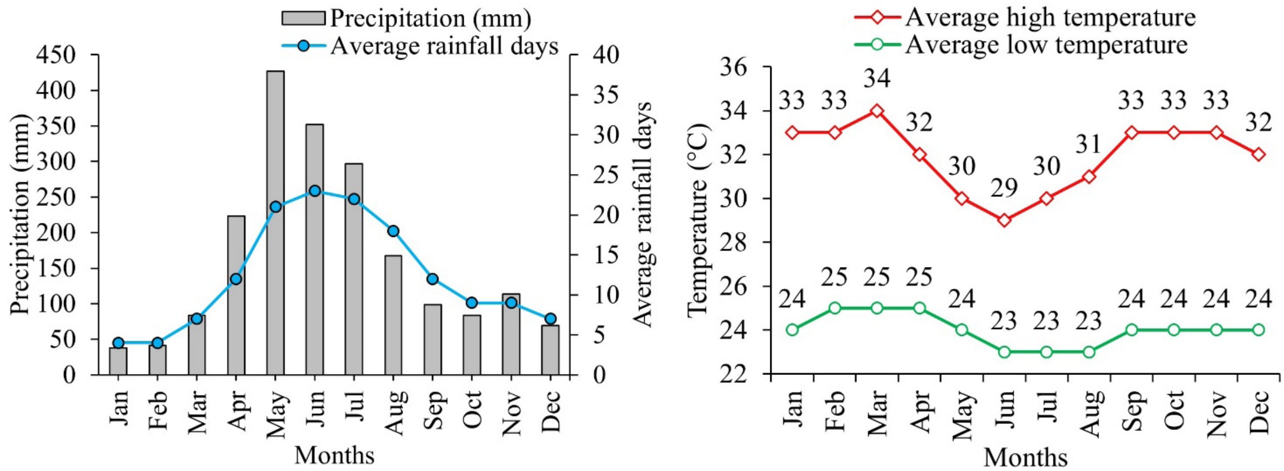

Figure 1. Climatic variables (temperature and rainfall) in the municipality of Caracaraí - RR, Brazil, in the last 12 years.
Source: Instituto Nacional de Meteorologia [INMET] (2024); World Weather Online (2024); Marsaro et al. (2011); Barni et al. (2022).

The study utilized established forage banks of elephant grass (*Pennisetum purpureum* Schum.) variety Roxo in the IFRR/CNP Agrostological Field, which were adapted to local conditions for better development. Activities commenced at the onset of the rainy season to capitalize on natural rainfall and thus avoid the need for irrigation.

A randomized block design was implemented, dividing the forage banks into 20 plots/blocks, each measuring 7.5 m², with a total experimental area of 150 m². Five treatments were tested based on different harvest times: T1 - 35 days, T2 - 45 days, T3 - 55 days, T4 - 65 days, and T5 - 75 days of growth. Each treatment included four replications. At each specified harvest time, only the centralmost plants were collected for analysis, while the border plots, containing the outermost lines/plants, were excluded from the sample collection.

Immediately after a uniformity cut at 20 cm from the soil, the soil fertility of the forage banks was corrected through the application of a top-dressing maintenance fertilizer, with 200 kg/ha of N (urea), 50 kg/ha of P_2O_5 (single superphosphate), and 200 kg/ha of K_2O (potassium chloride). The grass was manually harvested after the uniformity cut and following the established growth period for each treatment. Soon after, it was chopped into approximately 2-cm pieces using an electric forage chopper, homogenized, separated into plastic bags, labeled, and stored in a freezer for later analysis. The duration the grass remained in the freezer varied between five and 20 days, depending on the treatment.

These steps were designed to simulate the ensiling process commonly used in forage crop silage production.

