Agronomic characteristics of Tamani grass managed under different combinations of frequency and intensity of defoliation

Características agronómicas del pasto Tamani manejado bajo diferentes combinaciones de frecuencia e intensidad de defoliación

Características agronômicas do capim Tamani manejado sob diferentes combinações de frequência e intensidade de desfolhação

Francisco GS Alves[1]; Eulalia JC Méndez[1]; Bruno B Nascimento[1]; Rafael N Furtado[2]; Elayne CG Vasconcelos[1]; Emanoella KS Otaviano[3]; José BS Moreira[1]; Roberto CFF Pompeu[4]; Magno JD Cândido[1*].

[1]*Departamento de Zootecnia, Universidade Federal do Ceará, Fortaleza, Ceará, Brasil.*
[2]*Instituto Federal de Educação, Ciência e Tecnologia do Piauí, Paulistana, Piauí, Brasil.*
[3]*Departamento de Zootecnia, Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo, Piracicaba, São Paulo, Brasil.*
[4]*Empresa Brasileira de Pesquisa Agropecuária, Embrapa Caprinos e Ovinos, Sobral, Ceará, Brasil.*

[1*]**Corresponding author.** Avenue Mister Hull, 2977, Bl 808, Pici, 60440-554, Fortaleza, Ceara, Brazil. E-mail: magno@ufc.br

Received: *October 2, 2024.* ***Accepted:*** *October 21, 2024*

To cite this article:

Alves FGS, Méndez EJC, Nascimento BB, Furtado RN, Vasconcelos ECG, Otaviano EKS, Moreira JBS, Pompeu RCFF, Cândido MJD. Agronomic characteristics of Tamani grass managed under different combinations of frequency and intensity of defoliation. Rev Colomb Cienc Pecu *Year, Vol, number, and pages pending.* DOI: https://doi.org/10.17533/udea.rccp.v37n2a5

Abstract

Background: Management strategies may affect plant growth and herbage characteristics. Thus, understanding its impact may help to define appropriate management. **Objective:** To evaluate the effect of different defoliation intensities and frequencies on the 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% of 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 greater values for pastures managed at 95% of IPAR. The effect of intensity of defoliation was observed for the HTFB and HGLB variables, where pastures with lesser LAIr presented greater biomass values. Pastures managed at 95% of IPAR and higher LAIr reached the level of saturation of the normalized difference vegetation index more quickly. Pastures managed under the combination of 95% IPAR and LAIr of 0.8 showed greater production of harvestable green stem biomass and harvestable dead forage biomass. The combination of 95% of IPAR with LAIr of 0.8 or 1.8 enabled a greater number of new live leaves when compared to pastures with 85% of IPAR. **Conclusions:** Tamani grass must be managed with a frequency of defoliation of 95% of the 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

Antecendentes: Las estrategias de manejo pueden afectar el crecimiento de las plantas y las características del pasto. Por lo tanto, comprender el 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 arreglo factorial 2x3, 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 pre-defoliación, altura, biomasa forrajera total cosechable (HTFB), y lámina foliar cosechable (HGLB), con valores superiores para los pastos manejados con 95% IPAR. El efecto de la intensidad de defoliación se observó para 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 índice de vegetación de diferencia normalizada 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 ó 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 la 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; pastar; producción de forraje; radiación fotosintéticamente activa; región semiárida.*

Resumo

Antecedentes: Estratégias de manejo pode afetar o crescimento das plantas e as características da pastagem. Assim, o entendimiento do impacto pode ajudar a definir manjeos mais adequados. **Objetivo:** Avaliar o efeito de diferentes intensidades e frequências de desfolhamento sobre as características estruturais, 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 2x3, com duas frequências de desfolhação (85 e 95% de interceptação da radiação fotossinteticamente ativa (IPAR) e três intensidades de desfolhação (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-desfolha, altura, biomassa forrageira total colhível (HTFB), e lâmina foliar colhível (HGLB), com maiores valores para pastagens manejadas com 95% de IPAR. O efeito da intensidade de desfolha foi observado para as 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 índice de vegetação de diferença normalizada mais rapidamente. As pastagens manejadas com uma combinação de 95% 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 maior número de novas folhas vivas quando comparado a pastagens com 85% de IPAR. **Conclusões:** O capim Tamani deve ser manejado com uma frequência de desfolha de 95% da 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 indexes 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 to determine the most appropriate management.

