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Agronomic characteristics of Tamani grass under different defoliation frequencies and intensities

Características agronómicas del pasto Tamani bajo diferentes frecuencias e intensidades de defoliación

Características agronômicas do capim Tamani sob diferentes frequências e intensidades de desfolha

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Abstract

Background: Management strategies may affect plant growth and herbage characteristics. Thus, understanding their impact may help to define appropriate management. **Objective:** To evaluate the effect of different defoliation intensities and frequencies on structural characteristics, biomass components, and the potential use of NDVI (normalized difference vegetation index) in pastures with *Megathyrsus maximus* cv. BRS Tamani. **Methods:** A randomized block design in a 2x3 factorial arrangement was adopted, with two defoliation frequencies (85 and 95% interception of photosynthetically active radiation (IPAR) and three defoliation intensities (residual leaf area index (LAIr) of 0.8, 1.3, and 1.8). **Results:** The frequency of defoliation affected the pre-defoliation leaf area index, height, total harvestable forage biomass (HTFB), and harvestable leaf blade (HGLB), with higher values for pastures managed at 95% IPAR. The effect of defoliation intensity was observed for HTFB and HGLB, where pastures with lower LAIr presented higher biomass values. Pastures managed at 95% IPAR and higher LAIr reached the saturation level of the NDVI more quickly. Pastures managed under the combination of 95% IPAR and LAIr of 0.8 showed higher production of harvestable green stem biomass and harvestable dead forage biomass. The combination of 95% IPAR with LAIr of 0.8 or 1.8 enabled a higher number of new live leaves when compared to pastures with 85% IPAR. **Conclusion:** Tamani grass must be managed with a defoliation frequency of 95% interception of photosynthetically active radiation, maintaining a residual leaf area index between 0.8 and 1.3.

Keywords: *biomass; defoliation; forage production; leaf area index; Megathyrsus maximus; pasture; photosynthetically active radiation; semiarid region; vegetation index.*

Resumen

Antecedentes: Las estrategias de manejo pueden afectar el crecimiento de las plantas y las características del pasto. Por lo tanto, comprender su impacto puede ayudar a definir un manejo más adecuado. **Objetivo:** Evaluar el efecto de diferentes intensidades y frecuencias de defoliación sobre las características estructurales, los componentes de la biomasa y el uso potencial del NDVI (índice de vegetación de diferencia normalizada) en pastos con *Megathyrsus maximus* cv. BRS Tamani. **Métodos:** Se adoptó un diseño de bloques al azar en un arreglo factorial 2 × 3, con dos frecuencias de defoliación (85 y 95% de intercepción de radiación fotosintéticamente activa (IPAR)) y tres intensidades de defoliación (índice de área foliar residual (LAIr) de 0,8, 1,3 y 1,8). **Resultados:** La frecuencia de defoliación afectó el índice de área foliar previo a la defoliación, la altura, la biomasa forrajera total cosechable (HTFB) y la lámina foliar cosechable (HGLB), con valores superiores para los pastos manejados con 95% de IPAR. El efecto de la intensidad de defoliación se observó en las variables HTFB y HGLB, donde los pastos con menor LAIr presentaron mayores valores de biomasa. Los pastos manejados con 95% de IPAR y mayor LAIr alcanzaron el nivel de saturación del NDVI más rápidamente. Los pastos manejados con una combinación de 95% de IPAR y LAIr de 0,8 mostraron mayor producción de biomasa de tallo verde cosechable y biomasa de forraje muerto cosechable. La combinación de 95% de IPAR con LAIr de 0,8 o 1,8 permitió un mayor número de hojas vivas nuevas en comparación con los pastos con 85% de IPAR. **Conclusiones:** El pasto Tamani debe manejarse con una frecuencia de defoliación del 95% de intercepción de la radiación fotosintéticamente activa, manteniendo un índice de área foliar residual entre 0,8 y 1,3.

Palabras clave: *biomasa; defoliación; índice de área foliar; índice de vegetación; Megathyrsus maximus; pastoreo; producción de forraje; radiación fotosintéticamente activa; región semiárida.*

