RECIMA21 - REVISTA CIENTÍFICA MULTIDISCIPLINAR
ISSN 2675-6218

EFFECT OF PHOSPHATE FERTILIZATION ON FORAGE PRODUCTIVITY AND MORPHOGENESIS OF *AXONOPUS PURPUSII* PASTURES IN RORAIMA'S SAVANNAS

EFEITO DA FERTILIZAÇÃO FOSFATADA SOBRE A PRODUTIVIDADE DE FORRAGEM E MORFOGÊNESE DE PASTAGENS DE *AXONOPUS PURPUSII* NOS CERRADOS DE RORAIMA

EFECTO DE LA FERTILIZACIÓN FOSFATADA SOBRE LA PRODUCTIVIDAD FORRAJERA Y LA MORFOGÉNESIS DE PASTOS DE AXONOPUS *PURPUSII* EN LAS SABANAS DE RORAIMA

Newton de Lucena Costa[1], João Avelar Magalhães[2], Amaury Burlamaqui Bendahan[1], Braz Henrique Nunes Rodrigues[2], Francisco José de Seixas Santos[2]

e432904
https://doi.org/10.47820/recima21.v4i3.2904

RECEIVED: 02/02/2023 **APPROVED: 02/28/2023** **PUBLISHED: 03/16/2023**

ABSTRACT
Objective: To evaluate the effect of phosphorus fertilization on forage productivity and morphogenesis of *Axonopus purpusii* under natural field conditions in the Roraima's savannas. Material and Methods: Use of four doses of phosphorus (0, 40, 80 and 120 kg of P_2O_5 ha^{-1}) applied broadcast at the form of triple superphosphate. The estimated parameters were green dry matter yield (GDM), absolute growth rate (AGR), number of tillers $plant^{-1}$, number of leaves $tiller^{-1}$ (NLT), average leaf size (ALS), leaf tiller $área^{-1}$ (LTA), appearance rates (LAR), expansion (LER) and leaf senescence. Results: Phosphate fertilization promoted significant increases ($P<0.05$) on GDM productivity and optimized the morphogenetic and structural characteristics of the grass. The maximum yields of GDM, AGR, LAR, LER, NLT, ALS and LTA were obtained with the application of 81.52; 105.91; 68.9; 39.1; 96.4; 100.8 and 87.7 kg of P2O5 ha-1, respectively. The efficiency of P utilization was inversely proportional to the P doses applied. Conclusions: The agronomic evaluation of *A. purpusii* pastures submitted to different levels of phosphorus fertilization allows identifying and recommending the most adequate levels for efficient management. The process of renewal and senescence of grass tissues is accelerated with the application of increasing doses of phosphorus.

KEYWORDS: Leaves. Green dry matter. Tillering. Senescence.

RESUMO
Objetivo: Avaliar o efeito da fertilização fosfatada sobre a produtividade de forragem e morfogênese de *Axonopus purpusii* em condições naturais de campo nos cerrados de Roraima. Material e Métodos: Utilização de quatro doses de fósforo (0, 40, 80 e 120 kg de P_2O_5 ha^{-1}) aplicadas a lanço sob a forma de superfosfato triplo. Os parâmetros estimados foram produção de matéria seca verde (MSV), taxa absoluta de crescimento (TAC), 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. Resultados: A fertilização fosfatada promoveu acréscimos significativos ($P<0,05$) sobre a produtividade de MSV e otimizou as características morfogênicas e estruturais da gramínea. Os máximos rendimentos de MSV, TAC, TAF, TEF, NFP, AFP e TMF foram obtidos com a aplicação de 81,52; 105,91; 68,9; 39,1; 96,4; 100,8 e 87,7 kg de P_2O_5 ha^{-1}, respectivamente. A eficiência de utilização de P foi inversamente proporcional às doses de P aplicadas. Conclusões: A avaliação agronômica de pastagens de *A. purpusii* submetidas a diferentes níveis de adubação fosfatada permite identificar e recomendar os níveis mais adequados para seu eficiente manejo. O processo de renovação e senescência dos tecidos da gramínea é acelerado com a aplicação de doses crescentes de fósforo.

