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Morphogenetic characteristics and production of *Megathyrsus maximus* cv. Massai under different soil corrections

Características morfogênicas e produção de Megathyrsus maximus cv. Massai sob diferentes correções de solo

Mateus Pereira Sousa[1], Aureliano José Vieira Pires[2], Daniela Deitos Fries[3], Solange Silva de Amorim[4], Nadjane Vieira da Silva[5], Ingridy de Carvalho Dutra[6]

ABSTRACT: This study aimed to assess the productive and physiological characteristics of *Megathyrsus maximus* cv. Massai under different soil corrections. The experiment was performed in a greenhouse using a completely randomized design in a 2 × 5 factorial arrangement, with two liming treatments (without and with) and five NPK fertilization levels (no fertilization, 50%, 100%, 150%, and 200% of the recommended dose), with four replicates. The experiment lasted 56 days. Liming resulted in an increase in the leaf appearance rate (0.21 leaves/day); improved the phyllochron, reducing it to 5.3 days/leaf; increased the number of live leaves (4.8); elevated residual dry mass production by 2.02 g pot^{-1}. Fertilization exhibited a linear increasing effect on leaf appearance rate, stem elongation rate, and number of tillers; showed a quadratic response, reaching peak values for aerial dry mass production (249.6%), residual dry mass (305.7%), root dry mass (192.7%). The use of liming is recommended in association with 200% of the fertilization dose with NPK (suggested by the 5th approximation), due to the increase in dry mass production and morphogenic characteristics of *Megathyrsus maximus* cv. Massai.

Keywords: Fertilizers; Grass; Production.

RESUMO: Este estudo teve como objetivo avaliar as características produtivas e fisiológicas do *Megathyrsus maximus* cv. Massai sob diferentes correções do solo. O experimento foi realizado em estufa utilizando um delineamento inteiramente casualizado em um arranjo fatorial 2 × 5, com dois tratamentos de calagem (sem e com) e cinco níveis de adubação NPK (sem adubação, 50%, 100%, 150% e 200% da dose recomendada), com quatro repetições. O experimento teve duração de 56 dias. A calagem resultou em um aumento na taxa de aparecimento de folhas (0,21 folhas/dia); melhorou o filocrono, reduzindo-o para 5,3 dias/folha; aumentou o número de folhas vivas (4,8); e elevou a produção de massa seca residual em 2,02 g por vaso. A adubação apresentou um efeito linear crescente sobre a taxa de aparecimento de folhas, a taxa de alongamento do caule e o número de perfilhos; mostrou uma resposta quadrática, atingindo valores máximos para a produção de massa seca da parte aérea (249,6%), massa seca residual (305,7%) e massa seca das raízes (192,7%).Recomenda-se o uso da calagem associada a 200% da dose de fertilização com NPK (sugerida pela 5ª aproximação), devido ao aumento na produção de massa seca e nas características morfogênicas do *Megathyrsus maximus* cv. Massai.

Palavras-chave: Fertilizantes; Grama; Produção.

Corresponding author: Mateus Pereira Sousa
E-mail: mateuspereirampps@gmail.com
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[1] Mestre em Zootecnia pela Universidade Estadual do Sudoeste da Bahia (UESB), Itapetinga (BA), Brasil.
[2] Doutor em Zootecnia pela Universidade Federal de Viçosa (UFV). Professor do Programa de Pós-Graduação em Zootecnia (PPZ) da Universidade Estadual do Sudoeste da Bahia (UESB), Itapetinga (BA), Brasil.
[3] Doutora em Agronomia pela Universidade Federal de Lavras (UFLA). Professora do Programa de Pós-Graduação em Zootecnia (PPZ) da Universidade Estadual do Sudoeste da Bahia (UESB), Itapetinga (BA), Brasil.
[4] Mestra em Zootecnia pela Universidade Estadual do Sudoeste da Bahia (UESB), Itapetinga (BA), Brasil.
[5] Mestra em Zootecnia pela Universidade Estadual do Sudoeste da Bahia (UESB), Itapetinga (BA), Brasil.
[6] Mestra em Zootecnia pela Universidade Estadual do Sudoeste da Bahia (UESB), Itapetinga (BA), Brasil.

1 INTRODUCTION

Cattle farming has played a significant role in Brazil's economic development since its colonization, being widely spread throughout the country due to the favorable climatic conditions for forage production. Currently, Brazilian beef cattle farming holds an important global role, as the country has the largest commercial herd in the world (ABIEC, 2023).