Resumo

Antecedentes: Estratégias de manejo podem afetar o crescimento das plantas e as características da pastagem. Assim, o entendimento do impacto pode ajudar a definir manejos mais adequados. **Objetivo:** Avaliar o efeito de diferentes intensidades e frequências de desfolhamento sobre as características estruturais, os componentes da biomassa e o potencial de uso do NDVI (índice de vegetação de diferença normalizada) em pastagens com *Megathyrsus maximus* cv. BRS Tamani. **Métodos:** Adotou-se o delineamento de blocos casualizados em esquema fatorial 2 × 3, com duas frequências de desfolhamento (85 e 95% de interceptação da radiação fotossinteticamente ativa (IPAR)) e três intensidades de desfolhamento (índice de área foliar residual (LAIr) de 0,8, 1,3 e 1,8). **Resultados:** A frequência de desfolha afetou o índice de área foliar pré-desfolhamento, a altura, a biomassa forrageira total colhível (HTFB) e a lâmina foliar colhível (HGLB), com maiores valores para pastagens manejadas com 95% de IPAR. O efeito da intensidade de desfolha foi observado nas variáveis HTFB e HGLB, onde pastagens com menor LAIr apresentaram maiores valores de biomassa. As pastagens manejadas com 95% de IPAR e maior LAIr atingiram o nível de saturação do NDVI mais rapidamente. As pastagens manejadas com uma combinação de 95% de IPAR e LAIr de 0,8 apresentaram maior produção de biomassa de colmo verde e biomassa de forragem morta colhível. A combinação de 95% de IPAR com LAIr de 0,8 ou 1,8 possibilitou um maior número de novas folhas vivas quando comparado às pastagens com 85% de IPAR. **Conclusões:** O capim Tamani deve ser manejado com uma frequência de desfolhamento de 95% de interceptação da radiação fotossinteticamente ativa, mantendo um índice de área foliar residual entre 0,8 e 1,3.

Palavras-chave: *biomassa; desfoliação; índice de área foliar; índice de vegetação; Megathyrsus maximus; pastagem; produção de forragem; radiação fotossinteticamente ativa; região semiárida.*

Introduction

Pastures are the least expensive way of providing feed for herds, being the main feed used to produce ruminants in tropical areas. However, despite the importance of grazed pastures, one of the main causes of low production indices in animal production systems is the inadequate management of pastures. The evaluation of the impacts of management strategies on plant growth is of fundamental importance for determining the most appropriate management.

The adoption of appropriate management practices depends on an understanding of the physiological changes that occur in plants (Lima et al., 2020). According to Gastal and Lemaire (2015), the spatial arrangement of morphological components can affect plant growth, forage production, and pasture structural characteristics. To increase productivity and improve the structural characteristics of the canopy, it is necessary to adopt an adjusted frequency of defoliation and intensity (Silva et al., 2015), allowing pastures to have less stem elongation, a higher leaf/stem ratio, and greater tiller density.

Defoliation, determined by intensity and frequency, directly affects the development of the forage plant, and the plant's response to this process is dependent on the amount of tissue removed and the photosynthetic capacity of the remaining leaves (Cerato et al., 2010). The intensity and frequency of defoliation affect the structure of the canopy, influencing the distribution of structural components, which affects the production, quality, and consumption of forage.

A low frequency and intensity of defoliation increase senescence, causing forage losses and allowing greater stem accumulation, while higher frequency and intensity of defoliation decrease the persistence of pastures due to depletion of organic reserves and tiller decapitation (Vidal et al., 2010). The combination of defoliation frequencies and intensities can generate different results for the canopy structure, biomass production, and nutritive value of the forage.

The grasses of the *Megathyrsus* genus (syn. Panicum) have gained attention in tropical livestock production due to their high production (Vasconcelos et al., 2020), higher concentrations of crude protein, around 132.1 g kg^{-1} DM (Costa et al., 2022), and greater acceptance by animals. The cultivar Tamani (*Megathyrsus maximus* cv. BRS Tamani) stands out for its high biomass production, mainly of the leaf blade (Vasconcelos et al., 2020), adaptation to tropical edaphoclimatic conditions, high crude protein content, and flexibility regarding possible management errors. However, studies are necessary to evaluate the response of this cultivar when subjected to different management practices, aiming to find management strategies that are appropriate for this cultivar. Therefore, our hypothesis is that different combinations of defoliation frequency and intensity influence the agronomic characteristics of Tamani grass.

The present study aimed to evaluate the effect of different defoliation intensities and frequencies on pasture structural characteristics, biomass components, and the potential use of the normalized difference vegetation index (NDVI) in pastures planted with *Megathyrsus maximus* cv. BRS Tamani.

Materials and Methods

Location

The experiment was conducted at the Núcleo de Ensino e Estudos em Forragicultura – NEEF/DZ/CCA/UFC of Universidade Federal do Ceará, at the geographical coordinates 03° 45′ 47″ S, 38° 31′ 23″ W, with a climate classified as Aw’ (tropical rainy), according to Köppen's classification (Köppen, 1936). The climatic data (Figure 1) for the experimental period (April to August 2019) were obtained from the Estação Agrometeorológica of Universidade Federal do Ceará.

