FISH-BASED BIOFERTILIZER IN THE FERTILIZATION OF MOMBAÇA GRASS

BIOFERTILIZANTE A BASE DE PEIXES NA ADUBAÇÃO DO CAPIM MOMBAÇA

BIOFERTILIZANTE A BASE DE PESCADO PARA FERTILIZAR EL PASTO DE MOMBASA

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ABSTRACT

The use of biofertilizers has increased, enabling the partial or even total replacement of mineral fertilizers in agriculture. However, the effects of fish-based biofertilizers are not yet known. Therefore, the objective of this study was to evaluate the effect of fish-based biofertilizer doses on forage yield and morphogenetic and structural parameters of Mombaça grass. The treatments consisted of seven doses of fish-based biofertilizer, in addition to a treatment without biofertilizer application, used as a control. The experimental units consisted of 12-liter plastic buckets with four replicates per treatment, for a total of 32 experimental units in a greenhouse. The following variables were determined: fresh matter production, plant height, phyllochron, leaf emergence rate, leaf elongation rate, leaf lifespan, number of tillers, final leaf blade length, number of live leaves, and stem elongation rate. The dose required for the maximum leaf elongation rate was 11.5 L ha^{-1}, while the maximum leaf emergence rate was obtained with a dose of 8.72 L ha^{-1}. Therefore, the highest leaf emergence and elongation of Mombaça grass were obtained with a mean dose of 10.11 L ha^{-1} of fish-based biofertilizer.

Keywords: Sustainable Development. Organic Fertilizer. Morphogenesis.

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RESUMO

A utilização de biofertilizantes tem aumentado, possibilitando sua substituição parcial e/ou até mesmo total aos fertilizantes minerais na agricultura e pecuária. Entretanto, ainda não são conhecidos os efeitos de biofertilizantes à base de peixe. Diante disso, objetivou-se, com este trabalho, avaliar o efeito de doses de biofertilizante à base de peixe no rendimento forrageiro e nos parâmetros morfogênicos e estruturais do capim Mombaça. Os tratamentos consistiram em sete doses de biofertilizante à base de peixe, além de um tratamento sem aplicação do biofertilizante, utilizado como testemunha. As unidades experimentais foram constituídas por baldes plásticos com capacidade de 12 litros, com quatro repetições por tratamento, totalizando 32 unidades experimentais em casa de vegetação. Foram determinadas as seguintes variáveis: produção de matéria verde, altura de plantas, filocrono, taxa de aparecimento foliar, taxa de alongamento foliar, duração de vida das folhas, número de perfilhos, comprimento final da lâmina foliar, número de folhas vivas e taxa de alongamento de haste. A dose necessária para a máxima taxa de alongamento foliar foi de 11,5 L ha⁻¹, enquanto a máxima taxa de aparecimento foliar foi obtida com a dose de 8,72 L ha⁻¹. Conclui-se com isso, que o maior aparecimento e alongamento foliar do capim Mombaça com a dose média de 10,11 L ha⁻¹ de biofertilizante à base de peixe.

Palavras-chave: Desenvolvimento Sustentável. Fertilizante Orgânico. Morfogênese.

RESUMEN

El uso de biofertilizantes ha aumentado, lo que ha permitido su sustitución parcial o incluso total de los fertilizantes minerales en la agricultura y la ganadería. Sin embargo, aún se desconocen los efectos de los biofertilizantes a base de pescado. Por lo tanto, el objetivo de este trabajo fue evaluar el efecto de dosis de biofertilizante a base de pescado en el rendimiento forrajero y en los parámetros morfogénicos y estructurales del pasto Mombaça. Los tratamientos consistieron en siete dosis de biofertilizante a base de pescado, además de un tratamiento sin aplicación de biofertilizante, utilizado como control. Las unidades experimentales consistieron en baldes de plástico con capacidad para 12 L, con cuatro repeticiones por tratamiento, para un total de 32 unidades experimentales en el invernadero. Se determinaron las siguientes variables: producción de materia verde, altura de las plantas, filocrono, tasa de aparición foliar, tasa de elongación foliar, duración de vida de las hojas, número de macollos, longitud final de la lámina foliar, número de hojas vivas y tasa de elongación del tallo. La dosis necesaria para la tasa máxima de elongación foliar fue de 11,5 L ha⁻¹, mientras que la tasa máxima de aparición foliar se obtuvo con la dosis de 8,72 L ha⁻¹. Por lo tanto, se concluye que la mayor aparición y elongación foliar del pasto Mombaça se obtuvo con la dosis media de 10,11 L ha⁻¹ de biofertilizante a base de pescado.

