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Influence of silicon on wheat tan spot severity in the State of Goiás. Influência do silício na severidade da mancha amarela do trigo no Estado de Goiás.

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Resumo

O trigo (*Triticum aestivum* L.) é uma das culturas de maior importância no mundo. Na região Centro-Oeste do Brasil houve um grande crescimento da triticultura, entretanto, doenças como a mancha amarela (*Pyrenophora tritici-repentis*) são uma preocupação. Sabe-se que o silício atua em processos de defesa da planta, sendo assim, o objetivo deste trabalho foi avaliar a eficiência do silício associado a fungicidas na redução da severidade da mancha amarela do trigo no Estado de Goiás. O experimento foi realizado a campo, com duas cultivares de trigo e duas parcelas, onde uma recebeu quatro aplicações de silício + fungicidas e a outra apenas fungicida. A severidade foi avaliada através de uma escala de notas que varia entre 1 (pequenas manchas) e 5 (grandes áreas necróticas e cloróticas coalescentes) e se calculou o peso hectolitro. Com base no experimento, observou-se que o silício associado a fungicidas reduziu a severidade da mancha amarela em ambas as cultivares e também resultou em maior qualidade dos grãos. Conclui-se que a aplicação do silício reduz a severidade da mancha amarela do trigo, indicando o efeito do micronutriente como um indutor de resistência nas plantas nas condições do Cerrado goiano.
Palavras-chave: Barreiras físicas a doenças de plantas. Indução de resistência. Produtos à base de silício. Qualidade do trigo.

Abstract

Wheat (*Triticum aestivum* L.) is one of the most important crops in the world. In the Central-West region of Brazil, there wheat cultivation has increased greatly; however, diseases such as tan spot (*Pyrenophora tritici-repentis*) are a concern. Silicon is known to act on the plant's defense process; therefore, the objective of this work was to evaluate the efficiency of silicon associated with fungicides in reducing the severity of wheat tan spot in the State of Goiás. The experiment was carried out in the field, with two wheat cultivars and two plots, where one received four applications of silicon + fungicides and the other only fungicide. The severity was evaluated through a scale of points that varied between 1 (small spots) and 5 (large necrotic and chlorotic areas coalescing) and the hectoliter weight was calculated. Based on the experiment, it was observed that the silicon associated with fungicides reduced the severity of the tan spot in both cultivars and also resulted in higher grain quality. It was concluded that the application of silicon reduces the severity of tan spot in wheat, indicating the effect of the micronutrient as an inducer of resistance in plants under the conditions of the Goiás Cerrado.
Keywords: Physical barriers to plant diseases. Resistance induction. Silicon-based products. Wheat quality.

Introduction

The cultivation of wheat is an ancient practice which, over the years and through technological advances, has spread worldwide. Wheat (*Triticum aestivum* L.) has stood out for its importance to the global economy and for being one of the three most cultivated cereals in the world, along with corn and rice (FAOSTAT, 2020).

According to Embrapa, Brazil currently consumes around 11 million tons of wheat per year, but produced almost half of this, approximately 6.2 million tons in the 19/20 harvest (COÊLHO, 2021). However, the estimate for the 2021 harvest is encouraging, at 8.19 million tons (CONAB, 2021).

The Cerrado region appears as a possible solution, so that the country can move closer to self-sufficiency. In addition, there is the recognition that the region, is currently capable not only of producing large quantities of wheat, but also of high-quality wheat (MORAES, 2004; MIURA, 2020).

Another important factor for Brazil to come close to self-sufficiency is the increase in national production, but for this to occur, good crop management in terms of phytosanitary control is essential. One of the greatest limitations for wheat is the occurrence of diseases during its cycle, especially tan spot, caused by the fungus *Pyrenophora tritici-repentis* (Died.) Drechsler, which reduces the plant's photosynthetic area, resulting in a drop in production that exceeds 60%. Tan spot is present in all wheat regions, mainly under no-tillage and/or crops with inefficient seed treatment (REIS & CASA, 2007). The damage will depend on the amount of rain during the wheat-growing season, which affects the quantity of fungus spores that cause the infection. The number of lesions and their size will, in turn, affect the photosynthetic area and consequently result in less grain filling (SANTANA et al., 2012).

To manage tan spot, chemical (fungicides), cultural (crop rotation – two crops without wheat or barley) and genetic (resistant cultivars) strategies have been used. However, the great aggressiveness of the pathogen has challenged researchers in the development of resistant cultivars and in the efficiency of fungicides, resulting in control failures (ANTUNES, 2018). There are studies that demonstrate that the supply of silicon (Si) has significantly contributed to reducing the intensity of numerous diseases of economic importance (DATNOFF; RODRIGUES; SEEBOLD, 2007).