Experimental design

The experimental area covered 408 m^2, with 300 m^2 of usable area, where *Megathyrsus maximus* (syn. *Panicum maximum*) cv. BRS Tamani was pre-established in 2017, and subdivided into 24 plots, each measuring 12.5 m^2. A randomized complete block design was adopted, with four replications (2.5 × 5.0 m plots), in a 2 × 3 factorial arrangement. The treatments consisted of combinations of two defoliation frequencies (85 and 95% interception of photosynthetically active radiation) and three defoliation intensities (residual leaf area indexes of 0.8, 1.3, and 1.8).

The soil analysis was carried out at the beginning of the experiment and showed the following chemical characteristics, based on samples taken from a 0–20 cm layer depth: pH in water: 8.1; P (mg dm^{-3}): 12.0; K (mg dm^{-3}): 43.01; Ca^{2+} (cmolc dm^{-3}): 1.0; Mg^{2+} (cmolc dm^{-3}): 1.0; CTC (%): 2.6; V (%): 94; and MO (g kg^{-1}): 4.86. Based on the soil analysis, soil fertility correction was carried out following the recommendations of the Comissão de Fertilidade do Solo do Estado de Minas Gerais (CFSEMG, 1999) for grasses with high productive potential.

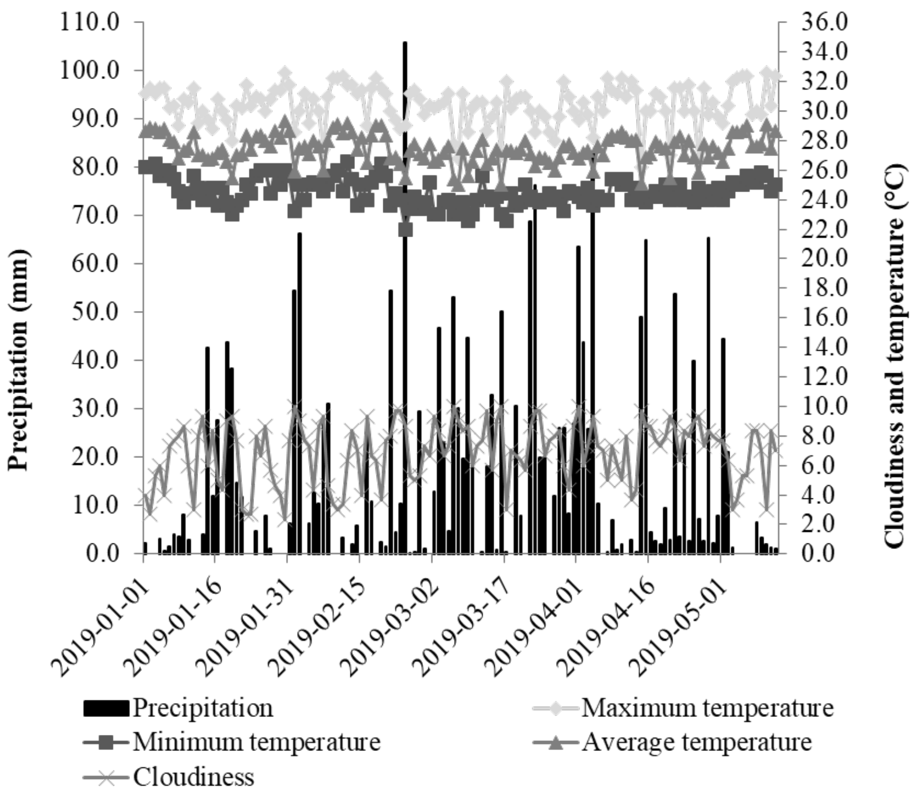

Figure 1. Precipitation, average, minimum, and maximum temperatures, and cloudiness during the experimental period (three regrowth cycles) in Fortaleza, Ceará, Brazil.

Nitrogen fertilization was carried out at a dose equivalent to 600 kg ha^{-1} $year^{-1}$ of nitrogen in the form of urea, phosphorus at a dose of 200 kg ha^{-1} $year^{-1}$ in the form of P_2O_5, potassium at a dose of 200 kg ha^{-1} $year^{-1}$ in the form of KCl, and micronutrients (FTE BR) at a dose of 35 kg ha^{-1} $year^{-1}$. The fertilizers were split across all regrowth cycles: the first half was applied after cutting (height according to the LAIr) and the second half in the middle of the growing cycle, except for micronutrient fertilization, which was applied in a single dose. The cycles were defined according to the IPAR (85 or 95%); when this threshold was reached, growth was interrupted, and cutting was performed. The pasture was managed using low-pressure sprinkler irrigation (service pressure ≤2.0 kgf cm^{-2}), applying a fixed daily amount of 6.8 mm of water per day.

To monitor the expected frequency of defoliation at the end of the cycle (85 and 95% interception of photosynthetically active radiation (IPAR)) and the intensity of defoliation (residual leaf area index (LAIr) of 0.8, 1.3, and 1.8), the PAR-LAI analyzer Accupar LP-80® (Decagon Devices Inc., Pullman, Washington, USA) was used, taking two readings for IPAR and LAIr per plot before and after harvesting, respectively.

