LEVELS OF SILICON APPLICATION IN ORYZA SATIVA L. INFLUENCED BY SOIL CORRECTION

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ABSTRACT – Rice has a great capacity to absorb silicon (Si) in the roots, which accumulates in the aerial part of the plant accompanying the flow of transpiration. This study aimed to evaluate how Si and liming affect the phytometry and silicon contents in rice plants (Oryza sativa L.). A total of 5 g of limestone was applied per pot containing 5 kg of soil. The silicon doses were: 0; 0.25; 0.50; 0.75 and 1 g per pot with and without correction, with four replicates. Five seeds were sown per pot and fertilization was performed according to the need of the crop. After two months, the plant material was collected, oven-dried at 60 °C and analyzed for silicon contents. Data were submitted to analysis of variance and regression using the Sisvar software. The results showed that liming provided higher Si uptake by the plants. The plants that were not submitted to liming presented increases of both dry mass and green mass. The silicon doses resulted in a linear increase in the production of shoot green mass and dry mass of rice plants.

Keywords: beneficial element, green mass, liming, rice.

NÍVEIS DE APLICAÇÃO DE SILÍCIO EM ORYZA SATIVA L. INFLUENCIADOS PELA CORREÇÃO DO SOLO

RESUMO – O arroz tem uma grande capacidade de absorver silício (Si) nas raízes, que se acumula na parte aérea da planta, acompanhando o fluxo da transpiração. Este estudo teve como objetivo avaliar como o Si e a calagem afetam a fitometria e o teor de silício em plantas de arroz (Oryza sativa L.). Foi aplicado um total de 5 g de calcário por vaso contendo 5 kg de solo. As doses de silício foram: 0; 0,25; 0,50; 0,75 e 1 g por vaso com e sem correção, com quatro repetições. Cinco sementes foram semeadas por vaso e a fertilização foi realizada de acordo com a necessidade da colheita. Após dois meses, o material vegetal foi coletado, seco em estufa a 60 ° C e o teor de silício foi analisado. Os dados foram submetidos à análise de variância e regressão utilizando o software Sisvar. Os resultados mostraram que a calagem proporcionou maior absorção de Si pelas plantas. Plantas que não foram submetidas à calagem apresentaram aumentos tanto na massa seca quanto na verde. As doses de silício resultaram em um aumento linear na produção de massa de broto verde e massa seca de plantas de arroz.

Palavras chave: arroz, calagem, elemento benéfico, massa verde.

INTRODUCTION

Irrigated agriculture, especially rice production, remains the largest user of water globally, accounting for nearly 70% of the use of drinking water in the world (FAO, 2009). Thus, upland rice farming comes as an alternative to produce rice saving more water. Although it has lower productivity, upland rice cultivation has a great potential to increase productivity through genetic improvement technologies (Peres, 2017). In addition, there are regions where water availability for irrigation is scarce. Lately, interest in upland rice cultivation has been growing because

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of the reduction in water availability (Filho et al., 2006; Lafitte et al., 2006; Heinemann et al., 2009).

Oriza sativa has good adaptability to soils that have received liming due to its adaptation to acid soils and upland conditions (Cobucci et al., 2001; Peres, 2017). Moreover, it has degrees of resistance to various diseases such as brown spot, leaf scald, grain spot and blast on panicles. Grains of O. sativa are classified as long and thin, showing good cooking ability (Castro et al., 2014).

Even considering tolerant varieties or with some degree of resistance, one of the factors that still influence the productivity and affect the rice grain quality is related to the onset of diseases and pests, which, especially in Brazil, are controlled by pesticides or resistant cultivars. However, in some regions, these strategies are not sufficient due to the high incidence of diseases favored by climate conditions and the specialization of pathogens (Santos et al., 2003).

Silicon (Si) has the potential to control diseases in the same degree as fungicides (Datnofft et al., 1997). In this way, the use of Si becomes an alternative of control, since it also increases productivity through several indirect actions, such as defense mechanisms to many diseases and insects. It also causes better morphophysiological conditions due to the smaller opening of the leaf angle, allowing a greater capitation of the light energy and providing erect leaves, reducing self-shading and lodging (Ávila et al., 2010; Epstein, 1994). Silicon also acts as a protection of the epidermis of leaves, and stems and bark of grains, since it accumulates in the cell wall, structuring a double layer of silica-cuticle and silica-cellulose (Raven, 2003).