One of the most widely used farming systems in Brazil is the extensive system, which primarily relies on pasture as the main food source for the animals. According to Barros *et al.* (2015), the productive performance of pasture-raised animals is directly related to the quality and quantity of forage available for grazing. Thus, well-managed pastures can meet most of the nutritional requirements of cattle.

Forage quality is directly dependent on the soil's physicochemical factors, with the most influential factor being the hydrogen potential (pH). When the soil pH becomes acidic due to the accumulation of aluminum and hydrogen ions, the availability of most nutrients for plants is reduced (Alvarez; Ribeiro, 1999).

A significant portion of soil faces acidity issues, and one way to address this problem is through liming. This technique involves applying lime to the soil, which increases the pH, reduces aluminum concentration, enhances the availability of nutrients, and releases calcium and magnesium into the soil (Fernandes *et al.*, 2003).

To further increase pasture productivity, fertilization can be applied following liming (Dutra *et al.*, 2025). The use of fertilizers provides nutrients to the soil, increasing their concentration in the substrate and allowing greater absorption by plants. When quality soil is paired with grass species that respond well to environmental conditions, pastures can be made more efficient (Gomide *et al.*, 2020).

One grass species with promising characteristics for dry regions is Massai grass, a cultivar widely used in Brazil due to being the *Megathyrsus* species most resistant to low-fertility soils. It adapts well to edaphoclimatic conditions in transition regions between the semi-arid and caatinga, thanks to its resistance to water deficit and its average dry matter production of about 15.6 tons hectare year^{-1} (EMBRAPA, 2001). These characteristics, along with its high productive response in corrected and fertilized soils, make it an attractive forage option as an alternative to *Urochloa's*, aimed at pasture deferment.

Considering the advancements in the study and improvement of new grass cultivars, current cultivars may potentially respond better to different doses than those suggested by traditional fertilization recommendations.

Thus, this study aims to evaluate the production and morphogenic characteristics of *Megathyrsus maximus* cv. Massai under different liming levels and doses of the NPK fertilization recommendation.

2 MATERIALS AND METHODS

The experiment was conducted in a greenhouse located at the State University of Southwest of Bahia, Campus Juvino Oliveira, in the municipality of Itapetinga, BA, situated at the following coordinates: 15°38'46.00'' S and 40°15'24.00'' W, with an average altitude of 280 m. According to the Köppen classification, the climate in the municipality is of the ‘Cw’ type, mesothermal humid and subhumid warm. The experiment began on October 17, 2023.

A completely randomized experimental design was used, with a 2 x 5 factorial scheme, consisting of two liming levels (with or without liming) and five NPK fertilization levels (no fertilizer, 50%, 100%, 150%, and 200% of the recommended dose), with four repetitions, totaling 40 experimental units. Forty polyethylene pots with a capacity of 12 liters were used to hold the soil.

The soil was collected at a depth of 0 to 20 cm on the Bela Vista farm, in the municipality of Encruzilhada, BA. It was classified as dark red latosol with sandy loam clay texture. Soil samples were taken from various points, then homogenized to create a composite sample, which was subsequently sent to the Department of Agricultural and Soil Engineering at UESB for chemical analysis, as described in Table 1. Following the sampling process, the 40 pots were filled with 12 kg of dry soil each.

Table 1. Chemical analysis of the soil

pH	*** mg/dm^{-3}**				*** cmolc/dm^{-3} of soil**					**%**	
H_2O	P	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+	S. B.	t	T	V	m
4.8	2	0.1	1.0	0.8	1.1	6.1	1.9	3.0	9.1	21	37

S.B: Sum of bases; t: effective cation exchange capacity; T: pH cation exchange capacity; V: base saturation; m: Aluminum saturation.

The methodology used for calculating liming and fertilization followed the recommendations of the Comissão de Fertilidade do Solo do Estado de Minas Gerais, 5th Approximation (Alvarez; Ribeiro, 1999), considering a high technological level for both. Based on the calculations using the base saturation method (Equation 1), it was determined that liming was necessary, using 3.22 tons ha^{-1} of dolomitic limestone.

$$NC = \frac{(V_2 - V_1)}{PRNT} * T \quad (1)$$

Where NC= limestone requirement; T= cation exchange capacity (Ca + Mg + K + H + Al); V2= desired base saturation for culture; V1= current soil base saturation; PRNT = relative total neutralization power of the limestone to be applied. Considering the soil volume present in the pot and its dimensions, approximately 20 g of limestone was used for the treatments with liming.