The measurement of the normalized difference vegetation index (NDVI) was performed using a GreenSeeker® portable device (Trimble Companies, Norcross, Georgia, USA). Readings were taken from each plot by placing the sensor at a height of 60 cm above the canopy for one minute.

The canopy height (cm) was measured at 20 random points within each plot using a retractable graduated rod, recording the distance from the ground to the curvature of the highest leaf touched by the tip of the rod. The tiller population density (TPD; tiller m^{-2}) was estimated by counting all live tillers inside a 0.25 × 0.25 m frame. To determine the number of new live leaves per tiller, 20 random tillers were sampled, assigning a value of 1.0 for leaves with an exposed ligule and 0.5 for leaves with an unexposed ligule.

The harvestable total forage biomass (HTFB), harvestable green leaf blade biomass (HGLB), harvestable green stem biomass (HGSB), and harvestable dead forage biomass (HDFB) were estimated by cutting. In each plot, two samples of 0.50 × 0.50 m were cut using scissors, following the LAIr specified for each treatment, and taken to the laboratory for separation into green and dead material. Within the living material, leaf blades were separated from stems. All fractions were weighed, dried in a forced-air oven at 55 °C until reaching constant weight, and weighed again. From the total dry weight and fractions, the harvestable forage biomass was quantified.

Statistical analysis

The data, obtained as averages per regrowth cycle, were subjected to analysis of variance and mean comparison tests. The interaction between defoliation frequencies and intensities was analyzed when significant ($p < 0.05$) using the F-test. To compare means, the Tukey test was applied at a 5% probability level. In the regression analysis, model selection was based on the significance of the linear and quadratic coefficients, considering a 5% significance level. For statistical analysis, the GLM procedure was adopted using the SAS software (version 9.0, SAS Institute Inc., Cary, NC, USA; 2002).

Results

The management objectives recommended for Tamani grass were achieved and can be observed in Table 1. For the interception of photosynthetically active radiation (IPAR), the observed defoliation frequency showed an adjustment of 92.33% to the recommended values (Figure 2A). Meanwhile, for the residual leaf area index (LAIr), the observed defoliation intensity showed an adjustment of 93.33% to the recommended values (Figure 2B).

Table 1. Target and observed management objectives, residual height, and residual normalized difference vegetation index (NDVIr) for Tamani grass under different combinations of defoliation frequencies and intensities in Fortaleza, Ceará, Brazil.

ID	FD		Mean	SEM	p-value		
	85	95			ID	FD	ID*FD
Interception of photosynthetically active radiation (IPAR %; CV= 1,37%)							
0.8	85.8	94.8	90.3				
1.3	86.9	93.6	90.2	1.171	0.308	0.002	0.293
1.8	84.9	94.4	89.7				
Mean	85.8b	94.3a					

			Residual leaf area index (LAIr; CV= 5.23%)				
0.8	0.92	0.82	0.88C				
1.3	1.29	1.32	1.31B	0.069	0.021	<0.001	0.051
1.8	1.83	1.68	1.75A				
Mean	1.35a	1.27b					
			Residual height (cm; CV = 3.10%)				
0.8	14.9	14.4	14.6C				
1.3	16.1	16.1	16.1B	0.504	0.289	<0.001	0.646
1.8	18.0	17.8	17.9A				
Mean	16.3	16.1					
			NDVIr (CV = 6.14%)				
0.8	0.39	0.43	0.41C				
1.3	0.61	0.61	0.61B	0.035	0.938	<0.001	0.113
1.8	0.70	0.66	0.68A				
Mean	0.57	0.57					

ID: intensity of defoliation; **FD:** frequency of defoliation; **SEM:** Standard error of the mean. Means followed by different uppercase letters within columns (for each variable) and lowercase within rows differ statistically from each other ($p<0.05$) by the Tukey test.

The high determination coefficient values for IPAR (Figure 2A) and LAIr (Figure 2B) indicate that the observed management closely matched the recommended practices, confirming that the target management conditions were achieved.

