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Potassium Fertilization Alters the Morphogenetic, Structural, and Productive Characteristics of *Panicum maximum* Cultivars

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Abstract: The objective was to evaluate the effects of potassium fertilization on the morphogenetic, structural, and productive characteristics of *Panicum maximum* (cvs. Tanzania, Quênia, Mombaça, Zuri, Massai, and Tamani). The design was in randomized blocks with four doses of potassium (K) 0, 205, 410, and 820 mg dm^{-3}, divided into 5 applications. The analyzed variables were leaf appearance rate (LAR), leaf elongation rate (LER), stem elongation rate (SER), leaf senescence rate (LSR), leaf life span (LLS), phyllochron (PC), number of live leaves (NLL), final leaf length (FLL), tiller population density (TPD), and forage mass (FM). LAR increased by 0.00216 leaves tiller on day-1 (p = 0.0354) and LER increased by 0.00980 cm tiller on day-1 for each milligram of K (p = 0.0402). There was an increase in FLL of 0.16, 0.08, and 0.07 days for the cultivars Mombaça, Massai, and Tamani, respectively, for each milligram of K applied (p = 0.0034). The TPD of the cultivar Tamani increased linearly by 0.074 tillers/pot for each milligram of K (p = 0.0226), and the cultivar Massai showed a quadratic behavior. The TPD of the other cultivars was not influenced by the increase in the K doses. For forage mass (FM), the cultivars Mombaça and Quênia increased by 0.16 and 0.39 g DM/pot for each milligram of K added to the soil. The cultivars Tanzânia, Zuri, Massai, and Tamani showed maximum point at doses of 261.35, 279.45, 300.57, and 275.86 mg dm^{-3} K, respectively. Potassium fertilization linearly increased leaf appearance and elongation, with maximum productivity reached at a K dose of 430 mg dm^{-3}, except for the cultivars Mombaça and Quênia, which responded up to a K dose of 820 mg dm^{-3}.

Keywords: forage mass; growth dynamics; *Megathyrsus maximus*; potassium

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1. Introduction

Agriculture has been facing a major paradigm: increasing food production with limited land and water resources to meet the needs of the annually growing human population. The increase in production would not be possible without the introduction of mineral, natural, and organic fertilizers [1]. However, the use of mineral fertilizers must be optimized, taking into account harvest estimates, maximum crop yield, and climate and soil conditions [2]. Otherwise, fertilization with nutrients alone without understanding these factors would lead to a waste of resources and low production efficiency [3].

Forage plants differ in their ability to acquire and utilize nutrients, which is influenced by both plant physiology and soil nutrient availability [1]. Moreover, commercial forage cultivars derived from *Panicum maximum* (syn. *Megathyrsus maximus*) exhibit varying nutrient demands [4–7].

Nitrogen (N), phosphorus (P), and potassium (K) are essential macronutrients for all crops, but their availability varies across soil types. While significant advances have been made in understanding N [8–10] e P [11,12] fertilization for forage grasses, there remains a knowledge gap regarding K [13], particularly in Quartzsandy Neossolos. These soils are prone to erosion due to their low water and nutrient retention capacity, limiting their agricultural potential. Given the importance of K for forage grasses and the challenges posed by Quartzsandy Neossolos, further research is needed to optimize K fertilization strategies in these soils. This soil class represents 11% of Brazilian soils and 15% of Cerrado soils [14].

Potassium plays a crucial role in forage plants, influencing root growth, root system architecture, cellular functions [15], homeostatic control of plants, internal transport of substances and energy, response mechanisms to biotic and abiotic stresses and control of plant growth and metabolism [16,17], ATP production during photosynthesis, and photosynthetic CO_2 fixation [18].

Forage grasses can adjust to the K content of the soil to some degree. These adaptations primarily involve modifications in the shoot, which can result in increased tissue death or growth stimulation [5]. Understanding these adaptive mechanisms through morphogenesis can provide valuable insights into optimizing K use in forage production. By studying morphogenesis, it is possible to describe the processes of development and growth, ecological adaptation, and how these processes modify the forage production of a given species [19]. Systematically investigating the responses of forage plants to K use can fill a significant gap in nutritional management, supporting the adoption of sustainable production practices, especially in regions where low natural fertility only limits production.