Following the fertilization recommendations, the amounts of fertilizer applied were: 150 kg ha^{-1} of Nitrogen (N), 110 kg ha^{-1} of Phosphorus (P), and 60 kg ha^{-1} of Potassium (K). Nitrogen fertilization was split into two applications to reduce the risk of losses caused by the high volatility of urea, which was used as the N source. Considering the soil volume in the pots, the dose corresponding to 100% fertilizer application consisted of 0.9 g of N, 0.66 g of P, and 0.36 g of K per pot.

Liming was carried out 40 days before transplanting the seedlings. From this point on, the pots with soil were kept moist at approximately 70% of the field capacity. To determine the field capacity, the methodology described by Dutra *et al.* (2025) was used: three pots with 12 kg of dry soil were weighed, then saturated with water until total saturation was reached. After three days, the pots were weighed again, and these weight values were used to define the soil's maximum water retention capacity. The pots were weighed daily to replenish water and maintain the soil at 70% field capacity.

The planting of *Megathyrsus maximus* cv. Massai was performed using commercial seeds, sown in seedbeds on the same day liming was conducted. After 40 days, the seedlings were transplanted into the pots, with four plants per pot, selecting those with similar characteristics. Twenty-one days after transplanting, a uniformity cut was performed at a height of 10 cm from the soil in all pots to start the experiment.

The first dose of N and the P and K fertilizations were applied on the day of the uniformity cut. The second dose of N was applied together with the first cut of the plots.

The experiment was divided into two periods of 28 days each. At the end of each period, a cut was performed on all plots at a height of 10 cm from the soil, and the samples were stored for subsequent analyses. Throughout the experimental period, maximum and minimum temperatures were recorded using a digital thermo-hygrometer. Morphogenetic and structural characteristics, as well as physiological and biochemical traits and the grass's water use efficiency, were evaluated.

2.1 DRY MASS PRODUCTION AND ROOT VOLUME

In the first cut, only the aerial part of the plants was collected, and they were separated into leaf and stem. At the end of the experimental period, the pots were dismantled to remove the entire plant. Running water was used to remove the soil. Subsequently, the plants were separated into leaf, stem, residue, and root. They were then weighed to determine fresh mass, dried in an oven, and weighed again to obtain the dry mass (DM).

Based on these data, the dry mass production of the aerial part (sum of the first and second cut), as well as the dry mass production of the residue and root, were calculated. The root volume was also determined using a graduated cylinder with a capacity of 1000 mL. The fresh root was introduced, and its volume was obtained by measuring the difference in liquid displacement.

2.2 MORPHOGENETIC AND STRUCTURAL CHARACTERISTICS

Throughout the experiment, two tillers per period were monitored. Every three days, the following were evaluated: the emergence of the leaf apex, stem length, number of leaves, leaf length, and leaf width. Based on this data, morphogenetic and structural characteristics were calculated:

- Leaf appearance rate (LAR, leaves/day): calculated by dividing the number of leaves that emerged on the marked tiller by the regrowth period.
- Phyllochron: obtained as the inverse of LAR (days/leaf).
- Leaf elongation rate (LER, cm/tiller/day): determined by the difference between the final and initial leaf length, divided by the interval of measurements.

- Stem elongation rate (SER, mm/tiller/day): calculated by the difference between the final and initial stem length, measured from ground level to the height of the ligule, and divided by the measurement interval.
- Final leaf size (FLS, cm).
- Total plant length (TPL, cm).

2.3 STATISTICAL ANALYSIS

The data were subjected to analysis of variance (ANOVA) considering liming (Lim), fertilization (Fert), and the Lim X Fert interaction as sources of variation. The means related to liming were compared using the Tukey test, while the means related to fertilization were compared through regression analysis. All analyses were performed using the SAEG® software at a 1% significance level.

3 RESULTS AND DISCUSSION

A significant interaction for liming ($P < 0.01$) was observed in the variables leaf appearance rate (LAR), phyllochron, and the number of live leaves (NLL) (Table 2). Liming proved beneficial for all these observed variables, with LAR showing an increase of 0.02 leaves/day in the treatments with liming, indicating that the rate of new leaf emergence per day was higher with the inclusion of liming.