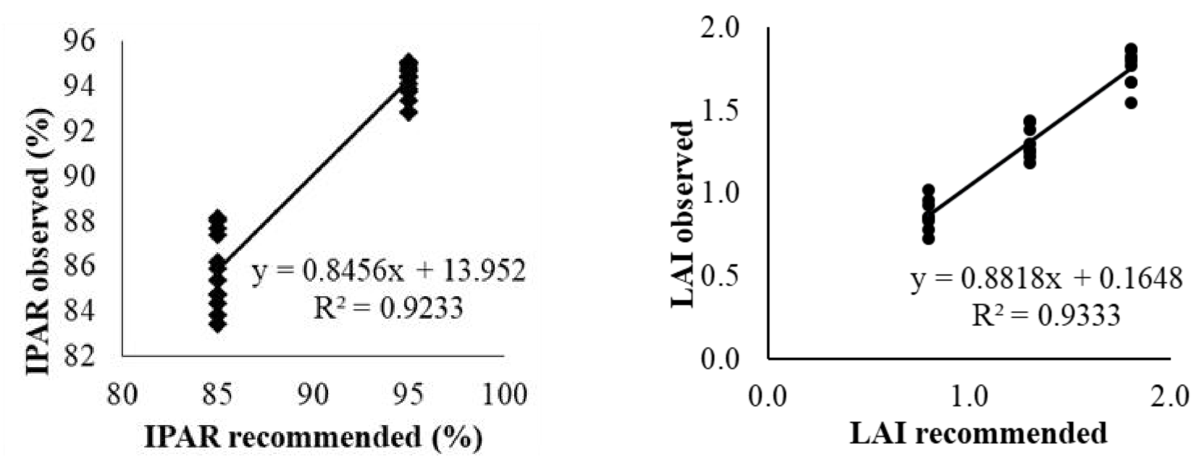

Figure 2A **Figure 2B**

Figure 2. Relationship between Recommended and Observed photosynthetically active radiation (IPAR) (A) and relationship between Recommended and Observed Leaf Area Indices (LAI) (B).

No difference was observed ($p>0.05$) in the interception of photosynthetically active radiation (IPAR) among defoliation intensities. However, there was an effect ($p<0.05$) regarding the frequency of defoliation for this variable, with a higher value for pastures managed under lower defoliation frequency (95% IPAR).

The pastures managed with 95% IPAR presented lower LAIr values than those managed with 85% IPAR, while pastures managed with lower intensity showed higher LAIr when compared to pastures managed with greater defoliation intensity (Table 1).

There was no effect of the frequency of defoliation ($p>0.05$) for the residual height and residual normalized difference vegetation index (NDVIr). However, intensity of defoliation ($p<0.05$) influenced both variables, with higher and lower values observed in pastures managed with the lowest and highest defoliation intensity, respectively (Table 1). The NDVIr and the residual height showed a high correlation with the LAIr, the residual management variable recommended ($r=0.93713$, $p<0.0001$ and $r=0.98065$, $p<0.0001$, respectively).

Pastures managed with 95% IPAR tended to reach saturation for NDVIr more quickly, and the distance between points equivalent to LAIr 1.3 and 1.8 was shorter in the pastures managed with 95% IPAR when compared to the distance between these same points in pastures managed with 85% IPAR (Figure 3A).

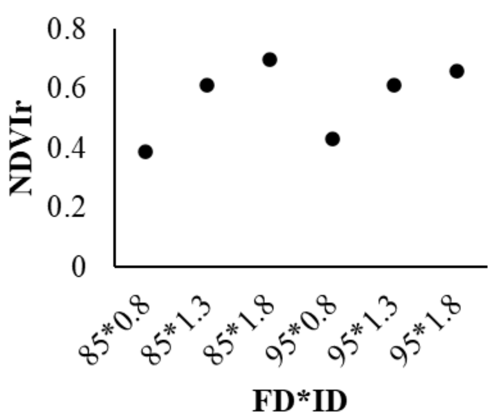

Figure 3A

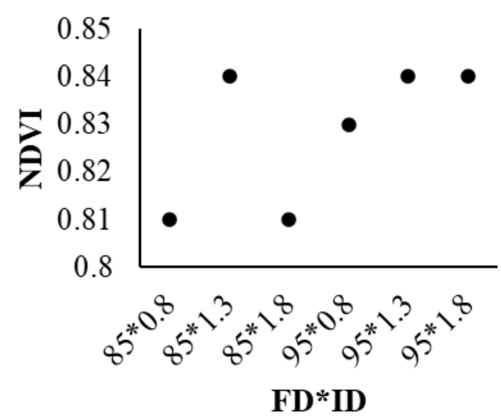

Figure 3B

Figure 3. Relationship between Defoliation Frequency (FD) and Defoliation Intensity (ID) with the Residual Normalized Difference Vegetation Index (NDVIr) (A), and relationship between FD and ID with the Normalized Difference Vegetation Index (NDVI) (B).

The NDVI in the pre-defoliation condition ranged from 0.81 to 0.84. Pastures managed with 85% of IPAR and LAIr of 1.3 showed the highest value. The pastures managed with 95% of IPAR and maintained with LAIr 1.3 and 1.8 presented equal values, demonstrating that the pasture reached the saturation level (Figure 3B).

