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Forage accumulation and morphogenetic and structural characteristics of *Megathyrsus maximus* cv. Tamani under defoliation intensities

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Abstract. The effects of defoliation intensity (10, 20, 30 and 40 cm above soil level) on green dry matter (GDM) yield and morphogenetic and structural characteristics of *Megathyrsus maximus* cv. Tamani were evaluated under field conditions in Roraima's savannas. The effects of defoliation intensity on the GDM yields, leaf area index and leaf elongation rates was adjusted to the quadratic regression model and maximum values recorded with cutting at 28.2; 33.3 and 21.6 cm above soil level, respectively. The population tiller density, number of leaves tiller⁻¹ and leaf appearance rate was inversely proportional to the defoliation intensity, while the opposite occurred for to average leaf length and leaf senescence rate. Apical meristem removing percentage was higher with increasing defoliation intensity. Regrowth vigor showed close negative correlation with defoliation intensity. Pastures of *M. maximus* cv. Tamani managed under 25 to 30 cm residue provides higher forage productivity, larger efficiency of forage utilization, greater tissue renewal and canopy structure more favorable to grazing.

Keywords: Green dry matter, leaves, tillering, senescence

Acúmulo de forragem e características morfológicas e estruturais de *Megathyrsus maximus* cv. Tamani sob intensidades de desfolhação

Resumo. O efeito da intensidade de desfolhação (10, 20, 30 e 40 cm acima do solo) sobre a produção de forragem e características morfológicas e estruturais de *Megathyrsus maximus* cv. Tamani foi avaliado nos cerrados de Roraima. Os efeitos dos níveis de desfolhação sobre a produção de matéria seca verde, índice de área foliar e taxa de expansão de folhas foram ajustados ao modelo quadrático de regressão e os máximos valores registrados com cortes a 28,2; 33,3 e 21,6 cm acima do solo, respectivamente. A densidade populacional de perfilhos, taxa de aparecimento de folhas e número de folhas perfilho⁻¹ foram inversamente proporcionais ao nível de desfolhação, ocorrendo o inverso quanto ao comprimento médio de folhas e taxa de senescência foliar. A eliminação de meristemas apicais foi incrementada com o aumento do nível de desfolhação. O vigor de rebrota foi direta e negativamente correlacionado com o nível de desfolhação. Pastagens de *M. maximus* cv. Tamani manejadas sob resíduos entre 25 a 30 cm proporcionam maior produtividade e eficiência de utilização da forragem, maior renovação de tecidos e estrutura do dossel mais favorável ao pastejo.

Palavras chave: Folhas, matéria seca verde, perfilhamento, senescência

Acumulación de forraje y características morfogénicas y estructurales de *Megathyrsus maximus* cv. Tamani bajo intensidades de defoliación

Resumen. El efecto de intensidades de defoliación (10, 20, 30 and 40 cm por encima del suelo) sobre la producción de forraje y características morfogénicas y estructurales de *Megathyrsus maximus* cv. Tamani se evaluó en las sabanas de Roraima. Los efectos de las intensidades de defoliación sobre la producción de materia seca verde, índice de área foliar y tasa de expansión de hojas fueron ajustados al modelo cuadrático de regresión y los máximos valores registrados con cortes a 28,2; 33,3 e 21,6 por encima del suelo, respectivamente. La densidad poblacional de macollas, la tasa de aparición de hojas y el número de hojas macolla⁻¹ fueron inversamente proporcional al nivel de defoliación, ocurriendo lo contrario en cuanto a la longitud media de las hojas y la tasa de senescencia foliar. La eliminación de meristemas apicales se incrementó con el aumento del nivel de defoliación. El vigor de rebrote fue directo y negativamente correlacionado con la intensidad de defoliación. Pastos de *M. maximus* cv. Tamani manejados bajo residuos de 25 a 30 cm proporcionan mayor productividad y eficiencia de utilización del forraje, mayor renovación de tejidos y estructura del dosel más favorable al pastoreo.

Palabras clave: Hojas, materia seca verde, macollamiento, senescencia

Introduction

In Roraima, cultivated pastures represent the most important forage resource for the feeding of cattle herds. The use of continuous grazing associated with minimum rest periods, high defoliation intensities and the non-replacement of nutrients removed via animal production are determining factors for the low availability and quality of forage, with negative effects on the growth performance and zootechnic performance indexes of the animals ([Costa et al., 2007](#)).