Phyllochron, in contrast, presented lower values in the treatment that received liming, with a difference of 0.5 days/leaf. This variable is inversely proportional to LAR, as it evaluates the number of days until the emergence of a new leaf. Thus, the smaller the interval, the faster the plant emits leaves (Oliveira *et al.*, 2020). The number of live leaves was also higher with liming. The presence of limestone in the soil resulted in a total of 0.5 additional leaves compared to treatments without limestone application.

These results relate the plant's leaf development to the improvement in nutrient availability and soil pH provided by liming. These benefits for plant development were also observed by Bossolani *et al.* (2021, 2022), who reported that liming practices led to improved root growth and distribution, increased photosynthetic activity, better water use, and higher chlorophyll content.

Abdalla *et al.* (2022) compiled data on the effects of liming in different soil types, grasses, and geographic regions. They concluded that liming creates an adequate environment for pastures to reach their growth potential, resulting in increased dry mass production.

There was a significant interaction for fertilization ($P < 0.01$) in the variables leaf appearance rate (LAR), leaf elongation rate (LER), stem elongation rate (SER), final leaf size (FLS), number of tillers (NT), and total plant length (TPL) (Table 2).

The regression equation for LAR exhibited an increasing linear trend, whereby each additional percentage unit of the fertilization recommendation resulted in an increase of 0.0001 leaves/day in LAR (Figure 1A). The total observed variation was 0.3 leaves/day.

Table 2. Morphological characteristics of *Megathyrsus maximus* cv. Massai under different soil corrections and percentages of the recommended NPK fertilization

Variable	Liming		Fertilization[1]					SEM	P-value		
	Without	With	0	50	100	150	200		Lim.	Fert.	Lim.*Fert.
LAR[2]	0.19	0.21	0,19	0,20	0.20	0.21	0.22	0.0071	0.0002	0.0024	0.6655
PHY[3]	5.8	5.3	5.8	5.8	5.6	5.3	5.4	0.2814	0.0088	0.3152	0.9520
LER[4]	4.7	4.8	3.1	4.5	4.7	5.5	5.7	0.1893	0.0263	<0.0001	0.2243
SER[4]	0.2	0.2	0.1	0.2	0.2	0.3	0.3	0.0263	0.0500	<0.0001	0.8488
FLS[6]	39.7	39.2	30.9	38.9	40.7	43.6	43.0	1.6359	0.6350	<0.0001	0.1829
NLL	4.3	4.8	4.2	4.4	4.5	4.8	4.8	0.1593	0.0003	0.0250	0.6934
NT	49.3	50.4	23.1	41.8	53.3	63.1	67.9	4.2734	0.6920	<0.0001	0.0286
TPL[6]	65.9	64.0	50.6	62.3	66.2	72.6	73.2	1.8308	0.1108	<0.0001	0.0818

LAR: leaf appearance rate; PHY: phyllochron; LER: leaf elongation rate; SER: stem elongation rate; FLS: final leaf size; NLL: number of live leaves; NT: number of tillers; TPL: total plant length. SEM: Standard error of the mean; Lim.: liming; Fert.: fertilization; Lim.*Fert.: interaction between liming and fertilization. [1] Fertilization corresponding to the percentage of the recommendation from the 5th Approximation; [2] Leaves/days; [3] Days/leaves; [4] cm/day; [5] Days; [6] cm.