There was an interaction effect between frequency and intensity of defoliation ($p<0.05$) for the number of new live leaves (NNLL). For the pre-defoliation leaf area index (LAI) and height, an effect was observed only for the frequency of defoliation ($p<0.05$). Tiller population density (TPD) was not affected ($p>0.05$) by the imposed management, with an average of 2,006 tiller m^{-2} (Table 2).

In the pasture managed with a lower frequency of defoliation, a higher LAI was obtained, with a value of 1.57 higher when compared to the pasture managed with 85% of IPAR (Table 2). The same response was observed for height, where pastures managed with a lower frequency of defoliation showed greater height, with a value of 9.7 cm higher than the pasture managed with the highest frequency of defoliation.

For the two defoliation frequencies, the NNLL was similar to the defoliation intensities adopted in the present study (Table 2). However, lower values of NNLL were observed in pastures managed with LAIr of 0.8 and 1.8 and a frequency of defoliation of 85% of IPAR (Table 2).

The NDVI in the pre-defoliation stage ranged from 0.81 to 0.84. Pastures managed at 85% IPAR and LAIr of 1.3 showed the highest NDVI values. For pastures managed at 95% IPAR and maintained at LAIr 1.3 and 1.8, NDVI values were identical, indicating that the pasture had reached the saturation level (Figure 3B).

There was a significant interaction effect between defoliation frequency and intensity ($p<0.05$) on the number of new live leaves (NNLL). For pre-defoliation leaf area index (LAI) and height, a significant effect was observed only for defoliation frequency ($p<0.05$). Tiller population density (TPD) was not affected ($p>0.05$) by the imposed management, with an average of 2,006 tillers m^{-2} (Table 2).

Pastures managed at lower defoliation frequency exhibited higher LAI, with an increase of 1.57 units compared to pastures managed at 85% IPAR (Table 2). A similar response was observed for height, where pastures managed at lower defoliation frequency were 9.7 cm taller than those managed at the highest defoliation frequency.

For both defoliation frequencies, NNLL values were similar across the defoliation intensities adopted in the present study (Table 2). However, lower NNLL values were observed in pastures managed at 0.8 and 1.8 LAIr and a defoliation frequency of 85% IPAR (Table 2).

Table 2. Structural characteristics of Tamani grass under different combinations of defoliation frequency and intensity, in Fortaleza, Ceará, Brazil.

ID	FD		Mean	SEM	p-value		
	85	95			ID	FD	ID*FD
Pre-defoliation leaf area index (LAI; CV= 5.28%)							
0.8	4.17	5.94	5.05				
1.3	4.43	5.74	5.08	1.401	0.002	0.308	0.293
1.8	3.99	5.60	4.80				
Mean	4.19b	5.76a					
Canopy height (cm; CV= 6.16%)							
0.8	28.3	39.8	34.0				
1.3	30.9	39.2	35.0	2.176	<0.001	0.599	0.350
1.8	30.2	39.6	34.9				
Mean	29.8b	39.5a					
Tiller population density (tiller m^{-2}; CV= 8.10%)							
0.8	2080	1893	1986				
1.3	1967	0.225	0.	49.6	0.873	0.995	0.205
1.8	1977	2048	2013				
Mean	2008	2004					

Number of new live leaves (leaves tiller^{-1}; CV= 11.15%)							
0.8	1.89Ab	2.56Aa	2.22				
1.3	2.07Aa	2.35Aa	2.21	0.268	0.003	0.225	0.078
1.8	1.88Ab	2.31Aa	2.09				
Mean	1.95	2.40					

ID: intensity of defoliation; **FD:** frequency of defoliation; **SEM:** Standard error of the mean. Means followed by different uppercase letters within columns (for each variable) and lowercase within rows differ statistically from each other (p<0.05) by the Tukey test.

Regarding biomass components, a significant interaction effect ($p < 0.05$) was observed between defoliation frequency and intensity for harvestable green stem biomass (HGSB) and harvestable dead forage biomass (HDFB). The variables harvestable total forage biomass (HTFB) and harvestable green leaf biomass (HGLB) were significantly affected ($p < 0.05$) by both defoliation frequency and intensity (Table 3).

Table 3. Mean regrowth cycles of biomass components in Tamani grass under different combinations of defoliation frequency and Intensity, in Fortaleza, Ceará, Brazil.