This element has been highlighted in the management of diseases, resulting in tolerance to water deficit and a lower intensity of diseases and pests. It also works by reducing plant stress at high temperatures and toxicity by iron, manganese (DATNOFF; RODRIGUES; SEEBOLD, 2007) and other salts (WANG et al., 2015). Theoretically, the resistance triggered by Si can be described by two basic mechanisms: the first is the deposition of silica, which leads to changes in the anatomy of the plant, such as an increase in the thickness of epidermal cells and to a mechanical defense against pest and disease infestation; and the second is the modification of the physiological and biochemical properties of the plant, such as the production of substances that inhibit infection by the pathogen, such as phytoalexins, lignin precursors, suberin biosynthesis and silicification, with silicon acting as a resistance activator (RODRIGUES et al., 2001; KIM et al., 2002; RODRIGUES et al., 2003; WANG et al., 2017).

Several studies have experimentally evaluated the effect of different Si sources on wheat diseases. Domiciano et al. (2010) evaluated calcium silicate in the resistance of the flag leaf to infection by *Bipolaris sorokiniana* Shoemaker, the causal agent of spot blotch. Later, Cruz &

collaborators (2011) analyzed potassium silicate in reducing the severity of wheat blast (*Pyricularia grisea* Cooke ex Sacc.). In this same sense, Wordell Filho et al. (2013) studied the effect of potassium silicate on leaf rust (*Puccinia triticina* Erikss) and tan spot (*P. tritici-repentis*) in Chapecó-SC. Pazdiora et al. (2018) studied the effect of silicon on tan spot under controlled conditions. Telaxka et al. (2019) investigated the impact of the application of silicon dioxide on this same disease, in Guarapuava-PR.

In addition, studies show that foliar application of silicon also results in increased agronomic performance such as that of dry mass, the number of ears and wheat productivity (SORATTO et al., 2012, GALINDO et al., 2021).

Given the above, the objective of this work is to evaluate the influence of silicon, associated with fungicides, on the severity of wheat tan spot in the conditions of the State of Goiás.

Material and Methods

Experimental location and wheat cultivars

The present work was carried out on a property (seed production field) located in Cristalina (Latitude: 16° 46' 4" South, Longitude: 47° 36' 47" West), in the State of Goiás, Brazil, during the 2021/2021 agricultural period, with planting carried out between April 6th and 9th and harvesting between July 26th and August 5th. According to the Köppen-Geiger classification, the region has a Cwa-type climate, which is characterized by being humid temperate, with a dry winter and a hot summer (CARDOSO et al., 2014).

Seeds of category S1 (not certified first generation) of two cultivars, obtained from the Federal District Farming Cooperative (Cooperativa Agropecuária do Distrito Federal – COOPA-DF), were used. Cultivar 1 (Cv. 1) is characterized by being more resistant to ear diseases and more susceptible to foliar diseases, while cultivar 2 (Cv. 2) is more resistant to foliar diseases and more susceptible to ear diseases.

Conducting the experiment and the silicon source

The experiment was carried out in two plots, both divided into four replicates. Cv.1 occupied 28 ha and Cv.2 22 ha, totaling 50 ha. During the experiment, four applications of pesticides and fertilizer were carried out (Table 1). Before planting, seed treatment was also carried out with the use of carboxine and tiram fungicide, and imidacloprid and bifenthrin insecticide. 150 kg of 05-35-00 fertilizer with boron was used at sowing and topdressing was carried out using 80 kg/ha potassium chloride and 100 kg/ha urea.

Silicon applications were carried out associated with fungicides, both of which were foliar applications. The first application was carried out on 06/05/2021, and the others at subsequent 15-day intervals. In the control plots, only the corresponding fungicides were applied in each application.

Table 1 - Spraying carried out in the field experiment to evaluate the influence of silicon on the severity of wheat tan spot in the Goiás Cerrado.

Applications/Active Principles			
1st Application	**2nd Application**	**3rd Application**	**4th Application**

Adjuvant	Adjuvant	Adjuvant	Adjuvant
Epoxiconazol + Piraclostrobina	Picozistrobin + Cyproconazole	Tebuconazole + Trifloxystrobin	Zeta-Cypermethrin
Mancozeb	Mancozeb	Orange oil	Mancozeb
Micronutrient + Si	Chlorpyrifos	Tricyclazole + Tebuconazole	Tricyclazole + Tebuconazole
-	Vegetable oil	Micronutrient + Si	Vegetable oil
-	Micronutrient + Si		Micronutrient + Si

The silicon source used was purchased from a commercial supplier, in the form of concentrated mixed mineral fertilizer registered with the Ministry of Agriculture, Livestock and Supply of Brazil, in which Si was present in the product with other nutrients at a proportional dose of 320 g/ha.