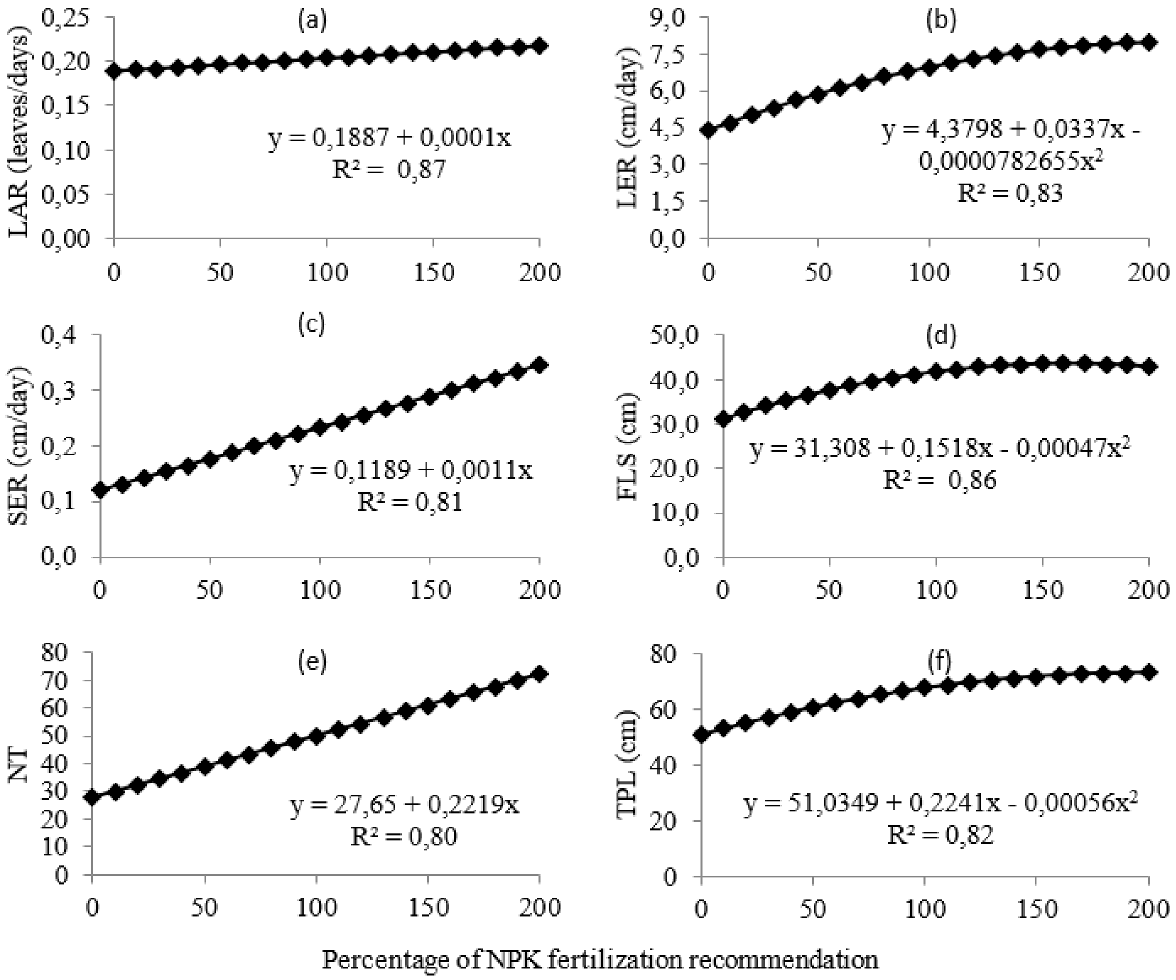

Figure 1. Effects of different soil corrections and percentages of NPK fertilization in the morphological characteristics of *Megathyrsus maximus* cv. Massai: (a) Leaf appearance rate - LAR; (b) Leaf elongation rate - LER; (c) Stem elongation rate - SER; (d) Final leaf size – FLS; (e) Number of tillers - NT; and (f) Total plant length – TPL

The increase in nutrient availability makes the plant's metabolism more active, accelerating growth processes and increasing the number of new leaves emitted per day.

This increase in LAR due to fertilization was observed by several authors (Vasconcelos *et al.*, 2020; Lage Filho *et al.*, 2024; Véras *et al.*, 2024) and is related to the enhanced nutrient availability in the substrate provided by fertilization. Nitrogen (N) is one of the nutrients that influences plant development, as the apical meristem has a high demand for nitrogen compounds (Lage Filho *et al.*, 2024). This is because nitrogen plays a role in the synthesis of new tissues, increases gas exchange, and consequently impacts enzymatic activity, stimulating the elongation of the plant's vegetative components (Lopes *et al.*, 2024).

The regression equation for LER showed quadratic behavior, with a maximum point for the fertilization percentage at a dose of 215%, which corresponded to 8 cm per day (Figure 1B). As observed, up to the evaluated limit of 200% of the recommended fertilization, the plant exhibited an increasing LER, with a total observed variation of 2.6 cm/day.