PALAVRAS-CHAVE: Folhas. Matéria seca verde. Perfilhamento. Senescência.

[1] Embrapa Roraima, Boa Vista, Roraima.
[2] Embrapa Meio Norte, Parnaíba, Piauí.

RECIMA21 - REVISTA CIENTÍFICA MULTIDISCIPLINAR
ISSN 2675-6218

RESUMEN
Objetivo: Evaluar el efecto de la fertilización fosforada sobre la productividad forrajera y la morfogénesis de *Axonopus purpusii* en condiciones de campo natural en las sabanas de Roraima. Material y Métodos: Uso de cuatro dosis de fósforo (0, 40, 80 y 120 kg de P_2O_5 ha^{-1}) aplicadas al voleo en forma de triple superfosfato. Los parámetros estimados fueron producción de materia seca verde (MSV), tasa de crecimiento absoluto (TCA), número de macollas $planta^{-1}$, número de hojas $macollas^{-1}$ (NFP), tamaño medio de hoja (TMH), área foliar de $macollos^{-1}$ (AFM), tasas de aparición (TAF), expansión (TEF) y senescencia foliar. Resultados: La fertilización con fosfato promovió incrementos significativos ($P<0.05$) en la productividad de MSV y optimizó las características morfogenéticas y estructurales del pasto. Los rendimientos máximos de MSV, TCA, TAF, TEF, NHM, AFM y TMH se obtuvieron con la aplicación de 81,52; 105,91; 68,9; 39,1; 96,4; 100,8 y 87,7 kg de P_2O_5 ha^{-1}, respectivamente. La eficiencia de utilización de P fue inversamente proporcional a las dosis de P aplicadas. Conclusiones: La evaluación agronómica de pastos de *Axonopus purpusii* sometidos a diferentes niveles de fertilización fosforada permite identificar y recomendar los niveles más adecuados para un manejo eficiente. El proceso de renovación y senescencia de los tejidos herbáceos se acelera con la aplicación de dosis crecientes de fósforo.

PALABRAS CLAVE: Hojas. Macollaje. Matéria seca verde. Senescencia.

INTRODUCTION

Livestock is one of the most relevant economic activities in Roraima and cultivated pastures are the main forage resource for feeding livestock. 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.

A great diversity of tropical forage grasses occurs naturally in the savannas of Roraima, among which *Axonopus purpusii* can represent up to 35% of its vegetation cover in the ecosystem of native pastures. Currently, however, the availability of technical information on the effects of phosphate fertilization on productivity and morphogenetic and structural characteristics that can support the recommendation of sustainable management practices and that ensure the perenniality of pastures is incipient.

RECIMA21 - REVISTA CIENTÍFICA MULTIDISCIPLINAR
ISSN 2675-6218

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, were evaluated the effects of phosphate fertilization on forage availability and morphogenesis of *Axonopus purpusii* in the Roraima´s savannas.

MATERIAL AND METHODS

The research was performed under natural field conditions using quantitative method. As there are still gaps about evaluation and determination of the most suitable phosphate fertilization levels for *Axonopus purpusii* pastures it was chosen to use the hypothetical-deductive method (PEREIRA et al., 2018).

The trial was carried out in the Experimental Field of Embrapa Roraima, located in Boa Vista, during the period from April to November 2016, which correspond to an accumulate precipitation of 1,135 mm and an average monthly temperature of 24.4ºC. About 80% of the precipitation occurs in the period from May to September. 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} = 4.7; P = 1.9 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, 40, 80 and 120 kg of P_2O_5 ha^{-1}), applied broadcast 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 $plant^{-1}$ (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 $tiller^{-1}$ area (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 an estimate of the leaf area of each tiller, samples of fully expanded green leaves were collected, seeking to obtain an area between 200 and 300 cm^2. The samples were digitized, and the leaf area was estimated using an electronic optical Planimeter (Li-Cor 3100C). Subsequently, the sample was taken to a greenhouse subjected to forced air at 65ºC until reaching constant weight,

RECIMA21 - REVISTA CIENTÍFICA MULTIDISCIPLINAR
ISSN 2675-6218

obtaining the leaf GDM. The specific leaf area (SLA) was estimated through the relationship between the green leaf area and its GDM (m^2/g of leaf GDM). The LTA was determined from the product of total green leaf GDM (g GDM/m^2) by SLA (m^2/g of leaf GDM). The LSR was obtained by dividing the length of the leaf that was yellowish or necrotic by age of regrowth.