The productivity and longevity of forage grasses result from their ability to reconstitute and maintain the leaf area after defoliation, which affects the structure of the canopy, determining its growth speed ([Pereira, 2013](#)). The growth stage of the grass is closely correlated with the accumulation of forage, as a result of the morphological and physiological changes that condition the balance between production and senescence of tissues, with reflexes on the chemical composition, regrowth capacity and persistence of pasture ([Nabinger & Carvalho, 2009](#); [Souza, 2018](#)).

The central point of grazing management consists of mediating the plant-animal encounter and determining the efficiency between the plant's growths, its consumption and animal production to keep the production system stable ([Hodgson, 1990](#)). The balance between productivity and quality must be achieved, aiming to ensure the nutritional requirements of the animals and, at the same time, maximizing the efficiency of the production, use and conversion processes of the produced forage.

The management intensity conditions differences in the structure of the pasture that affect the defoliation process by the animal and modify the growth dynamics of the pasture with influences on the biomass flows ([Pontes et al., 2004](#)). Defoliation intensity represents the proportion of plant tissue removed by the animal compared to that made available for grazing, impacting the remaining photosynthetically active leaf area, the remobilization of organic reserves and the removal of apical meristems ([Lemaire et al., 2011](#)). The visualization of the seasonal forage production curve and the possibility of predicting its chemical composition and/or nutritional value can be estimated through the knowledge of the grass morphogenic and structural characteristics ([Alexandrino et al., 2011](#); [Cargnelutti Filho et al., 2004](#); [Ferreira, 2017](#)), which can help in proposing specific management practices for each forage grass, aiming to maximize the efficiency of pasture use ([Pereira, 2013](#); [Santos et al., 2011](#)).

Morphogenesis describes the dynamics of the generation and expansion of grass tissues and organs in time and space, being synthesized by three variables: the rate of appearance, the rate of elongation and the life span of the leaves, which, despite their nature genetics, are strongly influenced by environmental conditions (temperature, light, water, and soil fertility) and pasture management practices. The interactions between these variables affect the structural characteristics: number of live leaves tillers⁻¹ (NLLT), average leaf length (ALL) and density of tillers, which will determine the leaf area

index (LAI), that is, the apparatus used for interception of radiation by the pasture canopy. The NLLT reflects the rate of appearance and the life span of the leaves, being genetically determined, while the rate of leaf elongation conditions the ALL ([Lemaire et al., 2011](#); [Vasconcelos, 2018](#)).

In this work, the effect of defoliation intensities on forage production and morphogenic and structural characteristics of *Megathyrus maximus* cv. Tamani were evaluated in Roraima's savannas.

Material and methods

The trial was conducted at the Embrapa Roraima Experimental Field, located in Boa Vista, from May to September 2015, which corresponded to an accumulated precipitation of 1,218 mm and an average monthly temperature of 24.9° C. The soil of the experimental area is a Yellow Latosol, medium texture, savanna phase, with the following chemical characteristics, at a depth of 0-20 cm: $\text{pH}_{\text{H}_2\text{O}} = 5.9$; $\text{P} = 13.8 \text{ mg kg}^{-1}$; $\text{Ca} + \text{Mg} = 1.21 \text{ cmol}_c\text{dm}^{-3}$; $\text{K} = 0.02 \text{ cmol}_c\text{dm}^{-3}$ and $\text{Al} = 0.17 \text{ cmol}_c\text{dm}^{-3}$.

The experimental design was in randomized blocks with three replications and the treatments represented by four defoliation intensities (10, 20, 30 and 40 cm above the ground). The plots measured 2.0 x 2.0 m, with a useful area of 1.0 m². The establishment fertilization consisted of the application of 50 kg of P₂O₅ ha⁻¹ and 60 kg of K₂O ha⁻¹, respectively in the form of triple superphosphate and potassium chloride. During the experimental period, four cuts were made at 35-day intervals.

The evaluated parameters were green dry matter yield (GDM), regrowth vigor (RV), apical meristem removing (AMR), tiller populational density (TPD), number of live leaves tiller⁻¹ (NLLT), leaf appearance rate (LAR), leaf expansion rate (LER), leaf senescence rate (LSR), average leaf length (ALL) and leaf area index (LAI).