As K fertilization can change the morphophysiology of forages [20], it is important to evaluate their responses to elucidate how the supply of this nutrient in the soil can change plant growth patterns. This study hypothesizes that increasing K fertilization will enhance plant growth and forage yield. To meet this need, the goal was to look at the morphogenetic, structural, and productive traits of *Panicum maximum* cultivars that were fertilized with various amounts of K.

2. Material and Methods

2.1. Experiment Location

The experiment was carried out in pots in a greenhouse at the Brazilian Agricultural Research Corporation—Embrapa Gado de Corte (20°26′48″ S 54°43′07″ W, 538 m above sea level), Campo Grande—Mato Grosso do Sul (MS), Brazil. The experimental period was from July 2019 to January 2020, totaling 164 days of evaluation.

According to the Köppen classification, the climate is a rainy tropical savanna, corresponding to the Aw subtype, characterized by a seasonal distribution of rainfall, with a well-defined occurrence of the dry period during the colder months. Average annual rainfall is ~1500 mm, of which 80% falls during the 7-month wet period (October–April). The experimental soil was classified as Typical Quartzarenic Neosol—Quartzipamments [21], collected in Campo Grande—MS. The collection was made in a layer of 0–20 cm depth, passed through a sieve with a 4 mm mesh, dried in the air (air-dried fine earth), and again passed through a sieve with a 2 mm mesh. Soil samples were collected for chemical analysis and texture determination before fertilization. The soil texture had a physical structure composed of 5.47% clay, 4.66% silt, and 89.87% sand (Table 1).

Table 1. Soil chemical properties at the beginning of the experimental period in the 0 to 20 cm layer.

Soil	pH	Ca^{2+}	Mg^{2+}	K^+	Al^{3+}	H + Al	S	T	t	V	m	MO	P
Qps	$CaCl_2$	-------------------------cmol$_c$ dm^{-3}-------------------------								-----------%----------			mg dm^{-3}
	5.79	1.70	1.07	0.15	0.00	1.15	2.92	4.07	2.92	71.7	0.00	1.46	44.6

Qps: Quartzipsamments; c: Carga; S: sum of bases (Ca + Mg + K); T: potential cation exchange capacity (CEC) (H + Al + Ca + Mg + K); t: effective CEC (Ca + Mg + K + Al); V: Base saturation [(S/T) × 100]; m: Aluminum saturation [Al/t] × 100; Ca and Mg Mehlich III; K and P Mehlich I; Al and KCl 1mol; H + Al Phmeter by SMP buffer solution; MO: Modified South Dakota Organic Matter.

Before sowing, fertilization was performed with 54.68 mg dm^{-3} of phosphorus (P), 1378 mg dm^{-3} of dolomitic limestone, 67.63 mg dm^{-3} of sulfur (S), 11.02 mg dm^{-3} of zinc (Zn), 11.02 mg dm^{-3} of copper (Cu), 2.76 mg dm^{-3} of boron (B), and 1.37 mg dm^{-3} of molybdenum (Mo). Then, the soil remained incubated for 40 days with moisture close to field capacity to facilitate the reaction of nutrients with the soil. Nitrogen fertilization (N, urea) was 100 mg dm^{-3}, carried out 30 days after germination, and subsequently reapplied in five applications supplied together with potassium (K), according to the proposed treatments.

2.2. Treatments and Experimental Design

The experimental design was in randomized blocks in a 6 × 4 factorial scheme, with six cultivars (cvs) of *Panicum maximum*: Tanzania, Quênia, Mombaça, Zuri, Massai, and Tamani, and four doses of potassium (K): 0, 205, 410, and 820 mg dm^{-3}, with three repetitions. The KCl solution was applied using a graduated pipette according to the proposed treatments. The first cut was performed 52 days after sowing, and the other cuts were performed every 28 days. KCl doses were applied immediately after each cut, totaling five cuts during the experimental period.

Each experimental unit consisted of a pot containing 2.55 dm^{-3} of soil. Sowing was carried out on 30 July 2019, and 50 seeds were used per pot. Thinning was performed from the 15th day after sowing and carried out weekly until reaching six plants per pot. Irrigation was conducted whenever necessary, with enough water to keep the soil moisture close to field capacity.