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).

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: $Y = 1,158 + 30.0973 X - 0.18433 X^2$ ($R^2 = 0.93$) and $Y = 24.098 + 0.6587 X - 0.00309 X^2$ ($R^2 = 0.90$). The doses of maximum technical efficiency were estimated at 81.52 and 105.91 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 coryphaeum* FCAP-16, reported maximum forage production with the application of 141.5 kg of P_2O_5 ha^{-1}, however, the highest P utilization efficiency rates were observed under fertilization levels between 80 and 110 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 *Axonopus purpusii*, 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	1,108 d	31.65 c	---	8.21 b	6.35 b	8,35 c	10.01 c	0.137 b	0.621 c	0.041 c
40	1,924 c	54.97 b	48.11 a	10.59 b	8.58 a	12.08 b	16.42 b	0.186 a	1.329 b	0.064 b
80	2,517 b	71.91 a	31.46 b	14.22 a	9.21 a	14.11 a	17.98 b	0.207 a	1.533 a	0.088 a
120	2,807 a	80.20 a	23.39 c	15.88 a	10.24 a	14.43 a	20.07 a	0.219 a	1.630 a	0.097 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 promotes relevant increases in the tillering of tropical forage grasses, which implies a greater leaf area index as a consequence of the greater available biomass. The tiller

RECIMA21 - REVISTA CIENTÍFICA MULTIDISCIPLINAR
ISSN 2675-6218

can be considered as the functional and growth regulating unit of grasses. For NTP, NLT, LTA and ALS, the relationships were adjusted to the quadratic regression model and defined, respectively, by the equations: $Y = 7.843 + 0.1412 X - 0.00075 X^2$ ($R^2 = 0.90$); $Y = 6.284 + 0.0906 X - 0.00047 X^2$ ($R^2 = 0.89$); $Y = 10.465 + 0.1934 X - 0.00094 X^2$ ($R^2 = 0.86$) and $Y = 8.451 + 0.1176 X - 0.00062 X^2$ ($R^2 = 0.92$) and the maximum values were obtained with the application of 98.1; 96.4; 100.8 and 87.7 kg of P_2O_5 ha^{-1}. Correlations between GDM yield and NTP (r = 0.9671; P=0.0019) and NLT (r = 0.9032; P=0.0039) were positive and significant, which explained in 93.1 and 93.8%, 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 *Trachypogon plumosus*, who estimated 4.03 tillers $plant^{-1}$; 4.11 leaves $tiller^{-1}$, 15.7 cm $leaf^{-1}$ and 7.55 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).

Phosphate fertilization, by increasing the number of tillers per tussock, favors the production of new leaves with a final length greater than that observed in non-fertilized pastures. The relationships between phosphate fertilization, LAR and LER were adjusted to the quadratic regression model and described, respectively, by the equations: $Y = 0.1245 + 0.00248 X - 0.000018 X^2$ ($R^2 = 0.86$) and $Y = 0.6583 + 0.0235 X - 0.000214 X^2$ ($R^2 = 0.90$). The maximum values were obtained with the application of 68.9 and 39.1 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.

Phosphate fertilization, by increasing the availability of biomass, favors its renewal process and, consequently, greater accumulation of senescent material, provided that appropriate pasture management practices are not adopted. The relationship between LSR and phosphorus fertilization was linear and defined by the equation: $Y = 0.0517 + 0.000382 X$ ($r^2 = 0.91$; P=0.0038). 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).

CONSIDERATIONS

The agronomic evaluation of *Axonopus purpusii* 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 81.52 kg of P_2O_5 ha^{-1}. The process of renewal and senescence of grass tissues is accelerated with increasing doses of phosphorus.