The adoption of appropriate management practices depends on an understanding of the physiological changes that occur in the 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's necessary to adopt an adjusted frequency of defoliation and intensity (Silva *et al*., 2015), allowing the pastures to have less stem elongation, higher leaf/stem ratio and higher 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 (Confortin *et al*., 2010). The intensity and frequency of defoliation affect the structure of the canopy, influencing the distribution of structural components, which will affect the production, quality, and consumption of forage.

The low frequency and intensity of defoliation increase senescence, causing loss of forage and allowing greater stem accumulation, while the greatest frequency and intensity of defoliation decrease the persistence of pasture due to the depletion of organic reserves and decapitation of tillers (Cutrim Junior *et al.,* 2010). The combination of frequencies and intensities of defoliation can generate different results for the canopy structure, biomass production, and nutritive value of the forage.

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

The present study aimed to evaluate the effect of different defoliation intensities and frequencies on the structural characteristics, biomass components and the potential use of normalized difference vegetation index (NDVI) in pastures 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, belonging to the Universidade Federal do Ceará, at geographical coordinates 03° 45' 47'' S, 38° 31' 23'' W, with climate Aw' (rainy tropical), according to the Köppen classification (Köppen, 1936). The climatic data (Figure 1) for the experimental period (April to August of 2019) were obtained at the Estação Agrometeorológica of Universidade Federal do Ceará.

Experimental design

The experimental area corresponded to 408 m^2, with 300 m^2 of usable area, with *Megathyrsus maximus* (syn. *Panicum maximum*) cv. BRS Tamani preestablished in 2017, subdivided into 24 plots measuring 12.5 m^2. A randomized complete block design was adopted, with four replications (2.5x5.0 m plots), in a 2x3 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 has the following chemical characteristics, carried out on samples taken at a 0-20 cm layer depth: pH in water: 8.1; P (m 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 e MO (g kg^{-1}): 4.86. Based on soil analysis, soil fertility correction was carried out as recommended by the Comissão de Fertilidade do Solo do Estado de Minas Gerais (CFSEMG, 1999), for grasses with high productive potential.