After removal from the freezer, the samples were placed in an oven at 60±5

°C for 72 h for pre-drying, then packaged, labeled, and sent for chemical analysis. The chemical composition of the grass was analyzed following procedures described by Silva and Queiroz (2002). The samples were ground using mills with 4-mm sieves and placed in nylon bags at approximately 3 g of dry matter/bag to maintain a ratio close to 20 mg of DM/cm² of bag surface area. After the stipulated period, the bags were removed from the rumen, where they had been attached to a 30 cm long nylon cord tied to the cannula lid. To ensure stability, a 0.5-kg weight was attached to the end of the nylon cord. This methodology was applied to Girolando cattle, averaging a weight of 500±50 kg, cannulated in the rumen, and maintained on Brachiaria brizantha pasture.

After all rumen bags were removed, they were washed under running water and then dried in an air oven with forced ventilation at 60 °C for 72 h and weighed to determine the DM disappearance. The residue from this process was used for neutral detergent fiber (NDF) analysis, following the methodologies described by Silva and Queiroz (2002).

For statistical analyses, assumptions of analysis of variance (ANOVA) were verified for normality using the Shapiro-Wilk test ($p > 0.05$) and homoscedasticity with the Bartlett test ($p > 0.05$). The quantitative variables were subjected to simple linear regression analysis with time as the explanatory variable and the dependent variables as response variables. Graphs were generated using the “ggplot2” package (Wickham, 2016). All statistical analyses were conducted in R version 4.2.3 (R Development Core Team [R], 2023), with a significance level set at 5%.

Results and Discussion

Dry matter (DM) comprises the portion of total mass that encapsulates all nutrients, excluding only moisture. The regression analysis from this study shows a positive relationship between harvest time and the percentage of DM in elephant grass. It was found that DM varied significantly with harvest time ($p = 0.001$), increasing linearly with the highest DM values (13.41%) observed at 75 days (Figure 2). The regression model revealed a 43% correlation ($R^2 = 0.43$) between harvest time and DM percentage in elephant grass, attributed to large variation in the data.

However, all observed treatments resulted in DM levels below those recommended for high-quality silage. According to Kung et al. (2018), ideal fermentation for high-quality silage occurs when DM levels exceed 25%, highlighting that the DM results for elephant grass were unsatisfactory in this study. The focus here was solely on the nutritional values of the forage, disregarding DM yield or total grass production, aiming to enhance the quality of feed provided to animals during critical periods. The same pattern was observed by Tonin et al. (2018), where elephant grass harvested 75 days after regrowth had a DM content of 15.6% in pre-ensiled forage. The study also noted that the inclusion of ground corn could increase the DM content up to 28% in fresh forage, suggesting that additives might be beneficial in enhancing DM levels.