2.3. Morphogenic, Structural, and Productive Characteristics

The morphogenetic and structural characteristics of the forage canopy were evaluated using a tagged-tiller technique. Two tillers per experimental plot were identified with colored threads and measured weekly using a ruler graduated in cm. Every seven days, the height of the pseudoculm, the extended tiller, and the length of each leaf were taken. These measurements were used to determine the following variables, according to [22]: leaf appearance rate (LAR, leaves tiller day^{-1}), leaf elongation rate (LER, cm tiller day^{-1}), stem elongation rate (SER, cm tiller day^{-1}), leaf senescence rate (LSR, cm tiller day^{-1}), leaf life span (LLS, days), phyllochron (PC, days), number of live leaves per tiller (NLL), and final leaf length (FLL, cm).

All tillers of each experimental unit were counted to evaluate the tiller population density (TPD). The first evaluation was carried out on the 45th day after sowing, and the others, with an average interval of 28 days between them, before each cut, totaling five evaluations.

The height of the residue for cutting established for the larger plants (Tanzania, Quênia, Mombaça, and Zuri) was 20 cm and the smaller ones (Massai and Tamani) at 15 cm from the ground level. After the last sampling, the residue was cut close to the ground. The forage mass (FM) cut in each of the pots and in each cut was placed in a paper bag, identified, and subsequently dried in a forced circulation oven at 55 °C until constant weight and weighed on an analytical balance. The sum of the mass of each pot in all cuts obtained the forage production of each cultivar at each evaluated K dose.

2.4. Statistical Analysis

All results were submitted for analysis. The data were subjected to analysis of variance, and when significant for cultivars and K doses, as well as their interactions, the cultivars were compared using a Tukey's test, using an ExpDes package, and the N doses to the study of regression at the 5% probability level using an Epr and Easynls package. All analyses were performed using R software version 3.6.1 (R Development Core Team, 2019).

3. Results

3.1. Morphogenic Variables

There was an interaction between cultivars and applied K doses for the variables SER and LSR ($p < 0.001$; Table 2). The SER showed linear behavior for most cultivars, except for Mombaça, which showed an average of 0.12 cm tiller day^{-1}, regardless of the dose used. In the absence of potassium fertilization and the inclusion of 205 mg dm^{-3} of K, cv. Mombaça had the highest values of SER. At the highest evaluated dose, 820 mg dm^{-3} of K, cv. Tamani showed higher SER and cv. Mombaça had the lowest value (Table 2).

Table 2. Interaction between *Panicum maximum* cultivars and increasing doses of potassium (K, mg dm^{-3}) for morphogenetic variables.

Cultivars	Doses of K (mg dm^{-3})				Equation	R^2
	0	205	410	820		
				SER (cm tiller day^{-1})		
Tanzania	0.03 b	0.07 ab	0.12	0.18 ab	$y = 0.03 + 9.13 \times 10^2x$	99.33
Quênia	0.05 b	0.09 ab	0.13	0.21 ab	$y = 0.05 + 9.33 \times 10^2x$	99.95
Mombaça	0.14 a	0.15 a	0.15	0.15 b	$y = 0.12$	-
Zuri	0.06 ab	0.11 ab	0.14	0.19 ab	$y = 0.07 + 7.39 \times 10^2x$	98.14
Massai	0.02 b	0.05 b	0.10	0.19 ab	$y = 0.02 + 1.03 \times 10^3x$	99.48
Tamani	0.03 b	0.08 ab	0.14	0.26 a	$Y = 0.02 + 1.41 \times 10^3x$	99.53
				LSR (cm tiller day^{-1})		
Tanzania	2.07 b	0.85	0.59	0.33	$y = 1.99 - 0.02x + 1.08 \times 10^2x^2$	96.39
Quênia	2.67 a	1.08	0.64	0.73	$y = 2.59 - 0.04x + 1.73 \times 10^2x^2$	97.86
Mombaça	2.00 b	0.78	0.53	0.19	$y = 1.92 - 0.03x + 1.03 \times 10^2x^2$	96.29
Zuri	1.64 bc	0.72	0.54	0.26	$y = 1.58 - 0.02x + 7.6 \times 10x^2$	96.27
Massai	1.37 c	0.75	0.54	0.21	$y = 1.18 - 0.01x$	88.70
Tamani	1.28 c	0.68	0.68	0.36	$y = 1.10 - 4.93 \times 10^3x$	81.57

SER = stem elongation rate; LSR = leaf senescence rate; The letters differ from each other in the columns by Tukey's test at 5% significance.