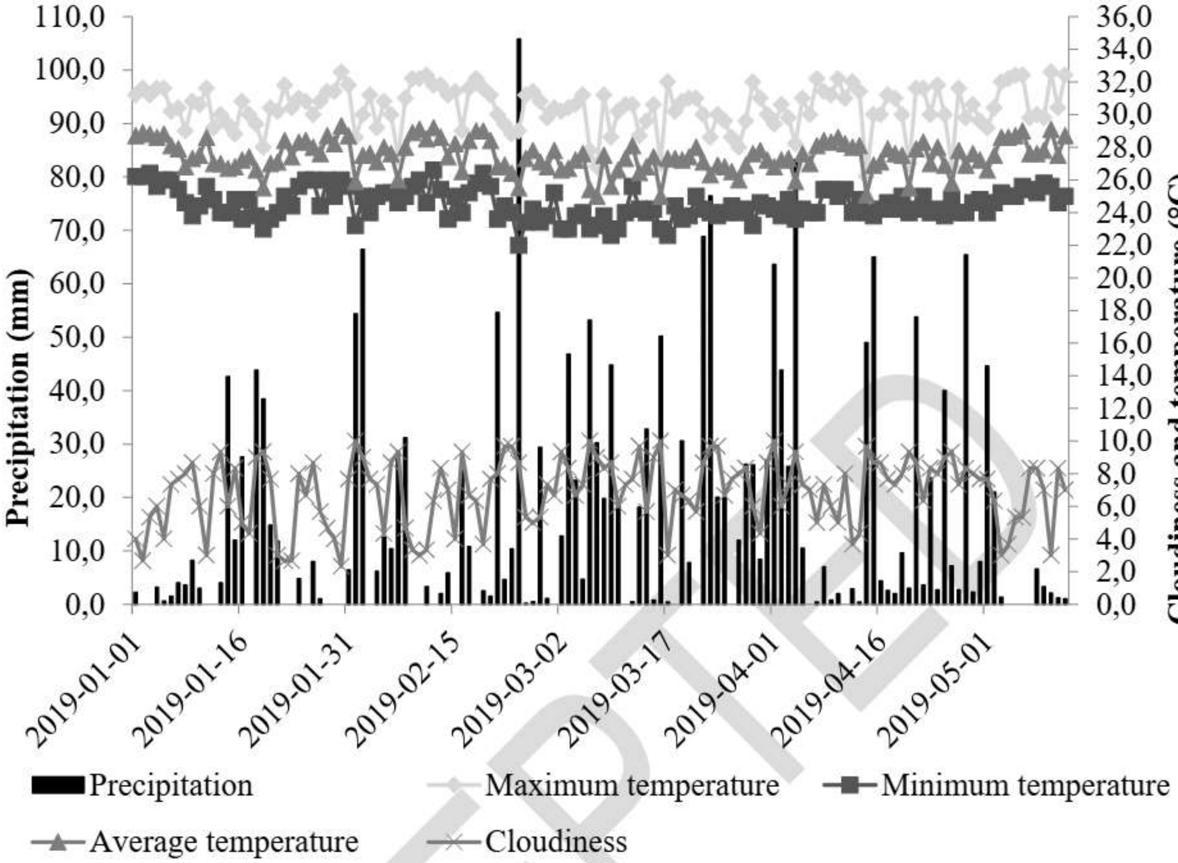

Figure 1. Precipitation, average, minimum, maximum temperature, and cloudiness during the experimental period (three regrowth cycles) in Fortaleza, Ceará, Brazil.

Nitrogen fertilization was carried out at a dose equivalent to 600 kg ha^{-1} $year^{-1}$ of nitrogen in the form of urea, phosphate 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 in all regrowth cycles, the first half was applied after cutting (height according to the LAIr) and the second in the middle of the growing cycle, except for the micronutrient fertilization that was applied in a single dose. The cycles were according to the IPAR (85 or 95%), when the condition was reached, the rest was interrupted and the cut was performed. The pasture was managed with a low-pressure sprinkler irrigation (service pressure ≤ 2.0 kgf cm^{-2}), with fixed daily liquid amount of 6.8 mm 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 model Accupar

LP-80® (Decagon Devices Inc., Pullman, Washington, USA) was used, with two readings for the IPAR and LAIr per plot in the pre and post-harvest, respectively.

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

The canopy height (cm) was measured in 20 random points within each plot with a retractable graduated rod, measuring 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 x 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 exposed ligula and 0.5 for leaves with unexposed ligula.

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 x 0.50 m were cut, using scissors, respecting the LAIr recommended for each treatment, taken to the laboratory and separated into green and dead material. Then in the living material, leaf blades were separated from the stems. All these fractions were weighed, dried in a forced-air ventilation 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 from the average by regrowth cycles, were submitted for analysis of variance and mean comparison test. The interaction between frequencies and intensities defoliation was presented when significant ($p<0.05$) by the F test. To compare means, the Tukey test was used, at the level of 5% probability. In the regression analysis, model selection was based on the significance of the linear and quadratic coefficients, using significance at the level of 5%. As a tool to perform the statistical analysis, the GLM procedure was adopted, using the SAS computer program, version 9.0 (SAS Institute Inc., Cary, NC, USA; 2002).

Results

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

Table 1. Management goals recommended and obtained, residual height and residual normalized difference vegetation index (NDVIr) for Tamani grass submitted to different combinations of frequencies and intensity of defoliation, 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 value of the determination coefficient for the IPAR (Figure 2A) and the LAIr (Figure 2B) demonstrate that the management observed was very close to the recommended management, indicating that the proposed management was achieved.