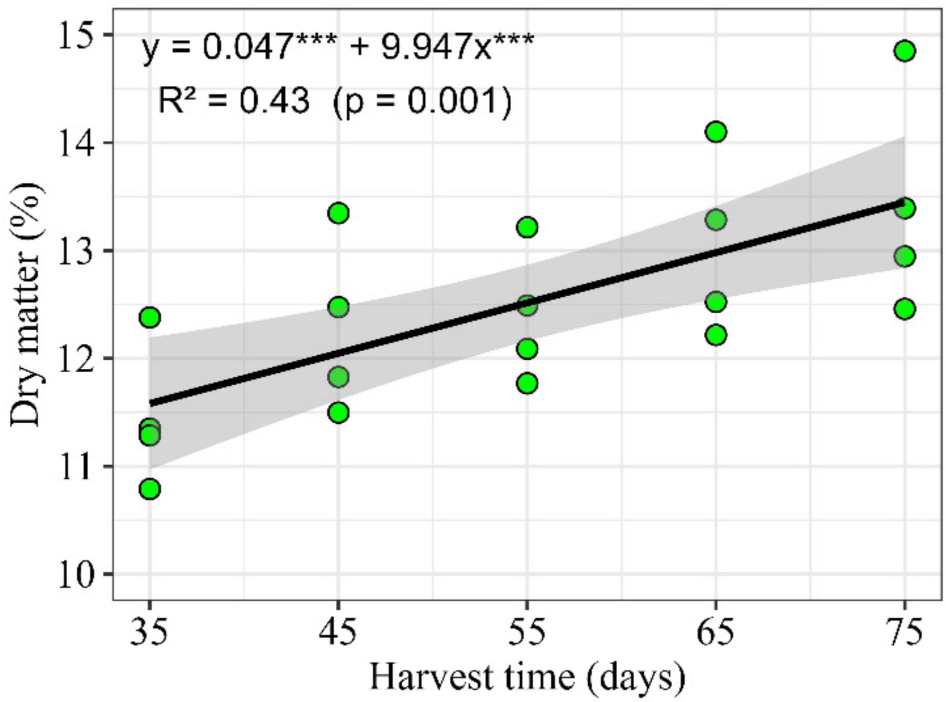

Figure 2. Linear regression of dry matter (%) in elephant grass as a function of harvest time in days.

Mineral matter (MM), obtained by ashing organic matter, represents the non-organic fraction and essentially the mineral content present in the analyzed feed. As MM levels increase, a corresponding decrease in energy levels is generally expected (Souza et al., 2017). In this study, MM levels showed a significant decrease with longer harvest intervals ($p = 0.001$) (Figure 3), as indicated by a negative relationship in the regression model between harvest time and MM percentage in elephant grass. The regression model revealed a moderate relationship ($R^2 = 0.45$) between harvest time and the percentage of MM in elephant grass, with the scattered values of repetitions contributing to increased data variability.

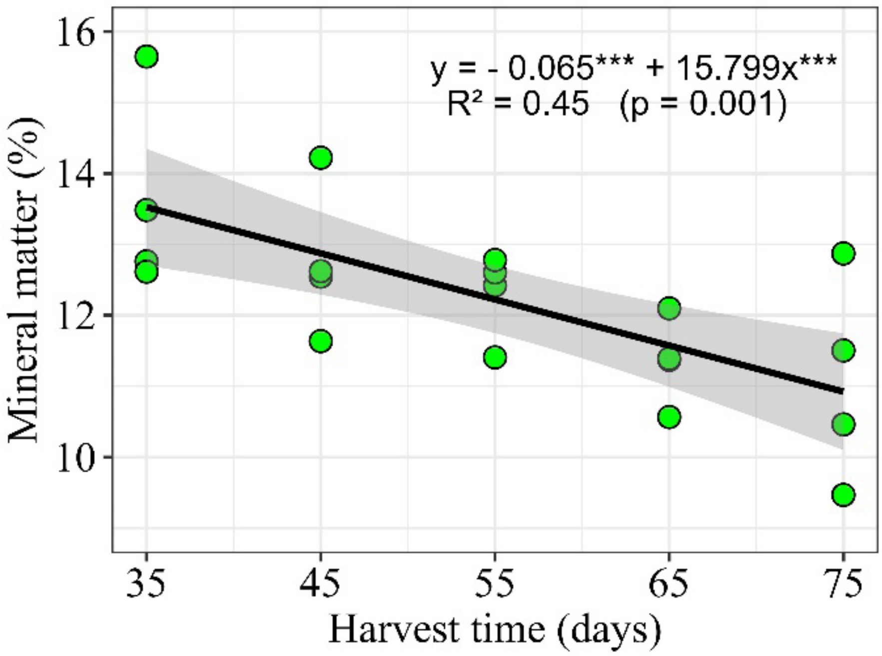

Figure 3. Linear regression of mineral matter (%) in elephant grass as a function of harvest time in days.

The analysis of the mineral fraction is important to ensure the provision of essential minerals required for the healthy development of animals. Carvalho (1985) mentioned that mineral matter (MM) levels in forage can vary between 3.8% and 11.6%, irrespective of the age of the grass. However, according to Prospero (1972), the ash content in elephant grass can exceed these values, reaching up to 15.79%. In this study, regardless of the age of the grass, the average MM values were similar to those reported in the literature and fell within the ideal range for this variable.

