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Phosphate fertilization of *Mesosetum chaseae* in Roraima's savannas

Fertilização fosfatada de pastagens de *Mesosetum chaseae* nos cerrados de Roraima

Fertilización fosfatada de pasturas de *Mesosetum chaseae* en las sabanas de Roraima

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Abstract
The objective of this work was to evaluate the effect of phosphate fertilization (0, 30, 60 and 120 kg of P_2O_5 ha^{-1}) on forage production and morphogenetic and structural characteristics of *Mesosetum chaseae* under natural field conditions in the savannas of Roraima. Phosphate fertilization positively and significantly ($P<0.05$) affected green dry matter (GDM) production, absolute growth rate (AGR), number of tillers $plant^{-1}$, number of leaves $tiller^{-1}$ (NLT), average leaf size (ALS), leaf tiller area (LTA), appearance rates (LAR), expansion (LER) and leaf senescence rates. The maximum yields of GDM, AGR, LAR, LER, NLT, LTA and ALS were obtained with the application of 89.17; 112.7; 47.7; 51.9; 102.9; 101.8 and 94.8 kg of P_2O_5 ha^{-1}, respectively. The efficiency of P utilization was inversely proportional to the P doses applied.
Keywords: Leaves; Green dry matter; Tillering; Senescence.

Resumo
O objetivo deste trabalho foi avaliar o efeito da fertilização fosfatada (0, 30, 60 e 120 kg de P_2O_5 ha^{-1}) sobre a produção de forragem e características morfogênicas e estruturais de *Mesosetum chaseae* em condições naturais de campo nos cerrados de Roraima. A adubação fosfatada afetou positiva e significativamente ($P<0,05$) a produção de matéria seca verde (MSV), taxa absoluta de crescimento, número de perfilhos $planta^{-1}$, número de folhas $perfilho^{-1}$(NFP), tamanho médio de folhas (TMF), área foliar $perfilho^{-1}$ (AFP), taxas de aparecimento (TAF), expansão (TEF) e senescência das folhas. Os máximos rendimentos de MSV, TAC, TAF, TEF, NFP, AFP e TMF foram obtidos com a aplicação de 89,17; 112,7; 47,7; 51,9; 102,9; 101,8 e 94,8 kg de P_2O_5 ha^{-1}, respectivamente. A eficiência de utilização de P foi inversamente proporcional às doses de P aplicadas.
Palavras-chave: Folhas; Matéria seca verde; Perfilhamento; Senescência.

Resumen
El objetivo de este trabajo fue evaluar el efecto de la fertilización fosfatada (0, 30, 60 y 120 kg de P_2O_5 ha^{-1}) sobre la producción de forraje y las características morfogenéticas y estructurales de *Mesosetum chaseae* en condiciones de campo natural en los cerrados de Roraima. La fertilización con fosfato afectó positiva y significativamente ($P<0,05$) la producción de materia seca verde (MSV), la tasa de crecimiento absoluto, el número de macollas $planta^{-1}$ (NMP), el número de hojas $macollas^{-1}$ (NHM), el tamaño medio de la hoja (TMH), el área foliar $macollas^{-1}$ (AFM), tasas de aparición (TAF), expansión (TEF) y senescencia foliar. Los rendimientos máximos de MSV, TAC, TAF, TEF, NHM, AFM y TMH se obtuvieron con la aplicación de 89,17; 112,7; 47,7; 51,9; 102,9; 101,8 y 94,8 kg de P_2O_5 ha^{-1}, respectivamente. La eficiencia de utilización de P fue inversamente proporcional a las dosis de P aplicadas.
Palabras clave: Hojas; Macollaje; Matéria seca verde; Senescencia.

1. Introduction

In Roraima, the soils under savannah vegetation represent about 4 million hectares of its territorial area. Soils are characterized by low organic matter content and predominance of low activity clays that provide low cation exchange capacity and high acidity (Gianluppi et al., 2001; Costa et al., 2016). Thus, livestock farming carried out in these areas has low animal productivity, low forage availability and reduced pasture persistence, implying a poor zootechnical performance of the herds (Braga, 1998; Costa et al., 2017).