The LER values are also greatly influenced by fertilization, as increasing fertilizer doses boost leaf growth. Oliveira *et al.* (2020), working with different nitrogen doses (0, 10, 20, 30, 40, and 50 kg of N ha^{-1}) for fertilizing *Megathyrsus maximus* cv. Mombaça, observed that the leaf elongation rate showed a linear growth response with the increase in nitrogen doses. This accelerated leaf elongation is also responsible for reducing the interval between the emergence of new leaves, having a direct relationship with LAR.

The regression equation for SER exhibited a linear increasing trend, whereby each additional percentage unit of the fertilization recommendation resulted in an increase of 0.0011 cm per day in SER (Figure 1C).

Following the effect observed in LAR and LER, the stem also tends to grow with the nutritional availability provided by fertilization. The total observed variation was 0.2 cm/day, a rate similar to that observed by various authors (Oliveira *et al.*, 2020; Camargo *et al.*, 2021; Lopes *et al.*, 2024) and is related to the growth of the apical meristem induced by fertilization.

Stem growth can lead to changes in the leaf-to-stem ratio, a parameter used to measure dry mass production and nutritional quality of the plant. There is a chance that stem growth might respond more significantly to fertilization than leaf growth. Lima *et al.* (2019) observed this phenomenon in their study, where stem elongation in *Urochloa ruziziensis* was more responsive to fertilization than leaf growth. This imbalance can increase the fiber content of the aerial part of the plant due to the higher proportion of stems and consequently reduce the nutritional quality of the grass.

The regression equation for FLS showed quadratic behavior, with a maximum point for the fertilization percentage at a dose of 162.3%, which corresponded to 43.6 cm of FLS (Figure 1D). The difference in length between the treatment without fertilization and the dose corresponding to the maximum point was 12.7 cm.

The increase in FLS with the inclusion of fertilization was also observed by Yiberkew *et al.* (2020) in their study, where this growth was associated with the increased availability of nutrients provided by fertilization.

The reduction in FLS from fertilization to 162.3% may be related to the increase in the number of tillers (Figure 1E). Possibly, with the emission of many tillers, leaves tend to shorten due to their greater quantity on the plant. Thus, FLS began to decrease after reaching the maximum point due to the tendency of an increase in the number of tillers, a factor that also resulted in a reduction in plant height.

The regression equation for the number of tillers showed a linear increasing trend, whereby each additional percentage unit of the fertilization recommendation resulted in an increase of 0.2219 tillers (Figure 1E). The total observed variation was 44.8 tillers.

This linear growth effect on the number of tillers due to fertilization was also observed by Filho *et al.* (2024) in their study. They evaluated establishment fertilization strategies on the morphogenic, structural characteristics, and productivity of *Urochloa brizantha* cv. Xaraés grass. Three establishment fertilization strategies were tested: Strategy 1: without lime/NPK; Strategy 2: lime + NPK; Strategy 3: natural reactive phosphate. The results indicated that using lime in combination with NPK resulted in superior tillering compared to the other strategies.

The influence of fertilization on the tillering of grass was also observed by Melo *et al.* (2023). They evaluated the impact of phosphorus deficiency and excess on morphogenic and chemical parameters, as well as digestibility, in *Megathyrsus maximus* cv. Zuri. The results revealed that phosphorus deficiency led to a reduction in the number of tillers and the protein content of the grass, along with an increase in lignin content.

The regression equation for TPL exhibited a quadratic behavior, with a maximum point for the fertilization percentage at a dose of 198.4%, which corresponded to a length of 73.3 cm (Figure 1F). The difference in length between the treatment without fertilization and the dose corresponding to the maximum point was 22.7 cm.

Plant height plays an important role in systems where there is competition with weeds. Stem elongation allows grasses to position their leaves higher, aiming to increase light capture (Costa *et al.*, 2022). On the other hand, stem elongation reduces the leaf-to-stem ratio, which influences the digestibility of the grass.

The presence of fertilization in the system directly impacts grass growth. Increasing fertilizer levels result in a final plant height superior to treatments without fertilization. Carvalho *et al.* (2019), working with *Urochloa decumbens* cv. Basilisk subjected to different doses of nitrogen fertilization in a silvopastoral system, observed that increasing nitrogen doses resulted in a linear increase in height. This growth was partially influenced by the availability of nitrogen in the soil. In the plant, this nutrient acts on the multiplication of cellular phytomers and mitotic processes, accelerating physiological maturity.

