BIA
BOLETIM DE INDÚSTRIA ANIMAL

MORPHOGENIC AND STRUCTURAL CHARACTERISTICS OF XARAÉS GRASS SUBJECTED TO DIFFERENT FERTILIZATION STRATEGIES

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Received: 23/10/2023
Approved: 13/09/2024

Abstract

Soil correction and fertilization are important in the formation of pastures, but many producers neglect them or use ineffective alternatives. Slow-release fertilizers may harm the establishment of forage plants, as this is a crucial moment during the pasture formation stage. The objective was to evaluate establishment fertilization strategies on the morphogenic, structural characteristics and productivity of Xaraés grass (*Urochloa brizantha* cv. Xaraés). To this purpose, two experimental trials were conducted in a greenhouse, both under a completely randomized design. In the first one, three establishment fertilization strategies were tested (strategy 1: without lime/NPK; strategy 2: lime + NPK; strategy 3: natural reactive phosphate), with six replications. In the second, a 3 × 10 factorial scheme was used, corresponding to the three establishment fertilization strategies and 10 evaluation dates (32, 39, 46, 53, 60, 67, 74, 81, 88, and 95 days) after emergence of plants (DAE). In experiment 1 the morphogenic characteristics of the plant were evaluated, in the second experiment the structure and dry mass production of the aerial part and roots of Xaraés grass were evaluated higher ($P<0.05$) rates of leaf elongation and appearance, stem elongation, and leaf senescence, in addition to higher ($P<0.05$) tiller densities and dry mass production, were obtained in strategy 2 than in the others. Forage production of Xaraés grass increased linearly ($P<0.05$) as a function of higher DAE. Therefore, using lime together with NPK fertilization provides greater growth and production of Xaraés grass.

Keywords Limestone, Nitrogen, Phosphorus, Potassium, *Urochloa brizantha*

CARACTERÍSTICAS MORFOGÊNICAS E ESTRUTURAIS DO CAPIM XARAÉS SUBMETIDO A DIFERENTES ESTRATÉGIAS DE ADUBAÇÃO

Resumo

A correção e adubação do solo são importantes na formação de pastagens, mas muitos produtores as negligenciam ou usam alternativas pouco efetivas. Adubos de liberação lenta podem vir a prejudicar o estabelecimento de plantas forrageiras, devido ser um momento crucial durante a etapa de formação da pastagem. Objetivou-se avaliar estratégias de adubação de estabelecimento sobre as características morfogênicas, estruturais e produtividade do capim Xaraés (*Urochloa brizantha* cv. Xaraés). Para tanto, foram conduzidos dois ensaios experimentais em casa de vegetação, ambos sob delineamento inteiramente casualizado. No primeiro, foram testadas três estratégias de adubação de estabelecimento (estratégia 1: sem calcário/NPK; estratégia 2: calcário + NPK; estratégia 3: fosfato reativo natural), com seis repetições. No segundo, foi utilizado um esquema fatorial 3 × 10, correspondendo às três estratégias de adubação de estabelecimento e 10 datas de avaliação (32, 39, 46, 53, 60, 67, 74, 81, 88 e 95 dias) após a emergência das plantas (DAE). Maiores ($P<0.05$) taxas de alongamento e de aparecimento foliar, de alongamento do colmo e de senescência foliar, além de maiores ($P<0.05$) densidades de perfilhos e produção de massa seca, foram obtidas na estratégia 2 do que nas demais. A produção de forragem do capim Xaraés aumentou linearmente ($P<0.05$) em função de maiores DAE. Portanto, o uso de calcário em conjunto com adubação de NPK proporciona um maior crescimento e produção do capim Xaraés.

Palavras-chave Calcário, Fósforo, Nitrogênio, Potássio, *Urochloa brizantha*

https://doi.org/10.17523/bia.2024.v81.e1939

INTRODUCTION

Due to the low fertility of most Brazilian soils and the nutrient requirements of forage plants, it is necessary to consider the use and investment in soil amendments and fertilizers for pasture establishment, renovation or recovery, as they contribute to increase the forage production and quality (JORIS et al., 2016; BANG et al., 2020).