For adequate pasture nutritional management, phosphorus (P) can be considered the most limiting nutrient for forage production and its deficiency significantly decreases its availability and chemical composition. In addition to triggering the initial processes that result in pasture degradation. In plant metabolism, P actively participates in the development of the root system and in the tillering of grasses, in addition to actively participating in the processes of cellular respiration, affecting the accumulation, transport, distribution and use of energy produced in the photosynthetic process (Sousa et al., 2007; Soares et al., 2011; Costa et al., 2019). The application of fertilizers is one of the items that most burden the production costs of cattle in pastures. Phosphate fertilizers have high acquisition costs. Therefore, it becomes very important to ensure its maximum technical efficiency by determining the most appropriate doses for the establishment and maintenance of pastures.

The Roraima´s savannas present a great diversity of grasses with forage potential, among which, *Mesosetum chaseae* (Luces) can contribute with up to 30% of the vegetation cover of its native pastures. However, currently, research on the effects of phosphate fertilization on its productivity and on its morphogenic and structural characteristics, aiming at proposing more sustainable management practices, are scarce.

During the vegetative growth period of forage grasses, their morphogenesis can be described by three main characteristics: appearance rate, elongation rate and leaf life span. The appearance rate and the lifetime of the leaves affect the number of live leaves/tiller, which are genetically determined and strongly affected by environmental conditions and the management practices adopted (Cabral et al., 2018; Pereira, 2018). The number of live leaves per tiller, constant for each species, may represent a clear, objective and easy-to-measure criterion for the definition of grazing systems to be imposed in forage management.

In this work, the effects of phosphate fertilization on forage availability and morphogenesis of *Mesosetum chaseae* (Luces) in the Roraima´s savannas were evaluated.

2. Methodology

The research was perform under natural field conditions using quantitative method. As there are still gaps about evaluation and determination of the most suitable phosphate fertilization levels for *Mesosetum chaseae* pastures it was choose 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, during the period from April to November 2015, which correspond to an accumulate precipitation of 1,115 mm and an average monthly temperature of 24.7ºC. 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 = 1.6 mg kg^{-1}; Ca + Mg = 0.87 $cmol_c.dm^{-3}$; K = 0.016 $cmol_c.dm^{-3}$; Al = 0.61 $cmol_c dm^{-3}$; H + Al = 2.82 $cmol_c.dm^{-3}$ and, Sum of Bases = 0.89 $cmol_c.dm^{-3}$. The experimental design was in complete randomized blocks with three replications. The treatments consisted of four levels of phosphorus (0, 30, 60 and 120 kg of P_2O_5 ha^{-1}), applied as triple superphosphate. The size of the plots was 2.0 x 3.0 m, with a useful area of 2.0 m^2. Phosphorus application was carried out by broadcast when the pasture was mowed at the beginning of the experiment. During the experimental period, three cuts were performed at 45-day intervals.

The evaluated parameters were green dry matter yield (GDM), absolute growth rate (AGR), phosphorus use efficiency, number of tillers/plant (NTP), number of leaves/tiller (NLT), leaf appearance rate (LAR), leaf expansion rate (LER), leaf senescence rate (LSR), average leaf size (ALS) and leaf tiller^{-1} area^{-1} (LTA). The AGR was obtained by dividing the GDM yield, at each cutting age, by the respective regrowth period. LER and LAR were calculated by dividing the accumulated leaf length and the total number of leaves on the tiller, respectively, by the regrowth period. The ALS was determined by dividing the total leaf elongation of the tiller by its number of leaves. To calculate the LTA, the formula for the area of the triangle (height x base/2) was used and, for this purpose, the length and width of all the leaves of the sampled tillers were recorded. The LSR was obtained by dividing the length of the leaf that was yellowish or necrotic by the age of the plant at cut.