The LSR showed a quadratic behavior for the Tanzania, Quênia, Mombaça, and Zuri cultivars and a linear behavior for the Massai and Tamani cultivars, increasing < 0.01 cm tiller/day for each milligram of K. In the absence of potassium fertilization, the Quênia cultivar showed higher LSR, and the other cultivars showed no difference in LSR with the addition of potassium fertilization (Table 2).

The PC, LAR, and LER showed positive linear behavior, with an increase of 0.13 days, 0.00216 leaves tiller day^{-1}, and 0.00980 cm tiller day^{-1} for each milligram of K, respectively. The LLS showed quadratic behavior (Table 3).

A higher PC was found for the cv. Mombaça ($p = 0.000$), with 25.58 days. The highest LAR and LLS were found for cv. Tanzania ($p = 0.011$), with 0.49 leaves tiller day^{-1} and 70.89 days, respectively. The LER showed significance by the F test; however, it did not show a difference between the means for Tukey, showing a higher numerical mean for cv. Quênia ($p = 0.035$), with 1.37 cm tiller day^{-1} (Table 4).

Table 3. Morphogenic variables of *Panicum maximum* cultivars under increasing doses of potassium fertilization.

Variables	Doses of K (mg dm^{-3})				Equation	R^2
	0	205	410	820		
PC	10.53	17.63	21.94	32.72	y = 11.21 + 0.13x	99.42
LAR	0.12	0.21	0.31	0.48	$y = 0.12 + 2.16 \times 10^3x$	99.93
LER	0.35	0.83	1.30	1.97	y = 0.41 + 0.01x	99.03
LLS	101.22	52.61	34.97	21.86	$y = 99.29 - 1.19x + 4.43 \times 10^3x^2$	98.74

K = potassium; PC = phyllo chron; LAR = leaf appearance rate; LER = leaf elongation rate; LLS = leaf life span.

Table 4. Morphogenic variables of different cultivars of *Panicum maximum*.

Variables	Cultivars de *Panicum*						SEM	Value *p*
	Tanzania	Quênia	Mombaça	Zuri	Massai	Tamani		
PC	17.87 b	17.23 b	25.58 a	21.13 b	21.46 ab	20.84 b	1.070	0.000
LAR	0.49 a	0.18 b	0.30 ab	0.28 ab	0.26 ab	0.16 b	0.067	0.011
LER	1.20	1.37	1.20	1.01	0.95	0.92	0.113	0.035
LLS	70.89 a	44.36 bc	46.00 bc	59.85 ab	51.28 bc	44.12 c	3.841	0.000

SEM = standard error of the mean; PC = phyllochron; LAR = leaf appearance rate; LER = leaf elongation rate; LLS = leaf life span. The letters differ from each other in the lines by Tukey's test at 5% significance.

3.2. Structural and Productive Variables

There was an interaction between *Panicum maximum* cultivars and increasing doses of K for FLL (Table 5). The FLL had a quadratic behavior for Tanzania, Quênia, and Zuri cultivars. For Mombaça, Massai, and Tamani, there was an increase of 0.16, 0.08, and 0.07 cm per milligram of K, respectively. In the absence of potassium fertilization, the Mombaça cultivar showed the highest FLL. At the dose of 205 mg dm^{-3} of K, the cultivars Tanzania, Zuri, Mombaça, and Quênia presented the highest FLLs. At the dose of 410 mg dm^{-3} of K, the cultivar Tanzania had the highest FLL, and at the dose of 820 mg dm^{-3} of K, the cultivars Tanzania and Quênia had the highest FLLs (Table 5).

Table 5. Interaction between *Panicum maximum* cultivars and increasing doses of potassium (K, mg dm^{-3}) for final leaf length (FLL).

Cultivars	Doses of K (mg dm^{-3})				Equation	R^2
	0	205	410	820		
Tanzânia	22.85 ab	40.49 a	55.12 a	69.23 a	$y = 22.68 + 0.50x - 1.31 \times 10^3x^2$	99.97
Quênia	16.53 b	35.39 a	51.97 ab	69.85 a	$y = 16.30 + 0.53x - 1.25 \times 10^3x^2$	99.96
Mombaça	29.93 a	36.16 a	42.64 b	56.72 b	y = 29.60 + 0.16x	99.91
Zuri	20.02 ab	39.57 a	48.40 ab	63.08 ab	$y = 20.82 + 0.45x - 1.21 \times 10^3x^2$	99.20
Massai	18.38 ab	22.01 b	23.74 c	31.85 c	y = 18.21 + 0.08x	98.34
Tamani	11.40 b	14.65 b	17.67 c	24.16 c	y = 11.40 + 0.07x	99.98

The letters differ from each other in the columns by Tukey's test at 5% significance.

