Effect of potassium silicate on development and productivity in soybean [*Glycine max* (L.) Merrill] cultivars in an experimental cultivation area in the Brazilian *Cerrado*

Jander Edmar Dutra dos Santos[1], Antonio Carlos Pereira de Menezes Filho[2], Aurélio Ferreira Melo[1], Porshia Sharma[3] & Matheus Vinícius Abadia Ventura[1,4]

[1] UniBRAS University Center of Rio Verde, Rio Verde, Goiás State, Brazil

[2] Menezes Agricultural Research, Rio Verde, Goiás State, Brazil

[3] University of Hohenheim, Stuttgart, Germany

[4] Goiano Federal Institute, Rio Verde, Goiás State, Brazil

Correspondence: Jander Edmar Dutra dos Santos, UniBRAS University Center of Rio Verde, Rio Verde, Goiás State, Brazil. E-mail: jander.dutra.agro@gmail.com

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Abstract

Silicon (Si) is considered an essential element for the development of several groups of vegetables, including legumes (Soy) [*Glycine max* (L.) Merrill.]. This study aimed to evaluate different doses of potassium silicate (K_2SiO_4) rich in Si (25%) regarding the effects on the vegetative and reproductive phases for two soybean cultivars with technology HO IPRO Corumbá and HO i2x Mogi in red distroferric soil in the Southwest of Goiás, Brazil. Si doses (0, 150, 300, 600, and 900 kg ha^{-1}) were evaluated for the parameters plant length, root length, aerial and root fresh mass, aerial and root dry mass, and number of pods for two cultivars Corumbá and Mogi. The results demonstrated positive effects for the Si doses applied, mainly at doses of 300-600 kg ha^{-1} for most parameters and for the dose of 900 kg ha^{-1} for the number of pods. Different dosages of Si expressed in potassium silicate demonstrated positive effects on the vegetative and reproductive increments of soybean cultivars Corumbá and Mogi.

Keywords: silicon, Si, *Glycine*, vegetative parameters, adubation.

Efeito do silicato de potássio no desenvolvimento e produtividade em cultivares de soja [*Glycine max* (L.) Merrill] em área experimental de cultivo no Cerrado Brasileiro

Resumo

Silício (Si) é considerado um elemento essencial para o desenvolvimento de diversos grupos de vegetais, inclusive leguminosas (Soja) [*Glycine max* (L.) Merrill.]. Este estudo teve por objetivo avaliar diferentes doses de silicato de potássio (K_2SiO_4) rico em Si (25%) quanto aos efeitos sobre as fases vegetativa e reprodutiva para dois cultivares de soja com tecnologia HO IPRO Corumbá e HO i2x Mogi em solo distroférrico vermelho no Sudoeste de Goiás, Brasil. Doses de Si (0, 150, 300, 600 e 900 kg ha^{-1}) foram avaliadas para os parâmetros comprimento de planta, comprimento de raízes, massa fresca aérea e de raízes, massa seca aérea e de raízes e número de vagens para dois cultivares Corumbá e Mogi. Os resultados demonstraram efeitos positivos para as doses de Si aplicadas, principalmente nas doses 300-600 kg ha^{-1} para a maioria dos parâmetros e para a dose de 900 kg ha^{-1} para o número de vagens. Diferentes dosagens de Si expresso em silicato de potássio demonstraram efeitos positivos para os incrementos vegetativos e reprodutivos de soja cultivares Corumbá e Mogi.

Palavras-chave: silicato, Si, *Glycine*, parâmetros vegetativos, adubação.

1. Introduction

Human beings, over time, have domesticated several grain-producing plants for their use (food, production of edible oil, biodiesel, and production of alcoholic beverages) and in the production of feed for domestic animals (poultry, pigs, cattle, goats, etc.) (Yusefi-Tanha et al., 2020; Dola et al., 2022). Among these grains, we mention soybeans [*Glycine max* (L.) Merrill] which today dominates large agricultural areas in the world and even in Brazil, being the most produced grain in the world (Naamala et al., 2023). With the growing demand for food, studies are developed to ensure greater productivity of domesticated plant species. For soybeans, several studies annually aim to ensure greater productivity per plant and thus minimize the effects that cause a decrease in yield and depreciation of the quality of this oilseed, with the occurrence of agricultural pests, phytopathology (nematodes, fungi, and viruses), fertility problems soil, cultivar development, and biotic and abiotic stress (Júnior et al., 2010).

According to Zelin et al. (2011), correct management for soybean cultivation consists of a set of attributes to provide conditions for sowing, high germination rate, development, and production. One of the practices adopted for large crops is the use of the direct planting system, which involves a range of soil conservation attributes. Crops require different cultural treatments, mainly in terms of macro and micronutrient content throughout the crop cycle, which may vary depending on the crop implemented. For soybean cultivation, several micronutrients must be applied before sowing, such as Boron (B), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo) and Zinc (Zn). However, the element Silicon (Si) has been incorporated into the list of micronutrients in several vegetable crops, including *G. max*. Its incorporation has brought good results where Si has demonstrated positive effects in studies at low doses, providing plant resistance to attack by insects, nematodes, bacteria, and fungi, improving nutritional status, and reducing transpiration and photosynthetic efficiency (Johnson et al., 2019; Tripathi et al., 2021; Islam et al., 2020).