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 phosphorus 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 yields and AGR were significantly ($P<0.05$) increased by phosphorus fertilization, with quadratic relationships and described, respectively, by the equations: $Y = 579.63 + 15.2122 X - 0.08530 X^2$ ($R^2 = 0.92$) and $Y = 12.8732 + 0.3382 X - 0.00151 X^2$ ($R^2 = 0.97$). The doses of maximum technical efficiency were estimated at 89.17 and 112.7 kg of P_2O_5 ha^{-1}, respectively for GDM yield and AGR. The efficiency of P utilization was inversely proportional to the doses used (Table 1). Similarly, Costa et al. (2019), evaluating the effects of phosphate fertilization (0, 60, 120 and 180 kg of P_2O_5 ha^{-1}), in *Paspalum secans* FCAP 12, reported maximum forage production with the application of 159.5 kg of P_2O_5 ha^{-1}, however, the highest P utilization efficiency rates were observed under fertilization levels between 80 and 120 P_2O_5 ha^{-1}. The GDM yields recorded in this work were lower than those reported by Costa et al. (2017) for native pastures of *Axonopus aureus*, not fertilized and submitted to different cutting frequencies (238, 487 and 799 kg of DM ha^{-1} P_2O_5 ha^{-1}, respectively for cuts frequencies of every 21, 35 and 42 days).

Table 1 - Green dry matter yield (GDMY - kg ha^{-1}), absolute growth rate (AGR - kg ha^{-1} day^{-1}), phosphorus use efficiency (PUE - kg of GDM/kg of P_2O_5 ha^{-1}), number of tillers plant (NTP), number of leaves tiller (NLT), average leaf size (ALS - cm), leaf tiller area^{-1} (LTA - cm^2 tiller^{-1}), leaf appearance rate (LAR - leaf 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 levels of phosphate fertilization. Means of three cuts.

Levels of P_2O_5 ha^{-1}	GDMY	AGR	PUE	NTP	NLT	ALS	LTA	LAR	LER	LSR
0	579 d	16.54 c	---	4.1 b	3.11 b	4.7 c	5.11 c	0.069 b	0.323 c	0.058 c
30	977 c	27.91 b	32.56 a	5.3 b	4.37 a	6.3 b	8.06 b	0.097 a	0.616 b	0.081 b
60	1,253 b	35.80 a	20.88 b	7.4 a	4.91 a	7.1 a	9.15 b	0.109 a	0.776 a	0.093 a
120	1,411 a	40.31 a	11.76 c	7.9 a	5.05 a	7.4 a	10.33 a	0.112 a	0.828 a	0.108 a

- Means followed by the same letter do not differ from each other ($P > 0.05$) by Tukey's test. Source: Research data.

For NTP, NLT, LTA and ALS, the relationships were adjusted to the quadratic regression model and defined, respectively, by the equations: $Y = 3.9255 + 0.0706 X – 0.00038 X^2$ ($R^2 = 0.98$), $Y = 3.1433 + 0.0453 X – 0.00022 X^2$ ($R^2 = 0.95$), $Y = 5.2349 + 0.0967 X – 0.00047 X^2$ ($R^2 = 0.94$) and $Y = 4.7307 + 0.0588 X – 0.00031 X^2$ ($R^2 = 0.95$) and the maximum values were obtained with the application of 92.9; 102.9; 101.8 and 94.8 kg of P_2O_5 ha^{-1}. Correlations between GDM yield and NTP (r = 0.9683; P=0.0015) and NLT (r = 0.9837; P=0.0036) were positive and significant, which explained in 93,7 and 96.8%, respectively, the increments verified in grass forage yields, as a function of phosphorus fertilization. The values recorded, in this study, for the NTP, NLT, LTA and ALS were lower than those reported by Costa et al. (2019) for A. aureus, who estimated 4.56 tillers $plant^{-1}$; 4.82 leaves $tiller^{-1}$, 14.2 cm $leaf^{-1}$ and 7.37 cm^2 $tiller^{-1}$. In tropical forage grasses, the tillering potential of a genotype, during the vegetative stage, depends on its rate of emission of leaves, which will produce buds potentially capable of originating new tillers, depending on the environmental conditions and the management practices adopted, the which will make it possible to ensure the perpetuity of the pasture (Lemaire et al., 2011; Barbero et al., 2015; Braga et al., 2019; Cruz et al., 2021).

