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Scientific and technological research article

Development of the southern corn leaf blight caused by *Bipolaris maydis* (teleomorph: *Cochliobolus heterostrophus* in sweet corn as a function of nitrogen, potassium, and silicon under greenhouse conditions

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Abstract

This work aimed to evaluate the development of the southern corn leaf blight caused by *Bipolaris maydis*, a common disease in sweet corn, depending on the dose and the accumulated nitrogen, potassium, and silicon, under greenhouse conditions. The treatments consisted of five doses of nitrogen (0, 200, 400, 800, and 1,200 kg/ha), application or not of potassium (240 kg/ha), and application or not of silicon (380 kg/ha). A completely randomized design with factorial arrangement 5 x 2 x 2 and three repetitions was used. All the treatments were inoculated on day 30 with a suspension of 2×10^5 conidia by mL of *B. maydis*. On day 42, the accumulated N, K, and Si were measured, as well as the infection percentage and the area under the disease progress curve (AUDPC). The treatments that received fertilization with Si and K showed higher accumulation of N, K and Si, and lower levels of disease intensity and AUDPC. The accumulated N, K, and Si exhibited variations compared to the fertilization interactions of K with N, and Si with N; however, the levels of the disease variables were lower in the fertilization with K or Si, combined with the doses of 0, 200 and 400 kg/ha of N.

Keywords: *Cochliobolus heterostrophus*, fertilizer application, fungal diseases, nutrient uptake, *Zea mays*

Desarrollo de la mancha foliar por *Bipolaris maydis* (teleomorfo: *Cochliobolus heterostrophus* en maíz dulce, en función de nitrógeno, potasio y silicio en invernadero

Resumen

El objetivo del trabajo fue evaluar el desarrollo de la mancha foliar causada por *Bipolaris maydis*, enfermedad común en maíz dulce, según la dosis y el acumulado de nitrógeno, potasio y silicio, en condiciones de invernadero. Los tratamientos consistieron en cinco dosis de nitrógeno (N) (0, 200, 400, 800 y 1.200 kg/ha), aplicación o no de potasio (K) (240 kg/ha) y aplicación o no de silicio (Si) (380 kg/ha). Se empleó un diseño experimental completamente aleatorizado con esquema factorial 5 x 2 x 2 y tres repeticiones. Se inocularon todos los tratamientos a los 30 días con una suspensión de 2×10^5 conidios por mL de *B. maydis.* A los 42 días se midió la acumulación de N, K y Si, así como el porcentaje de infección y el área bajo la curva de progreso de la enfermedad (ABCPE). Los tratamientos que recibieron fertilización con Si y K presentaron mayores acumulados de N, K y Si, y niveles más bajos de intensidad de ataque y ABCPE. Los acumulados de N, K y Si presentaron variaciones frente a las interacciones de la fertilización de K con N, y de Si con N; sin embargo, los niveles de las variables de la enfermedad fueron menores en la fertilización con K o Si, combinadas con las dosis de 0, 200 y 400 kg/ha de N.

Palabras clave: absorción de sustancias nutritivas, aplicación de abonos, *Cochliobolus heterostrophus*, enfermedades fungosas, *Zea mays*

Introduction

Corn cultivation is the second-largest grain-producing area worldwide, and in 2017, the United States, China, and Brazil were the largest producers (Agricultores, 2017). In the five continents, sweet corn is an integral part of the daily diet, and its consumption trend is increasing in both fresh and processed products (Parera, 2017).

The nutritional elements with the highest demand by corn plants are nitrogen (N) and potassium (K) (Sousa et al., 2010). Both nutrients are essential elements for the life of plants. The first is essential for the normal development of corn since it intervenes in the formation of chlorophyll in proteins, vitamins, and energy sources (Prado, 2008). On the other hand, potassium intervenes in the respiratory and photosynthetic processes; in the maintenance of the hydration state necessary for the more active functioning of the microstructures of the cellular colloids; in the cost economy of water consumption by transpiration when activating stomata closure once humidity is lacking; and as an activator of enzymes and transport of substances within the plant (Malavolta, 2006).