Deminicis et al. (2014) observed MM levels of 7.0% in silage made exclusively from elephant grass and 5.9% in silage mixed with cornmeal. Supporting these findings, Apráez Guerrero et al. (2012) suggested that MM levels exceeding 12% might be indicative of soil contamination during forage harvesting or silage preparation. Such contamination can lead to secondary fermentations and reduced consumption. Moreover, a deficiency in MM can diminish animal performance and increase the prevalence of health issues (Van Soest, 1994).

Organic matter (OM) in feed is a critical indicator of nutritional quality. In this study, OM was significantly influenced by harvest time ($p = 0.005$), exhibiting a linear increasing trend (Figure 4) with the highest values observed at 75 days of growth. The regression model accounted for 34% of the variation in OM percentage in elephant grass ($R^2 = 0.34$), with a wide dispersion of repetition values contributing to increased data variability. Most of these findings align with those of Martins et al. (2020), who observed OM percentages ranging from 88.80% to 92.90% in green elephant grass harvested at different regrowth intervals, specifically at 56, 84, and 112 days.

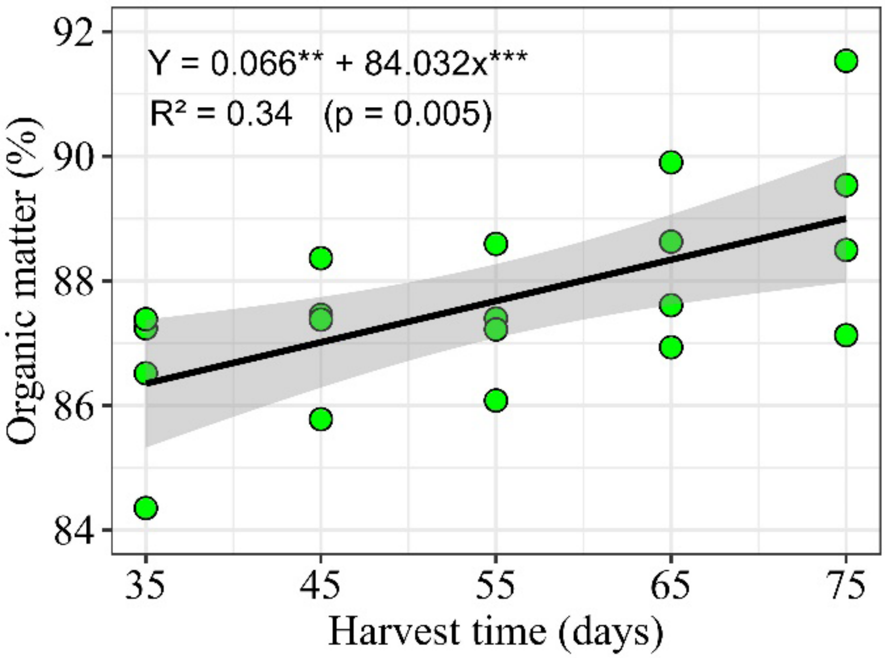

Figure 4. Linear regression of organic matter (%) in elephant grass as a function of harvest time in days.

Crude protein (CP) concentration was significantly affected by harvest time ($p = 0.001$). The derived regression model demonstrated a negative relationship between harvest time and CP percentage in elephant grass (Figure 5), explaining 90% of this relationship ($R^2 = 0.90$) with closely grouped repetition values, thus reducing data variation. Most CP values exceeded the minimum threshold of 7% recommended by Van Soest (1994), which is considered essential to prevent the restriction of ruminant consumption due to forage digestibility issues. The results indicate satisfactory levels for this variable.

To meet the minimum CP levels for ruminants, this study recommends using elephant grass from the Roxo variety harvested between 35 and 65 days. However, it is important that the dry matter content within this age range remain high enough for effective ensiling. Adjustments might be necessary through production management practices or techniques aimed at reducing grass moisture content prior to ensiling.

