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Agronomic performance and morphogenic and structural characteristics of *Axonopus aureus* pastures under phosphate fertilization levels in the Roraima's savannas

Desempenho agronômico e características morfogênicas e estruturais de pastagens de *Axonopus aureus* sob níveis de fertilização fosfatada nos cerrados de Roraima

Comportamiento agronómico y características morfogenéticas y estructurales de pastos de *Axonopus aureus* bajo niveles de fertilización fosfatada en las sabanas de Roraima

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Abstract
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 *Axonopus aureus* was 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 110.4; 108.5; 54.1; 83.5; 96.6; 59.8 and 90.6 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, 30, 60 e 120 kg de P_2O_5 ha^{-1}) sobre a produção de forragem e características morfogênicas e estruturais de *Axonopus aureus* 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 (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 110,4; 108,5; 54,1; 83,5; 96,6; 59,8 e 90,6 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
Se evaluó 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 *Axonopus aureus* en condiciones de campo natural en las sabanas 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 110,4; 108,5; 54,1; 83,5; 96,6; 59,8 y 90,6 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, 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. 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).

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´savannas, Axonopus aureus grass represents between 30 and 40% of its botanical composition. However, the 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 morphogenesis of a grass during its vegetative growth is characterized by three factors: 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 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 Axonopus aureus in the Roraima´s savannas.

2. Methodology

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

The trial was carried out at the Experimental Field of Brazilian Agricultural Research Company - Embrapa Roraima, located in Boa Vista, during the period from May to September 2018, which correspond to an accumulate precipitation of 1,353 mm and an average monthly temperature of 24.31ºC. 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 = 1.8 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 use was completely randomized with three replications. The treatments consisted of four levels of phosphorus (0, 30, 60 and 120 kg of P_2O_5 ha^{-1}), applied 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 perform 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 calculate 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 phosphate fertilization. The mathematical relationships were adjust to the quadratic regression model and describe, respectively, by the equations: $Y = 900.38 + 12.9494 X - 0.05862 X^2$ ($R^2 = 0.96$) and $Y = 21.4386 + 0.3082 X - 0.00142 X^2$ ($R^2 = 0.97$). The doses of maximum technical efficiency were estimate at 110.4 and 108.5 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). 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 secans* FCAP 43 estimated 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 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 defoliation 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.

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 $plant^{-1}$ (NTP), number of leaves $tiller^{-1}$ (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 *Axonopus aureus*, as affected by phosphate fertilization. Means of three cuts.

Levels of P_2O_5 ha^{-1}	GDM	AGR	PUE	NTP	NLP	ALS	LTA	LAR	LER	LSR
0	570 d	16.28 d	---	4.3 b	4.71 b	7.6 b	7.42 c	0.112.b	0.987 c	0.061 c
30	954 c	27.25 c	31.8 a	6.1 b	5.93 a	.11,3 a	14.38 b	0.141.a	1.807 b	0.074 b
60	1,224 b	34.97 b	20.4 b	7.9 a	6.34 a	12.3 a	16.32 b	0.151.a	2.113 a	0.088 a
120	1,496 a	42.74 a	12.5 c	8.2 a	6.52 a	13.2 a	18.09 a	0.155.a	2.360 a	0.098 a

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

The NTP was positively and linearly affected by P doses ($Y = 5.9614 + 0.0436 X$ - $r^2 = 0.92$), while for NLT, LTA and ALS the relationships were adjusted to the quadratic regression model and defined, respectively, by the equations $Y = 4.7491 + 0.04059 X - 0.00021 X^2$ ($R^2 = 0.91$), $Y = 2.2491 + 0.03225 X - 0.00027 X^2$ ($R^2 = 0.89$) and $Y = 7.7573 + 0.11597 X - X^2$ ($R^2 = 0.94$) and the maximum values obtain with the application of 96.6; 59.8 and 90.6 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 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 LAR and LER were adjust to the quadratic regression model and described, respectively, by the equations: $Y = 0.1131 + 0.00119 X – 0.000011 X^2$ ($R^2 = 0.97$) and $Y = 0.9511 + 0, 02571 X – 0.000154 X^2$ ($R^2 = 0.95$), with the maximum values obtained with the application of 54.1 and 83.5 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.

The mathematical relationship between LSR and phosphorus fertilization was linear and defined by the equation: $Y = 0.0636 + 0.00031 X$ ($r^2 = 0.97$; $P<0.02$). The values recorded in this study were lower than those reported by Costa et al. (2017) for *A. 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 TSF with the application of 120 (0.108 cm $tiller^{-1}$ 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^{-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)

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). 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). 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. Final Considerations

The agronomic evaluation of *Axonopus aureus* 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, with the opposite occurring regarding the rate of leaf senescence.

The maximum technical efficiency dose of phosphate for the GDM yield was estimate at 110.4 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.

References

Barbero, L. M., Basso, K. C., Igarasi, M. S., Paiva, A. J. & Basso, F. C. (2015). Respostas morfogênicas e estruturais de plantas tropicais submetidas à desfolhação. *Boletim de Indústria Animal*, 72, 321-330. https://dx.doi.org/10.17523/bia.v72n4p321

Bélanger, G.; Ziadi, N., Lajeunesse, J., Jouany, C., Virkajarvi, P., Sinaj, S. & Nyiraneza, J. (2017). Shoot growth and phosphorus–nitrogen relationship of grassland swards in response to mineral phosphorus fertilization. *Field Crops Research*, 204, 31–41. https://doi.org/10.1016/j.fcr.2016.12.006

Braga, R.M. (1998). *A agropecuária em Roraima:* considerações históricas, de produção e geração de conhecimento. Boa Vista: Embrapa Roraima. 63p. (Embrapa Roraima. Documentos, 1).