ID	**FD**		**Mean**	**SEM**	**p-value**		
	85	**95**			**ID**	**FD**	**ID*FD**
Harvestable total forage biomass (HTFB; kg ha^{-1}; CV= 19.94%)							
0.8	1569	2381	1975A				
1.3	1458	1801	1629A	331.9	<0.001	0.010	0.379
1.8	1137	1638	1388B				
Mean	1388b	1940a					
Harvestable green leaf biomass (HGLB; kg ha^{-1}; CV=20.48%)							
0.8	1499	2183	1841A				
1.3	1438	1654	1546AB	323.6	0.004	0.027	0.375
1.8	1127	1579	1353B				
Mean	1355b	1805a					
Harvestable green stem biomass (HGSB; kg ha^{-1}; CV=69.71%)							
0.8	39.2Ab	102.0Aa	70.6				
1.3	0.70Aa	49.8ABa	25.3	23.4	<0.001	<0.001	0.009
1.8	0.00Aa	9.50Ba	4.75				
Mean	13.3	53.8					

Harvestable dead forage biomass (HDFB; kg ha^{-1}; CV=35.08%)							
0.8	31.20Ab	96.70Aa	63.95				
1.3	19.60Ab	97.80Ba	58.7	17,9	<0.001	0.004	0.012
1.8	10.70Aa	50.10Ba	30.4				
Mean	20.5	81.53					

ID: intensity of defoliation; **FD:** frequency of defoliation; **SEM:** Standard error of the mean. Means followed by different uppercase letters within columns (for each variable) and lowercase within rows, differ statistically from each other ($p<0.05$) by the Tukey test.

The highest HTFB production was observed in pastures managed at a lower defoliation frequency. Pastures managed at LAIr 0.8 and 1.3 had the highest HTFB values, which were similar to each other but significantly different from those observed at LAIr 1.8 (Table 3). For HGLB, production was highest in pastures managed at a lower frequency of defoliation, while pastures managed at lower LAIr presented the highest HGLB values, whereas those managed at LAIr 1.3 had biomass values similar to the other two LAIr levels (Table 3).

Pastures managed at LAIr 0.8 exhibited higher HGSB at lower defoliation frequency, while the other two LAIr levels showed similar values between both defoliation frequencies. At the lower defoliation frequency, there was a significant difference among intensities, with the highest value observed at LAIr 0.8, whereas LAIr 1.3 had values similar to the other two LAIr levels. For pastures managed at 85% IPAR, there was no significant difference among the LAIr levels adopted (Table 3).

Regarding HDFB, pastures managed at a lower defoliation frequency had the lowest values at LAIr 1.3 and 1.8, which were similar to each other but significantly different from LAIr 0.8. However, pastures managed at 85% IPAR showed no significant difference among LAIr levels (Table 3). Pastures managed at LAIr 0.8 and 1.3 had the lowest HDFB under 85% IPAR compared to pastures managed at a lower defoliation frequency (Table 3).

Discussion

The response observed for NDVIr (Figure 3A) reinforces what was reported by Ji and Peters (2007), who stated that pastures with an LAIr higher than 1.8 tend to reach saturation levels more quickly. Therefore, when LAIr values are high, NDVI becomes insensitive in detecting biomass production changes due to index stabilization (Risso et al., 2012).

The highest residual height observed in pastures managed with LAIr 1.8 (Table 1) is attributed to their lower defoliation intensity, allowing a greater amount of remaining material. Similar results were reported by Cutrim Junior et al. (2011) and Silva et al. (2015), evaluating Tanzania and Guinea grasses, respectively. The greater residual height implies less use of organic reserves, enabling faster forage regrowth.

Although NDVI exhibits a strong correlation ($r > 0.9256$) with biomass production (Santos et al., 2017), saturation at high LAI values can introduce errors in estimating productivity. Thus, NDVI calibration is necessary for each forage species and cultivation condition (Povh et al., 2008). Regardless of management combination, the NDVI value before defoliation exceeded 0.80 (Figure 3B), indicating saturation, thereby reducing its efficiency in predicting biomass production.

The higher LAIr values in pastures managed with 95% IPAR (Table 2) may be related to longer growth periods, allowing greater accumulation of photothermal units, which favor growth. According to Villa Nova et al. (2007) and Almeida et al. (2011), the photothermal unit is a reliable index considering air temperature and photoperiod in forage production estimation, being more accurate for estimating forage production than these factors in an isolated manner.

Although tiller density was not significantly different across treatments, it is likely that pastures subjected to lower defoliation frequencies had longer leaves, contributing to higher LAIr values. Leaves experiencing greater shading, such as those in 95% IPAR defoliation frequency, tend to increase specific leaf area to enhance light capture (Lambers et al., 2008).

A higher defoliation frequency may have contributed to lower LAIr values in pastures managed with 85% IPAR, limiting new leaf formation. LAIr is a key biomass production indicator, as it correlates with solar energy utilization efficiency (Gomide, 1973). For Tamani grass fertilized with 600 kg ha^{-1} $year^{-1}$, Vasconcelos et al. (2020) estimated an LAIr value of 5.53, which is comparable to findings in this study.

