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Forage productivity and morphogenesis of Trachypogon vestitus as affected by phosphate fertilization levels in the Roraima's savannas

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Keywords: leaves, green dry matter, tillering, senescence

ABSTRACT

The effects of phosphate fertilization (0, 40, 80 and 120 kg of P_2O_5 ha^{-1}) on forage production and morphogenetic and structural characteristics of *Trachypogon vestitus* pastures were evaluated 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 109.2; 106.4; 56.1; 81.5; 97.4; 58.6 and 63.7 kg of P_2O_5 ha^{-1}, respectively. The efficiency of P utilization was inversely proportional to the P doses applied.

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ABSTRACT
The effects of phosphate fertilization (0, 40, 80 and 120 kg of P_2O_5 ha^{-1}) on forage production and morphogenetic and structural characteristics of *Trachypogon vestitus* pastures were evaluated 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 109.2; 106.4; 56.1; 81.5; 97.4; 58.6 and 63.7 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 efeito da fertilização fosfatada (0, 40, 80 e 120 kg de P_2O_5 ha^{-1}) sobre a produção de forragem e características morfogênicas e estruturais de pastagens de *Trachypogon vestitus* foi avaliado 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 109,2; 106,4; 56,1; 81,5; 97,4; 58,6 e 63,7 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.

1 INTRODUCTION

Cattle farming is one of the main economic activities of Roraima with relevant environmental and social effects. In recent years, livestock activity has shown significant growth and, currently, the cattle herd already exceeds one million of animals. In Roraima, soils under savanna vegetation are characterized by low natural fertility and high acidity, which limits the productivity and persistence of pastures, resulting in poor zootechnical performance of herds, especially beef and milk cattle (BRAGA, 1998). However, the use of fertilizers in native pastures is a rarely used practice, as a consequence of the lack of robust and consistent research results, in addition to economic and structural restrictions that do not allow the large-scale adoption of this management practice. Exploratory soil fertility tests carried out in Roraima found that phosphorus (P) was the most limiting nutrient to the growth of native pastures, significantly reducing yields and forage quality, in addition to its persistence (BRAGA, 1998; GIANLUPPI et al., 2001; COSTA et al., 2019).

Forage availability of tropical grasses are directly correlate with natural fertility of the soils used for the establishment of pastures and heavily affected by their nutritional requirements. The P plays an important role in the development of the root system and tillering of forage grasses, being essential for photosynthesis, synthesis and degradation of carbohydrates, in addition to actively participating in the processes of cellular respiration, influencing the storage, transport and use of energy produced in the photosynthetic process. (LEMAIRE et al., 2011; BARBERO et al., 2015; PEREIRA, 2018). Considering the high unit cost of phosphate fertilizers, it is necessary to ensure their maximum efficiency, through the determination of the most adequate doses for the establishment and maintenance of pastures (SANTOS, 2021). Among the various forage grasses that make up the native pastures of the Roraima´s savannas, the grass *Trachypogon vestitus* can be represents between 40 and 50% of its botanical composition. However, there are no technical information available on the effects of phosphate fertilization on its productivity and on its morphogenetic and structural characteristics, aiming at proposing more sustainable management practices (COSTA et al., 2019).

The development stages presented by tropical forage grasses are affected by environmental factors (light, radiation, temperature and humidity), in addition to biotic factors such as pests, diseases and weeds, which can contribute decisively to the longevity of the productive phase of pastures. The morphogenesis of a tropical forage grass during its vegetative growth can be characterize by three components: the rate of appearance, the rate of elongation and the longevity of the leaves. The morphogenesis of tropical forage grasses represents an extremely useful tool for recommending management practices that optimize animal productivity, due to the significant increase in the availability of forage with high nutritional value. The appearance rate and longevity of leaves determine the number of live leaves/tiller, which are genetically determined and affected by environmental factors and management practices adopted (NABINGER; CARVALHO, 2009; 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 imposed in the management of forages. Thus, studies on the dynamics of leaf and tiller growth of perennial tropical forage grasses are important to define specific management strategies for each forage grass (COSTA et al., 2019; CRUZ et al., 2021).

In this work were evaluated the effects of phosphate fertilization on forage production and morphogenic and structural characteristics of *Trachypogon vestitus* in the Roraima´s savannas.