Number of live leaves (NLL, leaves) of different cultivars of *Panicum maximum* are different ($p = 0.005$). Tanzania and Zuri presented the highest NLL among the evaluated cultivars (3.05 and 3.08); Quênia, Mombaça, and Massai presented intermediate values (2.74, 2.94, and 2.80, respectively) with no difference between them, while the Tamani cultivar was the grass with the lowest distributed NLL (2.68).

The NLL showed quadratic regression about K doses. Tanzânia and Zuri cultivars had the highest NLL values, with 3.05 and 3.08 leaves, respectively (Figure 1).

TPD did not show linear or quadratic regression for the cvs. Tanzania, Quênia, Mombaça, and Zuri, with averages of 27.19, 41.24, 28.36, and 31.34 tillers per pot, respectively.

The cv. Massai showed quadratic behavior, and cv. Tamani increased linear behavior, with an increase of 0.074 tillers/pot for each milligram of K (Figure 2).

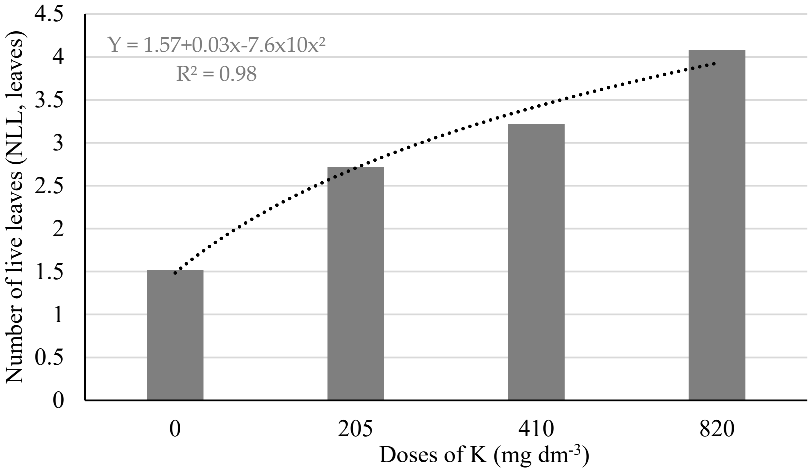

Figure 1. Number of live leaves (NLL, leaves) increasing doses of potassium (K, mg dm^{-3}).

