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AGRONOMIC CHARACTERISTICS OF CORN GRAINS FERTILIZED WITH DIFFERENT DOSES OF SILICON AND NITROGEN AND INOCULATED WITH *Azospirillum brasilense*

ABSTRACT – This work aimed to analyze the effects of using the *Azospirillum brasilense* bacteria with different doses of calcium ($CaSiO_3$) and magnesium silicate ($MgSiO_3$) applied on the soil, at different levels of nitrogen fertilization for the topdressing, on the agronomic characteristics of corn grain. The experiment was carried out in the Midwest region of Goiás under a randomized block design, in a 2x3x2 factorial scheme, formed by two doses of N in topdressing, three doses of *Azospirillum brasiliense*, and two doses of $CaSiO_3$ and $MgSiO_3$. The various agronomic characteristics of maize evaluated were plant height and stem diameter 35 and 55 Days After Seedling Emergence, weight of 100 grains, and yield, highlighting results of 30.7 and 29.2 g for weight of one hundred grains and 6712.9 and 6390.5 kg ha^{-1}for yield. Both results were obtained on the dosages of 50 kg ha^{-1} of N in topdressing and 200 kg ha^{-1} of fertilization with $CaSiO_3$ and $MgSiO_3$. The dosages of 50 kg ha^{-1} of N in topdressing and 200 ha^{-1} of $CaSiO_3$ and $MgSiO_3$ in planting increased the height of plants with 35 DASE, weight of one hundred grains, and yield, although the interaction of these two treatments was not statistically significant. These results confirmed the importance of N fertilization in topdressing and showed that the recommended $CaSiO_3$ and $MgSiO_3$ dosage for corn crops is less than 400 kg ha^{-1}.

Key-words: Fertilization; *Zea mays;* Nutrition.

CARACTERÍSTICAS AGRONÔMICAS DE GRÃOS DE MILHO ADUBADO COM DIFERENTES DOSES DE SILÍCIO E NITROGÊNIO E INOCULADO COM *Azospirillum brasilense*

RESUMO - Este trabalho teve como o objetivo analisar os efeitos do uso da bactéria *Azospirillum brasilense* com diferentes dosagens de silicato de cálcio e magnésio aplicado via solo, em diferentes níveis de adubação nitrogenada de cobertura, sobre as características agronômicas do milho grão. O experimento foi realizado na região Centro-Oeste de Goiás sobre um Delineamento de blocos casualizados, em esquema fatorial de 2x3x2, formados por 2 dosagens de N em cobertura; 3 doses de *Azospirillum brasiliense*; e 2 dosagens de $CaSiO_3$ e $MgSiO_3$, 200 e 400 kg ha^{-1}. As várias características agronômicas do milho avaliadas foram a altura da planta e diâmetro do colmo com 35 e 55 D.A.E, peso de 100 grãos e produtividade, tendo como destaque resultados de 30,7 e 29,2 g para peso de cem grãos e 6712,9 e 6390,5 kg ha^{-1} para produtividade, sendo que ambos os resultados foram obtidos sobre as dosagens de 50 kg ha^{-1} de N em cobertura e 200 kg ha^{-1} de $CaSiO_3$ e $MgSiO_3$. As dosagens de 50 kg ha^{-1} de N em cobertura e 200 ha^{-1} de $CaSiO_3$ e $MgSiO_3$ em plantio proporcionaram acréscimo na altura de plantas com 35 D.A.E, peso de cem grãos e produtividade, apesar que a interação desses dois tratamentos, não ter proporcionado diferença significativa. Confirmando a importância da adubação nitrogenada em cobertura, e evidenciando, que a dosagem de $CaSiO_3$ e $MgSiO_3$ recomenda para a cultura do milho, seja inferior a 400 kg ha^{-1}.

Palavras-chave: Adubação; *Zea mays;* Nutrição.

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Corn (*Zea mays L.*) is a plant cultivated on almost all continents. Its various uses range from animal feed to high-tech industries, such as producing biodegradable films and packaging, which is extremely important economically. Of all world corn production, about 70 to 85% is destined for animal feed, and only 15% is for human consumption, directly or indirectly (FARINELLI et al., 2012).