Tan spot severity assessment

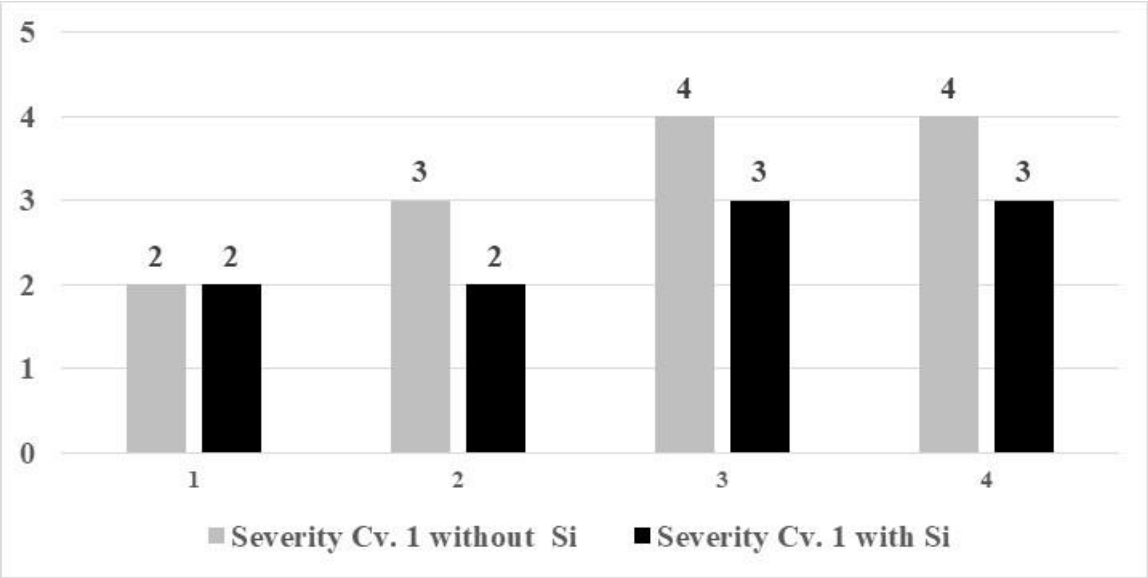
Before each application, an evaluation was carried out to determine the severity of tan spot on each cultivar. For this, the grade scale for lesions of *Pyrenephora tritici-repentis* was used, where: 1 = Small dark brown to black spots, without any surrounding chlorosis or brown necrosis (resistant); 2 = Small dark brown to black spots, with very little chlorosis or brown necrosis (moderately resistant); 3 = Small dark brown to black spots completely surrounded by a chlorotic, distinct or yellowish-brown necrotic ring; lesions usually non-coalescent (moderately resistant to moderately susceptible); 4 = Small dark brown or black spots completely surrounded by brown chlorotic or necrotic zones; some of the lesions coalescing (moderately susceptible); 5 = Dark brown or black centers may or may not be distinguishable; most lesions consist of coalescent (susceptible) chlorotic or necrotic zones (LAMARI & BERNIER, 1989).

The areas effectively assessed were of approximately 1 ha and divided into 4 blocks. In total, 16 severity evaluations were carried out, eight in each cultivar, being four evaluations in each block. At the end of the experiment, the general average of tan spot severity scores and the hectoliter weight of the areas of each treatment were calculated.

Results

Tan spot severity in cultivar 1

Based on the analyses carried out before the fungicide applications on cultivar 1 (Cv. 1), which is more susceptible to foliar diseases, it was observed that the severity of tan spot remained the same in the first evaluation, where silicon had not yet been applied, only the fungicide, receiving a grade of 2 (Graph 1). For the second reading/application, there was a difference between the evaluations, with the portion that received silicon keeping its initial grade and the one that did not receive silicon having an increase of 1 point in the initial grade: receiving grade 3. In the third reading, the tan spot severity increased in this cultivar (Cv.1) both with and without silicon (only fungicide), receiving grades 3 and 4, respectively, keeping these grades until the fourth and last evaluation. Visually, the plants with silicon were more developed (Figure 1).