Palabras clave: Desarrollo Sostenible. Fertilizante Orgánico. Morfogénesis.

1 INTRODUCTION

Brazil's agricultural activity is significant at both national and international levels (Castro et al., 2016), and forage grasses are used as the main source of feed for cattle in at least one stage of growth. Brazil has the largest commercial cattle herd in the world; it is the second-largest producer of beef and the fifth-largest producer of milk (USDA, 2016). Extensive production systems, in which forage forms the basis of the diet, are commonly practiced (Hoffmann et al., 2014). Therefore, intensifying forage production is essential. However, due to the low availability of nutrients in most Brazilian soils, forage production faces limitations. Thus, the adoption of management techniques aimed at improving plant nutrition is of fundamental importance for forage production (Biserra et al., 2017).

The use of organic waste can be a way to intensify forage production and reduce fertilization costs, while also providing an appropriate disposal method for such waste (Castro et al., 2016). Primo et al. (2015) highlighted that the use of alternative sources, such as residues from livestock production itself, is efficient and sustainable due to nutrient recycling within the system and the reduction of environmental contamination resulting from the improper disposal of residues.

Fertilization using animal waste can be an excellent alternative for pastures, as it supplies nutrients and represents a much cheaper option than formulated fertilizers. This makes it an attractive alternative for meat-producing companies that need to properly dispose of animal waste (Castro et al., 2016).

Biofertilizer is a by-product obtained from the fermentation of agricultural or animal waste that can replace or complement chemical fertilizers. It can be applied to the soil or used in foliar treatments (Lima et al., 2012), which increases the commercial value of the product while also helping agribusinesses solve problems related to the proper disposal of waste generated during product processing (Edvan et al., 2016).

Among the various beneficial effects of biofertilizers in agricultural systems, the stimulation of soil microbiota, improvement of soil physical conditions, biological and chemical buffering effects, thermal regulation, and greater water retention stand out (Boulal et al., 2011). Due to its direct and indirect effects on soil properties, organic matter (OM) has a strong influence on soil productivity (Paul et al., 2013).

In some regions of the country, biofertilizers have been empirically used on various plant species in organic production systems, and studies are needed to confirm or refute the efficiency of the applied products (Menezes Júnior et al., 2013).

Results obtained by Cavalcante et al. (2011) and Nunes et al. (2012) indicate that biofertilizer mitigates the high concentration of salts in irrigation water during the formation of seedlings of jatropha (Jatropha curcas) and neem (Azadirachta indica). Oliveira and Silva (2016) found that coating lettuce seeds with fish-based biofertilizer promoted the growth and development of both shoots and roots of lettuce seedlings, and that the best concentration for seed coating was 50%.

Brazil stands out as a major producer of animal protein, among which fish is particularly prominent on the national stage. The country also has a great diversity of freshwater and marine aquatic species (Sousa et al., 2024). Data from the Brazilian Fish Farming Association indicate that national fish production in 2021 reached 841,005 tons, representing an increase of 4.7% compared with the previous year (PEIXEBR, 2022). This growth was driven by favorable weather conditions, labor availability, increasing demand for fish, and native species with promising zootechnical performance, which significantly contribute to boosting production (Trombeta et al., 2020).

Associated with this production is the high generation of waste, which can reach approximately 65% of the total live weight slaughtered (Sousa et al., 2024). Waste is defined as any material that is not used during production or consumption, has no use or market value, and may cause environmental damage when not properly managed (Pires et al., 2014). In the case of fish, waste consists mainly of viscera, tail, spine, fins, scales, and meat scraps (Valente et al., 2016), which can cause significant environmental, health, and economic damage when no form of reuse or transformation into co-products is adopted (Sousa et al., 2024).