It is suggested 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. Respostas morfogênicas e estruturais de plantas tropicais submetidas à desfolhação. **Boletim de Indústria Animal,** v. 72, p. 321-330, 2015. https://dx.doi.org/10.17523/bia.v72n4p321

BÉLANGER, G.; ZIADI, N.; LAJEUNESSE, J.; JOUANY, C.; VIRKAJARVI, P.; SINAJ, S.; NYIRANEZA, J. Shoot growth and phosphorus–nitrogen relationship of grassland swards in response to mineral phosphorus fertilization. **Field Crops Research,** v. 204, p. 31–41, 2017. https://doi.org/10.1016/j.fcr.2016.12.006

BRAGA, G. J.; RAMOS, A. K. B.; CARVALHO, M. A.; FONSECA, C. E. L.; FERNANDES, F. D.; MALAQUIAS, J. V.; SANTOS, M. F.; JANK, L. **Produção de forragem e valor nutritivo de híbridos**

de *Panicum maximum* Jacq. em resposta à adubação. Brasília: Embrapa Cerrados. 2019. 18p. (Embrapa Cerrados. Boletim de Pesquisa e Desenvolvimento, 353).

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

CABRAL, C. E. A.; CABRAL, L. S.; BONFIM-SILVA, E. M.; CARVALHO, K. S.; ABREU, J. G.; CABRAL, C. H. A. Reactive natural phosphate and nitrogen fertilizers in Marandu grass fertilization. **Comunicata Scientiae,** v. 9, p. 729-736, 2018. https://doi.org/10.14295/cs.v9i4.1170.

CARDOSO, S.; VOLPE, E.; MACEDO, M. C. M. Effect of nitrogen and lime on Massai grass subjected to intensive cutting. **Pesquisa Agropecuária Tropical,** v. 46, p. 19-27, 2016. http://dx.doi.org/10.1590/1983-40632016v4638132.

COSTA, N. L.; GIANLUPPI, V.; BRAGA, R. M.; BENDAHAN, A. B. **Alternativas tecnológicas para a pecuária de Roraima.** Boa Vista: Embrapa Roraima. 2019. 35 p. (Embrapa Roraima. Documentos, 19). https://www.researchgate.net/publication/260303087

COSTA, N. L.; JANK, L.; MAGALHÃES, J. A.; RODRIGUES, A. N. A.; BENDAHAN, A. B.; GIANLUPPI, V.; RODRIGUES, B. H. N.; Productive performance, chemical composition and morphogenesis of *Megathyrsus maximus* cv. Tamani under rest periods. **Revista PubVet,** v. 14, p. 4-12, 2020. http://dx.doi.org/10.31533/pubvet.v14n4a554.1-8

COSTA, N. L.; MAGALHÃES, J. A.; PEREIRA, R. G. A.; TOWNSEND, C. R.; OLIVEIRA, J. R. C. Considerações sobre o manejo de pastagens na Amazônia Ocidental. **Revista do Conselho Federal de Medicina Veterinária**, v. 40, p. 37-56, 2017. https://www.academia.edu/1766236

COSTA, N. L.; TOWNSEND, C. R.; MAGALHÃES, J. A.; PAULINO, V.T.; PEREIRA, R. G. A. Formação e manejo de pastagens na Amazônia do Brasil. **Revista Electrónica de Veterinária,** v. 7, p. 1-18, 2016. https://www.researchgate.net/publication/26423548

CRUZ, N. T.; PIRES, A. J. V.; FRIES, D. D.; JARDIM R. R.; SOUSA B. M. L. Fatores que afetam as características morfogênicas e estruturais de plantas forrageiras. **Research, Society and Development,** v. 10, n. 7, p. e5410716180, 2021. https://dx.doi.org/10.33448/rsd-v10i7.16180

DA COSTA, C. H. M.; CRUSCIOL, C. A. C. Long-term effects of lime and phosphogypsum application on tropical no-till soybean–oat–sorghum rotation and soil chemical properties. **European Journal of Agronomy,** v. 74, p. 119–132, 2016. https://doi.org/10.1016/j.eja.2015.12.001.

FERREIRA, D. F. Sisvar: A computer statistical analysis system. **Ciência e Agrotecnologia**, v. 35, p. 1039-1042, 2011.