A similar result was observed by Véras *et al.* (2024) in their study, where they evaluated the effect of potassium fertilization on the morphogenic, structural, and productive characteristics of various cultivars of *Megathyrsus maximus*. The data related to stem elongation indicated that Massai grass, along with other cultivars, exhibited a linear increasing effect for the stem elongation rate in response to increasing potassium doses.

For the data related to the dry mass production of the structural components of the grass, there was a significant interaction for liming ($P < 0.01$) only for the dry mass of the residue (DMR) (Table 3).

The amount of DMR was higher in the treatment that received liming (21.90 g). This can be related to the increase in the number of tillers resulting from the improved soil pH conditions, as well as the greater photosynthetic activity, which leads to a higher LAR and LER, reducing the lifespan of the leaves and producing a larger amount of residue.

There was significant interaction for fertilization ($P < 0.01$) in the variables dry mass of aerial parts (DMA), dry mass of residue (DMR), dry mass of roots (DMRT), and root volume (RTV) (Table 3).

Table 3. Dry mass production of aerial parts (DMA), residue (DMR), root (DMRT), and root volume (RTV) of *Megathyrsus maximus* cv. Massai under different soil corrections and percentages of the NPK fertilization recommendation

Variable	Liming		Fertilization[1]					SEM	P-value		
	Without	With	0	50	100	150	200		Lim.	Fert.	Lim.*Fert.
DMA[2]	38.53	38.05	9.92	31.04	38.71	54.22	57.57	1.5485	0.6278	<0.0001	0.1215
DMR[2]	19.88	21.90	6.19	17.72	20.43	28.18	31.92	1.0859	0.0062	<0.0001	0.0506
DMRT[2]	20.26	18.03	7.51	18.28	20.31	23.77	25.86	1.6118	0.0367	<0.0001	0.2000
RTV[3]	140.50	141.00	72.50	141.25	152.50	155.00	182.50	13.6550	1.0000	<0.0001	0.5850

DMA: Dry mass production of aerial parts; DMR: Dry mass production of residue; DMRT: Dry mass production of root; RTV: Root volume. SEM: Standard error of the mean; Lim.: liming; Fert.: fertilization; Lim.*Fert.: interaction between liming and fertilization. [1] Fertilization corresponding to the percentage of the recommendation from the 5th Approximation; [2] g pot^{-1}; [3] Milliliters (mL).

The regression equation for aerial DM production showed quadratic behavior with a maximum point for the fertilization percentage at a dose of 249.6%, corresponding to 60 g DM pot^{-1} (Figure 2A). Within the evaluated fertilization range up to 200% of the recommendation, the plant exhibited an increasing quantity of DM, with a total observed variation of 47.65 grams.

A similar situation occurred with the regression equation for residue DM production, which showed quadratic behavior with a maximum point for the fertilization percentage at a dose of 305.7%, corresponding to 35.1 g DM pot^{-1} (Figure 2B). Therefore, up to the maximum recommended percentage used (200%), the trend was an increase in the quantity of dry mass of aerial parts, with a total variation of 25.73 grams.

Thus, it is possible to associate the production of aerial DM with the quantity of residue DM, as the residue is contained in the aerial part. If there is an increase in the number of leaves and stems, there is also greater residue production, which reflects the effect of fertilization on grass development.

Several studies indicate the positive effect of fertilization on increasing dry mass production in grasses. For example, Costa *et al.* (2021) worked with five different nitrogen doses (0, 75, 125, 175, and 225 mg dm^{-3}) and sought to evaluate the effect of nitrogen fertilization on the morphogenic, structural, and productive characteristics of *Urochloa brizantha* cv. Marandu. Production-related variables indicated that increasing the fertilizer dose resulted in linear growth in aerial DM production, with an increase of 0.188 g DM for each unit of nitrogen added.

Sacramento *et al.* (2019), working with *Megathyrsus maximus* cv. Aruana under different nitrogen doses (0, 75, 150, and 225 kg ha^{-1}), found positive results in DM production, with increases due to higher nitrogen doses used. Nitrogen possibly acts as a controlling factor for various plant growth and development processes, resulting in increased biomass through carbon fixation.

Following the trend observed in the aerial part, the roots also showed an increase in production with the inclusion of fertilization. The regression equation for root DM production exhibited quadratic behavior, with a maximum point for the fertilization percentage at a dose of 192.7%, corresponding to 25.3 g DM pot^{-1} (Figure 2C). The difference in root DM production between the treatment without fertilization and the dose at the maximum point was 17.79 grams.

