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Calcium and magnesium silicate in the production of Mombasa grass

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Highlights: "Use of silicated sources in forage fertilization" and is important because "It evidences that silicated sources despite being utilized to increase tolerance against some pathogens, under conditions only of nutrient supply there is no benefit from the use of sources.

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ABSTRACT - Silicon has been used in several ways to improve plant growth and development; however, there are few experimental results, especially for tropical grasses. Thus, the objective of this work was to evaluate the effects of applying calcium and magnesium silicate on the growth, structure, and herbage mass of Mombasa grass. A completely randomized design was used in a 3 x 3 factorial arrangement with 4 replications and 2 duplicates for replications. The experimental treatments corresponded to two doses of silicon (1,000 and 2,000 kg/ha) and control (0 kg/ha) over 3 growth cycles. The variables evaluated were plant height, number of tillers, specific leaf area, herbage mass, leaf mass, stem mass, the mass of dead material, and root mass. The application of silicate was not able to modify the variables studied. Considering the soil studied, the application of silicate is not recommended to increase the productivity of Mombasa grass, but similar longer-term studies are needed on soils with low Ca and Mg levels.

Keywords: Beneficial nutrient; *Megathyrsus maximus*; Silicon.

INTRODUCTION

Although Silicon (Si) is not an essential element for plants (Dias et al., 2017), it is considered a beneficial nutrient (Haynes et al., 2017), which can confer several benefits for plants, such as increased growth and plant production (Oliveira et al., 2015), greater resistance to insect and disease attack (Haynes et al., 2017), higher photosynthetic rate of plants (Brennecke et al., 2013), tolerance to water and saline stresses (Oliveira et al., 2013), besides to have its application considered a clean technology within the environmental sustainability.

Despite being an element of great abundance in the Earth's crust, the vast majority of soils in the Brazilian Cerrado are highly intemperate and consequently poor in Si available to the plants, making the fertilization containing silicon necessary for the agriculture (Korndörfer et al., 2010), especially in grasses, species considered accumulators of Si (Campos et al., 2014). Plants considered accumulators of Si are those that contain 10% to 15% of silicon oxide in their tissue (Cunha et al., 2012).

In soil, Si is absorbed by plants in the form of monosilicic acid (H_4SiO_4) along with mass flow (Brennecke et al., 2017). The beneficial effects of Si are related to indirect actions for their deposition in the leaves, resulting in greater rigidity of the tissues (Cunha et al., 2012), consequently improving the photosynthetic capacity due to the upright position of the leaves, improving the capacity solar absorption (Brennecke et al., 2017).

The benefits of Si can be observed in the growth and production of many grasses (Cunha et al., 2012). However, despite the several studies that have been performed with silicon for improvement in plant growth and development (Cunha et al., 2012; Dias et al., 2017; Oliveira et al., 2015), little is known about the benefits for tropical forage grasses.

The species *Megathyrsus maximus* cv*.* Mombasa is among the most used forage in Brazilian pastures and has a high demand for soil fertility, making it a suitable species to evaluate the benefits of soil fertilization with silicate in tropical grasses. For this reason, the objective of this study was to evaluate the source of silicon in the growth, structure, and herbage mass of Mombasa grass.

MATERIAL AND METHODS

The experiment was carried in Araguaína-TO, under the greenhouse (07º 12' 28"S and 48º 12' 26" W). The region is classified as Cerrado-Amazônia forest ecotone, with an Aw-type climate (Alvarez et al. 2013) with maximum temperatures of 40 ºC and minimum of 18 ºC, relative humidity with a mean of 76% and annual precipitation of 1,800 mm, with the dry season (june to september) and rainy (October to May). Evaluations started in september 2017 and finished in November, totaling 84 days.