2 METHODOLOGY

The trial was carried out at the Experimental Field of Embrapa Roraima, located in Boa Vista, during the period from May to September 2019, which correspond to an accumulate precipitation of 1,389 mm and an average monthly temperature of 24.55ºC. The soil in 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 = 1.76 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 = 2.61 $cmol_c.dm^{-3}$ and Sum of Bases = 0.96 $cmol_c.dm^{-3}$. The experimental design use was completely randomized with three replications. The treatments consisted of four levels of phosphorus (0, 40, 80 and 120 kg of P_2O_5 ha^{-1}), applied broadcast in the form of triple superphosphate. The size of the plots was 2.0 x 3.0 m, with a useful area of 2.0 m^2. The application of phosphorus was carried out by broadcast when mowing the pasture, at the beginning of the experiment. The maintenance fertilization consisted of the annual application, at the beginning of the rainy season, of 40 kg of N ha^{-1} and 40 kg of K_2O ha^{-1}, in the form of urea, and potassium chloride, respectively. During the experimental period, three cuts were performed at intervals of 45 days.

The evaluated parameters were green dry matter yield (GDM), absolute growth rate (AGR), phosphorus use efficiency (PUE), number of tillers $plant^{-1}$ (NTP), number of leaves $tiller^{-1}$ (NLT), leaf appearance rate (LAR), leaf expansion rate (LER), leaf senescence rate (LSR), average leaf size (ALS) and leaf tiller area (LTA). The AGR was obtain 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

Phosphate fertilization promotes significant increases ($P<0.05$) on grass GDM yields and AGR. The mathematical relationships were adjusted to the quadratic regression model and describe, respectively, by the equations: $Y = 1{,}003 + 33.6512 X - 0.15412 X^2$ ($R^2 = 0.96$) and $Y = 28.66 + 0.9615 X - 0.00452 X^2$ ($R^2 = 0.97$). The doses of maximum technical efficiency were estimate at 109.2 and 106.4 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). This phenomenon occurs frequently as a consequence of an effect of dilution of levels of P in biomass, in function of the greater productivity of forage. Likewise, Costa et al. (2016), evaluating the effects of phosphorus fertilization (0, 60, 120 and 180 kg of P_2O_5 ha^{-1}) in *Paspalum atratum* cv. Pojuca, found maximum forage production with the application of 132.5 kg of P_2O_5 ha^{-1}, however, the highest P utilization efficiency rates were observed under fertilization levels between 60 and 80 P_2O_5 ha^{-1}. The GDM yields recorded in this work were higher than those reported by Costa et al. (2017) for *Axonopus aureus* pastures, not fertilized and subjected to different cutting frequencies (238, 487 and 799 kg of GDM ha^{-1}, respectively for cuts frequencies every 21, 35 and 42 days). The reduction in the efficiency of phosphate fertilization with the increase in applied doses is a phenomenon that may be related to the chemical and physical characteristics of the soil, since the higher the clay content, the greater the phosphorus fixation, which will be unavailable to plants, as its release will be slow and gradual over time.

REVISTA CONTRIBUCIONES A LAS CIENCIAS SOCIALES

Table 1. Green dry matter yield (GDM - kg ha^{-1}), absolute growth rate (AGR - kg ha^{-1} day^{-1}), phosphorus use efficiency (PUE - kg of DM/kg of P_2O_5 ha), 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 *Trachypogon vestitus*, as affected by phosphate fertilization. Means of three cuts.

Levels of P_2O_5 (kg ha^{-1})	GDM	AGR	PUE	NTP	NLT	ALS	LTA	LAR	LER	LSR
0	1,035 c	29.57 c	---	5.16 b	5.65 b	9.12 b	8.90 c	0.134 b	1.184 c	0.055 c
40	1,789 b	51.11 b	44.72 a	7.32 b	7.11 a	13.56 a	17.25 b	0.169 a	2.167 b	0.069 b
80	2,531 a	72.31 a	31.63 b	9.48 a	7.60 a	14.76 a	19.59 b	0.181 a	2.535 a	0.082 a
120	2,811 a	80.31 a	23.42 c	9.84 a	7.82 a	15.84 a	21.70 a	0.186 a	2.832 a	0.138 a