Although research has been conducted to improve the management of fish waste, a large part of the production chain—especially artisanal fisheries and small processing industries—still disposes of this waste improperly, causing environmental problems (Pinto et al., 2017). One of the alternatives that can contribute to solving this problem is composting, which consists of a controlled aerobic process of decomposition and stabilization of organic matter, aiming to obtain a stable, sanitized product rich in humic compounds. Its application to the soil not only poses no risk to the environment but also promotes nutrient recycling for plants (Valente et al., 2017). The products obtained through this process can be used to produce fish-based biofertilizers.

Beneficial effects have been observed in some crops; however, studies evaluating the use of fish-based biofertilizers in pastures are still incipient. Therefore, the objective of

this study was to evaluate the performance of Mombaça grass fertilized with different doses of fish-based biofertilizer.

2 MATERIALS AND METHODS

The experiment was conducted in the municipality of Vilhena, Rondônia, at the geographical coordinates of 12°45'38.24" S latitude and 60°80'37.19" W longitude, at an average altitude of 600 m. According to the Köppen climate classification, the local climate is Am (tropical monsoon), characterized by high rainfall, humid summers, and a short dry season. The average annual rainfall is approximately 2,600 mm.

Before the experiment was established in the greenhouse, soil samples were collected at a depth of 0–20 cm. The soil presented the following chemical characteristics: pH = 5.8; P = 0 mg dm^{-3}; K = 14 mg dm^{-3}; Ca + Mg = 0.7 cmolc dm^{-3}; Al = 0.2 cmolc dm^{-3}; and OM = 11.2 g dm^{-3}. The granulometric composition was: sand = 815 g dm^{-3}, silt = 25 g dm^{-3}, and clay = 160 g dm^{-3}. The soil was collected from the topsoil layer (0–20 cm), broken up, sieved through a 6-mm mesh, and air-dried.

Based on the soil analysis, the soils were corrected and subsequently fertilized with simple superphosphate (390 kg ha^{-1}) and potassium chloride at a rate of 80 kg ha^{-1}, with 60% applied at planting and 40% applied together with urea (250 kg ha^{-1}, administered in three doses after each cut).

Megathyrsus maximum cv. Mombaça was sown directly in plastic pots. During the establishment period, thinning was carried out until five plants per pot remained, and the plants were irrigated by sprinkling. Four cuts were performed: one to standardize the plots 60 days after planting at a height of 5 cm, and three subsequent cuts at a height of 20 cm at 30-day intervals, totaling 150 experimental days. The data presented in this study refer to the average of the three subsequent cuts. Maximum, minimum, and average temperatures during the experiment were 28.2, 16.5, and 22.3 °C, respectively.

The treatments consisted of seven doses of biofertilizer derived from fresh fish waste from fish processing and fillet extraction industries: 2.5, 5.0, 7.5, 10.0, 12.5, 15.5, and 17.5 L ha^{-1}, in addition to a control treatment without biofertilizer (0 L ha^{-1}). Each dose was diluted in 500 mL of distilled water and applied to its respective experimental unit (plastic bucket). The experimental units corresponding to the control (0 L ha^{-1}) received only distilled water.

The experimental units consisted of 12-L plastic buckets, with four replicates per treatment, totaling 32 experimental units in the greenhouse, arranged in a completely

randomized design.

All forage mass within each experimental unit was harvested in the pre-cut condition and weighed using a digital scale. The measurements were then converted to tons per hectare (t ha⁻¹). Canopy height was measured immediately before cutting using a transparency sheet and a ruler graduated in centimeters for each experimental unit.

Morphogenic and structural characteristics were evaluated weekly on three randomly selected tillers per experimental unit. During this period, the following measurements were taken: stem length (from ground level to the ligule of the last expanded leaf), expanding leaves (from the ligule of the last expanded leaf to the apex of the emerging leaf), expanded leaves (length between the ligule and apex of the expanded leaf), senescent leaves (from the apex of the senescent leaf to the furthest point of dead tissue), and the number of living leaves per tiller.

From these measurements, the following variables were calculated:

- Leaf Appearance Rate (LAR): number of leaves emerging per tiller divided by the number of days in the evaluation period (leaves·tiller⁻¹·day⁻¹).

- Leaf Elongation Rate (LER): sum of all leaf blade elongation per tiller divided by the number of days in the evaluation period (cm·tiller⁻¹·day⁻¹).

- Phyllochron (FIL): interval between the appearance of two successive leaves (days·leaf⁻¹·tiller⁻¹).