The mineral macronutrients (calcium, magnesium, sulfur, nitrogen, phosphorus, and potassium) play a fundamental role on the growth and metabolic processes of grasses (YARBOROUGH et al., 2017; OLIVEIRA et al., 2020; NASCIMENTO et al., 2021; LOPES et al., 2024). They are essential components during pasture formation, with functions in the synthesis of organic compounds, enhancement of enzymatic reactions, appearance and production of tillers and morphological composition (BANG et al., 2020). However, for the efficiency of these nutrients in the soil, it is necessary to correct acidity.

The correction of acidity and fertilization constitute a significant portion of the expenses in pasture establishment, with the essential use of fertilizers that accelerate the growth of forage plants, increasing forage productivity with adequate nutritional value, while also minimizing production costs and enhancing the carrying capacity of pastures (JORIS et al., 2016; VASCO et al., 2021).

Despite the widespread use of soil amendments and fertilizers, these actions require a significant investment, and some producers may choose not to use them during pasture establishment or opt for alternative, cheaper sources, such as the substitution of soluble phosphates with natural phosphates. Natural phosphate offers the benefit of long-term reactivity in acidic soils, providing results comparable to soluble phosphorus, and it also comes at a more affordable price (SOMAVILLA et al., 2021). However, such recommendations are primarily intended for pasture maintenance and do not specifically address the efficiency of natural phosphate during the pasture establishment phase.

We aimed to evaluate the morphogenic and structural characteristics, morphological composition, and yield of palisade grass (*Urochloa brizantha* cv. Xaraés) under three fertilization systems during pasture establishment.

MATERIAL AND METHODS

The experiment was conducted inside a greenhouse at the Igarapé-Açu School Farm (FEIGA), which belongs to the Federal Rural University of the Amazon (UFRA) and is located in the municipality of Igarapé-Açu, Pará, Brazil (01°07'21.76" South latitude and 47°36'27.57" West longitude), at an altitude of 45 meters. The maximum and minimum temperatures observed inside the greenhouse during the experimental period were 30.7°C and 24.2°C, respectively.

It was divided into two experimental trials (1 and 2), both having the same duration. The experiment began on October 21, 2017 (application of limestone to the soil), until February 24, 2018 (last day of collection).

The following establishment fertilization strategies were tested for *Urochloa brizantha* cv. Xaraés: Strategy 1 (S1): Control (No liming and no NPK); Strategy 2 (S2): Liming + NPK; and Strategy 3 (S3): No liming + reactive natural phosphate fertilization. The use of reactive natural phosphate, without the application of lime and other nutrients, is a common and conventional practice in productive pasture systems in northern Brazil.

For soil analysis, samples were collected from a depth of 0-20 cm, which showed the following average values: pH (H_2O) = 5.1; 0.6 cmolc dm^{-3} of Al; 0.5 cmolc dm^{-3} of Ca; 0.2 cmolc dm^{-3} of Mg; 1.0 mg dm^{-3} of P; 23 mg dm^{-3} of K; 4.1 cmolc dm^{-3} of CEC (Cation Exchange Capacity); and 41.34% base saturation.

The collected soil was sieved to remove stones and other undesirable materials, and then placed in plastic buckets with a capacity of 15 kg. The bucket volume, together with the soil analysis results, it was used to calculate the average soil volume (40 dm^{-3}) and the doses of amendments and fertilizers to be applied in S2 and S3.

In S2, 2.9 ton ha-1 of dolomitic limestone with a PRNT of 95% was applied to increase the base saturation to 60%. This was incorporated into the soil 25 days before sowing. The doses and sources used for phosphorus, nitrogen, and potassium in S2 were, respectively: 140 kg ha^{-1} of P_2O_5 in the form of granulated single superphosphate (20% P_2O_5); 50 kg ha^{-1} of N in the form of urea; and 50 kg ha^{-1} of K_2O in the form of potassium chloride. In S3, 140 kg per hectare of P_2O_5 in the form of powdered Arad (28% P_2O_5) were applied.

Sowing took place on November 14, 2017, with twenty seeds sown per bucket at a depth of 2 cm. On the same day, phosphate fertilization was applied in S2 and S3. Thinning of the tillers was performed on December 2, 2017, leaving only three plants per bucket (CABRAL et al., 2020). Fertilization with N and K was carried out on December 14, 2017. Bucket irrigation was done manually once a day, watering until the soil reached field capacity (YARBOROUGH et a., 2017). The assessments for Experiment 1 began on December 9, 2017, and the assessments for Experiment 2 started on December 16, 2017. Both experiments were concluded on February 24, 2018.

