Produtividade de forragem e morfogênese de cultivares de *Megathyrsus maximus* nos cerrados de Roraima

Forage yield and morphogenesis of *Megathyrsus maximus* cultivars in Roraimas's savannas

Producción de forraje y morfogénesis de cultivares de *Megathyrsus maximus* en las sabanas de Roraima

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Resumo

Com o objetivo de avaliar a produtividade de forragem e as características morfogênicas e estruturais de cultivares de *Megathyrsus maximus* (Massai, Mombasa, Kenya, Tamani, Tanzânia and Zuri) conduziu-se um experimento sob condições ambientais naturais nos cerrados de Roraima. Os maiores rendimentos de matéria seca verde (MSV) foram constatados com as cultivares Zuri (4.317 kg ha^{-1}) e Mombasa (4.115 kg ha^{-1}), seguindo-se a Kenya (3.868 kg ha^{-1}) e Tamani (3.755 kg ha^{-1}), enquanto que a Massai (3.341 kg ha^{-1}) e a Tanzânia (3.225 kg ha^{-1}) foram as menos produtivas. O rendimento de MSV foi diretamente correlacionado com o índice de área foliar e inversamente proporcional a densidade populacional de perfilhos (DPP). As cultivares Tanzânia e Kenya apresentaram maior número de folhas perfilho e taxas de aparecimento de folhas, enquanto que as maiores taxas de expansão de folhas foram estimadas nas cultivares Zuri e Kenya. O maior comprimento médio de folhas $perfilho^{-1}$ foi registrado nas cultivares Zuri e Mombasa. As taxas de senescência foliar foram inversamente proporcionais a DPP e as maiores foram registradas com as cultivares Mombasa e Tamani. As seis cultivares de *M. maximus* apresentaram satisfatórios rendimentos de forragem e podem ser recomendadas para cultivo nas condições edafoclimáticas dos cerrados de Roraima. A determinação das características morfogênicas e estruturais pode contribuir para o estabelecimento de práticas de manejo adequadas e específicas para cada cultivar, visando otimizar sua produtividade e reduzir as perdas por senescência foliar.

Palavras-chave: Folhas; Matéria seca verde; Perfilhamento; Senescência; Produtividade.

Abstract

In order to evaluate the forage productivity and the morphogenic and structural characteristics of *Megathyrsus maximus* cultivars (Massai, Mombasa, Kenya, Tamani, Tanzania and Zuri), an experiment was conduct under natural environmental conditions in the savannahs of Roraima. The highest yields of green dry matter (GDM) were found with cultivars Zuri (4,317 kg ha^{-1}) and Mombasa (4,115 kg ha^{-1}), followed by Kenya (3,868 kg ha^{-1}) and Tamani (3,755 kg ha^{-1}), while Massai (3,341 kg ha^{-1}) and Tanzania (3,225 kg ha^{-1}) were the least productive. GDM yield was directly correlated with leaf area index and inversely proportional to tiller population density (TPD). The cultivars Tanzania and Kenya had the highest number of tiller leaves and leaf appearance rates, while the highest leaf expansion rates were estimate in cultivars Zuri and Kenya. The highest average length of tiller leaves was estimate in the cultivars Zuri and Mombasa. Leaf senescence rates were inversely proportional to TPD and

the highest recorded with the cultivars Mombasa and Tamani. The six cultivars of *M. maximus* showed satisfactory forage yields and can be recommend for cultivation in the edaphoclimatic conditions of the of Roraima's savannas. The determination of morphogenic and structural characteristics can contribute to the establishment of appropriate and specific management practices for each cultivar, aiming to optimize its productivity and reduce losses due to leaf senescence.
Keywords: Green dry matter; Leaves; Senescence; Tillering; Productivity.