Corn yield responds to increasing applications of nitrogen, most of which is accumulated by the plant before producing the cob, and in the case of sweet corn, in optimal doses of 240 kg/ha (Opazo et al., 2008). Potassium also shows increasing absorption in the first stage of plant growth, and the highest yields are reported with doses between 150 and 200 kg/ha in sweet corn in soils rich in this mineral (Meneses et al., 2017).

On the contrary, silicon (Si) is not considered an essential element for plants; however, its absorption can cause beneficial effects in various crops as it attenuates abiotic stress (Mahdieh et al., 2015; Olivera et al., 2019; Silva et al., 2016) and induces resistance to pests and diseases (Castellanos et al., 2015b). Among the Si accumulating crops, we find, among others, grasses such as sugarcane *Saccharum* spp., Rice *Oryza sativa* L., and corn *Zea mays* L. (Poaceae) (Raya & Aguirre, 2012).

Among the most important fungal diseases of corn cultivation worldwide is the southern corn leaf blight or helmintosporiosis caused by *Bipolaris maydis* (Y. Nisik & C. Miyake) Shoemaker (teleomorph: *Cochliobolus heterostrophus* Drechsler). The disease has been the subject of several studies due to the existence of races O and T (associated with hybrids that incorporate the Texas source of male sterility in the United States), and the possibility of differences in the morphological and pathogenic characteristics of the fungus. However, for most authors, race O is the most widespread and can cause epidemics in certain conditions (Pal et al., 2015). The southern corn leaf blight commonly attacks sweet corn when it develops in humid conditions and with temperatures between 20 °C and 32 °C, which can cause significant damage when the plant is infected young and the varieties are susceptible (Seminis, 2015).

Reports on the decrease in the incidence and severity of fungal diseases due to the application of Si in rice cultivation have been reported by several researchers (Santos et al., 2011; Santos et al., 2003; Zanão et al., 2009). However, no information has been found in the literature on the benefits of Si in reducing the severity of foliar diseases of corn, nor on the interaction of doses of N, K and Si on the development of diseases in this crop.

Considering the bac kground information, the aim of this research was to evaluate the development of the southern corn leaf blight caused by *B. maydis*, a common disease in sweet corn, according to the dose and accumulation of nitrogen, potassium, and silicon under greenhouse conditions.

Scientific contribution

The work makes a contribution to the knowledge of the effect of Si on the development of the southern corn leaf blight of sweet corn caused by *B. maydis*, depending on different doses and accumulations of N and K, and shows that the disease is less severe when silicon is present compared to when there is no excess of N in the plant or any dose of K.

Materials and methods

The experiment was carried out in an unheated greenhouse at Facultad de Ciencias Agrarias y Veterinarias of Universidad Estadual Paulista (Unesp-FCAV) located in Jaboticabal, São Paulo (Brazil), between May and June 2014. To evaluate the effect of the interaction of N, K, and Si on the development of the disease, sweet corn *Zea mays* L. variety Syngenta 41. 234 was used as an indicator crop, as well as the pathogenic fungus *B. maydis*. This sweet corn variety was obtained from the collection of Departamento de Horticultura (Unesp-FCAV) in Jaboticabal, characterized by being extremely sweet, having a good yield potential, a 90-day cycle, and recommended for the summer conditions of the São Paulo area.

The plants were developed on a Typic Hapludox soil, which, according to the analyzes carried out through the methodology of Raij (1990), showed the following characteristics: pH in $CaCl_2$ = 5.5; organic matter (OM) (g/dm^3) = 8; P resin (mg/dm^3) = 6; K (mmol$_{c/}$dm^3) = 1.4; Ca (mmol$_{c/}$dm^3) = 16; Mg (mmol$_{c//}$dm^3) = 9; H+Al (mmol$_{c/}$dm^3) = 15; sum of bases (SB) (mmol$_{c/}$dm^3) = 26.4; cationic exchange capacity (CEC) (mmol$_{c\ /}$dm^3) = 41.4; base saturation (V) (%) = 63.5, B (mg/dm^3) = 0.20; Cu (mg/dm^3) = 0.2; Fe (mg/dm^3) = 4.0; Mn (mg/dm^3) = 4.2; Zn (mg/dm^3) = 0.3; and Si 10.2 mg/dm^{-3}.