However, there is an obstacle among several researchers, who do not consider Si as an essential element for plants because it does not meet direct and indirect essentiality criteria as described by Malavolta (2006) and Lima Filho (2008), however, Maud et al. (2003) and Pereira et al. (2004), among others, agree that even though it is not essential, Si brings numerous benefits to the full development of plants. This element is found naturally inert in sands, quartz (pure SiO_2), kaolinite, micas, feldspar, and other silicate clay minerals (Sousa et al., 2010; Chung et al., 2020).

In this sense, Si is active in reducing toxic effects caused by excessive fertilization, including Fe, Mn, and Aluminum (Al) as discussed in the pioneering work by Ma & Takahashi (1991), in the regulation of ascorbate peroxidase (APX), catalase (CAT) and glutathione (GSH) (Shi et al., 2014; Tripathi et al., 2015; Kim et al., 2016; Rizwan et al., 2019; Sharifi et al., 2022) consecutively produces a potential reduction in the formation of reactive species of oxygen (ROs); in the modulation of mineral absorption (Jang et al., 2018), and in the formation of a cellular silica layer (Deshmukh; Bélanger, 2016). Savant et al. (1999) complement the study by Ma & Takahashi (1991) where they present encouraging data regarding the action of Si in plants to reduce the toxic activity of Mn and Fe not only by reducing their absorption but also by increasing the level of tolerance internal to excess Mn in plant tissues.

Fertilization enriched with Si has demonstrated good results in several plant groups around the world subjected to different types, e.g., stress such as water (biotic) and high light levels (abiotic). Darnoff et al. (2001). Several soybean cultivars studied demonstrated that it is a crop capable of absorbing considerable levels of Si in the soil, and this absorption is greater in soils with a high concentration of this element. Its absorption occurs via the leaves; however, it is mainly absorbed by the root system and is easily translocated to the aerial part (Miyake; Takahashi, 1985). Among the various forms of Si, plant roots generally absorb Si from the soil as H_4SiO_4, after being absorbed by the roots, Si is transported to the stele region, where it involves the expression of two genes, gene 1 with low Si content (LSi2) and low-Si gene 2 (LSi2) (Ma et al., 2006; Mitani et al., 2009; Yamaji et al., 2012; Chung et al., 2020).

As previously discussed, Si has desired effects for plants as it stimulates plant growth and production through the formation of more erect leaves; reduces the effects of self-shadowing; reduces lodging; provides greater structural rigidity of tissues; increases protection against abiotic stresses, minimizes the toxic effects of Fe, Mn, Al and Sodium (Na); increases tolerance to water stress and frost; greater protection against insect attacks, phytopathological diseases and herbivory (Marschner, 1995).

Camargo et al. (2008) found that Pinus taeda plants had a low incidence of attacks by “giant pine aphid our *pulgão-gigante-do-pinus*” (*Cinara pinovora* registered in 1996 and *Cinara atlantica* in 1998) in Brazil; “green aphid our *pulgão verde*” (*Schizaphis graminum*) on wheat by Goussain et al. (2005); in maize by “fall armyworm our *lagarta do cartucho*" (*Spodoptera frungiperda*) by Goussain et al. (2002) and Neri et al. (2005) and by "whitefly our *mosca branca*" (*Bemisia tabaci*) in cucumber culture by Correa et al. (2005) using Si treatments.

According to Lima Filho (2008), potassium silicate (K_2SiO_4) is a clean, safe, and sustainable technology, which can significantly reduce the use of phytosanitary products in agriculture and, with balanced fertilization, can result in more productive, healthy, and vigorous plants. The benefits of this compound are directly related to the accumulation of Si in the plant cell wall, reducing moisture loss, potentially improving cellular structure, and promoting a physical barrier against phytopathogens and cutting and sucking insects (Zago et al., 2010; Zelin et al., 2011).

This study aimed to evaluate different dosages of potassium silicate in two soybean cultivars Corumbá HO and Mogi IPRO in promoting vegetative and reproductive parameters in productive soil in Southwest Goiano, Brazil.

2. Materials and Methods

2.1 Experimental location

Initially, the *in vitro* study was conducted at the Technological Chemistry Laboratory at the Goiano Federal Institute, Rio Verde, Goiás, Brazil. In the second moment in the field, the study was carried out in the research area "Menezes Agricultural Research" Antônio Menezes & Filho Farm geographic coordinates (17º43'06.6''S and 50º53'06.7''W), in Rio Verde, Goiás, Brazil, between December 2023 and April 2024. The climate according to the Köppen classification is defined as humid tropical (AW), with average high temperatures of 26.5 ºC with rain in summer and drought in winter.