- Stem Elongation Rate (SER): sum of all stem elongation per tiller divided by the number of days in the evaluation period (cm·tiller⁻¹·day⁻¹).

- Final Leaf Blade Length (FLBL): average length of all expanded leaves on the tiller, measured from the apex to the ligule (cm).

- Leaf lifespan (LSL): Period of time between the appearance of a leaf and its death;

- Number of Live Leaves (NLL): Average number of elongating and elongated leaves per tiller, disregarding senescent leaves from each tiller.

Data on tiller population density were obtained by counting the number of tillers (NT) within each experimental unit (bucket). Tiller counting was performed only in the pre-cut condition.

A completely randomized design was used with eight treatments and four replicates for each plot. The collected data were submitted to analysis of variance and, when significant, the treatment means were submitted to regression analysis using the statistical program ASSISTAT version 7.6 (SILVA, 2012), according to the statistical model (Eq. 1):

$$Y_{ij} = \mu + B_i + C_j + e_{ij} \tag{1}$$

Where:

Y_{ij} = Observed value of cut height 'j', subjected to block 'i';

μ = A constant associated with all observations;

B_i = Effect of block 'i', with i = 1, 2,...,5;

C_j = Effect of cut height 'j', with j = 1, 2, 3 e 4;

e_{ij} = Effect of uncontrolled factors (experimental error), which by hypothesis has a normal distribution, mean zero, and variance 2.

3 RESULTS AND DISCUSSION

Table 1 presents the regression analysis of Mombaça grass fertilized with different doses of fish-based biofertilizer. The morphogenic and structural characteristics that showed significant differences ($p < 0.05$) were leaf appearance rate, leaf elongation rate, leaf lifespan, and stem elongation rate.

Table 1

Regression analysis of morphogenic and structural characteristics of Mombaça grass fertilized with different doses of fish-based biofertilizer

| Variable	Trataments								Equation
	0.00	2.50	5.00	7.50	10.00	12.50	15.00	17.50	
Forage yield (t ha^{-1})	9.2	10.4	10.4	10.9	9.9	10.1	11.8	11.8	Y= 11.6
Plant height (cm)	44.1	44.2	43.9	43.9	43.7	44.7	43.7	43.4	Y= 45.5
Morphogenic Characteristics									
LAR	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.05	Y = 0.0493 – 0.0014x – 0.0007x²
LER	1.55	1.73	1.84	2.14	2.25	2.08	1.90	2.05	Y = 1.524 + 0.1059x – 0.0046x²
LLS	113.89	113.89	118.17	109.45	96.84	105.63	106.96	117.97	Y= 125.95 – 8.22x + 0.83x²
Phyllochron	21.0	22.3	22.2	21.6	21.6	21.8	22.0	21.9	Y= 20.9
Structural Characteristics									
SER	0.05	0.04	0.09	0.02	0.10	0.03	0.03	0.03	Y = 0.0445 + 0.0057x – 0.0004x²
NS	8.9	9.5	10.2	9.5	9.7	11.2	10.5	9.5	Y = 9.8
FLBL	18.6	17.6	17.0	18.1	18.8	16.9	18.3	17.3	Y = 18.0
NLL	5.3	5.3	5.3	5.0	5.1	5.0	5.0	5.2	Y = 5.2

Forage yield (t ha-1), Plant height (cm), Leaf emergence rate (LAR) (leaves/shoot/day), Leaf elongation rate (LER) (cm/shoot/day), Leaf lifespan (LLS) (days), Phyllochron (days/leaf/shoot), Stem Elongation Rate (SER) (cm/shoot/day), Number of Shoots (NS), Final Leaf Blade Length (FLBL) (cm), and Number of Live Leaves (NLL).

No significant differences were observed for the variables forage yield, plant height, phyllochron, number of tillers, final leaf blade length, and number of living leaves. This may be due to the slower nutrient release of biofertilizers, which do not provide an immediate effect like mineral fertilizers (Junqueira, 2015). This phenomenon was also observed by Assis (2007), who evaluated the productivity of Brachiaria grass with different doses of chicken litter over time and found that higher productive potential occurred from the second year of application onward. Similarly, Melo et al. (2011) reported that the application of large amounts of organic fertilizer can impede nutrient absorption and soil gas exchange due to the formation of a compacted layer on the soil surface.