The soil used as substrate is classified as Quartzipsamment Entisol (=Neossolo Quartizarênico) (Embrapa, 2018), where it was collected in the layer 0.00-0.20 m deep. The soil had a sandy texture (Sand: 89.35 dag/kg; Silt: 0.65 dag/kg e Clay: 10.0 dag/kg) with the following chemical attributes (tests according to the procedure of Silva 2009): pH ($CaCl_2$): 4.54; organic matter: 6.02 g/kg; Ca^{2+}: 2.47 $cmol_c/dm^3$; Mg^{2+}: 1.19 $cmol_c/dm^3$; Al^{3+}: 0.04 $cmol_c/dm^3$; K^+: 8.0 mg/dm^3; P: 7.48 mg/dm^3.

A completely randomized design was used in a 3 x 3 factorial arrangement with four replications and two duplicates for replications, totaling in 72 experimental units. The experimental treatments corresponded to combinations of the doses of the silicon (1,000 and 2,000 kg/ha) and control (0 kg/ha) associated with plant growth three cycles. As experimental units consisted of pots (with 3dm^3 volume) filled with 5 kg of soil per pot. The silicon source (calcium silicate and magnesium) contained in its composition: 25% Ca, 34.9 CaO, 6% of Mg, 9.9% of MgO, 10.5% of Si, and 21.4% of SiO_2.

The sowing occurred in September, 30 days after application of silicate and incubation period of the soil, and this was periodically moistened. Together with sowing, fertilization was performed, according to soil analysis and the need for culture (Sousa and Lobato, 2004), of 80 kg/ha of P_2O_5 (single superphosphate), 40 kg/ha by K_2O (potassium chloride) and 20 kg/ ha of N (Urea). After seedling emergence, the thinning was performed, leaving 5 plants per pot. For the covering fertilization, performed at each 28-day cycle, 60 kg/ha was applied of N (Urea) and 60 kg/ha by K_2O (potassium chloride).

It was established that every 28 days of the previous cut would be performed assessments with data collection and herbage cut. The height of plants was measured with a ruler graduated in centimeters. The population density of tiller expressed in tillers per pot was performed using manual counting.

The herbage mass was determined through of total weight of the fresh herbage collected at 10 cm away from the soil, subsequently, the material was taken to the laboratory for the separation of the morphological components in live leaf, live stem, and dead material. Each component was dried separately in a forced-draught oven at 55°C for 48 h then weighed, for the determination of leaf mass, stem mass and mass of dead material. The sum of the dry mass of the morphological components resulted in an herbage mass expressed in g/pot. In the same sample, 30 units of fresh leaves 10 cm long were used, where the green leaf area was obtained by measuring the width of the center of the leaf with the aid of a ruler (cm), thus, the leaf area was calculated as a result of multiplying the area and length of the leaf (cm^2), thus, the specific leaf area was calculated as described by Gomes et al. (2020), the ratio of green leaf area to dry weight of that area expressed in cm^2/g.

At the end of the experiment, the plants were collected and separated the aerial part of the roots. To obtain the roots, we proceeded to wash in a sieve of 2 mm of opening, subsequently were identified and taken to the forced-draught oven at 55°C during 72 h for determination of the root mass.

Initially, the data were evaluated for normality (Shapiro-Wilk) and homoscedasticity (Levene). Test F was applied to the data and when significant the Tukey test was used ($p \leq 0.05$).

RESULTS

The analysis of variance showed that there was an interaction between the factors herbage mass, and of the leaf mass, stem mass, and dead material mass (Table 1). The variables plant height and tillers had significance only as a function of the cycle evaluated.

Table 1- Summary of the analysis of variance of variables plant height, tillers, specific leaf area, herbage mass, leaf mass, stem mass, dead material mass, and root mass of Mombasa grass plants submitted to silicate doses.