2.2 Soybean cultivars

The soybean cultivars evaluated were HO Corumbá IPRO super early, high thousand-grain mass, planting window flexibility, indeterminate growth habit, thousand-grain weight 210 g, average plant height 74 cm, high fertility requirement, gray pubescence, purple flower color, imperfect black hilum color; and HO Mogi i2x precosse with the high productive ceiling, resistant to cyst nematodes and flexibility of planting window, indeterminate growth habit, thousand-grain mass 190 g, average plant height 80 cm, high fertility requirement, gray pubescence, purple flower color, color of the imperfect black hilum.

2.3 Soil analysis

The soil in the area is classified as dystroferric red Oxisol. Soil parameters were determined in a layer between 0-20 cm deep with the following results: Ca = 2.13, Mg = 1.43, K = 0.30, P = 3.0, S = 9.0, Na = 1.0, organic matter (OM) = 61.1 and pH = 4.9 ($CaCl_2$). Clay = 30.3, Silt = 25.2 and sand = 44.4.

2.4 Si compound, planting, and cultural treatments

The silicate and potassium (K_2SiO_4) compound used has a formulation: 25% Si, 10% K, 3% Mg, and 0.01% Ca. Table 1 shows the dosages and amount of Si for each treatment.

Table 1. Doses in kg ha^{-1} and amount of K_2SiO_4 per treatment.

Doses	Quantity of Si (g)*
0 kg ha^{-1}	0.0 Si
150 kg ha^{-1}	37.5 Si
300 kg ha^{-1}	75.0 Si
600 kg ha^{-1}	150.0 Si
900 kg ha^{-1}	300.0 Si

Note: *Quantity of Si sample per experimental unit. Source: Authors, 2024.

The experiment was carried out in a randomized block design (RBD) 5x8+1, where 5 concentrations, 8 replications + 1 control. Black High-Density Polyethylene pots (FMT, Brazil) with a capacity of 5 L were used, with dimensions 19 cm x 21 cm, a mass of 0.8 g, an opening diameter of 21 cm, and a base diameter of 16 cm. In each experimental unit, 4 kg of soil amended with 5 g of limestone was deposited, which was stirred and for ten days daily watering was carried out with 1 L of natural lagoon water. After this period, concentrations of potassium silicate were added to the soil at the concentrations established in (Table 1), and the soil was disturbed again for each sampling unit, 5 soybean seeds were deposited for each cultivar evaluated, separately, with a depth of 1.5 cm.

20 days after germination, two applications were carried out at an interval of 10 days of the insecticide Fastac Duo® BASF via spraying using a pressurized backpack sprayer with CO_2 to control *Diabrotica speciosa* "little cow our *vaquinha*" and *Bemisia tabaci* "whitefly our *mosca-branca*".

2.5 Physiological, vegetative, and reproductive analyses

2.5.1 Germination assay

Germination trials were evaluated with five replications with 50 seeds of each cultivar. The germination test was carried out in a B.O.D germination chamber (Tecnal, Mod. TE-371, Brazil) with a temperature adjusted to 26 ºC for 10 days. "Germitest" germination paper was used as a moistened substrate with 2.5 times the mass of the paper. Germinated seeds that had a radicle of at least 2 mm were counted and the results expressed as a percentage (%) as described by Rossetto et al. (1995).

2.5.2 Moisture content

The moisture content was determined using the gravimetric method in an oven with air circulation (Thoth, Mod. Th-510-480, Brazil) at a temperature of 105 ºC for 12 h in four replications, as described by the adapted American Society of Agricultural Engineers (ASAE, 2000). The results were expressed as a percentage (%).

2.5.3 Electric conductivity

The electrical conductivity test (EC) of the hydration water was determined according to the methodology described by the International Seed Testing Association (ISTA, 2008). The test was carried out with five replications with 25 seeds each. The seeds were transferred to a 250 mL beaker, and then distilled and deionized water (75 mL) was added. The samples were transferred to a B.O.D type germinator (Tecnal, Mod. TE-371, Brazil) for 24 h with a temperature adjusted to 20 ºC. After this time, the solutions were stirred, and electrical conductivity was determined with a digital conductivity (MS Tecnopon, Mod. mCA-150, Brazil) meter and the results were expressed in $\mu S.cm^{-1}\ g^{-1}$.

2.5.4 Accelerated aging

The accelerated aging test (AA%) was determined in Gerbox-type plastic boxes with individual compartments (water and seeds). Thus, 100 seeds (24 g) were added to the internal metal screen, and 50 mL of distilled water was placed below the screen. The germination boxes were kept in a B.O.D germination chamber (Tecnal, Mod. TE-371, Brazil) with a temperature adjusted to 45 ºC for 48 h. After this time, the seeds were germinated according to subtopic 2.5.1. After 5 days, normal *in vitro* seedlings were counted, and the results were expressed in (%) as described by Rossetto et al. (1995).

2.5.5 Vegetative period analysis

Seedlings 30 days after germination were analyzed for the parameters plant length (PL) and root length (RL) using a tape measure and the results were expressed in cm; for aerial fresh mass (AFM), root fresh mass (RFM), aerial dry mass (ADM) and root dry mass (RDM). Data were obtained using a digital analytical balance (Shimadzu, Mod. AY220, Japan) and the results were expressed in grams (g).