A significant effect ($p < 0.05$) of fish-based biofertilizer doses was observed for LAR (Figure 1), which was best described by the quadratic equation $Y = 0.0493 + 0.0014x - 0.0007x^2$. The estimated dose required to achieve maximum LAR was 8.72 L ha^{-1} ($Y = 0.055$ cm).

Figure 1

Leaf appearance rate (LAR, leaves·tiller^{-1}·day^{-1}) of Mombaça grass fertilized with different doses of fish-based biofertilizer
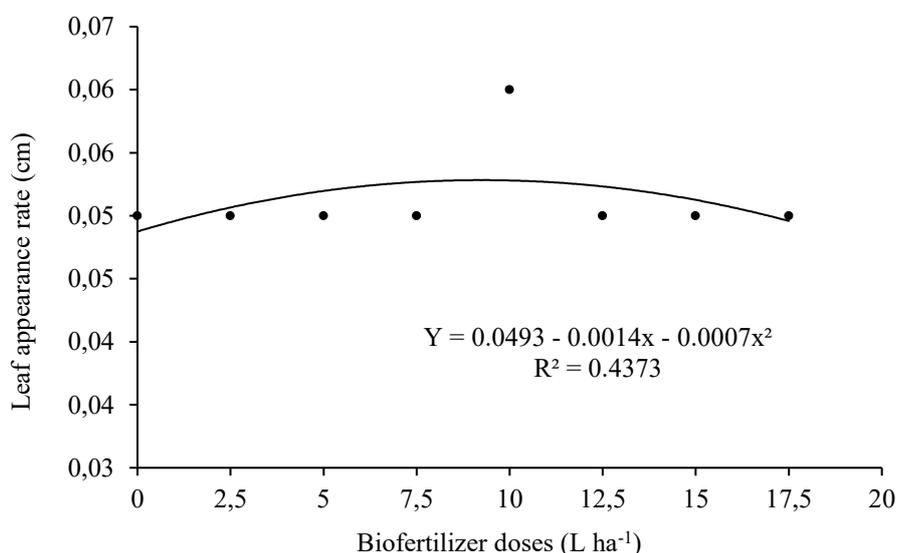
The rates of leaf appearance, leaf elongation, and leaf lifespan are morphogenic factors of tillers, which, under the influence of environmental factors such as light, temperature, water, and nutrients, determine structural characteristics such as the number of leaves per tiller, leaf size, and tiller density, which collectively contribute to the leaf area

index (LAI) of the turf (Gomide et al., 2006).

Organic residues have an indirect effect on forage production by improving the physical and chemical properties of the soil and enhancing microbial and enzymatic activity (Junqueira, 2015). Consequently, they may directly influence production; however, this effect was not observed in the present experiment. LAR is directly related to tiller population density, since the formation of each leaf on the stem triggers the appearance of a new phytomer (Taiz; Zeiger, 2013).

A significant effect ($p < 0.05$) of fish-based biofertilizer doses was observed on LER (Figure 2), which was best described by the quadratic equation $Y = 1.524 + 0.1059x - 0.0046x^2$. The estimated dose required to achieve maximum LER was 11.5 L ha^{-1} (Y=1.95 cm).

Figure 2

Leaf Elongation Rate (LER) (cm/shoot/day) of Mombaça grass fertilized with doses of fish-based biofertilizer

