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Forage productivity and morphogenesis of *Mesosetum chaseae* under potassium fertilization

Produtividade de forragem e morfogênese de *Mesosetum chaseae* sob fertilização potássica

Productividad de forraje y morfogénesis de *Mesosetum chaseae* bajo fertilización con potasio

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Abstract
The effect of potassium levels (0, 50, 100 and 200 kg of K_2O ha^{-1}) on green dry matter (GDM) yield and morphogenetic and structural characteristics of *Mesosetum chaseae* (Luces) was evaluated under natural field conditions. Potassium fertilization increased significantly (P<0.05) GDM yields, absolute growth rate (AGR), number of tillers/plant, number of leaves $plant^{-1}$, medium blade length, leaf area, leaf senescence rate, leaf appearance and elongation rates. Maximum GDM yields, AGR, number of tillers/plant, number of leaves/tiller, leaf area and medium blade length were obtained with the application of 167.8; 156.2; 82.7; 101.6; 101.2 and 77.5 kg of K_2O ha^{-1}, respectively. The potassium efficiency utilization was inversely proportional to the increased potassium levels.
Keywords: Leaves; Dry matter; Tiller; Senescence.

Resumo
O efeito de níveis de potássio (0, 50, 100 e 200 kg de K_2O ha^{-1}) sobre a produção de forragem e características morfogênicas e estruturais de *Mesosetum chaseae* (Luces) foi avaliado em condições de campo. A adubação potássica afetou positiva e significativamente (P<0,05) a produção de matéria seca verde (MSV), taxa absoluta de crescimento (TAC), número de perfilhos $planta^{-1}$, número de folhas vivas $perfilho^{-1}$, tamanho médio de folhas, índice de área foliar e taxas de aparecimento, expansão e senescência das folhas. Os máximos rendimentos de MSV, TAC, taxas de aparecimento e expansão foliar, número de perfilhos/planta, número de folhas/perfilho, área foliar e tamanho médio de folhas foram obtidos com a aplicação de 167,8; 156,2; 82,7; 101,6; 101,2 e 77,5 kg de K_2O ha^{-1}, respectivamente. A eficiência de utilização de potássio foi inversamente proporcional às doses aplicadas.
Palavras-chave: Folhas; Matéria seca; Perfilhamento; Senescência.

Resumen
Se evaluó el efecto de los niveles de potasio (0, 50, 100 y 200 kg K_2O ha^{-1}) sobre la producción de forraje y las características morfogénicas y estructurales de *Mesosetum chaseae* (Luces) en condiciones naturales de campo. La fertilización potásica afectó positiva y significativamente (P<0.05) la producción de materia seca verde (MSV), tasa absoluta de crecimiento (TAC), número de macollas/planta, número de hojas/macollas, tamaño promedio de hojas, índice de área foliar y tasas de aparición, expansión y senescencia de hojas. Los rendimientos máximos de MSV, TAC, tasas de aparición y expansión de hojas, número de macollas $planta^{-1}$, número de hojas $macollas^{-1}$, índice de área foliar y tamaño promedio de hoja se obtuvieron con la aplicación de 167.8; 156,2; 82,7; 101,6; 101,2 y 77,5 kg de K_2O ha^{-1}, respectivamente. La eficiencia de utilización de potasio fue inversamente proporcional a las dosis aplicadas.
Palabras clave: Hojas; Materia seca; Macolla; Senescencia.

1. Introduction

In Roraima, soils under savannas vegetation are characterize by low natural fertility and high acidity, which limits the productivity and persistence of pastures, resulting in poor zootechnical performance of the herds (Gianluppi et al., 2001). Exploratory soil fertility tests carried out in Roraima found that the low availability of potassium (K), after that of phosphorus, was the most limiting factor to the growth of native pastures, significantly reducing yields and the quality of their forage (Braga, 1998; Costa et al., 2013).

K has a fundamental action in plant metabolism, notably in the process of photosynthesis, acting in the reactions of transforming light energy into chemical, in addition to participating in the synthesis of proteins; neutralization of organic acids and in the regulation of osmotic pressure and pH within the plant; more efficient use of water, through better control over the opening and closing of stomata; control of leaf movements (nastias) and greater enzymatic efficiency (Lemaire et al., 2011; Pereira, 2018).