Epstein (1994) and Korndörfer et al. (1999) pointed out that the application of Si also contributes to the improvement of some soil properties, such as the increase of calcium contents by the addition of calcium silicate, increase in soil pH, base saturation and decrease aluminum saturation, stress inversion to heavy metal toxicity, and the improvement of plant resistance to salinity stress. Therefore, this study aimed to evaluate how Si and liming affect the phytometry and silicon contents in rice plants (Oryza sativa L.).

MATERIAL AND METHODS

The experiment was conducted from June 2017 to January 2018 under greenhouse conditions at the Institute of Agricultural Sciences (ICA), located at the Federal Rural University of Amazonia (UFRA), with latitude 1º27'13.29'' S and longitude 48º26'32.64'' W, in Belém, state of Pará, Brazil. The climate of the region is characterized as humid tropical, with relative humidity of 84%, 3.001 mm of rainfall, 2.338 hours of solar brightness and air temperature of 26.7 °C (Bastos et al. 2002).

The soil is classified as Yellow Oxisol with medium texture, according to the classification of EMBRAPA. Soil chemical and physical attributes were determined and are shown in Table 1.

Table 1 - Chemical analysis of the soil at a depth of 0 to 20 cm

Prof	N	pH	P	K	Na	Ca	Mg	Ca+Mg	Al
Cm	%	water	---------------mg/dm^3---------------			----------------------cmol/dm^3--------------------------			
0-20	0.05	4.6	6	22	14	0.3	0.2	0.5	1.4

The experimental design was completely randomized, distributed in a 5 x 2 factorial scheme with four replications. The factors were: five doses (0; 0.25; 0.50; 0.75 and 1 g per pot) of calcium and magnesium silicate, with and without soil correction.

After weighing and sieving, the soil was dried in the sun and at the end of two weeks, a sample was withdrawn to calculate the water capacity required for the complete action in the performed treatments, which resulted in the addition of 500 mL to reach the field capacity. After this, the soil was distributed in plastic bags with capacity of 10 dm^3, where the 5 dm^3 of soil were added. In the treatments with the soil correction, 5 g of limestone were added to correct the soil acidity based on the chemical analyzes. Pots were incubated for a period of 30 days. At the end of this period the soil pH was 5.8.

The pots that received the doses of pre-defined silicon and diluted in 120 mL of water were properly identified and incubated for a period of 15 days, according to the method described by Medina-Gonzales et al. (1988). After incubation, rice (BRS Esmeralda cultivar) was seeded, placing 5 seeds per pot, which were moistened daily. After one month, fertilization with 0.4 g of urea and 0.25 g of potassium chloride was carried out in all treatments according to the crop and soil requirement. The fertilizers were applied as a solution and mixed to the soil for greater uniformity (Freire et al., 1980).

After two months, the aerial part of the plant was collected for analysis. The variables used for the evaluation of the treatments were: dry matter of the air part (DMAP), green matter of the air part (GMAP) silicon contents in the air part (SL). The plants were thinned, separating the aerial part of each treatment that was weighed obtaining the green mass. Then, leaf washing was performed, as indicated by Carmo et al. (2000), with the objective of eliminating residuals from the application of the defensive agent, by purifying with 30 mL L^{-1} HCl, followed by washing using demineralized water. Samples were dried in a forced air circulation at 60 °C until constant weight was reached. The values of the last weighing determined the dry mass. Subsequently, the material was ground in a willy-type mill with sieves of 0.5- or 1-mm in diameter (20-40 mesh), according to Peres (2017).

The silicon extraction method used was dry digestion, described by Silva et al. (2009), in which the principle consists in the incineration of the vegetal tissue, which loses its organic matter resulting in ashes. Korndorfer et al. (2004) says laboratory materials that will be in contact with Si should be plastic so there is no interaction with other materials such as quartz and glass. This process is done in an electric muffle under manipulated temperature until reaching 500 ºC and maintaining it for three hours.

After cooling, the samples were collected and stored in falcon tubes with 10% NaOH in H_2O (w/v). It was necessary to filter the material due to its poor solubilization. In this way, 50 mL of sodium hydroxide was added to each 50-mL falcon (polyethylene) tube and transferred through the filter paper to other tubes. Thus, 5 mL was transferred to 50-mL plastic cups.

