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Características morfogênicas e estruturais de *Megathyrsus maximus* cv. Centenário sob intensidades de desfolhação

Morphogenetic and structural characteristics of *Megathyrsus maximus* cv. Centenário under defoliation intensities

Características morfogenéticas y estructurales de *Megathyrsus maximus* cv. Centenário bajo intensidades de defoliación

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Resumo

O efeito de intensidades de desfolhação (20, 30, 40 e 50 cm acima do solo) sobre a produção de forragem e características morfogênicas e estruturais de *Megathyrsus maximus* cv. Centenário foi avaliado em condições de campo nos cerrados de Roraima. Os efeitos das intensidades 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 35,8; 44,9 e 30,2 cm acima do solo, respectivamente. A densidade populacional de perfilhos, taxa de aparecimento de folhas e número de folhas perfilho^{-1} foram inversamente proporcionais à intensidade 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 da intensidade de desfolhação. O vigor de rebrota foi direta e negativamente correlacionado com a intensidade de desfolhação. Pastagens de *M. maximus* cv. Centenário manejadas sob resíduos entre 30 a 35 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.

Abstract

The effect of defoliation intensities (20, 30, 40 and 50 cm above soil level) on green dry matter (GDM) yield and morphogenetic and structural characteristics of *Megathyrsus maximus* cv. Centenário were evaluated under field conditions in Roraima´s savannas. The effects of defoliation intensities 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 35.8; 44.9 and 30.2 cm above soil level, respectively. The tiller population density, number of leaves tiller^{-1} and leaf appearance rate was inversely proportional to the intensity of defoliation, while the opposite occurred for to average leaf length and leaf senescence rate. Apical meristem removal percentage was higher with increasing defoliation intensity. Vigor regrowth showed close negative correlation with defoliation intensity level. Pastures of *M. maximus* cv. Centenário managed under 30 to 35 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; Tiller; Senescence

Resumen

El efecto de la intensidad de defoliación (20, 30, 40 y 50 cm por encima del suelo) sobre la producción de forraje y características morfogenéticas y estructurales de *Megathyrsus maximus* cv. Centenário 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 35,8; 44,9 y 30,2 cm 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 a la intensidad de defoliación, ocurriendo lo contrario en cuanto a la longitud media de las hojas y la tasa de senescencia foliar. La eliminación de meristemos apicales se incrementó con el aumento de la intensidad de defoliación. El vigor de rebrote fue directo y negativamente correlacionado con la intensidad de defoliación. Pastos de *M. maximus* cv. Centenário manejados bajo residuos de 30 a 35 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

1. Introduction

In Roraima, cattle ranching is one of the main economic activities and cultivated pastures represent the main forage resource for feeding herds. The use of continuous grazing or minimum rest periods, high defoliation intensities and the non-replacement of nutrients removed via animal production are factors that contribute to low availability and quality of forage, with negative effects on the zootechnical 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; Oliveira et al., 2019). The accumulation of forage is closely relate to the growth stage of the grass as a consecution of the morphological and physiological changes that modify the balance between the production and the senescence of tissues, with reflexes in the chemical composition, regrowth capacity and persistence of the pasture (Nabinger & Carvalho, 2009).

In grazing management, the central point is to mediate the plant-animal encounter and find an efficient balance between the plant's growth, its consumption and animal production to keep the production system stable (Hodgson, 1990; Oliveira et al., 2019). The adequate management of pasture must ensure the balance between productivity and quality, in order to supply 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 height provides differences in the structure of the pasture that affect the defoliation process by the animal and modify the growth dynamics of the pasture, changing the biomass flows (Pontes et al., 2004). The intensity of defoliation indicates the proportion of plant tissue removed by the animal in relation 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 knowledge of the morphogenic and structural characteristics can provides the visualization of the seasonal forage production curve and the possibility of estimating its chemical composition and/or nutritional value (Alexandrino et al., 2011; Oliveira eet al., 2020). In addition to allowing the proposition of specific management practices for each forage grass, aiming to maximize the efficiency of pasture use (Santos et al., 2012; Pereira, 2013). During grass vegetative growth, morphogenesis describes the dynamics of the generation and expansion of grass tissues and organs in time and space and can be to describe by three variables: the rate of appearance, the rate of elongation and the life span of the leaves. Despite their genetic nature, the physiological characteristics can be strong influenced by environmental conditions (temperature, light, water, and soil fertility) and management practices. The interactions between these variables condition the structural characteristics: number of live leaves tillers^{-1} (NLT), average length of leaves (ALL) and density of tillers, which will determine the leaf area index (LAI), that is, the apparatus used for the interception of radiation by the pasture canopy. The NLT 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).