The LER and LAR were obtained by dividing the accumulated leaf length and the total number of tillers-1 leaves, respectively, by the regrowth period. The ALL was determined by dividing the total leaf elongation of the tiller by its number of leaves. To calculate the leaf area, at each age of regrowth, samples of fully expanded green leaves were collected, trying to obtain an area between 200 and 300 cm², being estimated with an electronic optical planimeter (Li-Cor, model LI-3100C). Subsequently, the samples were taken to the oven with forced air at 65° C until they reached constant weight, obtaining the leaf DM. The specific leaf area (SLA) was determined through the relationship between green leaf area and its GDM (m²/g leaf GDM). The LAI was determined from the product between the total green leaf GDM (g GDM/m²) by SLA (m²/g leaf GDM).

The LSR was obtained by dividing the length of the leaf that was yellowish or necrotic in color by the regrowth period. The survival of apical meristems was estimated by relating the total number of tillers to those that presented with new truncated leaves, seven days after cutting the plants. The regrowth vigor was evaluated through the production of GDM 21 days after the first cut.

The data were submitted to analysis of variance and regression considering the significance level of 5% probability. In order to estimate the response of the parameters evaluated to the defoliation intensity, the choice of regression models was based on the significance of the linear and quadratic coefficients, using Student's "t" test.

Results and discussion

The relationship between GDM yield and defoliation intensities was adjusted to the quadratic regression model and the maximum estimated value with cuts at 28.2 cm above the ground ([Table 1](#)). The immediate effect of the level of defoliation on the growth of the grass is the reduction of its leaf area and, consequently, of the ability to intercept light and overall reduction of photosynthesis, processes that are affected by the proportion of tissue removed; the degree of defoliation of neighboring plants and the photosynthetic efficiency of the remaining leaf tissue after defoliation ([Canto et al., 2008](#); [Costa et al., 2007](#), [Pereira, 2013](#)).

Defoliation implies a rapid decline in the amount of soluble carbohydrates available for the growth of grass roots, as a consequence of the reduction in its photosynthetic rate as a whole and preferential allocation of carbon to the plant parts in order to restore its leaf area ([Costa et al., 2008](#); [Lemaire et al., 2011](#); [Pereira et al., 2011](#), [Silva, 2019](#)). The yields of GDM, for all defoliation levels, were higher than

suggested by [Minson \(2012\)](#) as a minimum forage limit available in tropical grass pastures (2,000 kg ha⁻¹), so as not to restrict access and intake voluntary forage by animals.

The retention of a larger photosynthetically active leaf area and a greater remobilization of nutrients with a reduction in the intensity of defoliation, provides greater recovery speed and allows the utilization of a shorter interval between grazing ([Cecato et al., 2000](#); [Euclides et al., 2019](#); [Nabinger & Carvalho, 2009](#); [Pereira, 2013](#)). [Costa et al. \(2008\)](#) reported higher yields of GDM for pastures of *M. maximus* cv. Vencedor managed under 40 cm residue (4,632 kg ha⁻¹), compared to 30 cm (3,297 kg ha⁻¹) or 20 cm above the ground (2,006 kg ha⁻¹). For *M. maximus* cv. Tanzania-1, [Canto et al. \(2008\)](#) showed linear increases in forage availability with the reduction of defoliation level (2,810; 3,155; 3,678 and 4,110 kg of GDM ha⁻¹, respectively, for 20, 40, 60 and 80 cm above the ground). Similar behavior was reported by [Costa et al. \(2007\)](#) for pastures of *M. maximus* cv. Centenário (4,133; 3,428 and 3,089 kg of GDM ha⁻¹, respectively for defoliation intensities of 40, 50 and 60%). For pastures of *M. maximus* cvs. Tamani and Kenya, [Tesk et al. \(2020\)](#) suggest the use of grazing intensities of 25 and 35 cm above the ground, respectively, which were correlated to high forage yields and higher recovery speed after the grazing.