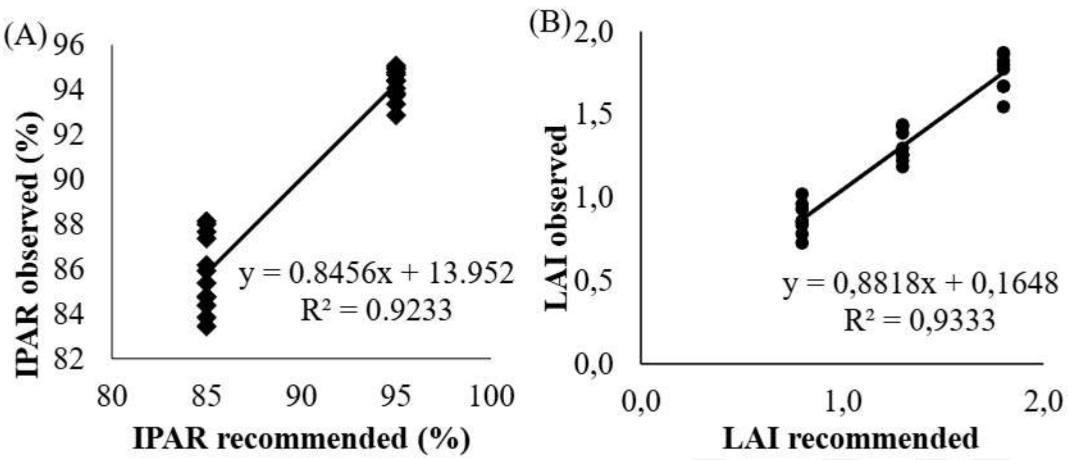

Figure 2. Relation between recommended and observed photosynthetically active radiation (IPAR) (A) and the relation between recommended and observed leaf area indices (LAI) (B).

There was no difference ($p>0.05$) in the interception of photosynthetically active radiation (IPAR) among the 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 with a lower frequency of defoliation (95% of IPAR).

The pastures managed with 95% of IPAR presented lower LAIr values than the pastures managed with 85% of IPAR. While the pastures managed with lower intensity showed higher LAIr when compared to pastures managed with greater intensity of defoliation (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, the intensity of defoliation ($p<0.05$) influenced both variables, with higher and lower values observed in pastures managed with the lowest and highest intensity of defoliation, 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).

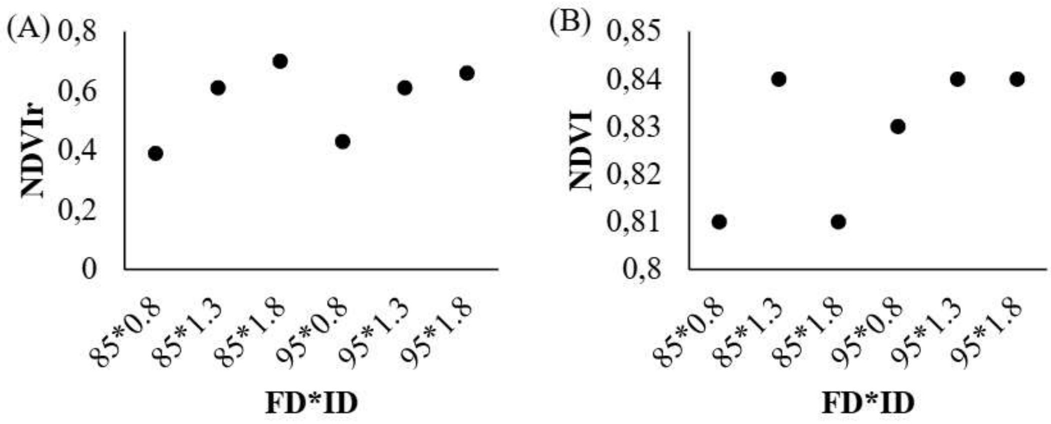

Figure 3. Relation between Frequency of defoliation (FD) and Intensity of defoliation (ID) with the Residual Normalized Difference Vegetation Index (NDVIr) (A) and the relation between FD and ID with the Normalized Difference Vegetation Index (NDVI) (B).

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. In 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).

Table 2. Structural characteristics of Tamani grass submitted to different combinations of frequencies and intensity of defoliation, 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 the biomass components, an interaction effect between frequency and intensity of defoliation ($p<0.05$) was observed for the harvestable green stem biomass (HGSB) and the harvestable dead forage biomass (HDFB). The variables harvestable total forage biomass (HTFB) and harvestable green leaf biomass (HGLB) showed an effect ($p<0.05$) for frequency of defoliation and intensity of defoliation (Table 3).