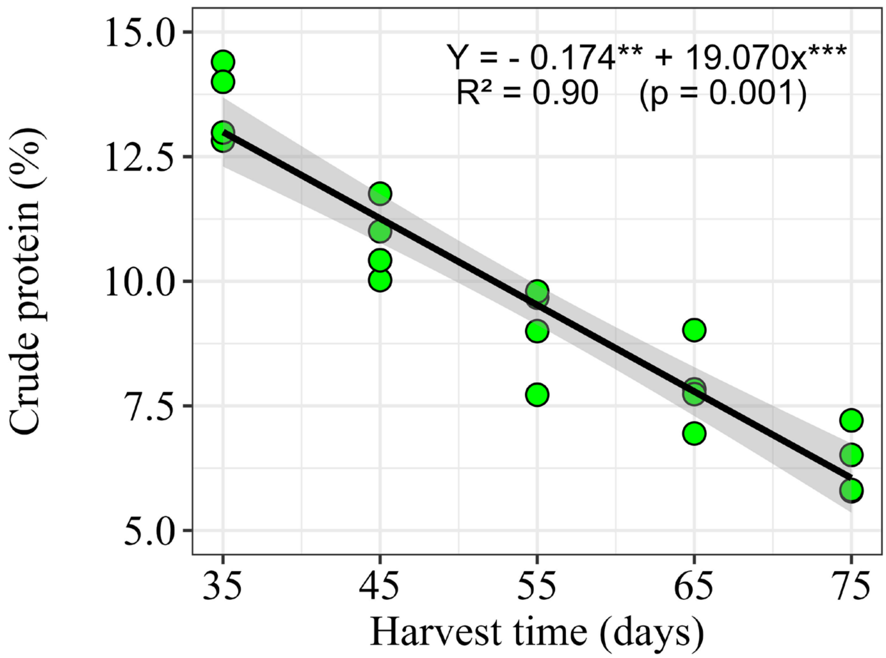

Figure 5. Linear regression of crude protein (%) in elephant grass as a function of harvest time in days.

Neutral detergent fiber (NDF), representing the indigestible or insoluble fibrous components of feed when exposed to a neutral detergent solution comprising cellulose, hemicellulose, lignin, pectin, and silica (Van Soest, 1994) was positively and significantly influenced by harvest time ($p = 0.001$), with NDF percentages increasing with extended growth periods (Figure 6). The regression model showed a positive correlation between harvest time and NDF percentage in elephant grass, explaining 56% of the variation ($R^2 = 0.56$). As the harvest time extends, NDF values increase.