In the first experiment, a completely randomized design was used, with three establishment fertilization strategies and six replicates per treatment. The evaluation of the Xaraés grass was conducted based on measurements of morphogenic and structural plant characteristics, which were carried out every seven days.

Assessments included the recording of leaf appearance, ligule exposure day, final length of expanded and expanding leaves, leaf senescence, number of live leaves per tiller, and stem length. With the data collected, the following variables were quantified: Leaf Elongation Rate (LER – cm leaf day^{-1}): Obtained by the difference between the final (last assessment) and initial (first assessment) length of expanding leaf blades for each tiller, divided by the number of days of evaluation. Leaf Appearance Rate (LAR – leaves day^{-1}): calculated by dividing the number of leaves that appeared during the evaluation period. Phyllochron (days leaf^{-1}): calculated as the inverse of LAR. Leaf Senescence Rate (LSR – cm leaf day^{-1}): obtained by the difference between the length of the leaf blade, measured based on the visible green fraction at the initial and final stages. Leaf Lifespan (LLS – days). Stem Elongation Rate (SER – cm stem^{-1}): Obtained similarly to TAlF Leaf Elongation Rate (LER) evaluation, but with measurements taken on the stem (DURU and DUCROCQ, 2000).

The second experiment, a completely randomized design in a 3 × 10 factorial scheme was employed (three establishment fertilization strategies and ten days after plant emergence - DAE) with three replications per treatment for a total of 90 buckets. Destructive assessments of above-ground and root variables were performed every seven days.

In the above-ground part of the plants, the following measurements were taken: plant height (cm), from the soil to the highest leaf curvature; number of tillers (NP; tillers vase^{-1}); dry matter production (DMP; g vase^{-1}); and leaf blades production (LBP; g vase^{-1}), stem production (SP; g vase^{-1}), and dead material production (DMP; g per bucket). For calculating dry matter production and morphological composition of the forage, the plants were cut at ground level and then separated into the morphological components of leaf blades, stem + sheath, and dead material. After component separation, they were dried in a forced-air circulation oven at 55°C until a constant weight was achieved, on average for 72 hours to obtain their dry masses. After the data collection was completed, the soil was removed from the buckets and the length of the roots in each replicate was measured, from the base of the soil to the tip of the longest root.

All data were subjected to variance homoscedasticity analysis using the Levene test and normality of residuals analysis using the Shapiro-Wilk test. The data were subjected to analysis of variance using the MIXED procedure in the SAS® (Statistical Analysis System) software, with a 5% probability of error. For the morphogenic and structural plant variables, the statistical model considered the establishment fertilization strategies as a fixed effect and the experimental error as a random effect. Treatment means were compared using the Tukey test ($P<0.05$). For dry matter production and morphological composition variables of the forage, the statistical model considered the establishment fertilization strategies, days after emergence (DAE), and the interaction between strategies × DAE as fixed effects, while the experimental effect was considered random. Means were compared using the Tukey test ($P<0.05$). The effects of DAE were analyzed using linear polynomial contrasts.

RESULTS

An effect of the establishment fertilization strategy was observed ($P<0.05$) for all morphogenic variables (Table 1).

Table 1. Morphogenic characteristics of Xaraés grass.

Variable	Strategy 1	Strategy 2	Strategy 3	SEM	p-value
LER (cm leaf^{-1} day^{-1})	4.63^{B}	6.61^{A}	5.10^{B}	0.27	<0.01
LAR (leaf day^{-1})	0.08^{B}	0.11^{A}	0.9^{B}	0.01	<0.01
Phyllochron (day leaf^{-1})	12.56^{A}	8.87^{B}	11.79^{B}	0.33	<0.01
LSR (cm leaf^{-1} day^{-1})	0.32^{B}	0.69^{A}	0.57^{A}	0.05	<0.01
LLS (days)	46.02^{A}	40.42^{B}	41.92^{B}	0.76	<0.01
SER (cm stem^{-1} day^{-1})	0.35^{B}	0.66^{A}	0.45^{B}	0.02	<0.01

LER: leaf elongation rate; LAR: leaf appearance rate; LSR: leaf senescence rate; LLS: leaf life span; SER: Stem elongation rate; SEM: Standard Error of the Mean. ^{A,B}Means followed by different letters in the lines differ from each other using the Tukey test ($P<0,05$).