Resumen

Para evaluar la productividad del forraje y las características morfogénicas y estructurales de los cultivares de *Megathyrsus maximus* (Massai, Mombasa, Kenia, Tamani, Tanzania y Zuri), se realizó un experimento en condiciones ambientales naturales en la sabana de Roraima. Los mayores rendimientos de materia seca verde (MSV) se encontraron con los cultivares Zuri (4.317 kg ha^{-1}) y Mombasa (4.115 kg ha^{-1}), seguidos de Kenia (3.868 kg ha^{-1}) y Tamani (3.755 kg ha^{-1}), mientras que Massai (3.341 kg ha^{-1}) y Tanzania (3.225 kg ha^{-1}) fueron los menos productivos. El rendimiento de MSV se correlacionó directamente con el índice de área foliar y fue inversamente proporcional a la densidad de población de macolla (DPM). Los cultivares Tanzania y Kenia tuvieron el mayor número de hojas por macolla y tasas de aparición de hojas, mientras que las tasas de expansión de hojas más altas se estimaron en los cultivares Zuri y Kenia. La mayor longitud promedio de las hojas de la macolla se registró en los cultivares Zuri y Mombasa. Las tasas de senescencia de las hojas fueron inversamente proporcionales a DPM y las más altas registradas con los cultivares Mombasa y Tamani. Los seis cultivares de *M. maximus* presentaron rendimientos de forraje satisfactorios y pueden recomendarse para el cultivo en las condiciones edafoclimáticas de la sabana de Roraima. La determinación de las características morfogénicas y estructurales puede contribuir al establecimiento de prácticas de manejo apropiadas y específicas para cada cultivar, con el objetivo de optimizar su productividad y reducir las pérdidas debido a la senescencia de las hojas.
Palabras clave: Hojas; Macollaje; Materia seca verde; Senescencia; Productividad.

1. Introduction

In Roraima, livestock is one of the economic activities in expansion and the cultivated pastures represent an important forage resource for feeding beef cattle and/or milk herds. The use of inappropriate management practices, characterized by the use of continuous grazing or minimum periods of rest and high intensities of defoliation are factors that contribute to low availability and quality of forage, with negative effects on the zootechnical animal performance indexes. Environmental conditions (temperature, light, water and soil fertility) and management practices strongly affect pasture productivity, while its longevity stems, among other factors, from the ability to replenish and maintain the leaf area after defoliation, which affects the canopy structure, determining its growth speed, forage accumulation, chemical composition and persistence (Nabinger & Pontes, 2002; Souza, 2018).

The central point of grazing management is to find an efficient balance between plant growth, consumption and animal production to keep the production system stable (Hodgson, 1990). Therefore, a balance must be obtain between productivity and quality, 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 forage produced.

The study of the morphological, physiological and structural characteristics of forage plants is necessary to promote the understanding of the dynamics of forage production and its relationships within animal production systems in pastures. The knowledge of the morphogenic and structural characteristics can provides the visualization of the seasonal forage production curve and the possibility of estimating its quality (Alexandrino et al., 2011), in addition to allowing the proposition of specific management practices for each forage grass (Santos et al., 2012; Pereira, 2013). The morphogenesis of a forage plant can be define as the dynamics of generation (genesis) and expansion/shape of the plant (morphos) in time and space. The morphogenic programming, whose rate is dependent on temperature, determines the functioning and the arrangement of meristems in terms of production and expansion rates of new cells, which in turn define the dynamics of organ expansion (leaf, internode, tiller) and the carbon and nitrogen requirements necessary to occupy the corresponding expansion volumes.

In grasses, during their vegetative growth, morphogenesis describe the dynamics of the generation and expansion of plant tissues and organs in time and space. This characteristic can be a synthesis by three variables: the rate of appearance, the rate of elongation and the life span of the leaves, which, despite their genetic nature, are strongly influence by environmental conditions (temperature, light, water, and soil fertility) and management practices. The interactions between these variables determine the structural characteristics: number of live leaves tillers^{-1} (NLT), average leaf length (ALL) and tillers density, which will determine the leaf area index (LAI), that is, the apparatus used for the interception of radiation by the pasture canopy. The NLT is due to the rate of appearance and the life span of the leaves, being genetically determined, while the rate of leaf elongation affect directly the ALL (Lemaire et al., 2011). Changes in plant management influence the number of dividing cells and the ability to cell elongation, which accelerates or retards the leaf elongation rate (LER) and increases or decreases the final length of the leaves; these factors modify the morphogenic rhythm of plants (Gomide et al., 2006).

In this work it was evaluated the forage productivity and the morphogenic and structural characteristics of *Megathyrsus maximus* cultivars in the Roraima's savannas.

2. Material and Methods

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

The trial was conduct 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 biome, with the following chemical characteristics, at a depth of 0-20 cm: pH_{H2O} = 5.7; P = 11.5 mg kg^{-1}; Ca + Mg = 1.15 $cmol_c$.dm-3; K = 0.019 $cmol_c$dm-3 and Al = 0.17 $cmol_c$dm-3.