The treatments consisted of five doses of N, application or not of K, and application or not of Si. Nitrogen doses were 0, 100, 200, 400 and 800 mg/dm^3 (0, 200, 400, 800 and 1,200 kg/ha of N –as urea, 45 % of N–). The two doses of K were 0 and 120 mg/dm^3 of K_20 as KCI (60 % K) (0 and 240 kg/ha). In treatments with Si, 190 mg/dm^3 of Agrosilicio Plus (10.25 % of Si; 25 % of Ca, 6 % of Mg, and PN of 81 %) was applied at a rate of 380 kg/ha of fertilizer.

Treatments that did not receive Si were limed to balance base saturation (%/V) at 8 % using calcareous at 190 mg/dm^3 (380 kg/ha of calcareous comprises 24 % of CaO, 17 % of MgO, and 81 % of PN). In all treatments, phosphorus (150 mg/dm^3 of P_2O_5) as triple superphosphate (soluble P_2O_5 = 41 %) (300 kg/ha of P_2O_5) was applied uniformly.

A completely randomized experimental design with a 5 x 2 x 2 factorial scheme (20 treatments) with three replicates was employed. The experimental unit was composed of a 5 dm^3 polypropylene pot, where five corn grains were planted, and four plants were finally left. Daily irrigations were carried out with a watering can, keeping soil moisture between 60 % and 70 % of field capacity.

Thirty days after germination (at sunset), all the plants in the experiment were inoculated with a suspension of 1.2 x 10^5 conidia per mL of *B. maydis,* using a 2 L manual sprinkler. The fungus was obtained from the strains collection of the Plant Pathology Laboratory of Unesp Jaboticabal and cultured in Petri dishes on potato dextrose agar (PDA) for seven days.

From the moment the inoculation was carried out until the end of the experiment, rows of 8 L capacity trays with water were placed inside the pots to increase the relative humidity, which were kept filled during the rest of the time the experiment lasted. Besides, daily irrigations in the greenhouse floor were made at 10 a.m., 12 p.m., 2 p.m., and 4 p.m. for 12 days from inoculation.

Plants were observed daily until the appearance of symptoms, and the percentage of infestation was evaluated at 6, 9, and 12 days after inoculation. Each plant was assigned a degree of severity of the attack based on a scale of six degrees (Püntener & Zahner, 1981) (0 without symptoms and 5 more than 50 % of the leaf area with symptoms). The percentage of infection per experimental unit was established using the Townsend and Heuberger formula (Püntener & Zahner, 1981). At 42 days, the area under the disease progress curve (AUDPC) was estimated according to the method of Campbell and Madden (1990).

At 42 days after germination (12 days after inoculation), the trial, scheduled for 45 days, was dismounted, since, at that point, there were notable differences between treatments.

At the end of the experiment, the dry matter was determined from the collection of the four plants in each pot (leaves and stems). For this, the plant material was placed in paper bags and dried in an oven with forced air circulation at 65 °C for 96 hours until constant weight. After drying, the samples were weighed, and the dry weight per pot was obtained. Next, the samples were grounded in a Willey mill, establishing the N and K content according to the methodology described by Bataglia et al. (1983), and the content of Si by the methodology of Kraska and Breitenbeck (2010). Based on the dry mass per pot, and the content of each element in leaves and stems, the accumulation of Si, K, and N (g per pot) was calculated.

The cumulative data for N, K, and Si, as well as the severity percentage for *B. maydis* at the end of the trial and the AUDPC, were subjected to an analysis of variance once the assumption of normality was verified by the Kolmogorov Smirnov test. The severity percentages were transformed into 2 arcsen $\sqrt{\%/100}$. The data of the means were compared using Tukey's test ($p < 0.05$). The SISVAR statistical program (Furtado, 2011) was used.