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

Phosphate fertilization positively and significantly affected the NTP ($Y = 5.642 + 0.0387 X$ - $r^2 = 0.95$), while for NLT, LTA and ALS the effects of phosphate fertilization relationships were adjusted to the quadratic regression model and defined, respectively, by the equations: $Y = 5.698 + 0.04871 X - 0.00025 X^2$ ($R^2 = 0.87$); $Y = 2.698 + 0.03871 X - 0.00033 X^2$ ($R^2 = 0.84$) and $Y = 9.075 + 0.13912 X - 0.00102 X^2$ ($R^2 = 0.90$) and the maximum values obtain with the application of 97.4; 58.6 and 63.7 kg of P_2O_5 ha^{-1}. Correlations between GDM yield and NTP ($r = 0.9883$; $P<0.01$) and NLT ($r = 0.9514$; $P<0.01$) were positive and significant, which explained in 97.7 and 90.2%, respectively, the increments verified in grass forage yields, as a function of phosphorus fertilization. The values recorded, in this study, for the NTP, NLT, ALS and LTA were higher than those reported by Costa et al. (2017) for *Axonopus aureus*, who estimated 4.56 tillers $plant^{-1}$; 4.82 leaves $tiller^{-1}$, 14.2 cm $leaf^{-1}$ and 7.37 cm^2 $tiller^{-1}$. The tillering potential of a tropical grass genotype, during the vegetative stage, depends on its leaf emission speed, which will produce buds potentially capable of originating new tillers, depending on the environmental conditions and the management practices adopted (SILVA; NASCIMENTO JÚNIOR, 2007; NABINGER; CARVALHO, 2009).

The effects of phosphate fertilization on LAR and LER were adjusted to the quadratic regression model and described, respectively, by the equations: $Y = 0.1357 + 0.001428 X - 0.0000132 X^2$ ($R^2 = 0.90$) and $Y = 1.1413 + 0,03012 X - 0.0001848 X^2$ ($R^2 = 0.91$), with the maximum values obtained with the application of 56.1 and 81.5 kg of P_2O_5 ha^{-1} (Table 1). LAR and LER are morphogenic characteristics that present a negative correlation, indicating that the higher the LAR, the shorter the time for leaf elongation (VOLPE et al., 2008; COSTA et al., 2016). In this work, the correlation between these two variables was positive and significant (r =

0.9684; $P<0.01$), possibly, as a consequence of greater soil fertility, which contributed positively to the maximization of the morphogenetic characteristics of the grass. Pereira (2018) observed that the LER was positively correlate 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. In this work, the correlation was positive and significant ($r = 0.9689$; $P<0.03$), showing the synchrony between these two variables. This behavior allows us to infer that the adoption of management practices whose basic premise is to monitor the physiology of tropical forage grasses, in order to optimize forage productivity and, above all, ensure its persistence over time.

Leaf senescence was increased by phosphate fertilization, reflecting the process of greater accumulation of biomass, which contributes to accelerate the mechanism of tissue renewal, through the senescence of the leaves present in the lower strata of the plants. The mathematical relationship between LSR and phosphorus fertilization was linear and defined by the equation: $Y = 0.0597 + 0.00037 X$ ($r^2 = 0.91$; $P<0.02$). The values recorded in this study were lower than those reported by Costa et al. (2017) for *Axonopus aureus* pastures in Roraima’s savannas, who estimated a LSR of 0.221 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 (0.109 cm tiller^{-1} day^{-1}) or 180 kg of P_2O_5 ha^{-1} (0.133 cm tiller^{-1} day^{-1}), compared to 60 kg of P_2O_5 ha^{-1} (0.077 cm^{-1} tiller^{-1} day^{-1}). The increase in senescence in the biomass of tropical forage grasses may be a consequence of the adoption of management practices that are incompatible with the physiological and anatomical processes that regulate their growth patterns (BÉLANGER et al., 2017)

Leaf senescence reduces the amount of good quality forage, as the green portions of the plant are the most nutritious for the animal diet, and can be caused by competition for metabolites and nutrients between old and young growing leaves (HERINGER; JACQUES, 2012; COSTA et al., 2016; SARMIENTO et al., 2016). Senescence is a natural process that characterizes 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, which implies shading of the leaves inserted in lower portion of the stem (NABINGER; CARVALHO, 2009; SANTOS et al., 2012; TESK et al., 2020). The use of native pasture management practices that minimize the occurrence of biomass senescence can contribute to the maximization of forage availability, which can positively contribute to a better zootechnical performance of the animals, at the same time that it reduces the need for nutrient replacement.

4 CONCLUSIONS

The agronomic evaluation of *Trachypogon vestitus* pastures submitted to different levels of fertilization phosphate makes it possible to identify and recommend the most appropriate levels for 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 and the opposite occurring in relation to the rate of leaf senescence.

The maximum technical efficiency level of phosphate for the GDM yield was estimate at 109.2 kg of P_2O_5 ha^{-1}. The process of renewal and senescence of grass tissues is accelerate with increasing doses of phosphorus.

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