The experimental design was complete randomized with three replications. The treatments consisted of six cultivars of *M. maximus* (Massai, Mombasa, Kenya, Tamani, Tanzânia, and Zuri). The size of the plots was 2.0 x 2.0 m, with a useful area of 1.0 m^2. The establishment fertilization consisted of the application of 50 kg of P_2O_5 ha^{-1} and 60 kg of K_2O ha^-1, respectively in the form of triple superphosphate and potassium chloride. During the experimental period, three cuts was make at 42-day intervals.

The parameters evaluated were green dry matter (GDM) yield, tiller population density m^{-2} (TPD), number 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 calculate by dividing the accumulated leaf length and the total number of leaves in the tillers, respectively, by the regrowth period. The ALS was determined by dividing the total leaf elongation of the tillers by the number of leaves.

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To calculate the leaf area, samples of completely expanded green leaves were collect, trying to obtain an area between 200 and 300 cm^2. The samples were digitalize and the leaf area estimated with the aid of an electronic optical planimeter (Li-Cor 3100C). Subsequently, the sample was take, to the greenhouse with forced air at 65ºC until they reached constant weight, obtaining the leaf GDM. Specific leaf area (SLA) was determine by the relationship between green leaf area and its GDM (m^2/g leaf GDM). The leaf area index (LAI) was determined from the product of 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 by the regrowth age.

Data were subject to analysis of variance and regression considering the significance level of 5% probability, using the soft statistical analysis program Sisvar (Ferreira, 2011).

3. Results and Discussion

The GDM yields were affected by *M. maximus* cultivars ($P<0.05$) and the highest values recorded in cultivars Zuri (4,317 kg ha^{-1}) and Mombasa (4,115 kg ha^{-1}), followed by Kenya (3,868 kg ha^{-1}) and Tamani (3,755 kg ha^{-1}), while Massai (3,341 kg ha^{-1}) and Tanzania (3,225 kg ha^{-1}) were the least productive (Table 1).

Table 1. Green dry matter (GDM - kg ha^{-1}) yield, 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* cultivars. Averages of three cuts[1].

Variables	Cultivars					
	Massai	**Mombasa**	**Kenya**	**Tamani**	**Tanzânia**	**Zuri**
GDM[1]	3,341 c	4,115 a	3,868 b	3,755 b	3,225 c	4,317 a
TPD	1,081 a	738 e	903 c	975 b	821 d	892 c
NLT	4.09 bc	4.41 b	5.43 a	3.75 c	5.82 a	5.31 a
ALL	30.8 d	38.9 b	37.1 c	37.8 c	35.8 c	42.5 a
LAI	3.35 d	4.12 b	3.98 bc	3.87 c	3.44 d	4.51 a
LAR	0.097 cd	0.105 c	0.129 b	0.089 d	0.142 a	0.119 b
LER	2.99 c	4.07 b	4.79 a	3.37 c	3.97 b	5.05 a
LSR	0.287 e	0.656 a	0.303 e	0.571 b	0.476 c	0.381 d

Source: Research data.

The forage productivity was directly proportional to the LAI and ALL, however negatively correlated with the TPD. Similar results were report by Costa et al. (2020) for *M.*

maximus cv. Centenário, with TPD and NLT being the main components most relevant and highly correlated with GDM productivity. The six cultivars showed satisfactory forage productivity and can be recommend for cultivation in the Roraima's savannas, as they showed superior agronomic performance to that reported by Costa et al. (2020) for cultivars of *M. maximus* Aruana, Centenário and Vencedor, under the same environmental conditions.

Evaluating several cultivars of *M. maximus*, Veras et al. (2020) found higher yields of GDM for cultivars Mombasa (3,249 kg ha^{-1}), Massai (2,979 kg ha^{-1}), Tamani (2,718 kg ha^{-1}) and Zuri (2,704 kg ha^{-1}), compared to cultivar Aruana (1.648 kg ha^{-1}). Tesk et al. (2020) found no significant differences in the GDM yields of the Kenya (4,345 kg ha^{-1}) and Tamani (4,055 kg ha^{-1}) cultivars, regardless of the season (spring, summer and autumn) and grazing intensity. Similarly, Valote (2018) did not detect significant variations in the forage yield of cultivars Kenya (3,400 kg ha^{-1}) and Zuri (3,165 kg ha^{-1}), however this cultivar showed a higher leaf/stem ratio (2.2), compared to that observed in the cultivar Kenya (1.5).