2.5.6 Reproductive period analysis

The number of pods per plant was determined by counting the green and dry pods of each plant recommended in the Rules for Seed Analysis (Brasil, 2009).

2.6 Statistical analysis

The average results obtained for both cultivars were evaluated by analysis of variance using the *F* test and when a significant difference was found, regression analysis was adopted using SISVAR software (Ferreira, 2019).

3. Results

The physiological parameters of germination, humidity, electrical conductivity, and accelerated aging are presented in (Table 2).

Table 2. Physiological parameters of the seeds of both soybean cultivars (Corumbá and Mogi) were evaluated for germination percentage (G%), moisture (%), electrical conductivity (EC $\mu S.cm^{-1}\ g^{-1}$) and aging rates accelerated (AA%).

Cultivar	G (%)	Moisture (%)	EC ($\mu S.cm^{-1}\ g^{-1}$)	AA (%)
Corumbá	93.0 ± 6.00	8.9 ± 0.03	100.21 ± 0.15	69.0 ± 0.02
Mogi	84.0 ± 6.32	8.1 ± 0.05	110.60 ± 0.08	53.4 ± 0.08

Source: Authors, 2024.

The analysis of variance indicated significant differences depending on the doses of K_2SiO_4 for the variables PL, AFM, RFM, ADM, RDM, and Pod for the Corumbá cultivar and the Mogi cultivar, with significant differences for all variables analyzed (Table 3).

Table 3. Summary of the mean square analysis of variance for the variables plant length (PL), root length (RL), aerial fresh mass (AFM), root fresh mass (RFM), aerial dry mass (ADM), root dry mass (RDM) and number of pods (Pods) of soybean plants in different doses of potassium silicate.

Corumbá	PL	RL	AFM	RFM	ADM	RDM	Pods
Si	6.08*	72.09ns	38.45*	7.04*	0.96*	0.31*	17.12*
Model	Linear	-	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic
CV%	12.43	11.95	14.39	20.88	20.88	33.37	21.12
Mogi	**PL**	**RL**	**AFM**	**RFM**	**ADM**	**RDM**	**Pod**
Si	416.11*	97.03*	16.98*	1.74*	1.08*	0.22*	47.75*
Model	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic
CV%	13.21	9.11	22.08	34.59	26.01	25.09	19.95

Note: *Significant at 5% probability by the *F* test. ns not significant. (-) not determined. CV = coefficient of variation. Source: Authors, 2024.

Regarding the length of the shoot, a significant difference was observed in both cultivars at different doses of K_2SiO_4 ($p < 0.05$). Positive and significant effects ($p < 0.05$) were observed at the highest dose of 900 kg ha^{-1} (Figure 1, A) for cultivar Corumbá where it demonstrated linear growth with an average PL of 27.1 cm and for (Figure 1, B) for cultivar Mogi where it demonstrated quadratic growth with a maximum length and average value of 24.8 cm.

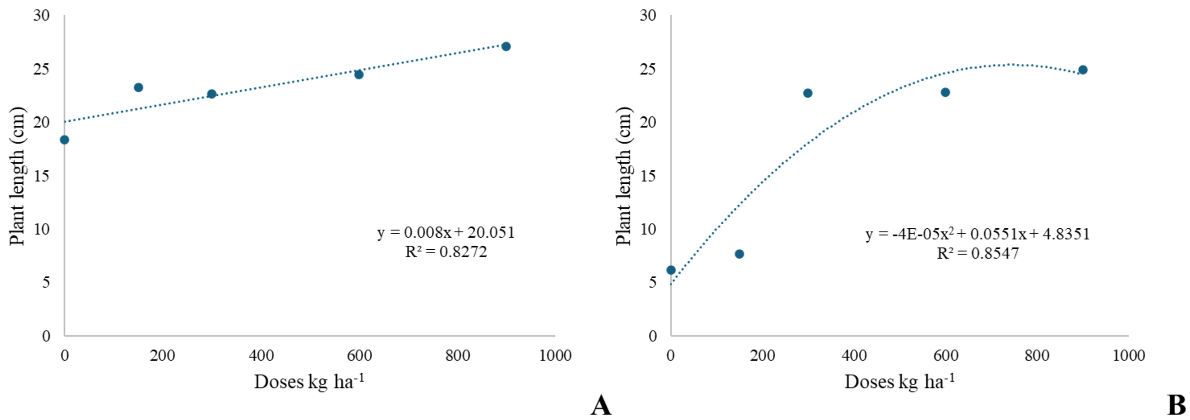

Figure 1. Plant length parameter for cultivars Corumbá (**A**) and Mogi (**B**). Source: Authors, 2024.

A positive effect for RL was observed with a significant difference ($p < 0.05$) only for the Mogi cultivar with an average length of 44.1 cm for the dose of 300 kg ha^{-1} (Figure 2).