The greater canopy height in pastures managed with 95% IPAR (Table 3) results from increased stem elongation due to shading effects in pastures with lower defoliation frequency (Lemos et al., 2019). According to Lemos et al. (2019), prolonged grazing intervals lead to heightened light competition, triggering stem elongation and taller forage plants.

Although pasture height is a practical indicator for grazing initiation, it should be complemented with morphophysiological parameters such as leaf senescence rate and number of live leaves due to the stem elongation process that is common in C4 grasses (Cutrim Junior et al., 2011; Silva et al., 2015). For Tamani grass, Tesk et al. (2020) recommended a grazing height of 35 cm, at which pastures reach 95% IPAR, a value similar to the findings of the present study.

The greater NNLL values in pastures managed with LAIr 0.8 and 1.3 at 95% IPAR (Table 2) are likely due to the need for enhanced light interception, promoting leaf emergence. Additionally, longer photothermal accumulation supports continued leaf production at the tiller level.

The fact that pastures under 95% IPAR showed 2.40 new leaves per tiller suggests growth limitations in this forage species. This may be attributed to unusual rainfall patterns in 2019, as the study period recorded 2,342.0 mm of precipitation (FUNCEME, 2019), exceeding the historical average of 1,456.7 mm. Consequently, lower radiation levels during the experiment may have hindered grass growth. This aligns with Vasconcelos et al. (2020), who reported that Tamani grass can sustain three new leaves per tiller. The lower NNLL in the present study compared to Vasconcelos et al. (2020), who conducted their study in a dry season under optimal irrigation, reinforces this climatic impact.

Although tiller population density (TPD) remained unaffected by management treatments, the recorded values were notably high. Vasconcelos et al. (2020) reported a TPD of 2,546 tillers m^{-2} for Tamani grass under irrigation during drought conditions, suggesting that Tamani grass retains strong forage potential even in suboptimal environments.

The high HTFB in pastures managed with 95% IPAR results from longer exposure to abiotic factors and extended growth duration. Moreover, these pastures exhibited higher LAI values (Table 2), which directly influences forage biomass production via canopy photosynthesis (Parsons et al., 1983). Vasconcelos et al. (2020) reported an HTFB of 1,501.04 kg ha^{-1} for Tamani grass fertilized with 600 kg N ha^{-1}, which is consistent with findings in this study. Among biomass components, HGLB contributed approximately 93% to HTFB, underscoring Tamani grass's ability to produce high-quality forage, considering that the leaf blade is the nutrient-rich fraction of the plant, as confirmed in Cano et al. (2004) for M.

maximus cv. Tanzania and Santos et al. (2010) for Urochloa decumbens cv. Basilisk. The higher HGLB in lower defoliation frequency pastures highlights Tamani grass's unique trait of reduced investment in structural support, yielding lower HGSB values than other M. maximus cultivars (Lemos et al., 2014; Silva et al., 2015; Sousa et al., 2019).

The high HDFB in 95% IPAR-managed pastures is linked to greater residual height (Table 1), which increased shading and consequently accelerated leaf senescence. Silva et al. (2015) observed similar trends in Aruana grass (M. maximus cv. Aruana), where lower grazing frequency resulted in higher BFM production.

The higher HTFB, HGLB, HGSB, and HDFB in higher defoliation intensity pastures stem from lower residue height (Table 1), facilitating greater biomass harvest efficiency. In a study on Tamani grass with defoliation intensities of 5 cm and 15 cm residual height, Martuscello et al. (2019) found that greater defoliation intensity enhanced biomass production, attributing it to higher harvest efficiency.

Conclusion

Tamani grass should be managed with a defoliation frequency of 95% IPAR interception, optimizing forage production without compromising quality, while maintaining a residual leaf area index between 0.8 and 1.3.

Declarations

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Conflicts of interest

The authors declare that they have no conflicts of interest regarding the work presented in this report.

Author contributions

Francisco GS Alves: Interpretation of data, drafting of the manuscript and critical revision of the manuscript for important intellectual content. Eulalia JC Méndez: Conception, design and acquisition of data, interpretation of data and drafting of the manuscript. Bruno B Nascimento: Conception, design and acquisition of data, statistical analysis. Rafael N Furtado: Conception, design and acquisition of data, statistical analysis. Elayne CG Vasconcelos: Interpretation of data and drafting of the manuscript, critical revision of the manuscript for important intellectual content. Emanoella KS Otaviano: Conception, design and acquisition of data, statistical analysis. José BS Moreira: Conception, design and acquisition of data. Roberto CFF Pompeu: Interpretation of data and drafting of the manuscript, critical revision of the manuscript for important intellectual content. Magno JD Cândido: Conception, design and acquisition of data, interpretation of data and drafting of the manuscript, critical revision of the manuscript for important intellectual content.

Use of artificial intelligence (AI)

No AI or AI-assisted technologies were used during the preparation of this work.

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