The solutions were: 2.0% ammonium molybdate, 1.0% NaOH, 2.0% oxalic acid, 1.5 mol L^{-1} H_2SO_4, 1000 mg L^{-1} Si (standard solution). Ascorbic acid p.a. was not added because it was contaminated by other elements and caused interference in the test results. In addition, the following concentrations were prepared: 1.0; 2.0; 3.0; 3.0 and 4.0 mg.L^{-1} in H_2O.

A volume of 2.0 mL of the aliquot was completed to 20.0 mL with H_2O. Then 5.0 mL (standard solution of Si) and 1.0 mL of 1.0% molybdate, 1.0 mL of 2.0% oxalic acid, 1.0 mL of 1.5 mol L^{-1} H_2SO_4 were added in each cup containing the samples. According to Korndorfer et al. (2004), after 20 minutes the extracts were analyzed by UV-VIS at 410 nm.

It was possible to obtain the silicon content of shoot values from the absorbance values obtained with the reading and through the formula "Y = 10 X + 0.005", in which, Y is the concentration value and X is the absorbance

The results of the variables were submitted to the Scott-Knott statistical test at 5% probability using the Sisvar software (Ferreira, 1998).

RESULTS AND DISCUSSION

Significant effects were observed with the application of the treatments for all evaluated variables either alone or with interactions (Table 2).

Table 2 – Summary of analysis of variance with coefficient of variation. For the arable: silicon content (SL), dry mass of aerial part (DMAP), green mass of aerial part (GMAP)

FV	G.L.	SL	DMAP	GMAP
Doses	4	**	**	**
Correction	1	**	**	**
Doses x Correction	4	**	**	**
CV%	-	3,44	3,61	3,61

* Significant value at 5.0%. ** Significant value at 1.0% and NS Not significant value.

* Valor significativo al 5.0%. ** Valor significativo al 1.0% y NS Valor no significativo.

The different applied Si contents showed increasing linear behaviour in the different treatments, with higher increases in the treatments that received liming (Figure 1).

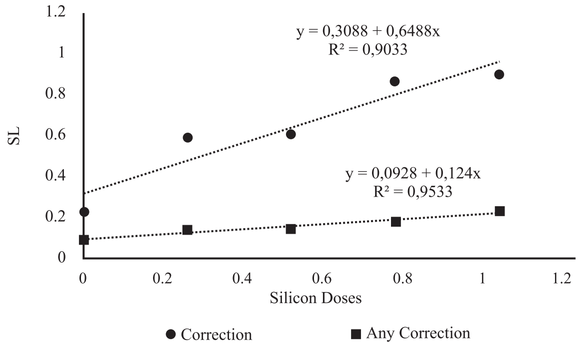

Figure 1 - Silicon levels in the plant considering the doses of Si applied in uncorrected (SC) and pH corrected (CC) soils.

As the Si doses increased, their contents in the plant also increased. This behavior reflects the high capacity of rice to absorb this nutrient, which is translocated in the xylem as H_4SiO_4, accompanying the transpiration flow of the different parts of the plant, accumulating in the aerial part. The largest accumulation of this mineral occurs in the stem and sheath followed by the leaves and the panicle. Si deposits in the epidermal cells below the cuticle of the cell wall, structuring a double layer of silica-cuticle and silica-gel or hydrated amorphous silica ($SiO_2.nH_2O$) and thus becomes immobile in the plant (Mauad et al., 2013); (Oliveira et al., 2007); (Raven, 2003). According to Oliveira et al. (2010), this phenomenon is related to the fact that Si is deposited in plant sites that require greater rigidity. Thus, there is a beneficial effect of silicon by limiting water loss through transpiration and hindering fungal infection on the leaf surface (Faquin, 2005 & Filho et al., 2000).

Ramos et al. (2008) & Sávio et al. (2011) pointed out that silicon sources and foliar applications might influence this accumulation, since the Wollastonite mineral increases the available Si in the soil and the absorption by the rice from the increase of the applied doses. Moreover, Si concentrates in shoot and bark.

In acid soil that had no liming application, the curve growth in the dose interaction with the without limestone factor is smaller in comparison to the increase in the Si content of with limestone soils. This is because the silicon content available in the soil and its absorption by the rice plant are proportional to the changes in the pH of the rhizosphere, because the higher the pH, the higher the ionization degree of H_4SiO_4, the greater the availability of silicon in the soil and their content in the plant, which absorbs it as a non-dissociated molecule (silicic acid) and ionic form (Lilian et al., 2007); (Ma et al., 2001) and (Oliveira et al., 2007).