Costa, N. L., Magalhães, J. A., Pereira, R. G. A., Townsend, C. R. & Oliveira, J. R. C. (2017). Considerações sobre o manejo de pastagens na Amazônia Ocidental. *Revista do Conselho Federal de Medicina Veterinária*, 40, 37-56. https://www.academia.edu/1766236

Costa, N. L., Townsend, C. R., Magalhães, J. A., Paulino, V.T. & Pereira, R.G.A. (2016). Formação e manejo de pastagens na Amazônia do Brasil. *Revista Electrónica de Veterinária*, 7, 1-18. https://www.researchgate.net/publication/26423548

Costa, N. L., Gianluppi, V., Braga, R. M. & Bendahan, A. B. (2019). *Alternativas tecnológicas para a pecuária de Roraima*. Boa Vista: Embrapa Roraima. 35p. (Embrapa Roraima. Documentos, 19). https://www.researchgate.net/publication/260303087

Cruz, N. T., Pires, A. J. V., Fries, D. D., Jardim R. R. & Sousa B. M. L. (2021). Fatores que afetam as características morfogênicas e estruturais de plantas forrageiras. *Research, Society and Development,* 10 (7), e5410716180. https://dx.doi.org/10.33448/rsd-v10i7.16180

Ferreira, D. F. (2011). Sisvar: A computer statistical analysis system. *Ciência e Agrotecnologia,* 35, 1039-1042.

Gianluppi, D., Gianluppi, V. & Smiderle, O. (2001). *Produção de pastagens no cerrado de Roraima.* Boa Vista: Embrapa Roraima, 4p. (Embrapa Roraima. Comunicado Técnico, 14).

Heringer, E. & Jacques, A. V. A. (2012). Acumulação de forragem e santosmaterial morto em pastagem nativa sob distintas alternativas de manejo em relação às queimadas. *Revista Brasileira de Zootecnia,* 31 (3), p.599-604. https://doi.org/10.1590/S1516-35982002000300009

Lemaire, G., Hodgson, J. & Chabbi, A. (2011). *Grassland productivity and ecosystem services*. Cabi, Wallingford. 287p.

Nabinger, C., & Carvalho, P. F. C. (2009). Ecofisiología de sistemas pastoriles: aplicaciones para su sustentabilidad. *Agrociencia*, 13(3), 18–27. http://beta.acuedi.org/book/5520

Pereira, V. V. (2018). A importância das características morfogênicas sobre o fluxo de tecidos no manejo de pastagens tropicais. *Revista em Agronegócios e Meio Ambiente*, 6, 289-309. https://doi.org/10.17765/2176-9168.2013v6n2p%25p

Pereira, A. S., Shitsuka, D. M., Pereira, F. J., & Shitsuka, R. (2018). *Metodologia da pesquisa científica*. [*e-book*]. Santa Maria. UAB/NTE/UFSM. Disponível em: https://repositorio.ufsm.br/bitstream/handle/1/15824/Lic_Computação MetodologiaPesquisaCientifica.pdf?sequence=1. Acesso em: 15 jan. 2023.

Santos, M. S. (2021). *Avaliação da produção e composição morfológica de cultivares de Megathyrsus maximus na Amazônia Legal*. 54 f. Dissertação. (Mestrado em Agronomia). Universidade Federal do Tocantins. https://repositorio.uft.edu.br/handle/11612/2737

Santos, M. R., Fonseca, D. M., Gomes, V. M., Silva, S. P., Silva, G. P. & Reis, M. (2012). Correlações entre características morfogênicas e estruturais em pastos de capim-braquiária. *Ciência Animal Brasileira,* 13 (1), 49-56. http://dx.doi.org/10.5216/cab.v13i1.13401

Sarmiento, G., Silva, M. P., Naranjo, M. E. & Pinillos, M. (2016). Nitrogen and phosphorus as limiting factors for growth and primary production in a flooded savanna in the Venezuelan Llanos. *Journal of Tropical Ecology,* 22, 203-212. https://doi.org/10.1017/S0266467405003068

Silva, S. C. da & Nascimento Júnior, D. (2007). Avanços na pesquisa com plantas forrageiras tropicais: características morfofisiológicas e manejo do pastejo. *Revista Brasileira de Zootecnia,* 36, 122-138. https://doi.org/10.1590/S1516-35982007001000014

Tesk, C. R. M., Cavalli, J., Pina, D. S., Pereira, D. H., Pedreira, C. G. S., Jank, L., Sollenberger, L. E. & Pedreira, B. C. (2020). Herbage responses of Tamani and Quênia guineagrasses to grazing intensity. *Agronomy Journal*, 201, 1-27. https://doi.org/10.1002/agj2.20189

Volpe, E., Marchetti, M. E., Macedo, M. C. M., & Lempp, B. (2008). Acúmulo de forragem e características do solo e da planta no estabelecimento de capim-massai com diferentes níveis de saturação por bases, fósforo e nitrogênio. *Revista Brasileira de Zootecnia,* 37(2), 228–237. https://doi.org/10.1590/S01516-35982008000200008.