$$Y = 1.524 + 0.1059x - 0.0046x^2$$
$$R^2 = 0.8027$$
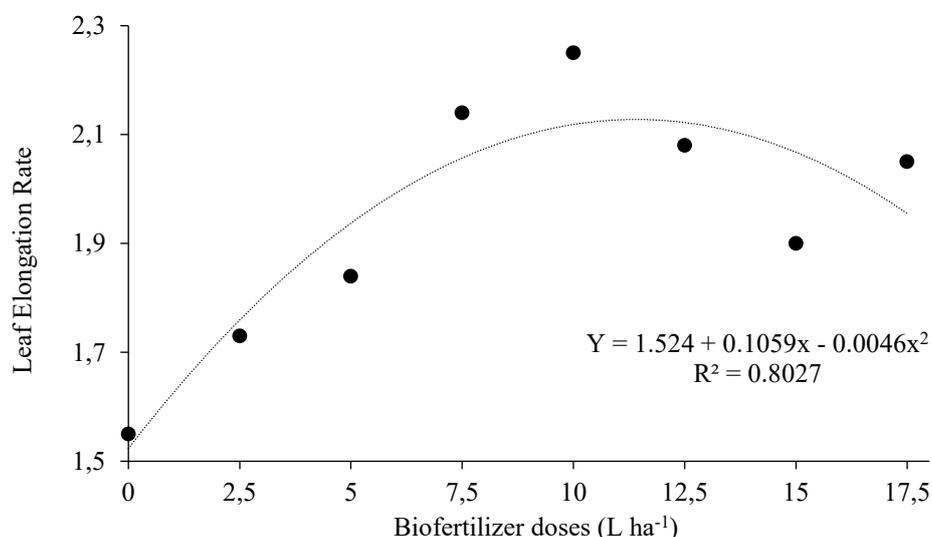
The increase in LER with biofertilizer doses has a positive effect on plant tissue development, as it is directly correlated with forage yield due to the increase in the carbon-to-nitrogen ratio (Alexandrino et al., 2004).

Robson (1988) reported that leaf and stem elongation rates, as well as leaf senescence, are influenced by temperature, light, and season, and also increase with forage availability (Grant et al., 1983). The study by Porto et al. (2014) supports these findings,

showing that average LER values in the fall represented 55% and 75%, respectively, of the values observed in the summer, indicating that reduced water availability in the fall had a more pronounced effect on leaf elongation.

According to Junqueira (2015), when using agricultural residues to fertilize forage plants, it is essential to know both the quantity and quality of these products, i.e., the volume produced and their nutritional composition. These values form the basis for calculating the fertilization requirements of the crop, depending on the desired productivity. While biofertilizers can directly influence crop and pasture yields, this effect was not observed in the present experiment. The direct effect depends on the nutrient content of the biofertilizer and the amount of mineral fertilizer that can be replaced by it (Melo et al., 2011).

Organic fertilizers, due to their slower incorporation into the soil, provide a more gradual nutrient release to plants, which affects the rate of growth and accelerates leaf senescence (Junqueira, 2015).

A significant effect ($p < 0.05$) of fish-based biofertilizer doses was observed on LLS (Figure 3), which was described by the quadratic equation $Y = 125.95 - 8.22x + 0.83x^2$. The estimated dose required to achieve the minimum leaf lifespan was 4.95 L ha^{-1} (Y=105.60 days).

Figure 3

Leaf lifespan (LLS, days) of Mombaça grass fertilized with different doses of fish-based biofertilizer

$$Y= 125.95 - 8.22x + 0.83x^2$$
$$R^2 = 0.3798$$
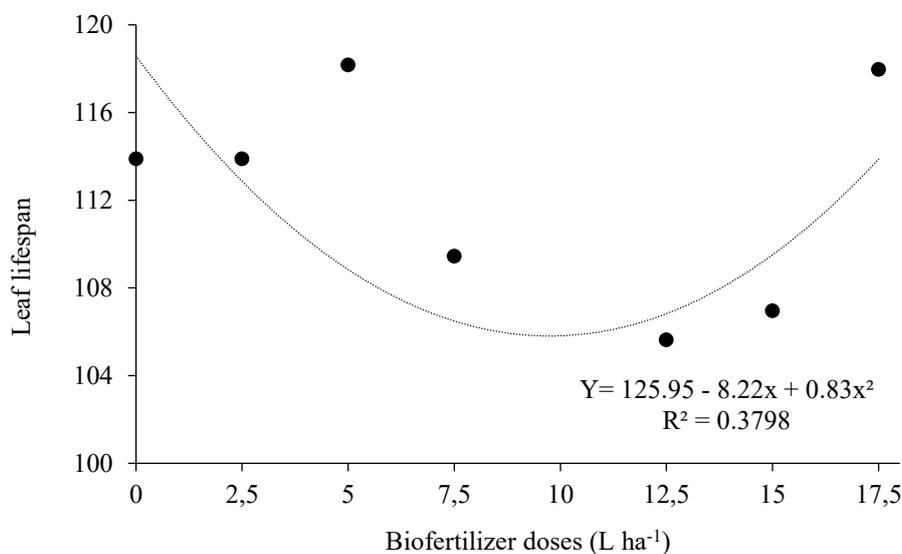
LLS is defined as the time interval between the appearance of a leaf and its senescence, representing the period during which the leaf remains green. It reflects the balance between leaf growth and senescence processes (Grant et al., 1983). LLS may be directly related to LER, since higher tiller density can increase mutual shading, thereby reducing leaf lifespan. Additionally, nitrogen can accelerate leaf senescence, leading to a decrease in LLS (Martuscello et al., 2006).