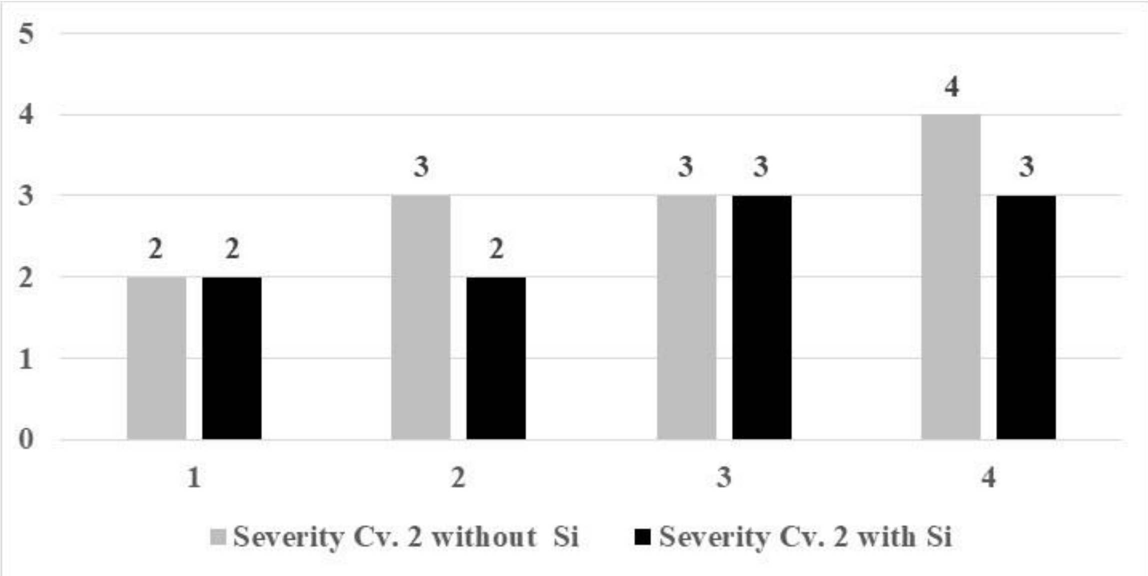


Graph 1 - Average scores obtained with cultivar 1 (Cv. 1) in an experiment on the influence of silicon on the severity of wheat tan spot (*Pyrenephora tritici-repentis*), where: gray bars represent only fungicide application and black bars represent the association of fungicide + silicon.

Figure 1 - Experiment on the influence of silicon associated with fungicides, on wheat tan spot, with cultivar 1 in A) and cultivar 2 in B), where in each figure the plant on the right is with silicon + fungicide and the left is without silicon (only fungicide).

Tan spot severity in cultivar 2

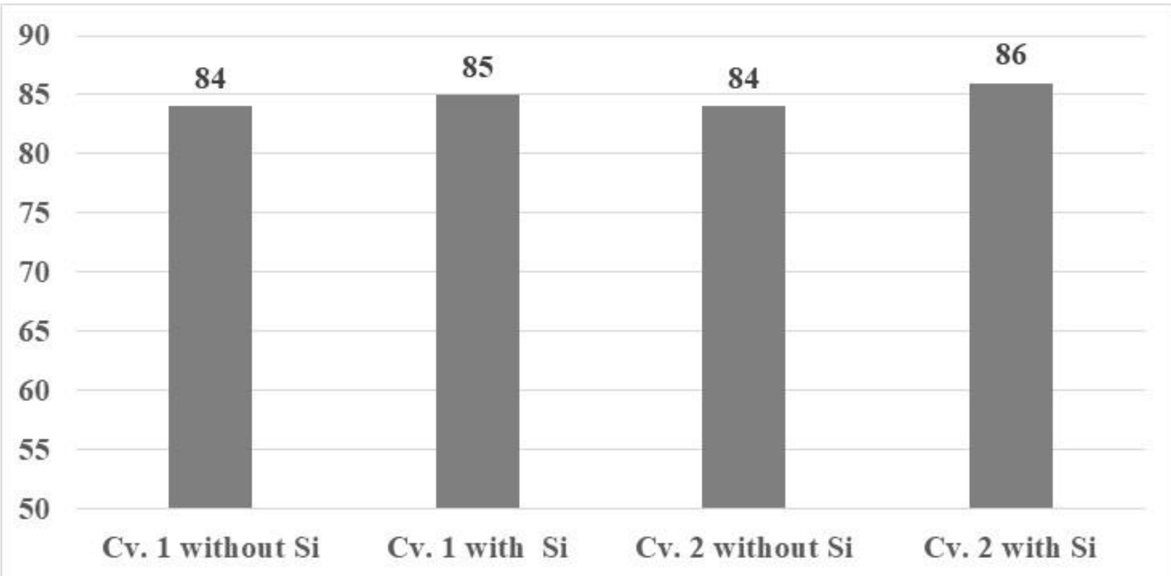
Regarding Cv. 2 (Graph 2), which is more resistant to foliar diseases, it was observed that in the first reading, without application, grade 2 was observed for both treatments; in the second reading the severity without silicon (only with fungicide) increased to grade 3, while the sample with silicon remained at grade 2. In the third reading, the severity was equal for both treatments, receiving grade 3. Finally, in the fourth reading, the treatment without silicon exhibited greater severity (grade 4) and the silicon treatment remained with grade 3.