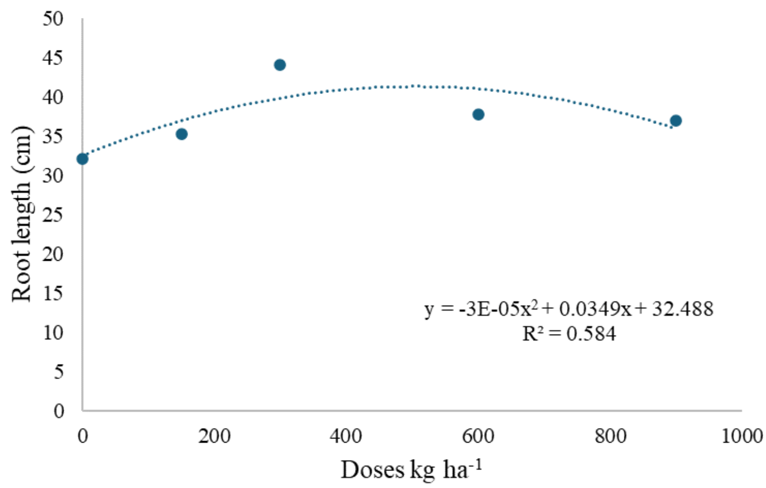

Figure 2. Root length parameter for the Mogi cultivar. Source: Authors, 2024.

For AFM, the plants of the Corumbá cultivar presented an average result of 9.5 g, and for the Mogi cultivar an average of 6.5 g both, significant for a dose of 300 kg ha^{-1} ($p < 0.05$) of K_2SiO_4 (Figure 3).

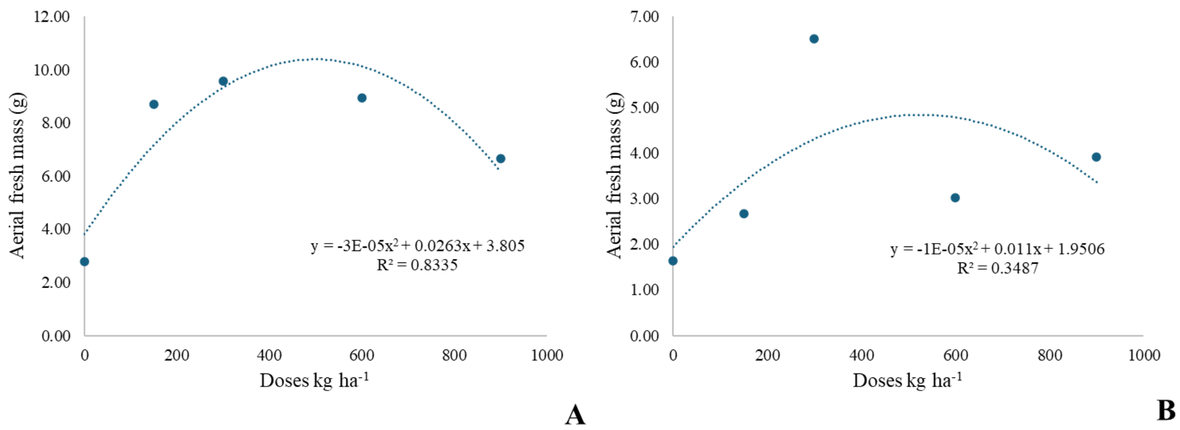

Figure 3. Aerial fresh mass of cultivars (**A**) Corumbá and (**B**) Mogi. Source Authors, 2024.

Significant results ($p < 0.05$) were obtained for both cultivars Corumbá and Mogi for RFM, however, the dose of K_2SiO_4 varied, where Corumbá had an average value of 3.9 g for a dose of 600 kg ha^{-1} (Figure 4, A) and 2.3 g for 300 kg ha^{-1} (Figure 4, B).

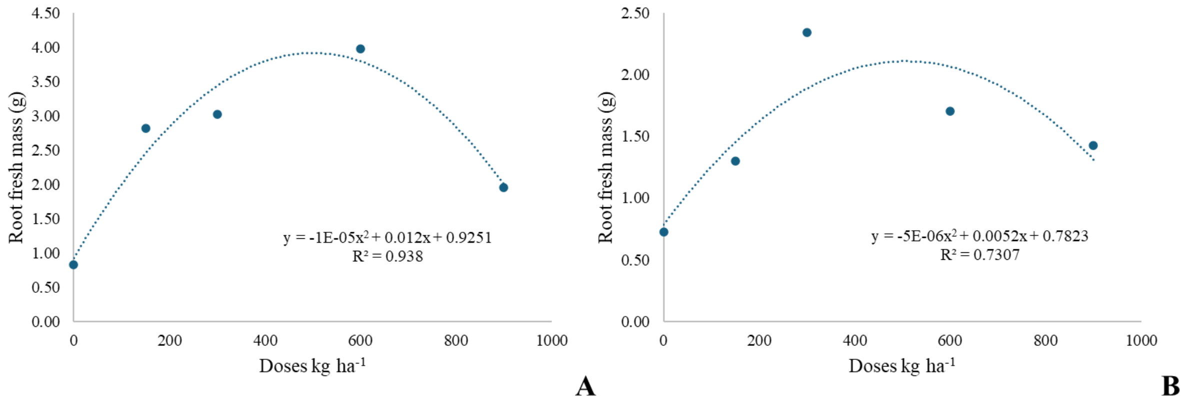

Figure 4. Root fresh mass of cultivars (**A**) Corumbá and (**B**) Mogi. Source Authors, 2024.