This work evaluated the effect of defoliation intensities on forage production and morphogenic and structural characteristics of *Megathyrsus maximus* cv. Centenário.

2. Methodology

The research was perform under controlled conditions using the quantitative method. As there are still gaps about the effect of the defoliation intensity on the productive performance of tropical pastures, it was choose to use the hypothetical-deductive method (Pereira et al., 2018).

The trial was carry out in 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: pH_{H2O} = 5.9; P = 12.6 mg kg^{-1}; Ca + Mg = 1.21 $cmol_c.dm^{-3}$; K = 0.025 $cmol_c dm^{-3}$ and Al = 0.17 $cmol_c dm^{-3}$.

The experimental design was in randomized blocks with three replications and the treatments represented by four defoliation intensities (20, 30, 40 and 50 cm above the ground). The plots measured 2.0 x 2.0 m, with a useful area of 1.0 m^2. The establishment fertilization consisted of the application of 80 kg of N ha^{-1}, 50 kg of P_2O_5 ha^{-1} and 60 kg of K_2O ha^{-1}, respectively in the form of urea, triple superphosphate and potassium chloride. The application of N was share in three times, coinciding with the cuts of evaluation of forage production. During the experimental period, three cuts were realize at 35-day intervals.

The evaluated parameters were green dry matter yield (GDM), regrowth vigor (RV), apical meristem removal (AMR), tiller population density (TPD), number of live leaves $tiller^{-1}$ (NLT), 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 obtain 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 cm^2, being estimated with an electronic optical planimeter (Li-Cor, model LI-3100C). Subsequently, the samples were submit to the oven with forced air at 65ºC until they reached constant weight, obtaining the leaf GDM. The specific leaf area (SLA) was determined through the relationship between green leaf area and its GDM (m^2/g leaf GDM). The LAI was determined from the product between the total green leaf GDM (g GDM/m^2) by SLA (m^2/g leaf GDM).

The LSR was obtain by dividing the length of the leaf that was yellowish or necrotic in color by the regrowth period. The survival of apical meristems was estimate 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 evaluate through the production of GDM 21 days after the first cut.

The data were submit 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 chose on the significance of the linear and quadratic coefficients, using Student's “t” test.

3. Results and Discussion

The Table 1 shows the effects of defoliation intensity on forage productivity and grass morphogenic characteristics. The GDM yields were affected by defoliation intensities ($P<0.05$) and adjusted to the quadratic regression model and the maximum estimated value with cuts 35.8 cm above the ground (Table 1).

Table 1. Green dry matter - GDM **(**kg ha^{-1}), apical meristem removal - AMR (%), regrowth vigor - RV (kg GDM/21 days), tiller population density m^{-2} (TPD), number of live leaves $tiller^{-1}$ (NLT), average leaf length - ALL (cm), leaf area index - LAI (m^2/m^2), 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 *Megathyrsus maximus* cv. Centenário, as affect by defoliation intensity. Averages of three cuts[1].

Variables	Defoliation Intensity (cm)				Regression Equation
	20	30	40	50	
GDM[1]	2,871	3,497	3,688	3,107	$Y = 343.15 + 220.21 X - 3.0175 X^2$ ($R^2 = 0.92$)
AMR	35.3	29.4	20.1	17.8	$Y = 47.28 - 0.6182 x$ ($r^2 = 0.91$)
RV	1,871	2,568	2,870	2,108	$Y = 2{,}015 + 265.46 X - 3.6475 X^2$ ($R^2 = 0.89$)
TPD	651	587	544	507	$Y = 607.7 - 5.872 x$ ($r^2 = 0.93$)
NLT	5.37	5.08	4.81	4.22	$Y = 6.172 - 0.0372 x$ ($r^2 = 0.93$)
ALL	28.55	33.71	39.12	42.58	$Y = 19.365 + 0.4751 x$ ($r^2 = 0.88$)
LAI	2.11	2.68	3.25	3.09	$Y = 0.435 + 0.1628 X - 0.00184 X^2$ ($R^2 = 0.91$)
LAR	0.153	0.147	0.137	0.121	$Y = 0.1737 - 0.0011 x$ ($r^2 = 0.93$)
LER	4.91	5.58	5.64	5.25	$Y = 1.91 + 0.1595 X - 0.00192 X^2$ ($R^2 = 0.92$)
LSR	0.135	0.161	0.185	0.198	$Y = 0.0952 + 0.00214 x$ ($r^2 = 0.88$)