Corn grain productivity in Brazil at the beginning of the 21st century (2001) was around 2600 kg ha^{-1} (AGUIAR et al., 2004), with a gradual increase, reaching 5922 kg ha^{-1} in the 2022/2023 harvest. , according to data provided by the National Supply Company - CONAB (CONAB, 2023). This increase is primarily related to the application of new technologies, ranging from genetic improvement to changes in management and cultural treatments.

For example, with the increasing appearance of pests, genetic improvement developed the Bt technology, which consisted of genetically modifying corn, introducing the genetic part of the Bacillus thuringiensis bacterium. With this genetic change, plants started to produce toxins harmful to insects, such as corn fall armyworm (*Spodoptera frugiperda*), without causing any problems for mammals. (MENDES, MARUCCI and WAQUIL, 2018; SILVA et al., 2020).

In the 2019/20 crop, the market had 196 cultivars available to Brazilian producers, making it possible to meet the most different specific needs of each production system and cultivation site (PEREIRA, BORGHI, 2020). This great variety of cultivars, with different production characteristics, provided another significant advance in the production of Brazilian corn, which is the planting of the second crop, commonly called off-season crop. The off-season crop consists of planting during the dry season, which takes place between January and April, usually right after the early soy planting, and does not use irrigation.

A new fertilization practice to optimize fertilizer costs has also been studied and developed, highlighting the symbiotic association with microorganisms such as Azospirillum spp. (FUKAMI et al., 2016) and introducing new nutrients considered essential, such as silicon (Si) (FREITAS et al., 2011). One of the most efficient ways to reduce nitrogen (N) fertilization required by crops has been biological nitrogen fixation (BNF), carried out mainly by bacteria of the genus *Azospirillum*. The members of this genus responsible for this process, called diazotrophs, can reduce atmospheric N (N_2) to ammonia (NH^{+3}); thus naturally increasing the availability of these macronutrients in the soil. When absorbed by plants, it act to both stimulating the plant growth, contributing for hormones production, and as

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agents for the biological control of pathogens (SANGOI et al., 2015).

Silicon (Si) use as fertilizer is becoming increasingly frequent in the most diverse cultures, and corn is not different (MIRANDA et al., 2018). Calcium and magnesium silicate (CaSiO3 and MgSiO3) fertilization has neutralized aluminum and iron in the soil, increasing the phosphorus availability (DE ALMEIDA et al., 2017). Until then, this procedure was considered a micronutrient; when absorbed by the plant, it is deposited on the plant cell wall, polymerizing and forming a double layer of cuticular silicon (Si), promoting a hardening of the wall. This effect has provided reasonable phytosanitary control of crops, such as controlling insects, including *Spodoptera frugiperda* in corn (RAHMAN, WALLIS, UDDIN, 2015).

In this context, the objective of this study was to analyze the effects of inoculating *Azospirillum brasilense* with different doses of calcium and magnesium silicate ($CaSiO_3$ and $MgSiO_3$), in different doses of N in top dressing, on the agronomic characteristics of corn grains.

Materials and methods

The experiment was carried out on the irrigated experimental campus of the State University of Goiás – Palmeiras de Goiás Campus in Palmeiras de Goiás – GO, at coordinates UTM (Universal Transversa de Mercator) 614583 m E and 8139606 m S, zone 22 K, Datum SAD 69 e elevation of 630 m. The experimental area has 864 m², with a conventional sprinkler irrigation system installed, allowing for cultivation throughout the year. The region has a tropical climate, classified as Aw climate (Tropical Savannah or Cerrado) according to the Köppen-Geiger classification.

This region has two contrasting seasons: a very long dry season (winter) and a very wet season (summer). In summer it rains a lot. It gets hot and very humid during the rainy season. Every day, warm, moist air rises from the ground, collides with the cooler air above, and turns into rain. In the afternoons, in the summer savannah, the rains fall for hours. In the coldest month, the temperature reached 12.5 ºC; in the hottest month, it could reach 27.9ºC. Its average monthly precipitation oscillates between 7 mm and 284 mm.