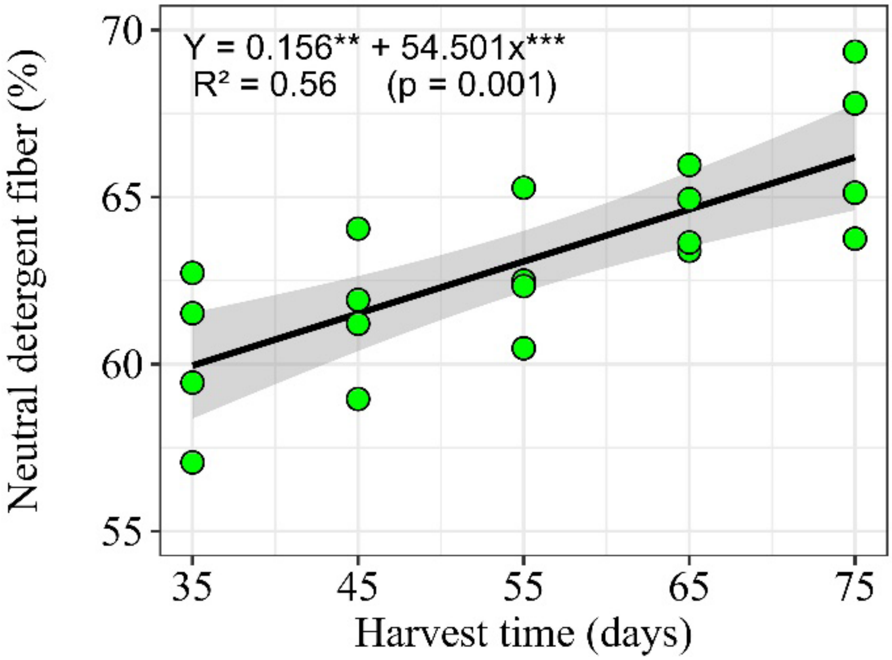

Figure 6. Linear regression of neutral detergent fiber (%) in elephant grass as a function of harvest time in days.

Understanding and evaluating the neutral detergent fiber (NDF) content of forage is crucial for assessing forage quality. Although an increase in NDF can signal robust fiber content, it also means that the digestion of elephant grass in the gastrointestinal tract becomes slower (Van Soest, 1994). This results in prolonged pre-gastric retention times when grass is harvested at more mature stages, causing the more fibrous pasture to occupy more space in the rumen for extended periods, which in turn delays further food intake. In the research by Martins et al. (2020), a decrease in forage protein content and an increase in the levels of indigestible NDF and lignin were also found with varying regrowth ages as well as harvest times. The NDF values at 56 days (66.76%) were similar to those observed in the current study at 55 days (62.65%).

Ether extract (EE), which measures total lipid content, consists of substances soluble in organic solvents like petroleum ether, chloroform, and benzene, encompassing fats, oils, and pigments. It represents one of the most energy-rich parts of food and is a significant metric in food analysis, providing essential information about the quality of the analyzed product (Silva & Queiroz, 2002). Ether extract was significantly influenced by harvest age ($p < 0.001$), showing a linear decrease (Figure 7). The regression model indicated a negative relationship between harvest time and EE percentage in elephant grass. The regression graph depicted a decreasing trend in EE over time. However, the regression model explained only 40% of the relationship between harvest time and EE percentage in elephant grass ($R^2 = 0.40$), likely due to the dispersion of values across repetitions, which increased data variability.

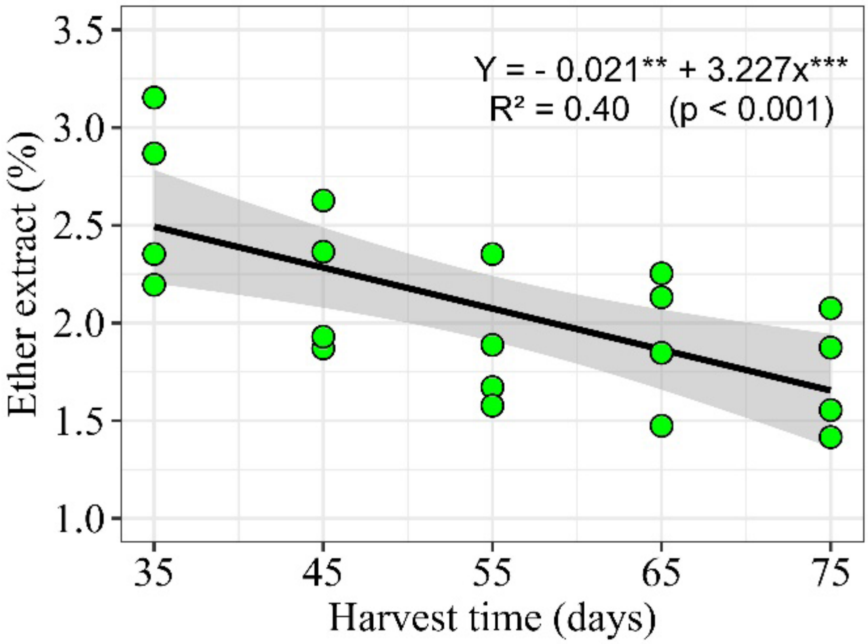

Figure 7. Linear regression of ether extract (%) in elephant grass as a function of harvest time in days.