SOURCE: Research Data

The main effect of the intensity of defoliation on the grass is the reduction of its leaf area and, consequently, the ability to intercept light and overall reduction of photosynthesis. These are affect by the proportion of tissue removed and the degree of defoliation of neighboring plants and the photosynthetic capacity of the remaining leaf tissue after defoliation (Costa et al., 2006; Canto et al., 2008; Oliveira et al., 2020).

After defoliation there is a rapid decline in the amount of soluble carbohydrates in the roots, as a consequence of the reduction in the photosynthetic rate of the plant as a whole and preferential allocation of carbon to the grass parts in order to restore its leaf area (Costa et al., 2008; Lemaire et al., 2011; Santos et al., 2011). For all defoliation intensities, the GDM yields were higher than the recommended by Minson (1990) as a minimum forage available in tropical grass pastures (2,000 kg ha^{-1}), so as not to restrict voluntary forage intake by animals (Benvenutti et al., 2015).

The reduction in defoliation intensity allows the retention of a larger photosynthetically active leaf area and greater nutrient remobilization, resulting in a faster recovery speed and a shorter interval between grazing (Cecato et al., 2000; Nabinger & Carvalho, 2009; Oliveira et al., 2020). Costa et al. (2008) found higher yields of GDM for pastures of *M. maximus* cv. Aruana managed under 30 cm above the ground (3,201 kg ha^{-1}), compared to 20 cm (2,342 kg ha^{-1}) or 10 cm above the ground (2,034 kg ha^{-1}). For *M. maximus* cv. Tanzania-1, Canto et al. (2008) reported linear increases in forage availability with reduced defoliation intensity (2,810; 3,155; 3,678 and 4,110 kg GDM ha^{-1}, respectively, for 20, 40, 60 and 80 cm above the ground).

The removal of apical meristems was inversely proportional to the intensity of defoliation (Table 1). Cecato et al. (2000) found greater removal of apical meristem from *M. maximus* cv. Tanzania-1 with cuts 20 cm above the ground (40.1%), compared to 40 (35.5%), which was negatively correlated with forage production. The defoliation intensity affected ($P < 0.05$) the regrowth vigor, with the quadratic relationship and the maximum yield of GDM estimated with cuts 36.4 cm above the ground. Costa et al. (2008) found that *M. maximus* cv. Vencedor was directly proportional to the intensity of defoliation (1,033; 1,366 and 1,872 kg of GDM/21 days, respectively for cuts at 20, 30 and 40 cm above the ground). The removal of apical meristems delays the leaf reconstitution of the grasses, which will originate from the development of axillary or basilar buds, which have a slower growth rate (Pereira, 2013; Oliveira et al., 2020). For *M. maximus* cv. Tanzania-1 pastures, Cecato et al. (2000) reported greater RV with cuts at 40 cm above the ground (9,124 kg GDM/21 days) compared to 20 cm (7,308 kg GDM/21 days).

For ALL and NLT the relationships were positive and linear, while the LAI was adjust to the quadratic regression model and the maximum estimated value with defoliation at 44.9 cm above the ground. The values recorded for NLT and ALL were higher than those reported by Macedo et al. (2010) for pastures of *M. maximus* cv. Mombaça managed under 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 a plastic characteristic and responsive to the intensity of defoliation and considered the morphological strategy of escape from plants when grazing. In general, lower values for ALL were estimate with greater defoliation intensities, probably due to the reduction of the cell multiplication phase and the distance that the blade should travel until the emergence of the pseudostem (Lemaire et al., 2011; Oliveira et al., 2020).