The area used in this study was 288 m² (12 m x 24 m). The soil preparation involved a deep harrow and later, a level harrow. The crop implementation was carried out in March 2020, with the planting of a non-commercial corn cultivar (until the date of implantation), with a long cycle and with the genetic modification technologies BT (Bacillus thuringiensis bacteria genes) and RR (Roundup Ready) and chemical seed treatments to control pests and/or diseases (Table 1). The spacing used

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Table 1. Chemical treatment performed directly on the seed by the manufacturing industry

Commercial Product	Dosage of Commercial Product (per 100 kg of seeds)
Maxim Advanced	150 ml
Actellic 500 EC	1.6 ml
K-Obiol 25 EC	8 ml
Cruiser 350 FS	600 ml
Cruiser 600 FS	350 ml
Fortenza 600 FS	200 ml

was 50 cm between rows and 20 cm between plants, with the planting of 5 to 6 seeds per linear meter, allowing a final population of 100,000 to 120,000 plants ha^{-1}, planting being carried out manually.

The planting fertilization was based on soil fertility (Table 2), with 15 kg ha^{-1} of nitrogen (N - urea), 100 kg ha^{-1} of phosphorus (P_2O_5 - simple superphosphate) and 60 kg ha^{-1} of potassium (K_2O - potassium chloride), together with the calcium and magnesium silicate ($CaSiO_3$ and $MgSiO_3$) dosage according to each specific treatment, being applied in the planting furrow.

The experimental method was a randomized block design (RBD) in a 2x3x2 factorial scheme, with four blocks, formed by two N coverage (0 kg ha^{-1}, and 50 kg ha^{-1}) three doses of *Azospirillum brasiliense* (0 ml, 100 ml and 200 ml for every 20 kg of seeds), and two doses of $CaSiO_3$ and $MgSiO_3$ (200 kg ha^{-1} and 400 kg ha^{-1}). Notably, nitrogen (N) coverage was performed 20 days after seedling emergence (DASE).

The treatments carried out with different dosages of $CaSiO_3$ and $MgSiO_3$ were implanted in the planting furrow, according to the recommended doses, using Calcium Silicate (Ca) and Magnesium (Mg) for treatments, presenting 22% of silicon (Si) in its composition. However, for treatments with *A. brasilense*, commercial

Table 2. Soil analysis of the experimental area with corn grain cultivation.

pH	P	K	Ca	Mg	Al	CTC effective	Sand	Silte	Clay
	mg dm^{-3}	----------- cmolc dm^{-3} -----------					----- g kg^{-1} -----		
6.1	1.2	21.3	1.7	0.3	0.0	1.1	240	130	630

material with a composition of 2x108 cfu/ml (colony forming unit per ml of product) was used, which the manufacturer recommends the application of a dose (100 ml) for each 20 kg of seeds to be treated.

In each treatment, the plots consisted of three lines, with a length of three linear meters, with an average of 15 plants each. For the evaluation of the agronomic characteristics of corn, only the central line and three random plants of each treatment were used, avoiding the border plants of the first and last linear meter, which made it possible to estimate the average value for each treatment. Among the various agronomic characteristics of maize, the present work evaluated plant height (Ht) and stem diameter (⌀) 35 and 55 days after seedling emergence (DASE), hundred-kernel weight (HKW), and grain productivity at the end of the cycle (average of 155 days after planting).

Data were subjected to analysis of variance by the F test at 5% probability, and the means were compared by the Scott-Knott test at a 5% significance level in Sisvar software.

Results and discussion

The results of the evaluated agronomic characteristics of maize cultivation on the effect of different doses of $CaSiO_3$ and $MgSiO_3$, N topdressing, and inoculation of *A. brasilense* can be seen in Table 3. It is observed that the agronomic characteristics, plant height with 55 DASE, and diameter with 35 and 55 DASE showed no significant difference between the treatments performed. However, the height of the plant with 35 DASE showed a significant difference between the dosages of $CaSiO_3$ and $MgSiO_3$, and the weight of one hundred grains and yield showed a significant difference between the dosage of N in coverage and of $CaSiO_3$ and $MgSiO_3$. We also highlight the absence of significant differences in the dosages of *A. brasiliense* in all the evaluated agronomic characteristics.