Defoliation intensities negatively and linearly affected the removal of apical meristems ([Table 1](#)). For *M. maximus* cv. Tanzania-1, [Cecato et al. \(2000\)](#) estimated greater removal of apical meristems with cuts 20 cm above the ground (40.1%), compared to 40 (35.5%), which was negatively correlated with forage production. The regrowth vigor was affected ($P < 0.05$) by the defoliation intensity, with the quadratic relationship and the maximum yield of GDM estimated with cuts at 31.15 cm above the ground. [Costa et al. \(2008\)](#) reported that *M. maximus* cv. Massai was directly proportional to the level of defoliation (1,233; 1,579 and 1,977 kg of GDM/21 days, respectively for cuts at 30, 40 and 50 cm above the ground).

The reconstitution of the grass leaf area, after the defoliation process, has a high correlation with the removal of apical meristems and, the greater its intensity, the greater the time required for new growth, originated from the development of axillary buds or baseline, which have a lower speed of differentiation and expansion ([Lemaire et al., 2011](#); [Pereira, 2013](#)). For *M. maximus* cv. Tanzania-1, [Cecato et al. \(2000\)](#) reported greater RV with cuts 40 cm above the ground (9,124 kg GDM/21 days) compared to 20 cm (7,308 kg GDM/21 days).

Table 1. Green dry matter (GDM - kg ha⁻¹) yield, apical meristem removing (AMR - %), regrowth vigor (RV - kg GDM/21 days), tiller populational density m⁻² (TPD), number of live leaves tiller⁻¹ (NLLT), average leaf length (ALL - cm), leaf area index (LAI - m²/m²), leaf appearance rate (LAR - leaf day⁻¹ tiller⁻¹), leaf expansion rate (LER - cm day⁻¹ tiller⁻¹) and leaf senescence rate (LSR - cm tiller⁻¹ day⁻¹) of *Megathyrus maximus* cv. Tamani, as affected by defoliation intensities. Averages of four cuts¹.

Variables	Defoliation Levels (cm)				Regression Equation
	10	20	30	40	
GDM ¹	2.578	3.269	3.541	3.097	$Y = 1.245 + 160.17 X - 2.8375 X^2$ ($R^2 = 0.91$)
AMR	31.9	27.5	21.8	17.3	$Y = 37.21 - 0.4952 X$ ($r^2 = 0.88$)
RV	1.276	1.851	2.077	1.933	$Y = 336.25 + 111.85 X - 1.7975 X^2$ ($R^2 = 0.92$)
TPD	497	425	366	321	$Y = 549.1 - 5.872 X$ ($r^2 = 0.89$)
NLLT	5.35	4.89	4.17	3.78	$Y = 5.91 - 0.0543 X$ ($r^2 = 0.91$)
ALL	31.98	38.44	41.06	43.54	$Y = 29.43 + 0.3731 X$ ($r^2 = 0.92$)
LAI	2.14	2.87	3.61	3.29	$Y = 0.617 + 0.1732 X - 0.00261 X^2$ ($R^2 = 0.93$)
LAR	0.153	0.140	0.119	0.108	$Y = 0.1687 - 0.0016 X$ ($r^2 = 0.88$)
LER	4.88	5.37	4.89	4.71	$Y = 4.382 + 0.0736 X - 0.00172 X^2$ ($R^2 = 0.90$)
LSR	0.152	0.183	0.207	0.245	$Y = 0.121 + 0.00325 X$ ($r^2 = 0.91$)

The effects of defoliation intensities on ALL and NLLT were positive and linear, whereas for LAI the adjusted regression model was the quadratic and the maximum estimated value with defoliation at 33.3 cm above the ground. The values recorded for NLLT and ALL were higher than those reported by [Macedo et al., \(2010\)](#) for pastures of *M. maximus* cv. Mombaça managed under a 25 cm residue, which estimated 3.95 tillers⁻¹ and 34.5 cm leaves⁻¹, with the opposite occurring as regards the LAI (10.40). The ALL is the plastic characteristic most responsive to the level of defoliation and considered the morphological strategy of escape from plants when grazing. In general, lower values for ALL were found with higher levels of defoliation, probably due to the reduction of the cell multiplication phase and the distance that the leaf blade should travel

until the emergence of the pseudostem ([Lemaire et al., 2011](#); [Souza, 2018](#)).

The NLLT is the morphogenic characteristic that has the highest correlation with the leaf life span, which is of great relevance for pasture management, representing an estimate of the potential yield ceiling of the grass (maximum amount of green biomass per area), in addition to being a practical indicator for determining the grazing intensity in the continuous stocking system or the frequency of grazing in the intermittent stocking system, which allows the LAI to be obtained close to the highest light interception efficiency and maximum growth rates ([Nabinger & Pontes, 2002](#)).