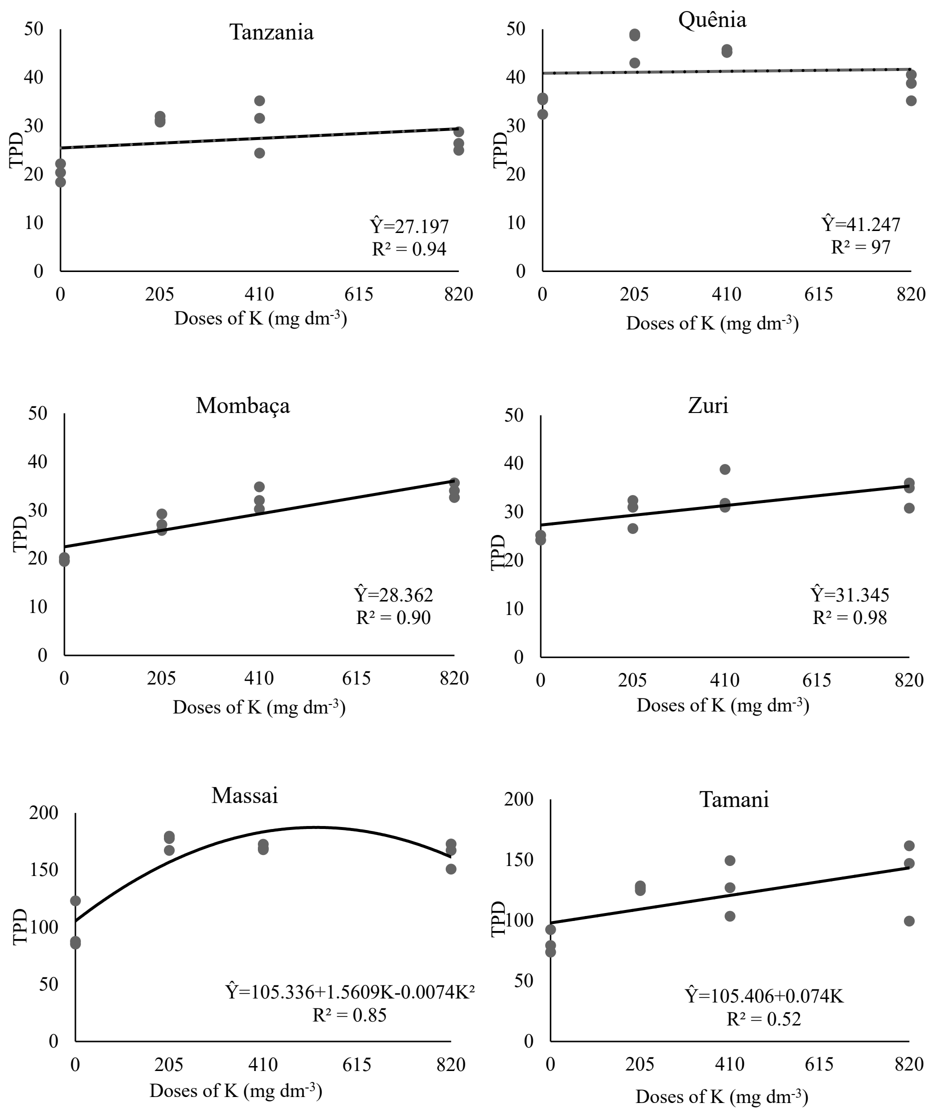

Figure 2. Population density of tillers of *Panicum maximum* cultivars submitted to increasing doses of potassium (K, mg dm^{-3}).

Tanzania, Quênia, Zuri, Massai, and Tamani cultivars responded quadratically to increasing doses of K for FM. Cultivar Mombaça showed a linear behavior at increasing doses of K, increasing 0.16 g of FM/pot for each milligram of K. In the absence of potassium fertilization, the cultivar Mombaça showed higher FM. At the dose of 205 mg dm^{-3} of K, the Quênia, Mombaça, and Zuri cultivars showed the highest FM. For the dose of 410 mg dm^{-3} of K, the cultivars Quênia and Zuri showed the highest values, and for the dose of 820 mg dm^{-3} of K, the highest FM was found in the cultivar Quênia. The lowest FM values were found for the Massai and Tamani cultivars (Table 6).

Table 6. Interaction between *Panicum maximum* cultivars and increasing doses of potassium (K, mg dm^{-3}) for forage mass (FM, g/pot).

Cultivars	Doses of K (mg dm^{-3})				Equation	R^2
	0	205	410	820		
				FM (g/pot)		
Tanzânia	15.72 c	42.82 b	46.47 b	48.37 d	$y = 17.49 + 0.60x - 2.58 \times 10^2x^2$	94.50
Quênia	30.79 ab	49.30 a	54.50 a	67.30 a	$y = 31.94 + 0.39x - 1.09 \times 10^3x^2$	97.63
Mombaça	33.69 a	48.26 a	47.44 b	62.77 b	$y = 36.45 + 0.16x$	90.64
Zuri	28.07 b	48.56 a	55.28 a	54.73 c	$y = 28.81 + 0.52x - 2.25 \times 10^3x^2$	98.62
Massai	16.97 c	30.54 d	34.38 d	36.38 f	$y = 17.62 + 0.32x - 1.27 \times 10^3x^2$	97.78
Tamani	18.54 c	36.06 c	41.11 c	41.62 e	$y = 19.29 + 0.43x - 1.83 \times 10^3x^2$	98.00

The letters differ from each other in the columns by Tukey's test at 5% significance.

4. Discussion

The increase in SER is undesirable in most cases, as it reduces the leaf/stem ratio and negatively affects grazing efficiency. The SER showed a positive linear behavior with increasing K doses (Table 2). In this case, stem elongation may be related to maintaining the plant's support structure [23]. Without potassium fertilization or at a dose of 205 mg dm^{-3}, cv. Mombaça had a higher SER, which is probably related to its structure, larger leaves, and thicker stems. Already at high doses of K, cv. Tamani showed an increase in SER, probably due to competition for light between tillers. The plant elongated the stem as a mechanism for the leaves to be exposed in the upper stratum of the canopy.