The cultivars Massai (1,081 tillers m^{-2}) and Tamani (975 tillers m^{-2}) had the highest TPD, while Zuri (892 tillers m^{-2}) and Mombasa (738 tillers m^{-2}) the lowest (Table 1). Tilling is a structural feature strongly influenced by nutritional, environmental and management factors (Garcez Neto et al., 2002). The production of new tillers represents a continuous and accelerated process due to the defoliation of the plant. The improvement of the luminous environment at the base of the canopy (greater reason of red radiation/distant red), being controlled by two main factors: the supply and quality of energy for photosynthesis and the number and activity of growth points (Gastal and Lemaire, 2002; Nabinger & Carvalho, 2009). In pastures of *M. maximus*, Miquilini (2019) report higher TPD for cultivars Tamani (2,199 tillers m^{-2}) and Zuri (1,143 tillers m^{-2}) and the lowest for Kenya (1,061 tillers m^{-2}) and Mombasa (593 tillers m^{-2}). However, Veras et al. (2020) found higher TPD for cultivar Massai (428 tillers m^{-2}), Tamani (325 tillers m^{-2}) and Tanzania (294 tillers m^{-2}), while the cultivars Zuri (197 tillers m^{-2}) and Mombasa (195 tillers m^{-2}) exhibit the lowest tillering and no relationship was found with forage productivity. The cultivars Zuri and Mombasa had the lowest tiller mortality rates during the growing season, which explained the maintenance of the growth pattern of the grasses, as well as greater uniformity in forage availability.

The individual tillers have a limited and variable life span, due to biotic and abiotic factors, and their population can be maintain by a continuous replacement of dead tillers, this behavior being the main determinant factor for the perennial growth of grasses (Lemaire et al., 2011; Santos et al, 2012). Generally, with the increase in LAR and LAI, the TPD is restrict by the low incidence of light radiation to stimulate the buds available at the base of the

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grass however it can be stimulated with the maintenance of the remaining apical meristems after the grazing process. 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 (Lemaire et al., 2011).

For ALL, the cultivars Mombasa (38.9 cm), Tamani (37.8 cm) and Kenya (37.1 cm) had the highest values, while the highest NLT were registered with the cultivars Tanzania (5.82 leaves tiller^{-1}) and Kenya (5.43 leaves tiller^{-1}). The values recorded for NLT and ALL were higher than those reported by Macedo et al. (2010) for pastures of *M. maximus* cv. Mombasa maintain under 25 cm residue, which estimated 3.95 tillers^{-1} and 34.5 cm leaves^{-1}. However, Miquilini (2019) found no significant differences for the NLT of the cultivars Tamani, Zuri, Mombasa and Kenya, which varied between 2.2 and 2.7 leaves tiller^{-1}. The ALL can be consider as the main plastic characteristic and that presents greater responsiveness to the management of defoliation and widely recognized as the morphological strategy of escape from the plants to the grazing process. In general, the lowest values for the ALL are report for greater defoliation intensities, probably due to the reduction in the cell multiplication phase and the distance that the leaf blade should travel until the emergence of the pseudostem (Lemaire et al., 2011).

The NFV is the morphogenic characteristic most closely correlated with the leaf life span, which is essential in grazing management. It can be used to estimate the yield potential of the grass (maximum amount of green biomass per area), in addition to being the most practical and easy-to-use parameter for determining the grazing intensity in the continuous stocking system or the grazing frequency in the intermittent stocking system. In this way, it is intend to ensure LAI close to the highest efficiency of light interception while ensuring maximum growth rates (Nabinger & Pontes, 2002).

The highest LAI were estimate with the cultivars Zuri (4.51), Mombasa (4.12) and Kenya (3.98), while Tanzania (3.44) and Massai (3.35) had the lowest values (Table 1). Costa et al. (2020) reported higher LAI for the cultivars Mombasa (5.12) and Kenya (4.87), compared to Centenário (3.77) and Vencedor (3.32). This pattern as consequence of the greater tillering and leaf emission, which were directly correlate to forage yields. The LAI synthesizes the contribution of morphogenic and structural characteristics to the net accumulation of biomass and represents the balance of the processes that determine the supply (photosynthesis) and demand (respiration, accumulation of reserves, synthesis and senescence of tissues) of photoassimilates, establishing the growth rate of pasture (Nabinger & Carvalho, 2009).