At doses of 600 and 300 kg ha^{-1} (K_2SiO_4), it was possible to obtain ADM (straw) with averages of 1.7 and 1.6 g respectively for the cultivars Corumbá and Mogi (Figure 5 A and B).

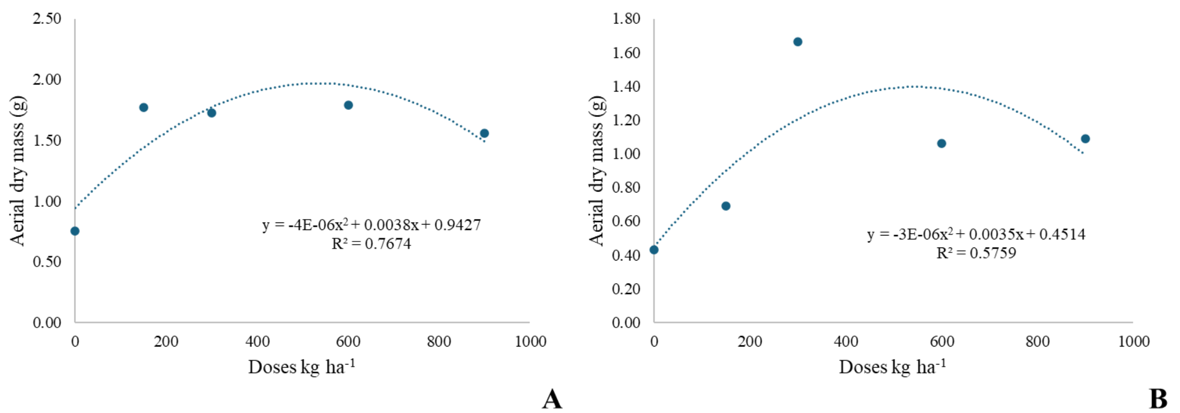

Figure 5. Aerial dry mass of cultivars (**A**) Corumbá and (**B**) Mogi. Source: Authors, 2024.

The RDM content demonstrated positive and significant effects ($p < 0.05$) for both cultivars (Figure 6, A and B) with an average of 1.1 and 0.9 g respectively for the dose of 300 kg ha^{-1} of K_2SiO_4.

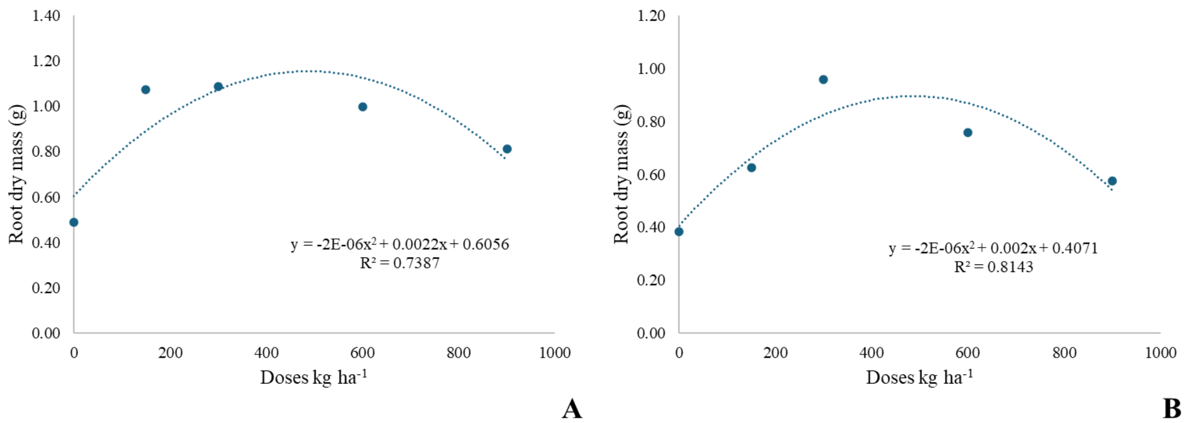

Figure 6. Root dry mass of cultivars (**A**) Corumbá and (**B**) Mogi. Source: Authors, 2024.

As for the number of Pods per cultivar, both demonstrated a significant difference ($p < 0.05$) for the doses of 300, 600, and 900 kg ha^{-1} (K_2SiO_4) with average values of 10, 9, and 10 (Figure 7, A) Corumbá and average value of 13.7 for a dose of 600 kg ha^{-1} (K_2SiO_4) Mogi (Figure 7, B).