Considering the price of fertilizers and their importance in the composition of the production costs of livestock systems, it is necessary to ensure their maximum efficiency, through the determination of the most adequate doses for the establishment and maintenance of pastures. Among the various forage grasses that make up the native pastures of the savannas of Roraima, *Mesosetum chaseae* constitutes between 20 and 30% of its botanical composition, notably in the higher areas and not subject to flooding during the rainy season. However, there is no research on the effects of potassium fertilization on its productivity and morphogenic and structural characteristics, aiming at proposing more sustainable management practices (Barbero et al., 2015; Costa et al., 2018; Costa et al., 2019).

The morphogenesis of a grass during its vegetative growth is characterized by three factors: the appearance rate, the expansion rate and the longevity of the leaves. The appearance rate and the longevity of the leaves affect the number of live leaves/tiller, which are genetically determined and affected by environmental factors and the management practices adopted (Lemaire et al., 2011; Pereira, 2018). The number of live leaves per tiller, constant for each species, constitutes an objective criterion in the definition of grazing systems to be impose in the management of forages. Thus, studies of leaf and tiller growth dynamics are important to define specific management strategies for each forage grass (Nabinger & Carvalho, 2009; Costa et al., 2016).

In this work, the effects of potassium fertilization on forage production and morphogenic and structural characteristics of *Mesosetum chaseae*, in the Roraima´s savannas were evaluated.

2. Methodology

The research was performed under field natural conditions using the quantitative method. As there are still gaps about the effect of the potassium fertilization on the productive performance of native tropical forage pastures, it was chosen to use the hypothetical-deductive method (Pereira et al., 2018).

The experiment was carried out in the Experimental Field of Embrapa Roraima, located in Boa Vista, from May to September 2015, which corresponded to an accumulated precipitation of 1,485 mm and average monthly temperature of 24.8ºC. The soil of the experimental area is a Yellow Latosol, medium texture, with the following chemical characteristics, at a depth of 0-20 cm: pH_{H2O} = 4.8; P = 1.8 mg kg^{-1}; Ca + Mg = 0.95 $cmol_c.dm^{-3}$; K = 0.01 $cmol_c$.dm-3; Al = 0.61 $cmol_c.dm^{-3}$; H+Al = 2.64 $cmol_c.dm^{-3}$ and Sum of Bases = 0.91 $cmol_c.dm^{-3}$.

The experimental design was completely randomized with three repetitions. The treatments consisted of four levels of potassium (0, 50, 100 and 200 kg of K_2O ha^{-1}), applied in the form of potassium chloride. The size of the plots was 2.0 x 3.0 m, with a useful area of 2.0 m^2. The application of potassium was carried out by casting when the pasture was mowed at the beginning of the experiment. During the experimental period, three cuts were performe at 45-day intervals and 15 cm above the ground.

The parameters evaluated were green dry matter (GDM) yield, absolute growth rate (AGR), potassium utilization efficiency PUE), number of tillers plant^{-1} (NTP), number of leaves tiller^{-1} (NLP), leaf appearance rate (LAR), leaf expansion rate (LER), leaf senescence rate (LSR), average leaf size (ALS) and leaf area index (LAI). The AGR was obtained by dividing the GDM yield, at each cutting age, by the respective regrowth period. LAR, LER and LAI were determined only in live tillers. LAR and LER were calculated by dividing the accumulated leaf length and the total number of leaves in the tiller, respectively, by the regrowth period.

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 digitalized and the leaf area estimated with the aid of an electronic optical planimeter (Li-Cor 3100C). Subsequently, the sample was taken, to the greenhouse with forced air at 65ºC until they reached constant weight, obtaining the leaf GDM. Specific leaf area (SLA) was determined by the relationship between green leaf area and its GDM (m^2/g leaf GDM). The 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 obtained by dividing the length of the leaf that was yellowish or necrotic by age of regrowth. The K contents were analyzed according to procedures described by Silva (2009), after nitroperchloric digestion and quantification by flame photometry. PEU was estimated by relating the GDM yield to the respective applied K level.