Results obtained, for example, by Lana et al. (2009) and Dartora et al. (2013), also demonstrate no significant effects on plant height when seed inoculation with *A. brasiliense* and performed different fertilization with N. However, contrary results are also found in the literature, for example, Barassi et al. (2008) reported that plants that receive inoculation with the bacteria have better plant development. These effects were confirmed by Kappes et al. (2014), who found a significant increase in plant height when seeds were inoculated with *A. brasilense*, resulting in an increase of 10 to 13 cm compared to plants without inoculation.

Means followed by the same letter in the column do not differ significantly; ns: not

Table 3. Analysis of agronomic characteristics, height (Ht), and stem diameter (Ø) at 35 and 55 days after seedling emergence (DASE), hundred-kernel weight (HKW), and grain productivity of corn cultivated with different doses of $CaSiO_3$ and $MgSiO_3$ (DSi), nitrogen (DNc) and inoculated with *A. brasilense* (DAb).

Cause of Variation	Ht 35 DASE	Ø 35 DASE	Ht 55 DASE	Ø 55 DASE	HKW	Productivity
	------------------ cm			--------------------	g	kg ha^{-1}
			F Test			
DNc	0.39ns	0.02ns	0.01ns	2.40ns	52.56**	21.98**
DAb	0.46ns	1.28ns	0.51ns	1.99ns	0.28ns	0.85ns
DSi	4.30*	0.81ns	3.18ns	1.47ns	19.73**	9.22**
DNc x DAb	0.65ns	0.56ns	1.59ns	1.07ns	0.28ns	1.07ns
DNc x DSi	0.63ns	0.06ns	1.18ns	0.26ns	0.35ns	0.24ns
DAb x DSi	0.54ns	3.42*	1.12ns	3.63*	0.97ns	0.78ns
DNc x DAb x DSi	0.47ns	0.01ns	0.50ns	0.02ns	0.00ns	0.21ns
Cause of Variation (%)	8.15	8.31	7.7	7.82	13,21	12.33
Average	139.7	1.52	149.5	1.64	270,03	5797.82
			Scott-Knott test			
Nitrogen (N) coverage (kg ha^{-1})						
0	138.6 a	1.5 a	149.3 a	1.6 a	23.2 b	4882.7 b
50	140.7 a	1.5 a	149.7 a	1.6 a	30.7 a	6712.9 a
D. of *A. brasiliense* (ml/20 kg seed)						
0	137.5 a	1.5 a	147.3 a	1.5 a	26.4 a	6109.8 a
100	140.1 a	1.5 a	149.8 a	1.6 a	27.1 a	5484.9 a
200	141.3 a	1.5 a	151.4 a	1.6 a	27.1 a	5798.7 a
D. of $CaSiO_3$ and $MgSiO_3$ (kg ha^{-1})						
200	143.1 a	1.5 a	152.5 a	1.67 a	29.2 a	6390.5 a
400	136.2 b	1.5 a	146.5 a	1.62 a	24.7 b	5205.1 b

Means followed by the same letter in the column do not differ significantly; ns: not significant, according to the F test; ** significant at 5% probability and * significant at 1% probability.

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significant, according to the F test; ** significant at 5% probability and * significant at 1% probability.

Camargo et al. (2022) found no effect of inoculation of *A. brasilense* on the stalk diameter of maize plants. Repke et al. (2013) also studied the effects of inoculation with the bacteria followed or not by N dosages; they found no influence on plant development and productivity in corn crops.

The deficiency in responses to such parameters may be due to several factors, such as described by Hungary (2011), which characterizes that this lack of results may be due to the colony-forming unit present in the commercial product, which in turn has a concentration of 200 million viable cells ml^{-1}. The authors also point out that, to affect the productivity and nutrition of maize cultivars, inoculation with *Azospirillum* sp., the type of cultivar, and climatic factors must be considered.

Hungary (2011) emphasizes the dependence on several biotic and environmental factors to interact with diazotrophic bacteria and corn and only thus generate an effect on such parameters. This variability in the effect of inoculation with the *Azospirillum* sp. is due to a possible inconsistency in the plant's root colonization, the survival of the inoculum, or even environmental conditions unfavorable to the bacteria.