Leaf senescence increases considerably when plants are subjected to fertilization, due to greater tissue flow [24]. Cultivars Massai and Tamani showed positive linear behavior for LSR with K doses. This same linear behavior was seen for the variables LAR and LER. As the leaves age, the released nutrients are exported to other developing organs, such as new buds, young leaves, or seeds, which leads to greater reproductive success [25] and leaf renewal. In this process, the use of potassium fertilizer, combined with a higher frequency of application, results in greater availability of nutrients and greater use of other nutrients, especially nitrogen, favoring its allocation to cell growth and expansion characteristics [13,26].

With accelerated leaf renewal due to fertilization, LLS is expected to be lower, that is, there is the appearance of one leaf and senescence of another, and this flow of tissues generates a reduction in the lifespan of the leaves. Generally, the LLS is higher when there is an absence or excess of K, when the plants' leaves remain alive longer, to the detriment of the expansion of new leaves. Among the cultivars, Tamani had the lowest LLS, probably due to greater tissue flow and tillering.

The LAR and the phyllochron are highly interconnected variables, as the higher the appearance rate, the shorter the emergence time between two consecutive leaves. The increase in the leaf appearance rate is positively associated with tillering, since for each new leaf, there is the formation of a new bud with the potential for the development and formation of a new tiller [27]. The cv. Tanzania stood out with higher LAR, LLS, NLL, and FLL, this is an important response, as leaves are the most photosynthetically active component, capable of promoting increments in the growth rate of forage plants [28].

The cultivars Tanzânia, Zuri, Massai, and Tamani showed quadratic behavior, with maximum productivity at doses of 261.35, 279.45, 300.57, and 275.86 mg dm^{-3} of K, respectively, presenting higher production per mg of K applied when going from dose 0 to dose 205 mg dm^{-3}. All cultivars exhibited increased FM with higher K doses, but the rate of increase followed the law of diminishing returns [29]. As K dosages increased, FM and other morphogenetic variables increased as well, but at a slower rate. It is important to recognize this quadratic response to the application of K, given the acquisition costs of this input for the production system.

Mombaça and Quênia grasses exhibited over 20% higher production at 820 mg dm^{-3} K compared to 410 mg dm^{-3}, showing themselves to be highly responsive to potassium fertilization. These responses are likely due to the higher nutritional demands of these cultivars, which require optimal nutrient levels to reach their full productive potential. Similar results for forage mass were reported by references [13,28], confirming the positive impact of K on Mombaça grass growth and productivity.

The interaction between the results of the morphogenic and structural variables provides clarification for the lower FM found in the Massai and Tamani cultivars (Table 6). These cultivars are smaller when compared to the other evaluated cultivars; however, they have a greater number of leaves and tillers, which can be evidenced by the higher TPD of these cultivars [30] (Figure 2). According to [31], the height of smaller cultivars is compensated with greater tillering, and this behavior can be explained due to the compensatory mechanism tiller size/population density [22]. When there is an increase in tillering, competition for light between tillers intensifies, and there is an increase in stem accumulation [32].

The compensation mechanism was not sufficient for FM to also be compensated. The lower LLS and higher LSR observed for these cultivars may explain the lower FM. Cultivars with LLS present higher FMs at the end of the growing period, when LSR does not increase at the same rate [33].

5. Conclusions

Potassium fertilization positively impacts morphogenetic, structural, and productive traits in *Panicum maximum* cultivars. All cultivars exhibited a linear increase in leaf appearance and elongation with increasing K doses. However, specific responses varied among cultivars. Massai and Tamani showed increased tillering but lower leaf expansion rates. Quênia, Mombasa, and Tanzania had greater leaf emergence and forage mass, while cv. Zuri exhibited the highest number of live leaves. Mombaça and Quênia demonstrated significant increases of 20% in forage mass at the highest K doses, while Tanzania, Kenya, Zuri, Massai, and Tamani achieved maximum productivity at doses of 261.35, 426.43, 279.45, 300.57, and 275.86 mg dm^{-3} of K, respectively.

Further investigation into the interactions between potassium and other nutrients, such as nitrogen and phosphorus, may provide a more comprehensive understanding of nutritional management in *Panicum maximum* cultivars, as well as the dynamics of other nutrient extraction as a function of increased potassium. In addition, longitudinal studies evaluating the effect of different fertilization regimes under varying climatic conditions may provide valuable data on the sustainability of K use in the long term.

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