Leaf responses to environmental stresses affect their metabolic and hormonal levels, triggering either an acceleration or a delay in senescence, depending on the type of stress (Meneses, 2015).

According to Martuscello et al. (2006), senescence represents the final phase of leaf development, beginning after full expansion. Its intensity progressively increases with leaf area due to shading of the leaves located in the lower portion of the stem.

Senescence initially appears in the first-formed leaves, shortly after they reach the LLS period. As reported by Robson (1988), leaves in the lower positions are smaller, resulting in a slower senescence rate compared with the growth and production rate of new tissues. As senescence progresses toward the upper leaves, the overall leaf development gradually decreases.

A significant effect ($p < 0.05$) of fish-based biofertilizer doses was observed on SER (Figure 4), which was described by the quadratic equation $Y = 0.445 + 0.0056x + 0.0003x^2$. The estimated dose required to achieve maximum SER was 8.95 L ha^{-1}.

Figure 4

Stem elongation rate (SER, cm·tiller^{-1}·day^{-1}) of Mombaça grass fertilized with different doses of Amazonian fish-based biofertilizer

$Y = 0.0445 + 0.0057x - 0.0004x^2$
$R^2 = 0.1827$
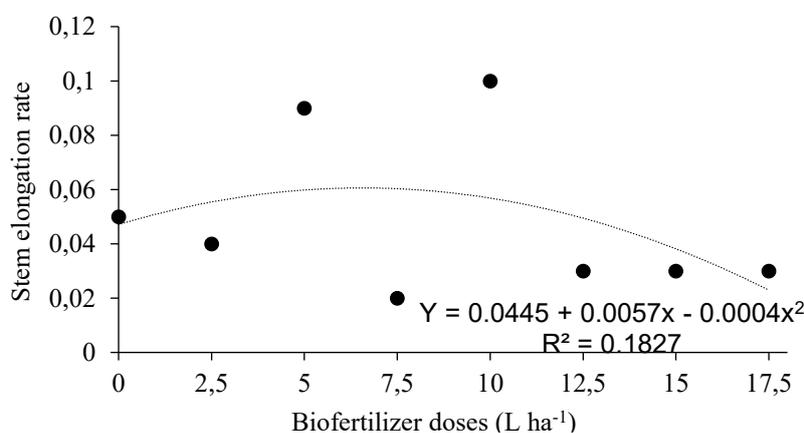
The increase in stem elongation rate (SER) with the application of biofertilizer can be attributed to the greater availability of nitrogen for forage growth and development (Oliveira et al., 2008). This increase in stem elongation is crucial for the forage canopy, as it enhances the capture of photosynthetically active radiation by plant leaves (Pereira et al., 2011).

Stem elongation rate is also a key component because it affects the leaf-to-stem ratio, with its greatest responses being influenced by light intensity (Meneses, 2015). According to Taiz and Zeiger (2013), a reduction in the red/far-red (R/FR) light ratio within the culm stimulates stem elongation by activating light-sensitive proteins, the phytochromes, which mediate this response.

In general, changes in pasture structure and morphogenic composition, driven by the number of green leaves per tiller and the final leaf size, determine the maximum accumulation of green leaf tissue per tiller. According to Lemaire (2001), this variable is critical for the efficiency of light absorption and the photosynthetic capacity of the canopy, and consequently, for overall pasture productivity (Porto et al., 2014).

4 CONCLUSION

The dose required to achieve maximum leaf elongation was 11.5 L ha⁻¹, while 8.72 L ha⁻¹ was required for maximum leaf appearance. Overall, greater leaf emergence and elongation of Mombaça grass occurred with an average dose of 10.11 L ha⁻¹ of fish-based biofertilizer; however, this dose reduced leaf lifespan.

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