The data were subject 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 potassium fertilization, the choice of regression models was reason on the significance of the linear and quadratic coefficients, using the student's "t" test, at the level of 5% probability. Data were statistically analyzed using the procedures described by Ferreira (2011).

3. Results and Discussion

The GDM and AGR yields were significantly ($P<0.05$) increased by potassium fertilization, with the relationships being quadratic and described, respectively, by the equations: $Y = 284.66 + 5.1994 X - 0.01529 X^2$ ($R^2 = 0.96$) and $Y = 6.32 + 0.1156 X - 0.00037 X^2$ ($R^2 = 0.96$). The maximum technical efficiency doses were estimate at 167.8 and 156.2 kg of K_2O ha^{-1}, respectively for GDM yield and AGR. The potassium utilization efficiency was inversely proportional to the fertilization doses used (Table 1), however the grass showed greater responsiveness than that reported by Costa et al. (2016) for pastures of *Axonopus aureus* (22.3, 15.6 and 11.1 kg of GDM/kg of K_2O ha^{-1}, respectively for levels of 40, 80 and 120 kg of K_2O ha^{-1}). In the Rondônia´s savannas, Costa et al. (2019), evaluating the effects of potassium fertilization doses (0, 60, 120 and 180 kg of K_2O ha^{-1}) for *Paspalum atratum* cv. Pojuca pastures, reported maximum forage production with the application of 142.8 kg of K_2O ha^{-1}, however, the highest efficiency rates of potassium utilization were observed at fertilization levels between 60 and 120 K_2O ha^{-1}. The DM yields recorded in this work were higher than those reported by Costa et al. (2018) for *Mesosetum chaseae* pastures, not fertilized and subjected to different defoliation frequencies (204, 356 and 498 kg GDM ha ha^{-1}, respectively for cuts every 21, 35 and 42 days).

Table 1. Green dry matter yield (GDM - kg ha^{-1}), absolute growth rate (AGR - kg ha^{-1} dia^{-1}), potassium utilization efficiency (PEU - kg de MS/kg de K_2O/ha), number of tiller plant (NTP), number of live leaf $tiller^{-1}$ (NLT), average leaf size (ALS - cm), leaf area index (LAI), leaf appearance rate (LAR - cm $tiller^{-1}$ day^{-1}), leaf expansion rate (LER - cm $tiller^{-1}$ day^{-1}) and leaf senescence rate (LSR - cm $tiller^{-1}$ day^{-1}) of *Mesosetum chaseae*, as affected by potassium fertilization.

Potassium levels (kg K_2O ha^{-1})	GDM[1]	AGR	PEU	NTP	NLT	ALS	LAI	LAR	LER	LSR
0	298c	6.62c	---	4.81c	4.72c	3.84c	2.77c	0.104d	0.41d	0.055d
50	471b	10.47b	9.42a	7.03b	5.54b	4.96b	4.12b	0.123c	0.61c	0.082c
100	679a	15.09a	6.79b	7.82a	6.12a	5.82a	5.34a	0.136b	0.79b	0.104b
200	711a	15.80a	3.56c	8.02a	6.54a	6.08a	5.96a	0.145a	0.88a	0.133a

- Means followed by the same letter do not differ (P >0.05) by Tukey's test. 1 - Total of three cuts. Source: Research data.

For NTP, NLT, LAI and ALS the relationships were fitted to the quadratic regression model and define, respectively, by the equations: $Y = 4.8894 + 0.0463 X - 0.000281 X^2$ ($R^2 = 0.95$), $Y = 4.7195 + 0.0189 X - 0.000093 X^2$ ($R^2 = 0.93$), $Y = 2.7311 + 0.0344 X - 0.00017 X^2$ ($R^2 = 0.94$) and $Y = 3.8215 + 0.0279 X - 0.00018 X^2$ ($R^2 = 0.94$), with the maximum values obtained with the application of 82.7; 101.6; 101.2 and 77.5 kg of K_2O ha^{-1}. The correlations between GDM yield and NTP (r = 0.9583; P=0.0021) and NLT (r = 0.9858; P=0.0012) were positive and significant, which explained in 91, 8 and 97.1%, respectively, the increments verified in the forage yield of the grass, in function of the potassium fertilization. The values recorded in this study for NTP, NLT, ALS and LAI were lower than those reported by Costa et al. (2018) for *M. chaseae*, who estimated 5.8 tillers $plant^{-1}$; 6.2 tiller $plant^{-1}$, 6.9 cm $leaf^{-1}$ and 7.8 cm^2 $plant^{-1}$.