Table 3. Mean regrowth cycles of biomass components of Tamani grass submitted to

different combinations of frequencies and Intensity of defoliation, 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 greatest production of HTFB was obtained for pastures managed with a lower frequency of defoliation, while pastures managed with the LAIr of 0.8 and 1.3 had the greatest HTFB, being similar to each other and different from the product obtained in the LAIr of 1.8 (Table 3). For the HGLB it was observed that the production was highest in the pastures managed with the lower frequency of defoliation, while pastures managed with the lower LAIr presented the highest HGLB, whereas the pastures with LAIR of 1.3 presented biomass similar to the other two LAIr (Table 3).

Pastures managed with LAIr of 0.8 showed the greater HGSB at the lower frequency of defoliation, while the other two LAIr demonstrated similar values between the two frequencies of defoliation. In the lower frequency of defoliation, there was a difference between the intensities, with the greater value for the LAIr of 0.8, while the value for the LAIr of 1.3 was similar to the other two LAIr. For pastures managed with IPAR of 85% there was no difference between the adopted LAIr (Table 3).

Regarding to the HDFB, pastures managed with a lower frequency of defoliation showed the lowest values in the LAIr of 1.3 and 1.8, being similar to each other and different from the value obtained in the LAIr of 0.8, while pastures managed with 85% of IPAR showed no difference between the adopted LAIr. Pastures managed with LAIr of 0.8 and 1.3 had the lowest HDFB in pastures managed with IPAR of 85% when compared to pastures that had a lower frequency of defoliation (Table 3).

Discussion

The response observed for NDVIr (Figure 3A) reinforces what was reported by Ji and Peters (2007) when stating that pastures with a LAIr higher than 1.8 tend to reach saturation levels more quickly. Therefore, when there are high LAIr values, NDVI becomes insensitive to identify changes in biomass production, because there is a stabilization of this index (Risso *et al*., 2012).

The highest residual height observed in pastures managed with LAIr of 1.8 (Table 1) is due to the fact that these pastures were defoliated with less intensity, allowing a greater amount of remaining material; similar results were reported by Cutrim Junior *et al*. (2011) and Veras *et al*. (2015), evaluating Tanzania and Guinea grasses, respectively. The highest residual height implies less use of organic reserves, allowing a faster regrowth of the forage plants.

Although the NDVI has a high correlation ($r>0.9256$) with the production of biomass (Santos *et al*., 2017), the occurrence of saturation of this index in high LAI can cause losses to estimate the production of biomass, generating errors in determining the productivity of the evaluated culture. Therefore, it is necessary that this index be calibrated for each forage species and for each cultivation condition (Povh *et al*., 2008).

In any case, the NDVI value observed in the pre-defoliation condition, regardless of the management combination adopted, was greater than 0.80 (Figure 3B), therefore a value already within the saturation range for this variable, which reduces the efficiency of this index in predicting biomass production.

Greater LAIr value for pastures managed with IPAR of 95% (Table 2) may be related to longer growth time, associated with greater accumulation of photothermal units by the plant, providing favorable conditions for growth. According to Villa Nova *et al*. (2007) and Almeida *et al*. (2011), the photothermal unit is an index that considers the combined action of air temperature and photoperiod on the production of forage grasses, and is more accurate in estimating forage production than these factors in an isolated manner.

Although the population density of tillers did not differ between the managements evaluated in the present study, it is possible to assume that the pastures with lower frequency of defoliation presented leaves with greater length, contributing to the elevation of the LAIr. In fact, leaves submitted to greater mutual shading, such as the IPAR of 95% frequency of defoliation, tend to increase their specific leaf area to increase the possibility of light capture (Lambers *et al*., 2008).

The higher cutting frequency may have contributed to the lower LAIr in pastures managed with IPAR of 85%, not allowing the formation of a greater number of new leaves. It is worth mentioning that the LAIr is an important indicator of biomass production, being related to the efficiency of use of solar energy (Gomide, 1973). Vasconcelos *et al*. (2020) estimated an LAIr value of 5.53 for Tamani grass fertilized with 600 kg ha^{-1} $year^{-1}$, value close to that found in the present study.