In evaluating fertilization in the planting furrow with different Si dosages, it is possible to observe that the dosage of 200 kg ha^{-1} constituted the best numerical increments among the evaluated variables, showing a statistical difference when compared with the dosage of 400 kg ha^{-1} in the variables (or parameters) height 35 DASE, weight of one hundred grains, and productivity.

However, the other variables analyzed (diameter 35 and 55 DASE and height 55 DASE), despite showing numerical increments with the dosage of 200 kg ha^{-1}, did not differ statistically compared to the dosage of 400 kg ha^{-1}. For example, at the height of the plants at 35 DASE, the dosage of 200 kg ha^{-1} of $CaSiO_3$ and $MgSiO_3$ promoted a numerical increase of 6.8 cm when compared to the dosage of 400 kg ha^{-1} of $CaSiO_3$ and $MgSiO_3$. Miranda et al. (2018), when evaluating the height of maize plants, also did not observe any difference caused by soil fertilization with silicon (Si). The authors also evaluated the height of the plants at 15 and 60 A.D. and found that they did not present significant differences concerning the height variable.

As for the stem diameter, Freitas et al. (2011), investigating the $CaSiO_3$ and $MgSiO_3$ fertilization in maize crops, also found no significant effect concerning stem diameter.

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These results contradict the study by Francischini et al. (2018) who found a positive effect of $CaSiO_3$ and $MgSiO_3$ in increasing the diameter of the stalk, thus making silicon (Si) a mineral of paramount importance in corn cultivation, which can increase its capacity to resist lodging. Another positive effect of $CaSiO_3$ and $MgSiO_3$ is that these elements can act by promoting the strengthening of stems and leaves.

In the analysis of the weight of one hundred grains, as in the height of the plants at 35 DASE, it was possible to verify that the dose of 200 kg ha^{-1} of $CaSiO_3$ and $MgSiO_3$ presented a numerical increase of 4.5 g with the dose of 400 kg ha^{-1}. These results suggest that maize plants that received a dosage of 400 kg $ha^{-1}$of $CaSiO_3$ and $MgSiO_3$, there was a negative effect of $CaSiO_3$ and $MgSiO_3$ on the development of these plants compared to the development promoted by fertilization with 200 kg ha^{-1} of $CaSiO_3$ and $MgSiO_3$.

Sandim et al. (2010), also evaluating the effects of $CaSiO_3$ and $MgSiO_3$ doses on maize yield, found that the weight of one hundred grains did not influence the applied $CaSiO_3$ and $MgSiO_3$ doses (0; 1000; 2000; 3000 and 4000 kg ha^{-1}). In a study of other crops, for example, soybean, Juliatti et al. (2004), when evaluating the effect of different $CaSiO_3$ and $MgSiO_3$ dosages (0, 250, 500, 1000, 2000 kg ha^{-1}), proved that there was no significant difference in the weight of 100 soybean grains.

In the analysis of corn yield with different $CaSiO_3$ and $MgSiO_3$ dosages, the treatment with 200 kg ha^{-1} of $CaSiO_3$ and $MgSiO_3$ had the highest yield, reaching 6390.54 kg ha^{-1}. This result was superior to that obtained by the treatment with 400 kg ha^{-1}, which presented a yield of 5205.10 kg ha^{-1}, and even close to the average yield of 5700 kg ha^{-1} reached in the 18/19 crop in Brazil (MENDES, 2019).

Positive effects were also verified by De Sousa et al. (2010), who found that yield, mass of 1000 (thousand) grains, and stalk of corn increased with the application of potassium silicate via the leaves. On the other hand, Munaro and Simonetti (2016) observed that when cultivating corn with five different dosages of silicon (Si) applied via the foliar they could obtain an increase in productivity, resulting in 3.7 tons. ha^{-1} more than the culture without silicon (Si).

In other cultures it is also possible to find positive productivity results by applying silicon (Si). For example, in the soybean crop, Moreira et al. (2010) found that the use of silicon (Si) via foliar application increased the yield by 18 to 20 bags ha^{-1}, increasing (not permanently) the mass of the grains. In comparison, Monzon et al. (2021) reported

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divergent results, where increasing silicon (Si) doses do not influence soybean crop yield.