The NLT can be consider the morphogenic characteristic most correlated with the leaf life span. This is fundamental in the management of pasture, as it is an estimate of the maximum potential yield of the grass (maximum amount of green biomass per area). On the other hand, is a practical indicator for the determination of grazing intensity in the continuous stocking system or the frequency of grazing in the intermittent stocking system that allows obtaining LAI close to the highest efficiency of light interception and maximum growth rates (Nabinger & Carvalho, 2009). The LAI represents the synthesis of morphogenic and structural characteristics and represents the balance of the processes that determine the supply (photosynthesis) and demand (respiration, accumulation of reserves, synthesis and tissue senescence) of photoassimilates, establishing the growth rate of the pasture (Difante et al., 2011; Pereira, 2013).

The TPD was linear and inversely proportional to the defoliation intensity (Table 1). The tillering is a structural feature strongly influenced by nutritional, environmental and management factors, which define the physiological characteristics that condition the morphogenic response of forage plants to management systems (Cecato et al., 2000; Garcez Neto et al., 2002). The emission of new tillers is a normal and continuous process and accelerated because the plant defoliation improve the luminous environment at the base of the canopy (major reason for red radiation/distant red). This process is mediate 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. Massai, Costa et al. (2008) found higher TPD for defoliation at 20 cm (856 tillers m^{-2}), compared to 20 (751 tillers m^{-2}) or 30 cm above the ground (677 tillers m^{-2}).

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The defoliation intensity affected the LAR linearly and negatively, while for the LER the adjustment was to the quadratic regression model and the maximum value estimated with cuts at 30.2 cm above the ground (Table 1). In general, smaller leaves are associated with higher LAR values, while LER is directly correlate to ALL (Nabinger, & Pontes, 2002; Pereira, 2013; Fernandes et al., 2020a). LAR can be consider the morphogenic characteristic that deserves more emphasis, as it directly influences the final leaf size, the population density of tillers and the number of tillers^{-1} leaves (Nabinger & Carvalho, 2009; Difante et al., 2011). LAR and LER generally present a negative correlation, showing that the faster the appearance of leaves, the shorter the time available for their complete expansion (Lemaire et al., 2011; Pereira, 2013; Oliveira et al., 2020).

The LSR was positive and linearly affected by the defoliation intensity (Table 1). Costa et al. (2007) found a higher LSR for pastures of *M. maximus* cv. Mombaça under residues of 40 cm (0.235 cm tiller^{-1} day^{-1}), compared to 30 cm (0.215 cm tiller^{-1} day^{-1}) or 20 cm (0.186 cm tiller^{-1} day^{-1}). Senescence is a natural process that characterizes the last stage of leaf development, which started after its complete expansion. This intensity progressively increases with the increase of LAI and ALL, due to the shading of the leaves arranged in the lower portion of the plant and the lower supply of photosynthetically active radiation, in addition to strong competition for light, nutrients and water (Ferlin et al., 2006; Nabinger & Carvalho, 2009; Fernandes et al., 2020a, b).

When the tiller display a certain NLT there is a balance between the LAR and the senescence of the leaves that have exceeded their life span. So the appearance of a new leaf implies the senescence of the previous leaf in order to keep the NLT relatively constant (Lemaire et al., 2011; Rodrigues et al., 2012; Oliveira et al. 2019). Senescence despite the negative effect on the quality of forage represents an important physiological process in the flow of grass tissue, since around 35; 68; 86 and 42% 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).

In this work, a reduction in macronutrient uptake can be observed with the increase of the defoliation intensity, showing a nutrient dilution effect. However, there is some mechanism of translocation between the old leaves and the new leaves in expansion, since the macronutrient levels did not fall below the critical levels which could make forage productivity unfeasible. The expanding leaves exert a strong force in draining nutrients from senescent leaves, so that their development is not compromised, which ensures high levels of internal nutrient recycling

4. Final Considerations

Defoliation intensity affects the production of green dry matter 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.

The rate of leaf appearance and the tiller population density are inversely proportional to the defoliation intensity, occurring the inverse as to the average leaf length, leaf area index and leaf senescence rate.

The maintenance of *M. maximus* cv. Centenário under residues between 30 and 35 cm provides greater productivity and efficiency of forage use, greater tissue renewal and canopy structure more favorable to grazing.

The installation of experiments are suggest under field conditions and preferably with the use of animals in order to endorse the recommended defoliation intensities for the grass.

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