Higher values of LER and LAR were obtained for S2, while the highest values of phyllochron and LLS and the lowest value of SER were observed for S1, in comparison to the other establishment fertilization strategies.

Higher values of LAR (P<0.05) were observed in S2 when compared to S1 and S3. The values of LAR also showed superiority in S2 compared to the others, with the opposite trend observed in the phyllochron variable, as it is expressed as the inverse of LAR. The different fertilization strategies used in S2 and S3 led to higher TSeF (P<0.05) when compared to S1 (control).

Plants subjected to S1 showed higher LLS (P<0.05) when compared to those in the other establishment fertilization strategies, surviving approximately four to six days longer than S2 and S3, respectively. Regarding SER, S1 exhibited the highest SER (P<0.05).

An interaction effect between establishment fertilization strategies × DAE (P<0.01) was observed for the number of tillers per vase (Figure 1). In all three fertilization strategies, there was a linear increase (P<0.05) in this variable as a function of DAE, with S2 showing a higher tiller population than the other systems, and the most significant growth occurring after DAE 53.

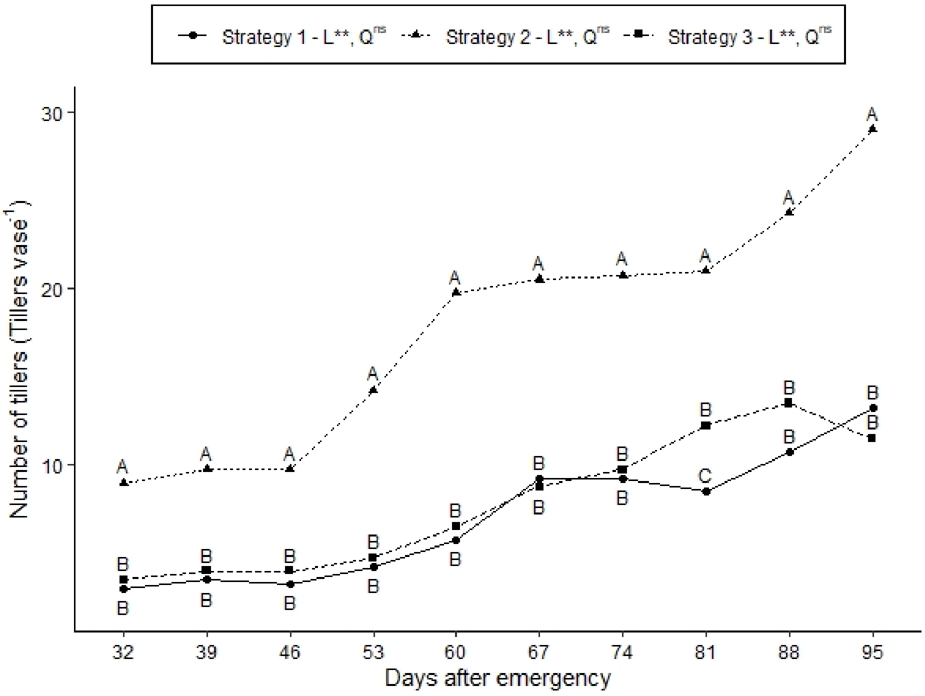

Figure 1. Number of tillers in Xaraés grass subjected to pasture establishment systems and days after emergence. $^{A, B, C}$ Same letters on the same day after emergence do not differ from each other (*P*>0.05). **: *P*<0.001; *: *P*<0.05; ns: not significant.

Plant height showed an interaction between system × DAE (P<0.05). Plant height increased quadratically (P<0.001) (Figure 2) with the passage of DAE in all systems, and it was observed that until day 60, the heights were similar among the systems. After day 67, S2 provided accelerated plant growth.