Few works refer to studies of the effects of silicon (Si) on the corn crop in the literature. However, according to Mauad et al. (2016), this lack of response to silicon (Si) fertilization is associated with genetic differences found in cultivars, in which the potential for absorption, transport, and accumulation of them is, in many cases, still unknown.

Regarding the topdressing nitrogen fertilization, in general, a low numerical increment can be observed with the fertilization of 50 kg ha^{-1} N in topdressing in the evaluated characteristics of Height 35 and 55 DASE and Diameter 35 and 55 DASE compared to the absence of fertilization (0 kg ha^{-1} N coverage). These results diverge from Soratto et al. (2010), the authors demonstrate that plant height and diameter of corn stalks show significant increases with increasing N doses applied in topdressing (0, 30, 60, and 120 kg ha^{-1}), results that are similar to those of Kappes et al., (2014) who observed a greater height of plants when 100 kg ha^{-1} of N was applied in topdressing. However, GOES et al. (2014) did not find an additional effect on the application of different N sources on the diameter of the stalk of irrigated corn.

When analyzing the effects of different doses of N in topdressing on the weight of one hundred grains and yield, it is observed that maize plants that received a dosage of 50 kg $ha^{-1}$of N in topdressing presented results of 30.74 g for the weight of 100 grains and 6712.93 kg ha^{-1} for yield. Plants that did not receive N fertilization in topdressing obtained 23.27 g for the weight of one hundred grains and 4882.71 kg ha^{-1} for yield. Thus, corn plants that received fertilization of 50 kg ha^{-1} of N topdressing showed the best production results, confirming the paramount importance of N fertilization in topdressing, as it directly influences the economic return factors for producers: grain weight and yield.

Kappes et al. (2014) also showed a significant increase in corn yield, but on a dosage of 70 kg ha^{-1} of N in coverage, yielding 6,377.7 kg ha^{-1} as well as Lana et al. (2009), that verified an increase in the grain mass through the application of nitrogen (N) in topdressing, also verifying productivity of 14,239.00 kg ha^{-1} with a dosage of 90 kg ha^{-1} of N in topdressing. Goes et al. (2012) reported that evaluating different sources and doses of N applied in topdressing, they did not observe a significant increase for the mass of 100 grains and maize yield.

Analyzing the factor interactions obtained by the F test (Table 3), it is possible to verify that of all possible interactions, only the interaction Dosages of *Azospirillum b.* (DAb) x $CaSiO_3$ and $MgSiO_3$ Dosages (DSi) showed a significant difference at 1% probability in the Diameter 35 and 55 DASE variables. However, no significance was observed for the other variables. In this study, the F test was used to compare the evaluations of variance of the treatments, considering if there was at least a difference between two statistical means at work.

It is noteworthy that this experiment was carried out in an open environment, where previously there had been no type of cultivation, and the corn cultivar used has yet to be available on the market, as it is a material still being tested by the manufacturing industry. However, it is a cultivar that showed several beneficial effects in the experiment, such as good resistance to pests and diseases and dispensing the use of pesticides throughout the crop cycle. This factor may also be related to the use of Si fertilization, a micronutrient that promotes phytosanitary control in the crop, in addition to increasing production.

Conclusions

In general, the dosages of 50 kg ha ha^{-1} of N in topdressing and 200 kg ha^{-1} of $CaSiO_3$ and $MgSiO_3$ in planting were the treatments that improved the agronomic characteristics of the corn analyzed, although the interaction of these two treatments did not provide a significant difference. This confirms the importance of nitrogen fertilization in topdressing, and evidence that the Si dosage recommended for corn crops is less than 400 kg ha^{-1}.

Applying different dosages of 0, 100 e 200 ml/20 kg seed of *Azospirillum brasilense* in seed treatment did not provide significant differences between the analyzed variables. It is recommended that, before using these technologies, the sensitivity of microorganisms to possible chemical treatments also carried out on the seeds be checked, as well as the analysis of the actual concentration of the colony forming unit per ml of product and its growth viability.