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The highest LAR were registered with the cultivars Tanzania (0.142 leaf tiller^{-1} day^{-1}) and Kenya (0.129 leaf tiller^{-1} day^{-1}), while for LER, the cultivars Zuri (5.05 cm tiller^{-1} day^{-1}) and Kenya (4.79 cm tiller^{-1} day^{-1}) had the highest values (Table 1). Miquilini (2019), evaluating several cultivars of M. maximus, found higher LAR and LER for the cultivars Kenya, Mombasa and Tamani, which were positively correlated to greater tillering and availability of forage. In general, smaller leaves are associated with high LAR values, while LER is directly correlate to ALL (Nabinger & Pontes, 2002). This response pattern is relate to the reduction of the apical dominance of tillers, by reducing the influence of the action of their apical meristem. Since the reduction of shading allows a greater amount of light to fall on the base of plants, stimulating the development of basilar buds present in the lower internodes of the stalk and, consequently, greater appearance of new leaves with greater final length.

The LAR is the morphogenic characteristic that require greater emphasis, as it directly affects the leaf size, the population density of tillers and the number of leaves tillers^{-1} (Nabinger & Carvalho, 2009; Difante et al., 2011). The LAR and LER have a negative correlation, indicating that the faster the appearance of leaves, the shorter the time available for their expansion, depending on the frequency of defoliation imposed (Lemaire et al., 2011). The grasses with higher LAR and LER, theoretically, have greater forage availability in less time, allowing greater grazing frequencies, especially when management practices that favor leaf architecture are used, reducing the light extinction coefficient, in addition to structure of the canopy more compatible with the grazing process.

The highest LSR were estimate with the cultivars Mombasa (0.656 cm tiller^{-1} day^{-1}), Tamani (0.571 cm tiller^{-1} day^{-1}) and Tanzania (0.476 cm tiller^{-1} day^{-1}) (Table 1). This behavior shows that the adopted rest period, 42 days, can be consider adequate for the cultivars Massai, Kenya and Zuri, while for Mombasa, Tanzania and Tamani it was too long. Possibly extrapolated the critical leaf area index, where 95% of the incident radiation is absorb by the canopy and from which there is a strong shading of the lower portion of the grass and high LSR. Likewise, Miquilini (2019) reported higher LSR for the cultivars Kenya (4.10 cm day^{-1}), Mombasa (3.61 cm day^{-1}), compared to Zuri (3.28 cm day^{-1}) and Tamani (3.07 cm day^{-1}).

Senescence represents a natural process that characterizes the last stage of leaf development, started after complete expansion. Its intensity increases progressively with the increase in the LAI and ALL, due to the shading of the leaves inserted in the lower portion and the reduced supply of photosynthetically active radiation, in addition to strong competition for light, nutrients and water (Pontes et al., 2004; Nabinger & Carvalho, 2009). When the tiller reaches a certain NLT, a balance is establish between the LAR and the senescence of those leaves that have exceeded their life span. In this way, the appearance of a new leaf implies the senescence of the leaf that preceded it, keeping the NLT relatively constant (Lemaire et al., 2011; Costa et al., 2013). Senescence, despite the negative effect on the quality of forage, expresses an important physiological process in the flow of grass tissue. In general, about 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, the agronomic evaluation of *M. maximus* cultivars allowed the discrimination of their morphogenic and structural characteristics, which can be used as subsidies for the determination of appropriate management practices that optimize their forage productivity and persistence.

4. Final Considerations

The cultivars of *M. maximus* differ in terms of forage productivity and their morphogenic and structural characteristics.

Zuri and Mombasa cultivars were the most productive, followed by Kenya and Tamani, while Massai and Tanzania had the lowest forage yields.

Six cultivars showed satisfactory forage productivity and can be recommend for cultivation in the Roraima’s savannas.

The determination of morphogenic and structural characteristics can contribute to the establishment of appropriate and specific management practices for each cultivar, aiming to optimize its productivity and reduce losses due to leaf senescence.

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

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