SV	Mean square values								
	GL	PH	Tillers	SLA	HM	Leaf	Stem	DM	RM
Rates	2	1034.0 ^{ns}	365.5 ^{ns}	2018.4^{ns}	1.22^{ns}	0.54^{ns}	0.07^{ns}	0.01*	35.4
Cycle	2	23.5*	12.1*	957.8^{ns}	36.07*	31.1*	0.93*	0.22*	-
R x C	4	24.7 ^{ns}	6.3^{ns}	600.4^{ns}	4.96*	2.45*	0.32*	0.001*	-
Error	63	13.6	7.2	775.2	0.87	0.6	0.08	0.004	41.4
CV(%)	-	7.9	17.1	11.0	15.1	13.9	46.1	80.3	32.8

*Significant at 5% probability level; NS not significant.; SV, Source variation; PH, Plant Height; SLA, Specific leaf area; HM, herbage mass; DM, dead material; RM, root mass.

There was no effect of the doses of silicate ($p > 0.05$) on the height and number of tillers of Mombasa grass (Figure 1A and 1B). The Heights and numbers of tillers showed the same behavior during the third evaluation cycle, where there was a distinction between growth periods ($p < 0.05$), and for both variables, it was observed that the third cycle resulted in greater superiority.

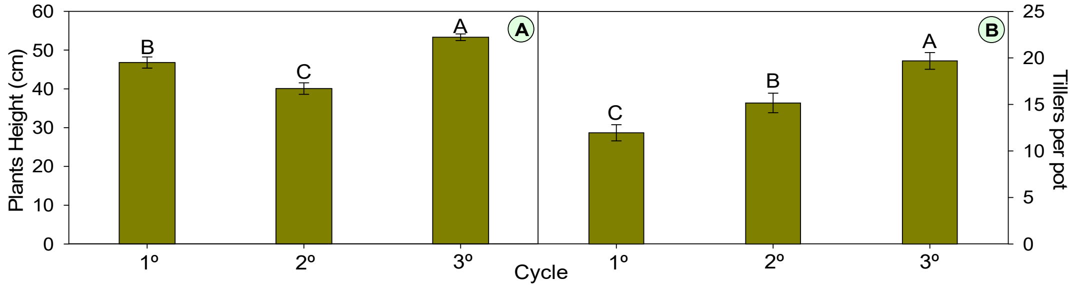

Figure 1. Plants height (A) and the number of tillers (B) of Mombasa grass as a function of silicate application in evaluation cycles. Averages with equal uppercase letters for cycles do not differ significantly by the Tukey test ($p \leq 0.05$).

The highest observed value of the number of tillers in the third cut was 65.02% and 29.73% compared to the first and second cut, respectively, in the average tiller between the doses of silicate (Figure 1B). The tillering dynamics is a process that suffers from both the defoliation of the plant and the availability of nutrients in the soil, in this study the continuous increase in the number of tillers during the experimental period may have been in response to the nitrogen fertilization and cut that was performed every 28 days of evaluation.

The silicate doses applied showed no significant effect ($p > 0.05$) for the variable specific leaf area (Figure 2A). There was no difference between the treatments and cycles evaluated, the plants had a specific leaf area of 267 cm^2/g with a standard deviation of 28 cm^2/g between all the values evaluated.

The doses of silicate exerted an effect on the evaluation cycles ($p < 0.05$) in the herbage mass (Figure 2B). It was observed that the absence of silicate (without application) resulted in higher herbage mass in the first cycle (145 % at dose 1000 kg/ha and 122 % at dose 2000 kg/ha), and in the course of the other periods of growth, second and third cycle, there was no distinction of response between the doses of silicate of 0, 1,000 and 2,000 kg/ha. The third cycle showed the highest herbage mass, where this response is justified by the highest height observed in the third cycle (Figure 1A).