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References

AGUIAR, CG; SCAPIM, CA; PINTO, RJB; JÚNIOR, ATA; SILVÉRIO, L; ANDRADE, CAB. Análise dialélica de linhagens de milho na safrinha. **Ciência Rural**, v. 34, n. 6, p. 1731-1737, 2004. DOI: https://doi.org/10.1590/S0103-84782004000600010

BARASSI, CA *et al*. Potencialidad de Azospirillum en optimizar el crecimiento vegetal bajo condiciones adversas. Azospirillum sp.: cell physiology, plant interactions and agronomic research in Argentina. **Argentina: Asociación Argentina de Microbiologia**, v. 1, p. 49-59, 2008.

CAMARGO, KC; CASTRO, B; MENEZES, LM; LOPES, MM. Inoculação com Azospirillum brasilense para a produção de milho para silage. **Research, Society and Development**, v. 11, n. 3, p. 1-11, 2022. DOI: https://doi.org/10.33448/rsd-v11i3.26165

DARTORA, J; GUIMARÃES, VF; MARINI, D; SANDER, G. Adubação nitrogenada associada à inoculação com Azospirillum brasilense e Herbaspirillum seropedicae na cultura do milho. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 17, n. 10, p. 1023-1029, 2013. DOI: https://doi.org/10.1590/S1415-43662013001000001

DE ALMEIDA, LHC; Klein, PH; Oliveira, EC; Miglioranza, E. Silício e disponibilidade de fósforo no crescimento e desenvolvimento de mudas de café. **Cultura Agronômica: Revista de Ciências Agronômicas**, v. 26, n. 2, p. 123-131, 2017. DOI: https://doi.org/10.32929/2446-8355.2017v26n2p123-131

DE SOUSA, JV *et al*. Silicato de potássio via foliar no milho: fotossíntese, crescimento e produtividade. **Bioscience Journal**, v. 26, n. 4, 2010.

FARINELLI, R; PENARIOL, FG; FORNASIERI FILHO, D. Características agronômicas e produtividade de cultivares de milho em diferentes espaçamentos entre linhas e densidades populacionais. **Científica**, v. 40, n. 1, p. 21-27, 2012. DOI: https://doi.org/10.15361/1984-5529.2012v40n1p21%20-%2027

FRANCISCHINI, R; SILVA, AG; TESSMANN, DJ. Eficiência de bioestimulantes e fungicida nos caracteres agronômicos e econômicos na cultura do milho verde. **Revista Brasileira de Milho e Sorgo**, v.17, n.2, p. 274-286, 2018. DOI: https://doi.org/10.18512/1980-6477/rbms.v17n2p274-286

FREITAS, LB*;* COELHO, EM; MAIA, SCM; SILVA, TRB. Adubação foliar com silício na cultura do milho. **Revista Ceres**, v. 58, n. 2, p. 262-267, 2011. DOI: https://doi.org/10.1590/S0034-737X2011000200020

FUKAMI, J; NOGUEIRA, MA; ARAUJO, RS; HUNGRIA, M. Accessing inoculation methods of maize and wheat with *Azospirillum brasilense*. **Amb Express**, v. 6, n. 1, p. 3, 2016. DOI: https://doi.org/10.1186/s13568-015-0171-y

GOES, RJ, RODRIGUES, RAF; TAKASU, AT. Fontes e doses de nitrogênio em cobertura para a cultura do milho em espaçamento reduzido. **Agrarian**, v. 7, n. 24, p. 257-263, 2014.

GOES, RJ; RODRIGUES, RAF; ARF, O; VILELA, RG. Nitrogênio em cobertura para o milho em sistema plantio direto na safrinha. **Revista Brasileira de Milho e Sorgo**, v. 11, n. 2, p. 169-177, 2012.

HUNGRIA, M. **Inoculação com Azospirillum brasilense: inovação em rendimento a baixo custo**. Embrapa Soja-Documentos (INFOTECA-E), 2011.

JULIATTI, FC *et al*. Influência do silício na redução de podridão de sementes por Fusarium semitectum na cultura da soja. **Bioscience Journal**, v. 20, n. 2, 2004.