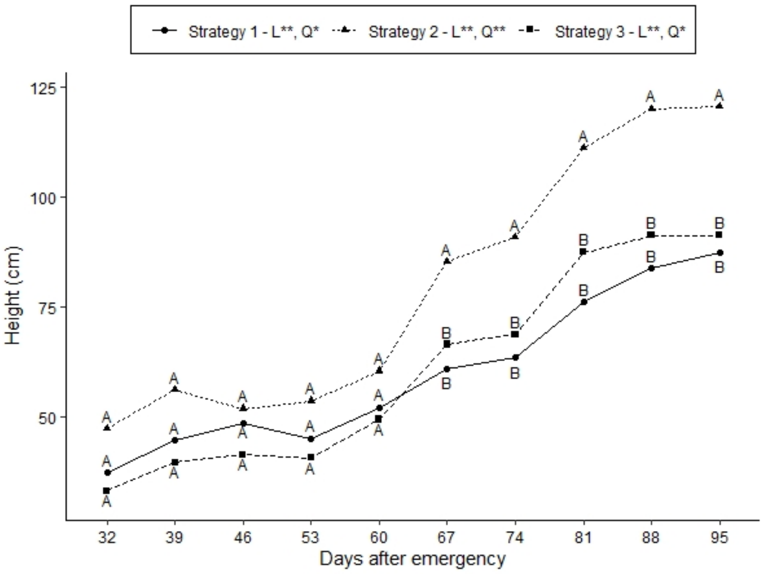

Figure 2. Height of Xaraés grass subjected to pasture establishment systems and days after emergence. $^{A, B}$ Same letters on the same day after emergence do not differ from each other (*P*>0.05). **: *P*<0.001; *: *P*<0.05; ns: not significant.

Dry matter production (PMS) showed a quadratic effect in all systems (P<0.001) as DAE progressed, with S2 providing the highest production from the first day to the last day of evaluations (Figure 3).

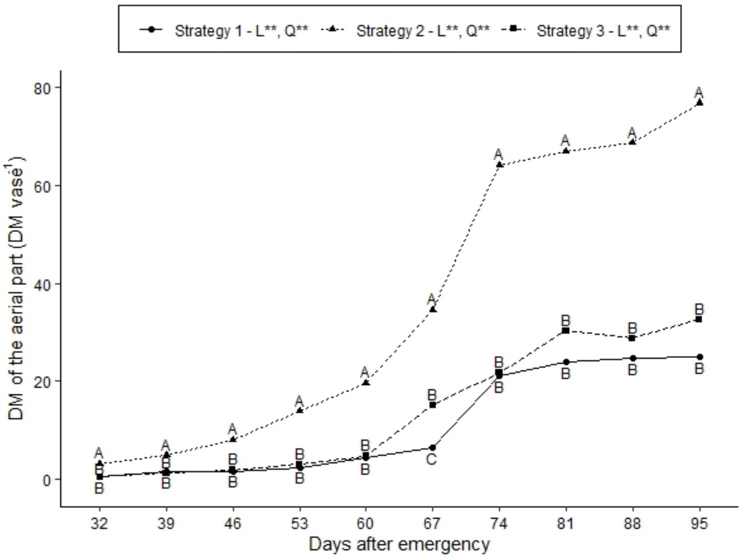

Figure 3. Dry matter production of Xaraés grass subjected to pasture establishment systems and days after emergence. $^{A, B, C}$ Same letters on the same day after emergence do not differ from each other (P>0.05). **: P<0.001; *: P<0.05; ns: not significant.

The LBP showed a quadratic effect ($P<0.05$) with respect to days in all strategies, with a greater increase observed after DAE 67, and S2 exhibited higher production than the others (Figure 4A). A similar effect is observed in SP (Figure 4B), where S2 showed greater production throughout the days. Meanwhile, DMP (Figure 4C) began to show differences between the strategies only after DAE 81, with S2 and S3 exhibiting greater responses.