Greater canopy height in pastures managed with IPAR of 95% (Table 3) can be explained by the greater elongation of the stems caused by the greater mutual shading in pastures maintained with lower frequency of defoliation, considering that the greater participation of the stem provides the increase at canopy height (Lemos *et al*., 2019). According to Lemos *et al*. (2019), when the plant takes a long time to graze, there is an increase in competition for light, stimulating the elongation of the stem and, consequently, the forage plants become taller.

The height is a practical and easy to use criterion to define the entry of animals in the pasture; however, it should not be used as a single criterion and must be associated with morphophysiological characteristics, such as the number of live leaves and the leaf senescence rate, due to the stem elongation process that is common in C_4 grasses (Cutrim Junior *et al*., 2011; Silva *et al*., 2015). When working with Tamani grass, Tesk *et al*. (2020) recommends a height of 35 cm for animals to enter, height at which the pasture reached IPAR of 95%, a value close to that found in the present study for the same condition of IPAR.

The greater NNLL in pastures managed with LAIr of 0.8 and 1.3 and 95% of IPAR (Table 2) is due to the need to produce leaves capable of intercepting a greater amount of radiation to achieve the recommended IPAR. In addition, there was a longer time of accumulation of photothermal units, providing conditions for the continuity in the emission of leaves at the tiller level.

The fact that the pastures under IPAR of 95% showed 2.40 new leaves per tiller demonstrates a limitation to the growth of this forage plant. This can be explained by the fact that the experiment was conducted during the rainy season, which in 2019 was atypical at the site of the experiment, with a total of 2,342.0 mm during the experimental period (Figure 1), with the annual historical average being 1,456.7 mm (FUNCEME, 2019), which may have affected the growth of the grass due to less incident radiation during the evaluation period. This result is corroborated by Vasconcelos *et al*. (2020), who mentioned that Tamani grass can maintain three new leaves per tiller. The fact that the present study had lower NNLL results from the effect of rain, since the work of Vasconcelos *et al*. (2020) was carried out in the dry season under irrigation with an optimal water supply.

Although the tiller population density (TPD) was not influenced by the adopted managements, the values found are expressive, considering that Vasconcelos *et al*. (2020) obtained values for TPD of 2,546 tillers m^{-2} for Tamani grass in the drought under irrigation, that is, without limitation for to cloudiness and excess water, showing that even under unfavorable conditions for its development Tamani grass present potential for forage production.

The highest HTFB observed in pastures with IPAR of 95% is due to greater exposure to abiotic factors, due to the longer growth time. Furthermore, these pastures also had a higher LAI than pastures with IPAR of 85% (Table 2), and the total forage biomass is due to crude photosynthesis canopy, which in turn is directly affected by the LAI (Parsons *et al*., 1983). Vasconcelos *et al*. (2020) reported HTFB of 1,501.04 kg ha^{-1} for Tamani grass fertilized with a dose of 600 kg N ha^{-1}, a value close to that observed in the present study. Among the biomass components, the HGLB contributed approximately 93% to the HTFB value, demonstrating the high capacity of this grass to produce good quality forage, considering that the leaf blade is the fraction with the best nutritional value, as demonstrated in the studies by Cano *et al.,* 2004, evaluating *M. maximus* cv. Tanzania, and Santos *et al.* (2010), studying *Urochloa decumbens* cv. Basilisk. The fact that the pastures with lower frequency of defoliation presented higher HGLB, demonstrates a peculiar characteristic of Tamani grass and of great livestock interest, which is the low investment in the production of support structures, presenting HGSB values lower than those reported for other *M. maximus* cultivars (Lemos *et al*., 2014; Silva *et al*., 2015; Sousa *et al*., 2019).

The highest HDFB observed in the pastures managed with IPAR of 95% is since the highest residual height (Table 1) favored the greater mutual shading and, therefore, there was greater senescence of the leaves of the lower layer of the canopy. Silva *et al*. (2015) working with Aruana grass (*M. maximus* cv. Aruana) reported that in the lower grazing frequency, an increase in BFM production was observed.

The highest HTFB, HGLB, HGSB, and HDFB found for pastures managed with the higher defoliation intensities are due to the lower residue height (Table 1), which allowed more biomass to be harvested at the time of harvest, ensuring greater harvest efficiency. When studying Tamani grass under two defoliation intensities (5 and 15 cm residual height), Martuscello *et al*. (2019) also reported the greater biomass production at greater intensity of defoliation, the authors attributed this response to greater harvest efficiency.