All evaluated treatments produced EE results within the expected limits, between 2.49% and 1.37%, aligning with benchmarks set by Jorge et al. (2008). These values fall below the critical level for lipids in the diet, established at a maximum of 6% of EE in DM. Thus, the findings suggest that under the conditions investigated, the EE content of elephant grass remains at satisfactory levels, staying within safe limits for ruminal degradation without exceeding thresholds that could hinder ruminal degradation (Jorge et al., 2008).

Similar to findings from Martins et al. (2020), the mean EE contents throughout the growth cycle of elephant grass also showed a decreasing trend, with values diminishing from 2.27% at 56 days to 1.68% at 84 days, and further to 1.45% at 112 days.

In the present study, the mean values of EE varied over time. At 35 days, the mean was 2.49%, followed by 1.82% at 45 days, 1.37% at 55 days, 1.88% at 65 days, and 1.74% at 75 days. Both studies showed similar means of EE, especially at 56 days and in the period between 65 and 84 days of grass age.

These convergences and divergences in EE levels highlight the influence of factors such as management, climate conditions, and other aspects, demonstrating the importance of considering temporality and the diversity of factors when interpreting the results to ensure adequate nutrition for animals.

Regarding the values of DM degradability and NDF degradability, higher values correspond to better nutritional value and forage quality, as they exhibit high degradation when they come into contact with the digestive tract of the animal. The degradability of DM and NDF was influenced by harvest time, being highly significant ($p < 0.001$) and decreasing linearly (Figures 8 and 9). The trend was negative, indicating that as time passes, the response variables are lower. For this reason, the treatment at 35 days of growth exhibited the highest level of degradability for DM and NDF. As for the DM degradability, the regression model explained 82% of the relationship between harvest time and the percentage of the variable ($R^2 = 0.82$), similar to the NDF degradability, where the regression model explained 78% of the relationship between the cut-off age and the percentage of the variable ($R^2 = 0.78$). This is due to the repetition values being closer together, thus reducing data variation.

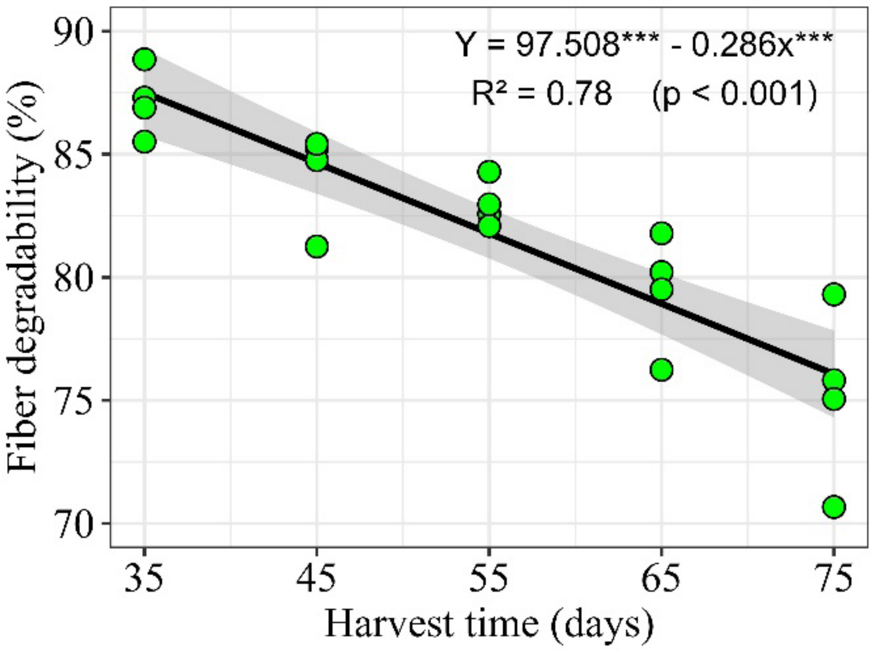

Figure 8. Linear regression of neutral detergent fiber degradability in elephant grass as a function of harvest time in days.