The LAI represents the synthesis of the morphogenic and structural characteristics of the grass and reflects the balance of processes that determine the supply (photosynthesis) and demand (respiration, accumulation of reserves, synthesis and senescence of tissues) of photoassimilates, which establish the rhythm of growth from the pasture (Nabinger & Carvalho, 2009; Pereira, 2018). For *Axonopus aureus* a native grass of Roraima's savannas, Costa et al. (2019) reported the low availability of K severely limited the tillering, which caused a lower forage production and delay in the development of plants. This resulted in a pasture deficient formation and caused the high appearance of weeds.

The tillering potential of a genotype, during the vegetative stage, depends on its leaf emission speed, which will produce buds capable of originating new tillers, depending on the environmental conditions and the management practices adopted (Lemaire et al., 2011; Cruz et al., 2021). The relationships between potassium fertilization, LAR and LER were adjusted to the linear regression model and described, respectively, by the equations: $Y = 0.1098 + 0.00021 X$ ($R^2 = 0.97$) and $Y = 0.4721 + 0, 00234 X$ ($R^2 = 0.96$) (Table 1). LAR and LER present a negative correlation, indicating that the higher the LAR, the shorter the time available for leaf elongation (Mochiutti et al., 2015; Costa et al., 2018; Tesk et al., 2020). In this work, the correlation between these two variables was positive and significant (r = 0.9983; P=0.0011), possibly as consequence of the higher soil fertility, which contributed positively to the maximization of the morphogenic characteristics of the grass. Lemaire et al. (2011) observed that LER was positively correlated with the amount of green leaves remaining on the tiller after defoliation, with tiller size being responsible for the long duration of LER. In this work, the correlation was positive and significant (r = 0.9984; P=0.0011), evidencing the synchrony between these two variables.

The relationship between potassium levels and LSR was linear and defined by the equation: $Y = 0.0662 + 0.000342 X$ ($r^2 = 0.98$). The values recorded in this study were lower than those reported by Costa et al. (2018) for *M. chaseae* who estimated a LSR of 0.187 cm $tiller^{-1}$ day^{-1}, for plants evaluated at 45 days of regrowth. Costa et al. (2019), evaluating *Paspalum* genotypes, reported higher LSR with the application of 60 (0.126 cm $tiller^{-1}$ day^{-1}) or 120 kg of K_2O ha^{-1} (0.134 cm $tiller^{-1}$ day-

^{1}), compared to 30 kg of K_2O ha^{-1} (0.072 cm $tiller^{-1}$ day^{-1}). Senescence reduces the quality of forage, however it is an important physiological process in the flow of grass tissues, 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 (Carrèrre et al., 2007; Heringer & Jacques, 2012; Santos et al., 2012; Sarmiento et al., 2016).

Senescence is a natural process that characterizes the last stage of a leaf development, which begins after the complete expansion of the first leaves, whose intensity progressively increases with the increase of the leaf area, which implies the shading of the leaves inserted in the lower portion of the stem (Nabinger & Pontes, 2002; Barbero et al., 2015; Pereira, 2018; Cruz et al., 2021). Senescence reflects the natural physiological process that characterizes the last stage of leaf development, started after its complete expansion and progressively accentuated with the increase in leaf area, due to the shading of the leaves inserted in the lower portion and the low supply of photosynthetically active radiation, characterized by intense competition for light, nutrients and water between the different strata of the plant (Lemaire et al., 2011).

4. Final Considerations

Potassium fertilization positively affects forage availability and morphogenic and structural grass characteristics.

The potassium utilization efficiency is inversely proportional to the applied doses. The maximum technical efficiency dose for the green dry matter yield was estimate at 167.8 kg of K_2O ha^{-1}.

The process of renewal and senescence of grass tissues is accelerate with increasing doses of potassium.

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