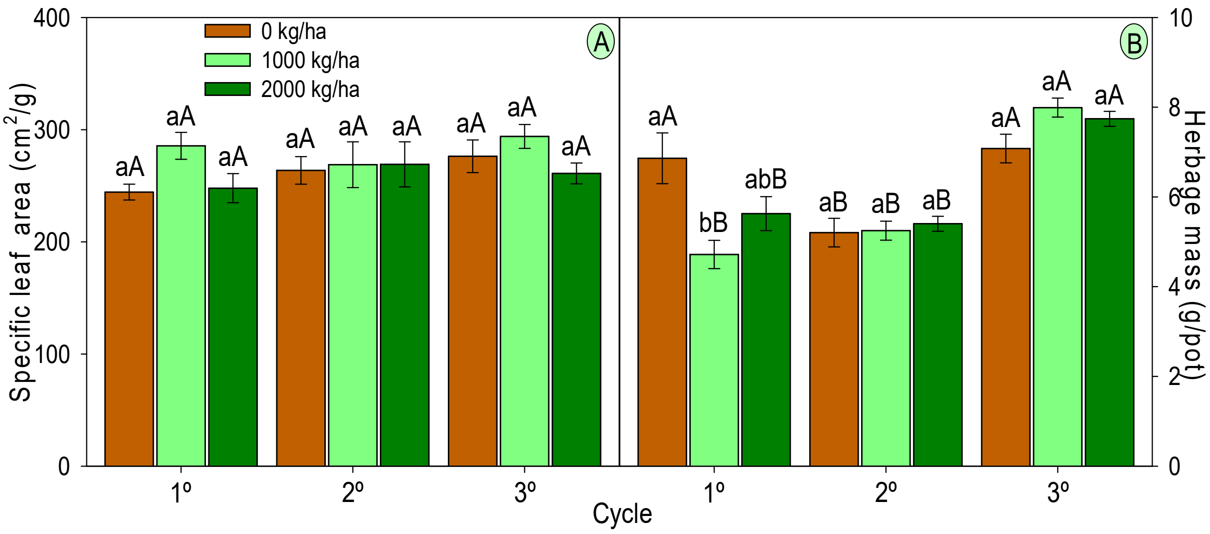

Figure 2. Specific leaf area (A) and herbage mass (B) of Mombasa-grass as a function of silicate application in evaluation cycles. Averages with equal letters, uppercase for cycles, and lowercase for rates, do not differ significantly by the Tukey test ($p \leq 0.05$).

Regarding the morphological components, the doses of silicate showed an effect on the cycle ($p < 0.05$) for leaves mass and stem mass (Figure 3A, 3B, and 3C). It was possible to observe the difference between the doses of silicate only in the first cycle, where the absence of silicate showed the superiority (36% increase) of the results of leaf mass compared to dose 1,000 kg/ha in the first growth cycle, however similar to 2,000 kg/ha dose (Figure 3A). The leaf mass increased in the course of the evaluated cycles, being observed higher values in the third cycle of evaluation, similar behavior was observed for the number of tillers, which increased tillering during the period of growth evaluated in the experiment (Figure 1B).

Concerning the of stem mass, there was an influence ($p < 0.05$) of the doses of silicate only for the first cycle (Figure 3B). The plants cultivated in the absence of silicate were higher than the plants at the dose of 1,000 kg/ha but equal the plants at the dose 2,000 kg/ha of silicate in the first cycle, being the highest values observed during the evaluation period.

In general, the doses of 1,000 and 2,000 kg/ha showed a low increment of the crop in the plant growth periods (Figure 3B). The lower participation of stems in the herbage mass is related to the low elongation of the stem, this effect has a great impact on the leaf and stem ratio, so possibly the application of silicate promotes a higher proportion of leaves.

For the dead material variable, there was the death of leaves only in the first cycle (Figure 3C). Plants that grew in the absence of silicate applied to the soil obtained higher value of dead material and the doses of 1,000 and 2,000 kg/ha showed similarity. However, in the following cycles, there was no occurrence of dead material in any of the treatments evaluated.