The regression equation for root volume, in turn, showed a linear increasing trend, whereby each additional percentage unit of the fertilization recommendation resulted in an increase of 0.4675 mL in root volume (Figure 2D). The total observed variation was 110 milliliters.

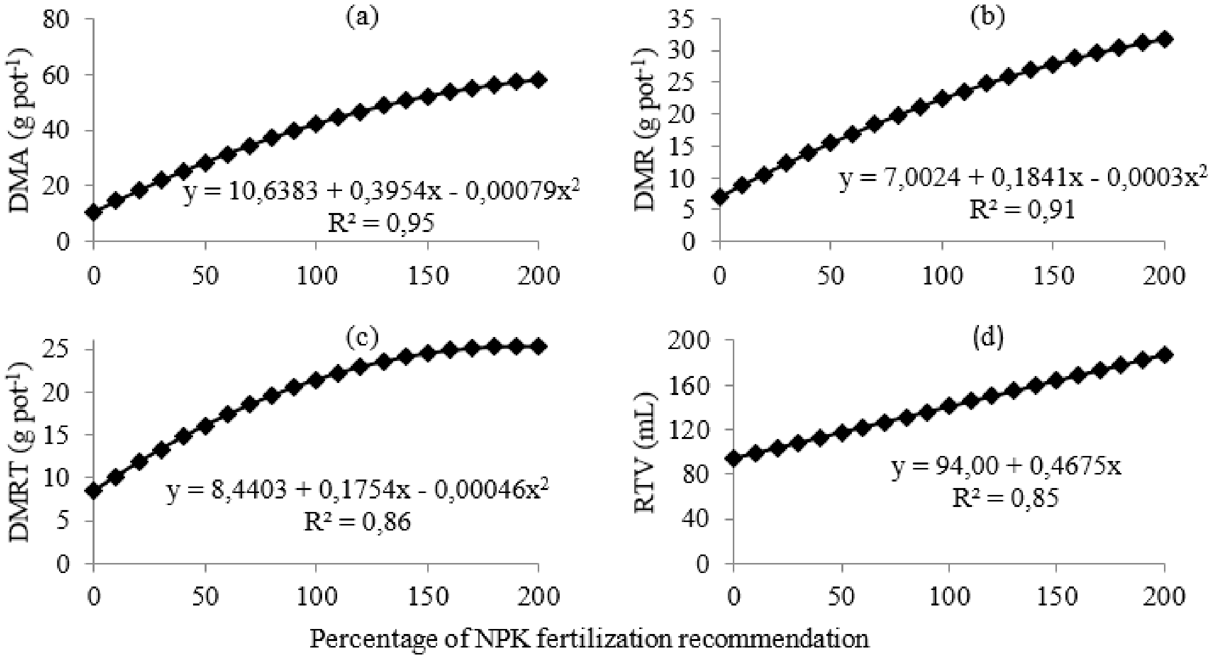

Figure 2. Effects of different soil corrections and percentages of NPK fertilization in the dry mass production of *Megathyrsus maximus* cv. Massai: (a) Dry mass production of aerial parts - DMA; (b) Dry mass production of residue - DMR; (c) Dry mass production of roots - DMRT; and (d) Root volume - RTV

This root growth effect was observed by Costa *et al.* (2021), who worked with *Urochloa brizantha* cv. Marandu under different nitrogen doses (0, 75, 125, 175, 225 mg dm^{-3}). They also obtained a regression equation with quadratic behavior for root DM production. According to the authors, this phenomenon can be explained by the increase in aerial biomass, resulting in a compensatory effect where the increase in aerial biomass leads to root mass growth to support aerial plant growth.

The rapid initial growth of the roots may reflect the plant's response to enhance the absorption of nutrients in the soil, which justifies the linear growth of root volume as fertilization increases (Figure 2D). Lage Filho *et al.* (2024), working with different fertilization strategies for Xaraés grass, found that the grass exhibited greater root elongation when it received fertilization with NPK combined with liming. This demonstrates that nutrient availability in the soil also drives root development, aiming to increase the contact surface for greater nutrient absorption by the plant.

4 CONCLUSION

It is recommended to use liming combined with 200% of the NPK fertilization dose suggested by the 5th Approximation, due to its contribution to increased dry mass production and morphogenic characteristics of *Megathyrsus maximus* cv. Massai.

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