Graph 2 - Average scores obtained with cultivar 2 (Cv. 2) in an experiment of silicon influence on wheat tan spot severity (*Pyrenephora tritici-repentis*), where: gray bars represent only fungicide application and black bars represent the association of fungicide + silicon.

Hectoliter weight

Analyzing the hectoliter weight (Graph 3), the behavior was as expected for both cultivars, where the values, in kg/hl, were slightly higher in the treatments with silicon, being 84 kg/hl for Cv 1. without silicon and 85 kg/hl with silicon, respectively. And for cultivar 2, the values were 84 kg/hl without silicon and 86 kg/hl with silicon.



Graph 3 - Hectoliter weight (kg/hl) of wheat seeds in two different cultivars (Cv. 1 and Cv. 2), with and without silicon associated with fungicides in the treatment of tan spot (*Pyrenephora tritici-repentis*).

Discussion

In the present work, it was observed that the two cultivars, one more susceptible to foliar diseases and the other more resistant, were shown, according to the scale of Lamari & Bernier (1989), to be moderately resistant to the application of fungicides associated with silicon, at first. The chemical barrier hypothesis is based on the fact that when soluble Si is applied, it activates the plant's natural defense system when a pathogen infects it, forming a protective barrier. Furthermore, silicon also stimulates the production of phenolic compounds, chitinases, peroxidases and the accumulation of lignin, associated with the plant's defense mechanism against the pathogen's attack. Thus, these compounds are accumulated in the cell wall, preventing or hindering the colonization of the plant by the fungus (RODRIGUES et al., 2001; KIM et al., 2002; RODRIGUES et al., 2003; WANG et al., 2017). This hypothesis was also raised for rice blast (RODRIGUES et al., 2001; RODRIGUES et al., 2003).

Other reports in the literature cite the effect of Si regarding wheat diseases. Domiciano et al. (2010) reported that calcium silicate exhibited a positive effect by increasing the resistance of the flag leaf to infection by *B. sorokiniana* (brown spot). Cruz et al. (2011) also observed a reduction in the severity of blast (*P. grisea*) when potassium silicate was used.

Regarding tan spot, Wordell Filho et al. (2013) reported that the association of fungicides and potassium silicate provided smaller areas under the progress curve in an experiment carried out in Chapecó in the state of Santa Catarina, Brazil. The results of the present work also corroborate those of Pazdiora et al. (2017), where in an experiment under controlled conditions, there was greater resistance to tan spot even in susceptible cultivars; however, the greatest reduction in tan spot was in moderately resistant cultivar. Later, Telaxka et al. (2019) also observed that the chemical treatment of fungicide and SiO_2 reduced the severity of tan spot in Virmond and Guarapuava in the state of Paraná, Brazil, corroborating the results of the present study. These authors, as well as Dorneles et al. (2018), add that treatment with Si leads to greater activity of the enzymes polyphenoloxidase (PPO) and phenylalanine ammonia-lyase (PAL); that is, defense mechanisms of wheat plants that interfered in the infectious process of pathogens were activated.

Finally, about the hectoliter weight (HW), it is important to highlight that it is an indirect attribute for the quality of wheat grains and expresses a certain mass, within a known volume; thus, the higher the HW, the greater the yield. According to Corrêa et al. (2006), this parameter is an indicator of quality and yield in flour extraction. In this attribute, both cultivars that received silicon exhibited higher quality and yield, when compared to treatments without the addition of the micronutrient, which once again indicates the beneficial effect of its use. These results also corroborate those presented by Soratto et al. (2012), Wordell Filho et al. (2013), Telaxka et al. (2019) and Galindo et al. (2021).

Conclusions

It was concluded that the application of silicon associated with fungicides reduced the severity of tan spot in wheat, indicating the effect of the micronutrient as an inducer of resistance in plants. Si application also resulted in higher quality and yield of both cultivars evaluated, regardless of the level of susceptibility or resistance to disease.

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