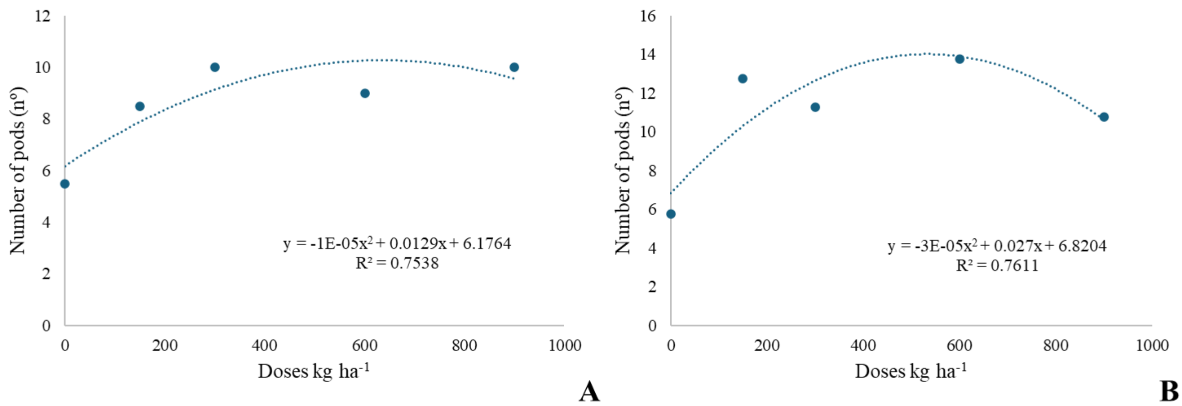

Figure 7. Number of pods for cultivars (**A**) Corumbá and (**B**) Mogi. Source: Authors, 2024.

4. Discussion

Regarding the physiological rates for seeds in different soybean cultivars, the Mogi cultivar presented results of less than 90% germination, humidity, higher electrical conductivity, and a lower rate of accelerated aging, these being serious problems for a cultivar. The Mogi cultivar produced less than encouraging results when compared to several other cultivars. Superior results were found by Ferrazza et al. (2020) with a germination rate averaging 98% for the TMG 7062 IPRO INOX soybean cultivar. Rocha et al. (2017) studied the soybean cultivar M 7739 IPRO where they obtained a germination rate greater than 90% and greater than 85% for accelerated aging. Costa et al. (2005) found an average moisture content of 14%. Harter & Barros (2011) obtained an average germination result of 81% for the cultivar BR 36. In this study, the authors inoculated Si in the seeds where they found germination rates higher than the control with an average of 88%, electrical conductivity of 87.0 umhos/ cm^{-1}/g^{-1} for the control and between 71.3-69.2 for seeds inoculated with Si-40 and Si50.

According to Toledo & Marcos Filho (1977) and Rocha et al. (2017), the low germination rate is the most pronounced manifestation of seed deterioration. The accelerated aging test estimates seed storage potential as described by Delouche & Baskin (1973). Ellis et al. (1991) add that deterioration and aging are continuous degenerative processes, that involve a sequence of biochemical and physiological events that lead to a drop in seed quality and loss of viability. Our EC results are considered high and worrying, as the electrical conductivity test as described by Vieira & Krzyzanowski (1999) and Vidigal et al. (2008) is measured in the seed imbibition solution and shows the researcher the number of leached ions, being directly related to the integrity of cell membranes. Thus, poorly structured membranes and damaged cells are generally associated with the seed deterioration process (low-vigor seeds).

As for the morphological parameters of the vegetative phase in our study, the potassium silicate compound containing 25% Si was demonstrated to interact with most of the analyzed parameters providing significant increments for soybean plants in both cultivars Corumbá and Mogi. Similar results were also reported in other studies with significant increases in both the vegetative and reproductive phases. In this sense, Teodoro et al. (2015) observed quadratic behavior regarding the average value of 105 cm for the plant height variable in R5 for soybean cultivar 5DR615 where doses of Si showed a positive effect for this variable about the control. As seen in our results and the studies compared here, the use of Si stimulates several actions in the plant, such as greater structural rigidity of tissues, increased mechanical resistance of cells, reduced transpiration, more erect leaves, decreased self-shading, and greater growth. plant effectiveness (Deren, 2001; Teodoro et al., 2015). Encouraging results were also described by Pereira Júnior et al. (2010) where the application of 350 kg ha^{-1} of Si in the furrow provided greater height of soybean plants when compared to the control.

The dry mass content in our study demonstrated that Si concentrations influenced the straw content in plants in the vegetative phase. Corroborating our results, Teodoro et al. (2015) found a greater dry mass of soybean plants when different doses of Si were applied via furrows. In R6, the researchers found maximum results of 2,679.0 and 2,245.5 kg ha^{-1} for the highest dose of Si and control, respectively. Possibly the increase in this parameter may be related to the greater photosynthetic capacity of plants and better water use efficiency (Korndörfer et al., 1995).

In this study, we reported excellent results for the dry phytomass of the aerial part and roots even in the vegetative phase, whereas Moreira et al. (2010) add that the greatest content of this phytomass (straw) is produced in the reproductive phase where there is an increase in this accumulation. Therefore, future studies evaluating these two soybean cultivars could be carried out by comparing the rate of aerial and root dry mass in the vegetative phase with the reproductive phase and thus better discuss this hypothesis supported by Moreira et al. (2010).