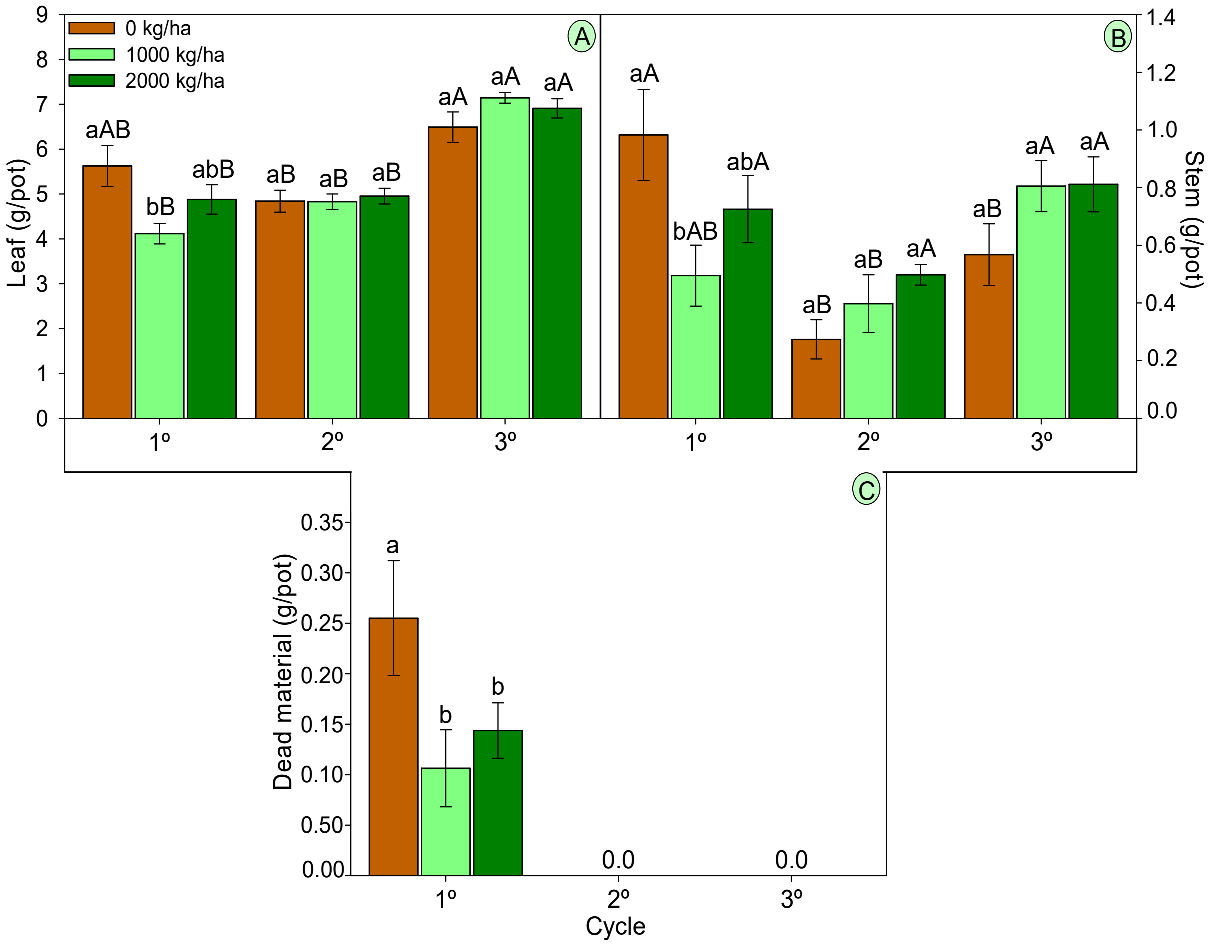

Figure 3. Mass of morphological components: leaf (A), stem (B), and dead material (C) of Mombasa grass as a function of silicate application in evaluation cycles. Averages with equal letters, uppercase for cycles, and lowercase for doses, do not differ significantly by the Tukey test ($p \leq 0.05$).

The root mass was not influenced by the doses of silicate and plant growth cycles ($p > 0.05$). The absence of effect verified for roots is due to the short period that the plant was subjected to defoliation, not being enough to observe the effects of silicate doses for this variable.