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

HALING, R. E.; YANG, Z.; SHADWELL, N.; CULVERNOR, R. A.; RYAN, M. H.; SANDRAL, G. A.; KIDD, D. R.; LAMBERS, H.; SIMPSON, R. J. Growth and root dry matter allocation by pasture legumes and a grass with contrasting external critical phosphorus requirements. **Plant and Soil,** v. 407, p. 67-79, 2016. https://doi.org/10.1007/s11104-016-2808-2.

HEINRICHS, R.; MONREAL, C. M.; SANTOS, E. T.; SOARES FILHO, C. V.; REBONATTI, M. D.; TEIXEIRA, N. M.; Moreira, A. Phosphorus sources and rates associated with nitrogen fertilization in Mombasa grass yield. **Communications in Soil Science and Plant Analysis,** v. 47, p. 657-669, 2016. . http://dx.doi.org/10.1080/00103624.2016.1141923.

RECIMA21 - REVISTA CIENTÍFICA MULTIDISCIPLINAR
ISSN 2675-6218

LEMAIRE, G.; HODGSON, J.; CHABBI, A. **Grassland productivity and ecosystem services.** Cabi: Wallingford, 2011. 287p.

MARTHA JÚNIOR, G. B.; VILELA, L.; SOUSA, D. M. G. **Cerrado:** uso eficiente de corretivos e fertilizantes em pastagens. Planaltina: Embrapa Cerrados, 2007. p.145-177. https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1113533/1/Livro.pdf.

PEREIRA, A. S.; SHITSUKA, D. M.; PEREIRA, F. J.; SHITSUKA, R. **Metodologia da pesquisa científica.** Santa Maria, UAB/NTE/UFSM. 2018. [*e-book*]. https://repositorio.ufsm.br/bitstream/handle/1/15824/Lic_ComputaçãoMetodologiaPesquisaCientifica.pdf?sequence=1. Acesso em: 15 jun. 2022.

PEREIRA, L. E. T.; HELING, V. R.; AVANZI, J. C.; SILVA, S. C. Morphogenetic and structural characteristics of signal grass in response to liming and defoliation severity. **Pesquisa Agropecuária Tropical,** v. 48, p. 1-11, 2018. https://doi.org/10.1590/1983-40632018v4849212.

PEREIRA, R. C.; RIBEIRO, K. G.; ANDRADE, R. D.; SILVA, J. L.; SILVA, E. B.; FONSECA, D. M.; CECON, P. R.; PEREIRA, O. G. Structural and productive characteristics of Marandu and Xaraés grasses fertilized at different times after harvesting. **Revista Brasileira de Zootecnia,** v. 41, p. 557-564, 2012. http://dx.doi.org/10.1590/S1516-35982012000300012.

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

SARMIENTO, G.; SILVA, M. P.; NARANJO, M. E.; PINILLOS, M. Nitrogen and phosphorus as limiting factors for growth and primary production in a flooded savanna in the Venezuelan Llanos. **Journal of Tropical Ecology,** v. 22, p. 203-212, 2016. https://doi.org/10.1017/S0266467405003068

SILVA, S. C. da; NASCIMENTO JÚNIOR, D. Avanços na pesquisa com plantas forrageiras tropicais: características morfofisiológicas e manejo do pastejo. **Revista Brasileira de Zootecnia,** v. 36, p. 122-138, 2007. https://doi.org/10.1590/S1516-35982007001000014

SOARES, W.; LOBATO, E.; SOUSA, D. M. G.; VILELA, L. **Adubação fosfatada para manutenção de pastagem de *Brachiaria decumbens* no Cerrado.** Planaltina: Embrapa Cerrados, 2011. 5p. https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/566167/1/comtec53.pdf.

SOUSA, D. M. G.; MARTHA JÚNIOR, G. B.; VILELA, L. Adubação fosfatada. *In:* MARTHA JÚNIOR, G. B.; VILELA, L.; SOUSA, D. M. G**. Cerrado:** uso eficiente de corretivos e fertilizantes em pastagens. Planaltina: Embrapa Cerrados, 2007. p. 145-177. https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/1113533/1/Livro.pdf.