The relationships between phosphate fertilization, LAR and LER were adjusted to the quadratic regression model and described, respectively by the equations: $Y = 0.0697 + 0.00124\ X + 0.000013\ X^2$ ($R^2 = 0.95$) and $Y = 0\ .3266 + 0.0111X - 0.000107X^2$ ($R^2 = 0.96$). The maximum values were obtained with the application of 47.7 and 51.9 kg of P_2O_5 ha^{-1}, respectively (Table 1). LAR and LER generally show a negative correlation, demonstrating that the higher the LAR, the shorter the time available for leaf elongation and, consequently, the full recovery of the desirable canopy for grazing (Silva & Nascimento Júnior, 2007; Costa et al., 2020; Cruz et al., 2021). In this work, the correlation between these two variables was positive and significant (r = 0.9973; P=0.0028), possibly as a consequence of greater soil fertility, which contributed positively to the maximization of the morphogenetic characteristics of the grass. Heinrichs et al. (2016) and Bélanger et al. (2017) observed that the LER was positively correlated with the amount of green leaves remaining on the tiller after defoliation, with the tiller size being responsible for the long duration of the LER and, consequently, for the greater availability of forage in the pasture. In this work, the correlation was positive and significant (r = 0.9974; P=0.0123), showing the synchrony between these two variables.

The relationship between LSR and phosphorus fertilization was linear and defined by the equation: $Y = 0.0642 + 0.000431\ X$ ($r^2 = 0.96$; P=0.0032). The values recorded in this study were lower than those reported by Costa et al. (2016) for *Axonopus aureus* who estimated a LSR of 0.224 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 120 (0.108 cm $^{-1}$ tiller day^{-1}) or 180 kg of P_2O_5 ha^{-1} (0.129 cm $tiller^{-1}$ day^{-1}), compared to 60 kg of P_2O_5 ha^{-1} (0.081 cm $tiller^{-1}$ day^{-1}), as a consequence of the greater renewal of grass tissues and high pasture growth rates. Senescence is a natural process that represents the last phase of development of a leaf, which begins after the complete expansion of the first leaves, whose intensity progressively increases with the increase in leaf area, as a consequence of the shading exerted by the superior leaves on the leaves inserted in the lower portion of the stem (Martha Júnior et al, 2007; Da Costa & Crusciol, 2016; Pereira et al., 2018). Leaf senescence reduces the amount of good quality forage, as the green portions of the plant are the most nutritious for the animal diet, being caused by competition for metabolites and nutrients between old and young growing leaves, however it is an efficient mechanism of translocation of nutrients from older tissues to those in early stages of development (Pereira et al., 2012; Cardoso et al., 2016; Haling et al., 2016; Sarmiento et al., 2016).

4. Final Considerations

The agronomic evaluation of *Mesosetum chaseae* pastures under different levels of fertilization phosphate makes it possible to identify and recommend the most adequate levels for its efficient management.

Phosphate fertilization positively affects forage production and optimizes the morphogenetic and structural characteristics of the grass.

Phosphorus utilization efficiency is inversely proportional to the applied doses, with the opposite occurring regarding the rate of leaf senescence.

The maximum technical efficiency dose of phosphate for the GDM yield was estimate at 89.17 kg of P_2O_5 ha^{-1}. The process of renewal and senescence of grass tissues is accelerate with increasing doses of phosphorus.

It is suggest to carry out experiments under field conditions and, preferably, with the use of animals, in order to endorse the levels of phosphorus fertilization recommended for the grass.

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