In legumes such as soybeans, Si absorption occurs in a “rejective” way, that is, the plant absorbs this element without translocating it (Ma et al., 2001). Other authors corroborate this theory, Korndorfer & Datnoff (2000) discuss the role of Si where it presents low mobility within plants, this is reinforced by Marschner (1995) evaluating rice, wheat, and soybean crops where absorption and radial distribution of Si through soybean roots to the xylem vessels are more restrictive at high concentrations of Si, indicating a restrictive exclusion mechanism, which is also presented in the study by Moreira et al. (2010) for soybean varieties. Regarding the increase in root length, our results demonstrate a significant effect only for the Mogi cultivar, where dosages greater than 300 kg ha-1 hurt root length and consecutively lower fresh and dry root masses. Furthermore, it is possible to verify that the Mogi cultivar does not show tolerance at doses greater than 300 kg ha^{-1} when compared to the Corumbá cultivar, which demonstrated a positive effect up to a concentration of 600 kg ha^{-1} for these parameters.

The number of pods per soybean cultivar demonstrated that the doses of Si in K_2SiO_4 had a positive influence on both cultivars tested. Similar results were described by Oliveira et al. (2015) with a good response to agronomic parameters and increased mass and vigor in seeds of the soybean cultivar BMX turbo RR used as an alternative source of Si via gray rice husk soil. Similar results were also described by Pereira Júnior et al. (2010) where they found an increase in the number of pods with increasing doses of Si applied to the furrow at the time of sowing.

Another promising study was described by Moreira et al. (2010) where researchers found productivity increases in the soybean cultivar BRS Favorita RR under field conditions with foliar application of Si in three phenological studies. Our results differ from the study carried out by Coelho et al. (2019) where they evaluated the cultivars AS 3730 RR2 and NA 7490 RR. The researchers did not find significant interactions between Si doses and cultivars for the parameters number of pods, number of grains, weight of one thousand grains, and productivity, however, a significant effect was observed for the number of soybean grains per pod. Concentrations of up to 600 kg ha^{-1} of Si have a positive effect on the variable number of pods for the Mogi cultivar, however, this also demonstrated that it is not tolerant to higher doses with loss of this production component, however, the Corumbá cultivar tolerates concentrations up to 900 kg ha^{-1} of Si.

In other cultures, Moraes et al. (2018) evaluating doses of calcium and magnesium silicate in the cultivation and production of okra, found no relationship between Si dose and increased productivity. Possibly the lack of response regarding okra plants and the addition of Si may be related to the good condition of the soil and acidity with pH at 5.8 and good levels of Ca and Mg which are requirements for this crop. In rice plants, Rodrigues et al. (2011) found a relationship between Si doses and increased grain yield. Furthermore, the authors add that the yield attributes are linked by soil chemical attributes such as pH, Ca, Mg, and Si. For corn, Souza et al. (2015) found satisfactory results in the addition of calcium and magnesium silicate with a high rate of seedling emergence and growth.

The production parameter by number of grains and dry mass of grains was not presented in this study, however, it is possible to present a theory that the parameter number of pods per plant, having presented a positive effect, could influence a higher production rate, however, such information is still speculative. Although further studies demonstrate that the Si element influences production as discussed by Zelin et al. (2011) where they found that Si doses and productivity showed a significant interaction with productivity between 1500-2000 kg^{-1} with a silicate dose of 0.96 L ha^{-1} via foliar application in soybeans. Results of dose-production interaction of soybeans were also reported by Teodoro et al. (2015) where they discuss the interaction of Si doses on the increase in dry mass of soybean seeds with averages of 890.0 and 770.0 kg ha^{-1}, for Si dose and control respectively, and by Crusciol et al. (2013) and Moreira et al. (2010) where the research groups of these authors also obtained similar results in foliar fertilization with Si for soybean productivity. However, in the study by Philippsen & Simonetti (2010), researchers disagree that Si influenced the number of grains per pod using solutions between 124-289 mL of Supa silica®, but they obtained a significant result for the number of pods per plant for the cultivar V-Max soybean via foliar use. Still in this study, the researchers reached an ideal dose of 207 mL of Supa silica® foliar product for productivity with 3,466 kg ha^{-1} and for a mass of 100 grains doses between 207-289 mL with average values of 17.88-17.24 g.

5. Conclusions

The morphological parameters of the vegetative phase and the number of pods in the reproductive phase in the Corumbá and Mogi soybean cultivars were positively influenced by the doses of Si-expressed potassium silicate. Doses between 300-600 kg ha^{-1} demonstrate positive increases for most of the evaluated parameters and positive effects for doses up to 900 kg ha^{-1} for the number of pods per plant.

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7. Authors' Contributions

Jander Edmar Dutra dos Santos: study design, planting, harvesting the experiment, analysis, writing the article, and corrections. *Antonio Carlos Pereira de Menezes Filho*: translation, text corrections, writing, and final corrections. *Aurélio Ferreira Melo*: corrections, laboratory analyses and final corrections. *Porshia Sharma*: translation, grammatical corrections, article writing, publication standards. *Matheus Vinícius Abadia Ventura*: statistical analysis, post-evaluation corrections and publication.

8. Conflicts of Interest

No conflicts of interest.

9. Ethics Approval

Not applicable.

10. References

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