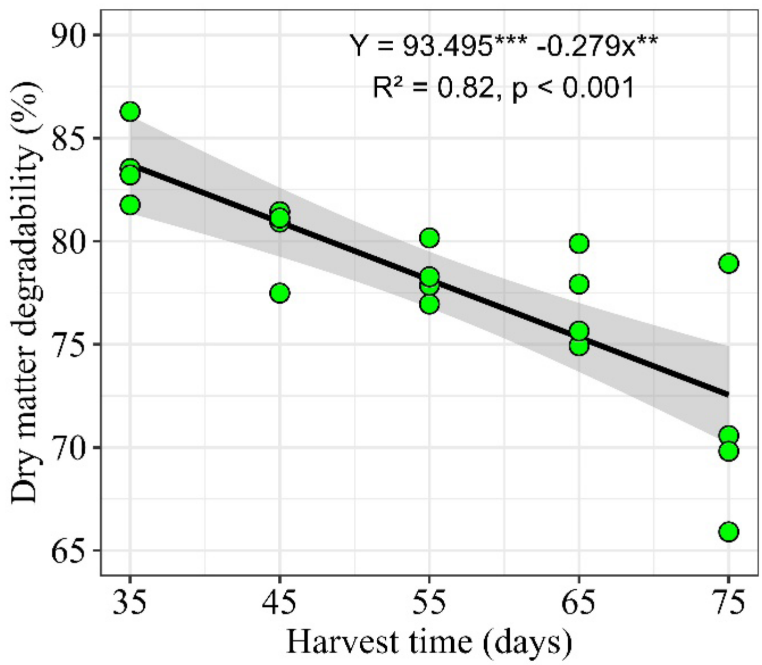

Figure 9. Linear regression of dry matter degradability (%) in elephant grass as a function of harvest time in days.

In a study on the degradability of elephant grass at different maturity stages, Campos et al. (2002) observed results similar to those found in this work, comparing the means between the stem and the leaf of elephant grass. The results indicated that the advancement of the plant's maturity stage directly influences the degradability of DM and NDF in the stem and leaf fractions of elephant grass. A decrease in the degradability of the elephant grass fractions was noted with the advancement of the maturity stage, with this effect being more pronounced in stems due to greater lignification of the cell wall.

Sanchês et al. (2018) reached the same conclusion when investigating the quantitative anatomy and in situ ruminal degradation parameters of elephant grass under different defoliation frequencies. The authors observed that the DM degradation in the two fractions evaluated decreased significantly with increasing plant maturity. Therefore, the pattern where the degradation of elephant grass decreases over time is confirmed.

Elephant grass has shown significant potential for forage production in Roraima. For silage, harvesting should take place between 55 and 65 days to ensure better nutritional balance. For direct feeding during scarcity periods, it is recommended to harvest the forage between 35 and 45 days, when it offers greater degradability and nutritional quality.

Conclusions

The harvest time negatively affected the nutritional value of elephant grass, characterized by a linear reduction in the levels of crude protein and ether extract, and a linear increase in the insoluble fractions of dry matter and neutral detergent fiber, accompanied by a decrease in degradability of grass fractions as the maturity stage advanced. For silage usage, the grass should be harvested between 55 and 65 days, while for direct feeding, harvesting is optimal between 35 and 45 days.

For future research, incorporating productivity data such as biomass production and economic value could assess the practical viability of managing different harvest times. This would allow for a more comprehensive evaluation of the suggested management effectiveness, enabling an improved balance between the nutritional quality and productivity of the forage, whether for silage or direct consumption.

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