DISCUSSION

The lack of response about the application of silicon source doses is in accordance with the results obtained by Sávio et al. (2011), who evaluated the use of different silicon sources (Si) on the agronomic characteristics and leaf contents of Si in U. decumbens cv. Basilisk and M. maximus cv. Mombasa observed differences in the accumulation of Si in the leaves of both grasses, but these responses were not sufficient to affect the development of forage in relation to plant height and dry matter production.

The influence of Si on the blade height of the plants only in the second cut, without influence of the first and third cycles, was observed by Silva et. (2018), in a study with doses of Si to reduce stress in grass plants from U. brizantha "MG5".

In contrast to the results found in the present study, Stocco et al. (2010), evaluating the development of *U. decumbens* and *U brizantha* cv. Marandu (soil-Latossolo) with the use of steel slag, verified effect of the doses of silicate applied in the form of slag on the tillering, thus influencing the development of the grasses. Fortes et al. (2008), evaluating the effect of soil acidity correction, through the application of Ca and Mg silicate levels, in the production of grasses *U. brizantha* cv. Marandu and *M. maximus* cv. Tanzania (soil-Neossolo), also observed an increased number of tillers due to soil saturation and cuts to Tanzania grass, with a reduction of 0.45 tiller per pot for each 1% elevation in base saturation. However, these studies were carried out in soils with low Ca and Mg content, different from the soil used as the substrate in our study.

For plants in a saline stress situation, Yin et al. (2013), mention that its silicate promotes the increase of leaf area and chlorophyll content since it improves the structure of chloroplast. The study did not provoke stress for the plant and the soil had amounts of calcium and magnesium ideal that contributed so that the increase in doses of silicate did not imply in greater increments of herbage mass along with the plant growth cycles, this shows that the increase of mass with the application of silicate can be is significant in conditions that the plant suffers stress.

The absorption of silicon by the plant in relation to the amount applied in the soil suffers variations, where the increase in the doses applied in the soil does not cause the same proportion of absorption through the plant (Melo et al. 2010). Thus, the amount of 2,000 kg/ha may have increased the concentration of silicon in the soil, but it may not have been enough to modify the concentration of this element in the leaf and finally contribute to the increase of the specific leaf area along with the cycles of plant growth.

The little influence of the application of silicate on soil cultivated with Mombasa-grass may have been due to good calcium levels (2.47 $cmol_c/dm^3$) and magnesium (1.19 $cmol_c/dm^3$) in the soil, being considered adequate levels in the soil (Sousa and Lobato, 2004), since although it is a source of silicon, silicates contain calcium and magnesium in its composition.

Considering the good availability of calcium (Ca^{2+}) and magnesium (Mg^{2+}) of the present study, the results showed no influence of silicate on the herbage mass. Corroborating with Melo et al. (2003) and Korndörfer et al. (2010), who worked with silicon application in *Brachiaria brizantha*. According to Campos et al. (2014), this can be explained partly due to the conditions in which these species were studied, that is, they were not subjected to stress, whether biotic or abiotic, because the use of Si in fertilization manifests positively, especially when plants are subjected to some kind of stress.

CONCLUSION

The application of silicate was not able to modify the variables studied. Considering the soil studied, the application of silicate is not recommended to increase the productivity of Mombasa grass.

Are necessary longer periods of evaluation of the effect of silicate doses on herbage mass and studies of the benefits of using this fertilization in environments that provide greater stress for the plant and in soils with low levels of calcium and magnesium.

CRediT AUTHOR STATEMENT

Rubson da Costa Leite: Investigation, Writing - Original Draft and Writing - Review & Editing; **Ana Kassia Ribeiro de Oliveira, Denise Vieira da Silva and Robson da Costa Leite**: Investigation and Writing - Original Draft; **Antonio Clementino dos Santos:** Conceptualization, validation, Supervision and Writing- Reviewing and Editing.

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