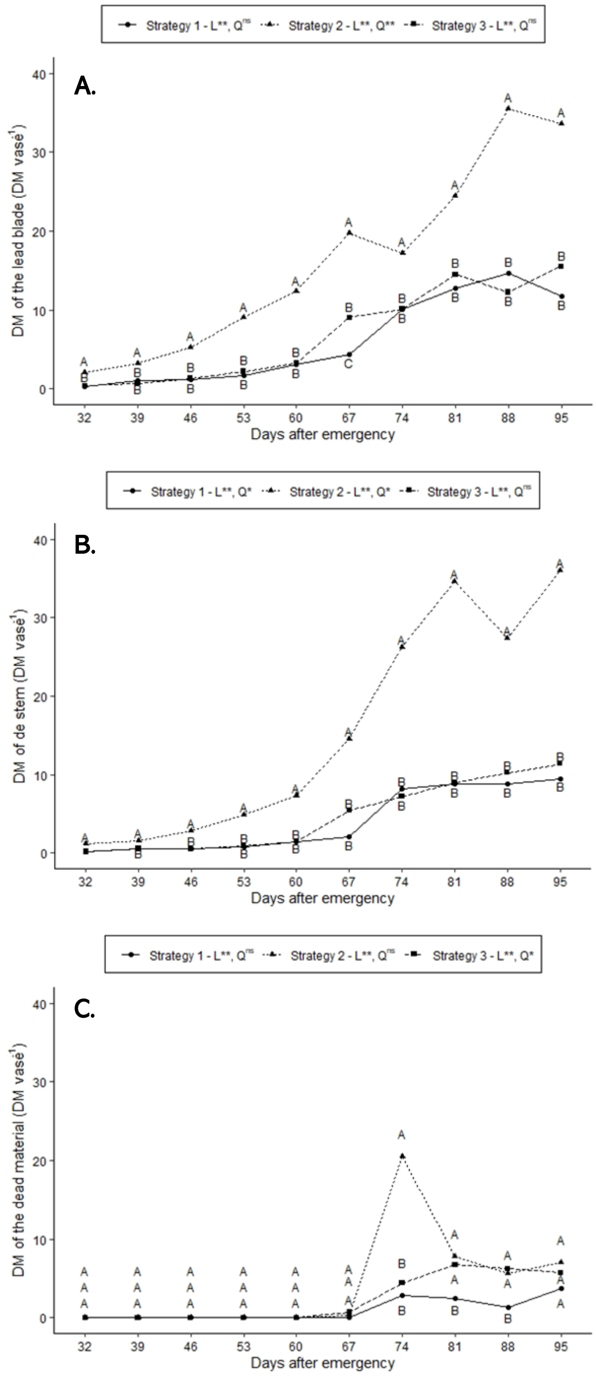

Figure 4. Dry matter production of leaf blades (A), Dry matter production of stem (B), and Dry matter production of dead material (C) of Xaraés grass subjected to pasture establishment systems and days after emergence. $^{A, B}$ Same letters on the same day after emergence do not differ from each other ($P>0.05$). **: $P<0.001$; *: $P<0.05$; ns: not significant.

The root length (CR) exhibited a quadratic behavior in all systems, increasing until approximately day 81 (Figure 5). An effect between systems was observed only at DAE 32; after that, root lengths did not differ between systems.

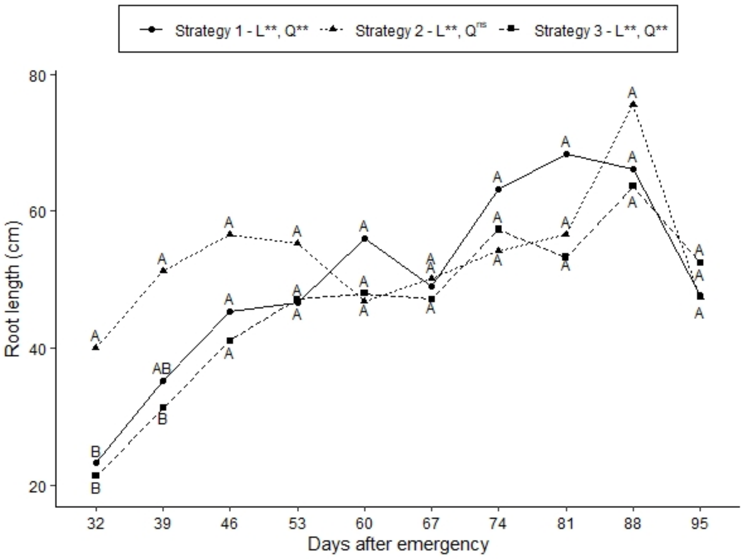

Figure 5. Root length of Xaraés grass subjected to pasture establishment systems and days after emergence. ^{A,B}Same letters on the same day after emergence do not differ from each other (P>0.05). **: P<0.001; *: P<0.05; ns: not significant.

DISCUSSION

The higher values of LAR in the systems receiving fertilizers are due to the accelerated growth dynamics of the plant, driven by the nutrients present in the soil. The combined addition of macronutrients to the pasture accelerates plant growth (DELEVATTI et al., 2019; OLIVEIRA et al., 2020; CUNHA et al., 2021; LAGE FILHO et al., 2024), in contrast to the isolated application of P (YARBOROUGH et al., 2017b).