In addition, in soils with low pH, Si is absorbed in the available form of monosilicic acid (H_4SiO_4), which is adsorbed by Al and Fe oxides. This fact is a beneficial effect of Si, since its addition raises the availability of P (Faquin, 2005; Lilian et al., 2007). Wallace (1992) found that the absorption of anions exceeds that of cations, increasing the solubility of the silicon, due to the elevation of the pH. Moreover, at acidic pH conditions, the monomer (H_4SiO_4) polymerizes to form amorphous silica precipitates (Iler, 1979), which can cause loss of soluble Si.

The green and dry mass showed an increasing linear behavior up to the last dose of silicon (Figure 2).

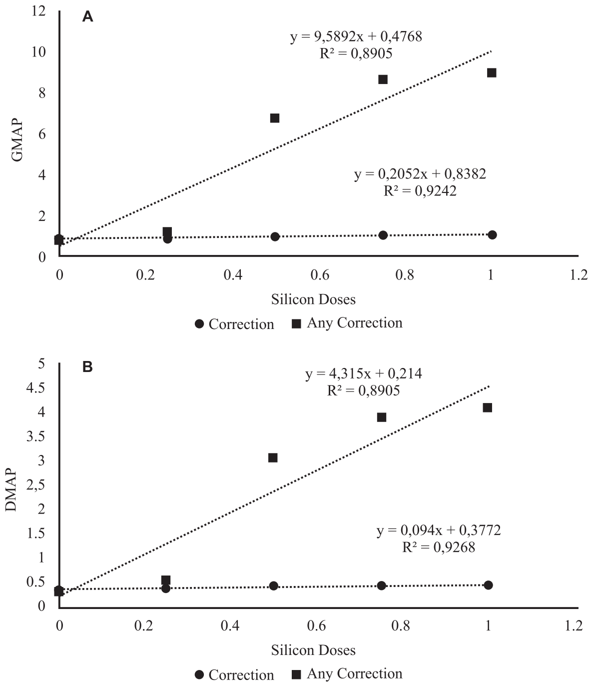

Figure 2 - Production of GMAP shoot green matter (A) and DMAP shoot dry matter (B) in uncorrected (SC) and pH corrected (CC) soils, considering the doses of Si applied.

Several studies pointed out that the production of green mass aerial part and dry mass aerial part of rice is not altered with the application of Si (Carvalho, 2000) and (Ma et al., 1989). However, the results obtained in the present study pointed to opposite effects. The approach of the results found by the authors was the application of dolomitic limestone as soil corrective. Therefore, it was assumed that the silicon action was sufficient to provide the necessary nutrients at the beginning of the vegetative development of the rice (Cassol et al., 2017).

Such production might be due to the reduction of the available Si, which caused a greater supply of Ca and Mg in the soil. Calcium is a structural component of the cell wall, and magnesium is the central atom of chlorophyll molecules (Freitas et al., 2015).

It was also attributed to the fact that N has the same active carrier site of Si available in the plant, causing competition between them. In this way, N is better absorbed, increasing production, since it is responsible for the growth and accumulation of green and dry mass (Wallace, 1989 e Fageria, 1984).

Although liming is important for increasing soil N efficiency, it is likely to cause loss of this nutrient (Rosolem et al., 1991), probably by denitrification (Rosolem et al., 2003), which might have contributed to reduce pH, causing physiological and nutritional stress limiting the production of green mass aerial part and dry mass aerial part.

It is possible that there has been a competitive inhibition interaction between silicon and other nutrients such as Al, Mn, N, Zn and Fe. This phenomenon gives Si the ability to avoid the absorption, translocation and distribution of these elements to rice shoot (Júnior et al., 2010). For some of these elements, the effects on the plant are beneficial; however, for others, they negatively affect their chemical composition, reflecting the lower responses.

CONCLUSIONS

Liming provided higher Si content and absorption by plants. The content of Si in rice was proportional to the increase of the doses of the element applied in the soil and these doses caused an increase in the production of shoot green and dry mass. The highest production of green mass and dry mass of shoot was found in plants from soils that did not receive liming.

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