In conclusion, Tamani grass must be managed with a frequency of defoliation of 95% of interception of photosynthetically active radiation, favoring production and without prejudice to quality, maintaining a residual leaf area index between 0.8 and 1.3.

Declarations

Funding

The authors received no specific funding for this work.

Conflicts of interest

The authors declare 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.

References

Almeida ACS, Mingoti R, Coelho RD, Lourenço LF. Simulation of irrigated Tanzania grass growth based on photothermal units, nitrogen fertilization and water availability. Acta Sci Agron 2011; 33(2): 215-222. https://doi.org/10.4025/actasciagron.v33i2.4901

Cano CCP, Cecato U, Canto MW, Santos GT, Galbeiro S, Martins EM, Mira RT. Nutritive value of Tanzania grass (*Panicum maximum* Jacq. cv. Tanzânia-1) grazed at different heights. R Bras Zootec 2004; 33(6): 1959-1968.

Comissão de Fertilidade do Solo do Estado de Minas Gerais - CFSEMG. Recomendações para uso de corretivos e fertilizantes em Minas Gerais, Viçosa: UFV; 1999.

Confortin ACC, Quadros MG, Glienke CL, Rossi GE, Moraes AB. Structural and morphogenical characteristics of black oats and Italian ryegrass on pasture submitted to two grazing intensities. R Bras Zootec 2010; 39(11): 2357-2365. https://doi.org/10.1590/S1516-35982010001100007

Costa NL, Jank L, Magalhães JÁ, Bendahan AB, Rodrigues BHN, Santos FJS. Agronomic performance and chemical composition of genotypes and cultivars of Megathyrsus maximus in Roraima's savanas. Res Soc Dev, 2022; 11(9): e55011932285. https://doi.org/10.33448/rsd-v11i9.32285

Cutrim Júnior JAA, Cândido MJD, Valente BSM, Carneiro MSS, Carneiro HAV, Cidrão PML. Biomass flow of the Tanzânia grass under three defoliation frequencies and two post-grazing residues. Rev Bras Saúde Prod Na 2010; 11(3): 618-629

Cutrim Júnior JAA, Cândido MJD, Valente BSM, Carneiro MSS, Carneiro HAV. Structural characteristcs of Tanzania grass canopy submitted to three frequencies of defoliation and two post-grazing residues. R Bras Zootec 2011; 40(3): 489-497. https://doi.org/10.1590/S1516-35982011000300005

Fundação Cearense de Meteorologia e Recursos Hídricos – FUNCEME. (2019). Calendários das chuvas no estado do Ceará. [access date: 09/20/2019]. http://www.hidro.ce.gov.br/municipios/chuvas-diarias.

Gastal F, Lemaire G. Defoliation, shoot plasticity, sward structure and herbage utilization in pasture: review of the underlying ecophysiological processes. Agriculture 2015; 5(4): 1146-1171. https://doi.org/10.3390/agriculture5041146

Gomide JA. Fisiologia e manejo de plantlas forrageiras. R Soc Bras Zootec 1973; 2(1): 17-26.

Ji L, Peters AJ. Performance evaluation of spectral vegetation indices using a statistical sensitivity function. Remote Sens Environ 2007; 106(1): 59-65. https://doi.org/10.1016/j.rse.2006.07.010

Köppen W. Das geographische System der Klimate. In: Köppen WR. Geiger (Eds). Handbuch der Klimatologie, Berlin: Gebrüder Borntraeger; 1936. 1-44.

Lambers H, Chapim III FS, Pons TL. Plant physiological ecology. New York: Springer 2008. https://doi.org/10.1007/978-0-387-78341-3

Lemos NLS, Ruggieri AC, Silva CV, Campos AF, Malheiros EB, Teixeira IAMA. Tanzania grass structure grazed by goats managed with different residual leaf area index under intermittent stocking. Biosci J 2014; 30(6): 1811-1818.