During pasture establishment, phosphorus is of great importance for the development of leaf area and forage tillering. Therefore, a soluble source of P, as applied in S2, accelerates the plant's growth rate as the nutrient is available to the plant more efficiently (NASH et al., 2019). The application of limestone in S2 also aids in the development of Xaraés grass, as it raises the soil pH, creating a favorable environment for nutrient mobilization and allowing the uptake of NPK by the plant (ABDALLA et al., 2022).

Furthermore, the presence of nitrogen in the soil of S2 contributed to a faster leaf appearance rate, as nitrogen is involved in the photosynthesis process, increasing the flow of tissues in the meristem and enhancing the productivity of tropical grasses (OLIVEIRA et al., 2020; VASCONCELOS et al., 2020; CUNHA et al., 2022;LAGE

FILHO et al., 2024). Potassium, on the other hand, directly regulates stomatal behavior in the forage plant, optimizing the photosynthesis process and controlling water loss by the plant (ANICÉSIO and MONTEIRO, 2022). The opposite effect is seen in the phyllochron since it is measured as the inverse of LAR. Therefore, higher rates of development are observed in S2, resulting in a shorter interval between leaf appearance and leaf expansion, as also observed by Lage Filho et al. (2021).

Even the reactive phosphate in S3 influenced leaf senescence, increasing leaf mortality. The reactive phosphate used in S3 is primarily designed to act in more acidic soils, with a gradual release according to the plant's needs (NASH et al., 2019). High doses of P may have been absorbed by the plant, resulting in greater senescence, as observed in S2. LSR has a direct correlation with LLS, as systems without fertilization (S1 - Control) reduce their leaf appearance and growth rates, which promote less shading in the lower leaves of the plants (ONGARATTO et al., 2021).

The higher SER values can also be explained, in combination, by the higher values of LAR and LER observed in S2. This occurs due to increased shading of the leaves at the base of the canopy, causing the plant to elongate its stem more in search of light (ZANINE et al., 2018).

Soluble phosphorus acts more efficiently in nutrient availability for the plant, explaining the fact that at DAE 32, S2 already had a higher population density of tillers (HEINRICHS et al., 2016). Another important point to highlight is soil correction in S2. As limestone reacts with water in the soil and forms neutral ions, it increases the cation exchange capacity of the soil, favoring nutrient absorption by the roots of the forage and providing more energy for the plant to perform tillering (HOLLAND et al., 2018; CUNHA et al., 2021; MACEDO et al., 2022; LAGE FILHO et al., 2024).

The significant increase in the height of Xaraés grass in S2 can be explained by the increased population of tillers in the pot. After 60 days, the growth dynamics began to increase considerably, leading to more shading at the base of the plant and causing it to elongate its stems in search of light (VÉRAS et al., 2020; LAGE FILHO et al., 2021).

The higher dry matter production in S2 is associated with the increased tillering resulting from soluble phosphorus and nitrogen fertilization, which leads to higher LFP due to the greater number of tillers in the vase (YUAN et al., 2020). Plant nutritional factors have a positive correlation with plant productivity, regardless of whether they are based on increased tillering or leaf elongation (MACEDO et al., 2022).

The higher leaf blade proportion (LBP) had a greater effect on the system with higher leaf elongation rate (LER) and leaf appearance rate (LAR), explaining why S2 outperformed the other systems (CUNHA et al., 2022). The responses observed in PMSLF and PMS are attributable to the competition for light within the forage canopy. The greater population density of tillers, height, and LBP explain this, as shading at the base of the canopy will lead to greater stem elongation and accelerate the death of leaves at the base of the canopy (ZANINE et al., 2018; MACEDO et al., 2022). Additionally, a higher leaf senescence rate (LSR) is observed in S2 and S3, supporting the idea that these systems will produce more dead material (ONGARATTO et al., 2021)).

The response in root length is due to the development of the grass's root system, which tends to deepen in the soil, increasing its contact surface and thus searching for more nutrients (HUOT et al., 2020). After DAE 81, the pot limited further root growth.

CONCLUSION

Liming and fertilization with NPK accelerate the initial growth and increase the production of *Urochloa brizantha* cv. Xaraés, resulting in the rapid establishment of this forage plant. The use of only reactive natural phosphate has a limited effect on forage production, structure, and leaf dynamics of the cultivar. Other studies must be carried out at the field level to better demonstrate the real effect of ARAD and whether its use combined with other nutrients can improve the production and performance of Xaraés grass, studying the establishment and the maintenance of the pasture.

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