Results and discussion

On the fifth day of inoculation, some small spots were observed in the experiment in the leaves of the corn plants, and, on the sixth day, generalized symptoms were observed in all the treatments, but with different levels of intensity in the plants (figure 1). The samples that were taken to the laboratory allowed to re-isolate and identify the *B. maydis* fungus. Subsequently, the typical conidia of the fungus could be observed from direct stain preparations.

a b

Figure 1. a) leaf without symptoms belonging to the treatment K 240 kg/ha, Si 380 kg/ha, and N 200 kg/ha; b) leaf belonging to the treatment K 240 kg/ha, silicon 0 kg/ha, and N 200 kg/ha.
Source: Elaborated by the authors

The mean average temperature during the incubation period of the fungus was 22.8 °C, and the average relative humidity was 63.7 %. During the disease development period, the mean temperatures ranged between 23.1 °C and 27.5 °C, and the mean relative humidity ranged between 56.0 % and 68.5 % (figure 2).

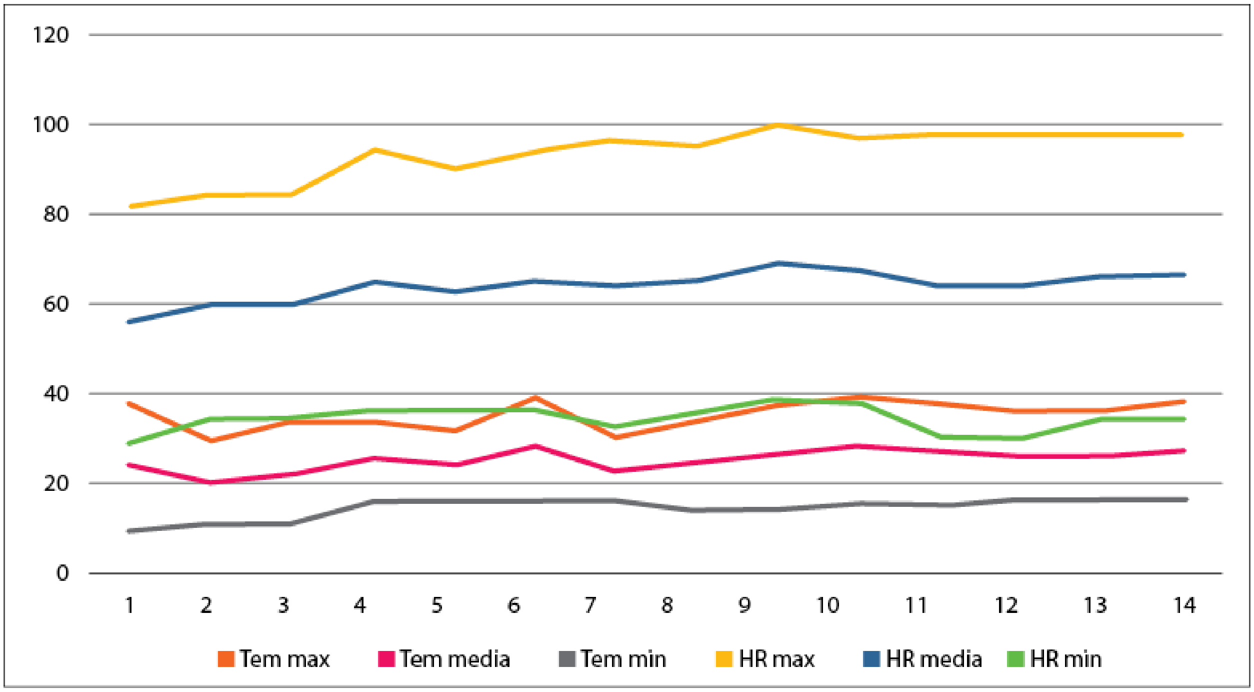

Figure 2. Temperature (maximum, mean, and minimum) and relative humidity (maximum, mean, and minimum) conditions that occurred from the time *B. maydis* was inoculated until the test concluded.
Source: Elaborated by the authors

These meteorological conditions in the greenhouse correspond to those reported as favorable for the development of the southern corn leaf blight caused by *B. maydis* in corn –in general– (Naz et al., 2013) and in sweet corn –in particular– (Seminis, 2015), which favored the successful development of the experiment.

In the analysis of variances, significant F values were verified for the simple effects of the doses of N, K, and Si on the accumulated N, K, and Si in the corn plants, as well as for the severity of *B. maydis* and the AUDPC. The F values were significant for the interaction effects between Si and K on the accumulations of K, the severity of *B. maydis,* and the AUDPC. Likewise, the F values of the interaction of Si x N on the accumulated values of N, K, and the severity of *B. maydis* and AUDPC were significant. The F values were also significant for the effects of the interaction of K x N in all the variables studied (table 1).