Lemos NLS, Ruggieri AC, Silva CV, Meister NC, Alari FO, Malheiros EB. Residual leaf area index as strategy to management of pasture: structure of Tanzania grass. Rev Bras Ciênc Agrár 2019; 14(3): e5679. https://doi.org/10.5039/agraria.v14i3a5679

Lima JRL, Rodrigues RC, Sousa GOC, Costa CS, Parente HN, Santos FNS. Ecophysiology of Andropogon grass subjected to different cutting frequencies and intensities. Rev Bras Eng Agrí Ambient 2020; 24(9): 610-615. https://doi.org/10.1590/1807-1929/agriambi.v24n9p610-615

Martuscello JA, Rios JF, Ferreira MR, Assis JA, Braz TGS, Cunha DV. Production and morphogenesis of BRS Tamani grass under different nitrogen rates and defoliation intensities. Bol Ind Anim 2019; 76: 1-10. https://doi.org/10.17523/bia.2019.v76.e1441

Parsons AJ, Leafe EL, Collett B, Penning PD, Lewis J. The physiology of grass production under grazing. II. Photosynthesis, crop growth and animal intake of continuously-grazed swards. J Appl Ecol 1983; 20(1): 127-139. https://doi.org/10.2307/240338

Povh, FP, Molin JP, Gimenez LM, Pauletti V, Molin R, Salvi JV. Behavior of NDVI obtained from an active optical sensor in cereals. Pesq Agropec Bras 43(8): 1075-1083. https://doi.org/10.1590/S0100-204X2008000800018

Risso J, Rizzim R, Rudorffm BFT, Adami M, Shimabukuro YE, Formaggio AR, Apiphanio RDV. Modis vegetation indices applied to soybean area discrimination. Pesq Agropec Bras 2012; 47(9): 1317-1326. https://doi.org/10.1590/S0100-

204X2012000900017

Santos GO, Rosalen DL, Faria RT. Use of active optical sensor in the characteristics analysis of the fertigated *Brachiaria* with treated sewage. Journal of the Brazilian Eng. Agriv 2017; 37(6): 1213-1221. https://doi.org/10.1590/1809-4430-Eng.Agric.v37n6p1213-1221/2017

SAS Institute. SAS system for windows. Version 9.0. Cary, NC, USA: SAS Institute Inc. 2002.

Santos MER, Fonseca DM, Balbino EM, Silva SP, Monnerat JPIS. Nutritive value of tillers and morphological components on deferred and nitrogen fertilized pastures of Brachiaria *decumbens* cv. Basilisk. R.Bras Zootec 2010; 39(9): 1919-1927.

Silva LV, Cândido MJD, Pessoa JPM, Cavalaznte ACR, Carneiro MSS, Silva NA. Biomass components and structural features in Guinea grass under different frequencies and intensities of defoliation. Pesq Agropec Bras 2015; 50(12); 1192-1200. https://doi.org/10.1590/S0100-204X2015001200009

Sousa GJ, Alexandrino E, Santos AC, Freitas MVL. *Megathyrsus Maximus* cv. Massai at different cutting frequencies. Semin Ciênc Agrár 2019; 40(5): 1913-1924. https://doi.org/10.5433/1679-0359.2019v40n5p1913

Stobbs TH. The effect of plant structure on the intake of tropical pastures. II. Differences in sward structure, nutritive value, and bite size of animals grazing *Setaria anceps* and .*Chloris gayana* at various stages of growth. Aust J Agric Res 1973; 24(809): 821-829. https://doi.org/10.1071/AR9730821

Tesk CRM, Cavalli J, Pina DS, Pereira DH, Pedreira GS, Jank L, Sollenberger LE, Pedreira BC. Herbage responses of Tamani and Quênia guineagrasses to grazing intensity. Agron J 2020; 112(3): 2081-2091. https://doi.org/10.1002/agj2.20189

Vasconcelos ECG, Cândido MJD, Pompeu RCFF, Cavalcante ACR, Lopes, MN. Morphogenesis and biomass production of 'BRS Tamani' guinea grass under increasing nitrogen doses. Pesq Agropec Bras 2020; 55: e01235. https://doi.org/10.1590/S1678-3921.pab2020.v55.01235

Villa Nova NA, Tonato F, Pedreira CGS, Medeiros HR. Alternate method to compute the base temperature of forage grasses. Cienc Rural 2007; 32(2): 545-549. https://doi.org/10.1590/S0103-84782007000200039