The LAI synthesizes the functionality of the morphogenic and structural characteristics and represents the balance of the processes that determine the supply (photosynthesis) and the demand (respiration, accumulation of reserves, synthesis and tissue senescence) of photoassimilates, establishing the growth rate of the pasture ([Pereira, 2013](#)). The canopy architecture interferes with the interception and distribution of light within the plant population, as well as air circulation, affecting the CO₂ transfer processes and evapotranspiration, making it possible to infer that small differences in plant height can have major effects on competition for light, as a minimum difference is sufficient for one leaf to overlap the other ([Lemaire et al., 2011](#)).

The TPD was linear and inversely proportional to the defoliation intensity ([Table 1](#)). The tillering represents a structural feature strongly influenced by nutritional, environmental and management factors, which define the morphogenic characteristics that condition the physiological response of forage plants to management systems ([Cecato et al., 2000](#); [Garcez Neto et al., 2002](#), [Rios, 2018](#)).

The emission of new tillers is a constant process and potentiated when the grass is defoliated as a consequence of the improvement of the luminous environment at the base of the canopy (highest relation reason for red radiation/distant red), which is mediated by two main factors: the supply of energy for photosynthesis and the number and activity of growth points ([Gastal & Lemaire, 2002](#); [Nabinger & Carvalho, 2009](#)). In pastures of *M. maximus* cv. Vencedor, [Costa et al. \(2006\)](#) estimated higher PPD for defoliation at 20 cm (411 tillers m⁻²), compared to 30 cm (372 tillers m⁻²) or 40 cm above the ground (315 tillers m⁻²).

The effect of defoliation intensities on LER was adjusted to the quadratic regression model and the maximum estimated value with cuts at 21.6 cm above the ground, whereas for LAR the relationship was linear and negative ([Table 1](#)). Smaller leaves, in general, are associated with higher LAR values, while LER has a positive and significant correlation with ALL ([Nabinger and Carvalho, 2009](#); [Pereira, 2013](#)). LAR can be recognized as the morphogenic characteristic that deserves greater relevance, as it directly affects ALL, TPD and NLLT ([Difante et al., 2011](#)). LAR and LER, generally, present a negative correlation, because the faster the appearance of leaves, the shorter the time available for their complete expansion and differentiation ([Pereira, 2013](#); [Nascimento, 2014](#)).

Defoliation intensities positively and linearly affect the LSR ([Table 1](#)). [Costa et al. \(2007\)](#) reported higher LSR for pastures of *M. maximus* cv. Aruana under 30 cm (0.295 cm tiller⁻¹ day⁻¹) or 20 cm (0.201 cm tiller⁻¹ day⁻¹) residues, compared to 30 cm (0.179 cm tiller⁻¹ day⁻¹). Senescence represents a natural process that characterizes the last stage of leaf development, initiated after its complete expansion, whose intensity progressively increases with the increase of LAI and ALL, due to the shading of the leaves in the lower portion of the plant and the low supply of photosynthetically active radiation, in addition to strong competition for light, nutrients and water ([Ferlin et al., 2006](#); [Nabinger & Carvalho, 2009](#)).

With the stabilization of the NLLT there is a balance between the LAR and the senescence of the leaves that have exceeded their life span, so that for the appearance of a new leaf, the senescence of the previous leaf must occur in order to keep the NLLT relatively constant ([Lemaire et al., 2011](#); [Paciullo et al., 2017](#); [Rodrigues et al., 2012](#)). Thus, the negative effect of senescence on the quality of forage, it represents an important physiological process in the flow of grass tissue, since around 35.1; 68.3; 86.7 and 42.2% of nitrogen, phosphorus, potassium and magnesium, respectively, can be recycled from senescent leaves and used for the production of new leaf tissues ([Sarmiento et al., 2006](#)).

Conclusions

The defoliation level affects the forage production and the morphogenic and structural characteristics of the grass.

The elimination of apical meristems is directly proportional to the level of defoliation, with the opposite occurring as regards the vigor of regrowth.

Pastures of *M. maximus* cv. Tamani managed under 25 to 30 cm residue provides higher forage productivity, larger efficiency of forage utilization, greater tissue renewal and canopy structure more favorable to grazing.

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