KAPPES, C *et al*. Manejo do nitrogênio em cobertura na cultura do milho em sistema plantio direto. **Revista Brasileira de Milho e Sorgo**, v. 13, n. 2, p. 201-217, 2014. DOI: https://doi.org/10.18512/1980-6477/rbms.v13n2p201-217

LANA, MC *et al.* Arranjo espacial e adubação nitrogenada em cobertura na cultura do milho. **Acta Scientiarum. Agronomy**, v. 31, n. 3, p. 433-438, 2009. DOI: https://doi.org/10.4025/actasciagron.v31i3.788

MAUAD, M *et al.* Effects of silicon and drought stress on biochemical characteristics of leaves of upland rice cultivars. **Revista Ciência Agronômica**, v. 47, n. 3, p. 532-539, 2016. DOI: https://doi.org/10.5935/1806-6690.20160064

MENDES, SM; MARUCCI, RC; WAQUIL, JM. **Manejo de pragas nos sistemas de produção de milho no Brasil: inovações tecnológicas no manejo de lagartas em lavouras de milho convencional e Bt.** Embrapa Milho e Sorgo - Capitulo 9 em livro científico (ALICE), 2018.

MENDES, L. G. **Todas as perspectivas para produção de milho 2019 e seu mercado de preços.** Lavoura 10. Aegro, jul., 2019. Disponível em: <https://www.aegro.com.br/producao-demilho-2019/>.

MIRANDA, PS *et al*. Aplicação de silício na cultura do milho. **Revista de Ciências Agroambientais**, v. 16, n. 1, p. 1-6, 2018. DOI: https://doi.org/10.5327/rcaa.v16i1.1853

MONZON, DLR *et al*. Influência da aplicação foliar de silício e sílica amorfa e sua resposta na cultura de arroz. **Brazilian Journal of Development**, v.7, n.3, p. 25932-25945, 2021. DOI: https://doi.org/10.34117/bjdv7n3-343

MOREIRA, A; FAGAN, EB; MARTINS, KV; SOUZA, CHE. Resposta da cultura de soja a aplicação de silício foliar. Bioscience Journal, v. 26, n. 3, 2010.

PEREIRA FILHO, IA; BORGHI, E. **Sementes de milho: nova safra, novas cultivares e continua a dominância dos transgênicos.** Sete Lagoas: Embrapa Milho e Sorgo, 2020. (Embrapa Milho e Sorgo. Documentos, 251).

RAHMAN, A; WALLIS, CM; UDDIN, W. Respostas de defesa sistêmica induzidas por silício em azevém perene contra infecção por *Magnaporthe oryzae*. **Phytopathology**, v. 105, n. 6, pág. 748-757, 2015.

REPKE, RA. **Eficiência da Azospirillum brasilense na fixação de nitrogênio em milho.** 2013. 68 p. (Mestrado em Agronomia - Agricultura) - Faculdade de Ciências Agronômicas da UNESP - Campus de Botucatu.

SANDIM, AS; RIBON, AA; DIOGO, LO; SAVI, MA. Doses de silício na produtividade do milho (Zea mays L.) híbrido simples na região de Campo Grande–MS. **Cultivando o Saber**, v. 3, n. 1, p. 171-178, 2010.

SANGOI, L *et al.* Desempenho agronômico do milho em razão do tratamento de sementes com Azospirillum sp. e da aplicação de doses de nitrogênio mineral. **Revista Brasileira de Ciência do Solo**, v. 39, n. 4, p. 1141-1150, 2015. DOI: https://doi.org/10.1590/01000683rbcs20140736

SILVA, CLT *et al.* Interaction between Corn Genotypes with Bt Protein and Management Strategies for *Spodoptera frugiperda* (Lepidoptera: Noctuidae). **Florida Entomologist**, v. 102, n. 4, pág. 725-730, 2020. DOI: https://doi.org/10.1653/024.102.0409

SORATTO, RP; PEREIRA, M; COSTA, TAM; LAMPERT, VN. Fontes alternativas e doses de nitrogênio no milho safrinha em sucessão à soja. **Revista Ciência Agronômica**, p. 511-518, 2010. DOI: https://doi.org/10.1590/S1806-66902010000400002