Table 1. F values of the ANOVA for the accumulated values of the elements N, K, and Si, and the variables of the disease

Factors	Accumulated			AUDPC [a]	Severity 2 arcsen √ %/100
	N	K	Si		
	F values				
Silicon	18.33**	27.91**	135.92**	475.46**	474.98**
Nitrogen	9.45**	5.84**	30.00**	36.04**	35.43**
Potassium	7.36**	121.07**	40.50**	80.26**	80.97**
Si x N	3.02*	4.64**	3.49*	16.82**	16.56**
Si x K	43.89**	5.22**	4.09*	12.60**	10.29**
N x K	8.13**	5.60**	7.89**	21.61**	22.35**
CV (%)	15.67	7.54	14.17	6.30	4.32

* Significant for $p \leq 0.05$, ** significant for $p \leq 0.01$.

Source: Elaborated by the authors

Castellanos et al. (2015a) also verified the influence of the interactions of Si x K, Si x N, and K x N on the accumulation of K and Si, as well as the last two elements on the accumulation of N in corn plants under hydroponic conditions.

The increase in N accumulation that occurred in the presence of Si is explained by Feng et al. (2010), who pointed out that Si can improve N metabolism and increase the enzymatic activity responsible for the reduction and assimilation of N.

The application of K to the corn plot was reflected in a higher accumulation of this element in the leaf of the plant, which corresponds to the description stated by Andreotti et al. (2000), who obtained an increase in the concentration of K with an upwards increase in the doses of K.

Results of the increase in the accumulation of N as a function of N doses were also obtained in the aerial part of the corn plants (leaves, stems, cobs, straws, and grains) by Gava et al. (2010).

Many authors have noted the increase in silicon accumulation in different crops in response to the application of this beneficial element in corn (Ávila et al., 2010; Barbosa et al., 2011) and rice under hydroponic conditions (Mauad et al., 2013).

The accumulation of N, K, and Si in corn plants increased compared to the rest of the interactions at the dose of 380 kg/ha of Si and 240 kg/ha of K. The accumulation of N was lower in the treatment where Si and 240 kg/ha of K were not applied; moreover, also in the one with K in the two interactions where K was not applied, and the one with Si in the interactions where K was not applied as fertilizer. The intensity of *B. maydis* and AUDPC were higher in the interaction dose 0 of Si and dose 0 of K, while lower values of the disease severity were observed in the interaction of the dose of 380 kg/ha of Si with 240 kg/ha of K (table 2).

Table 2. Comparison of the means of the accumulated N, K, and Si and the AUDPC, and the intensity of *Bipolaris maydis* for the Si x K interaction

Treatments		Accumulated (mg per pot)			*Bipolaris maydis*	
Doses of Si (kg/ha)	Doses of K (kg/ha)	N	K	Si	AUDPC	Severity (%/)
0	0	61.51 b	1450.94c	118.37 d	12.33 a	75.8 a
0	240	51.70 c	2326.09b	158.68 c	11.44 b	69.0 b
380	0	55.64 bc	1751.80c	192.82 b	9.33 c	56.1 c
380	240	79.06 a	3085.92a	234.56 a	7.27 d	43.7 d
Typical error*		2.18	86.98	5.58	0.14	

* Different letters in the column differ for $p \leq 0.05$.

Source: Elaborated by the authors

In the interaction of dose 0 of Si and dose 0 of K, more N was accumulated compared to the interaction 0 of Si and 240 kg/ha of K, contrary to what Castellanos et al. (2015a) observed in corn under hydroponic conditions. This could be explained by the Si present in the soil, which helps in the absorption of N under stress conditions due to a lack of K.

This result agrees with Kaya et al. (2006), who observed an increase in the amounts of K in the corn plant in the presence of Si when they were subjected to water stress.

Other investigations have shown that Si increases stomatal conductance in a way that it promotes a better water use efficiency, such as in the cultivation of canola *Brassica napus* L. (Brassicaceae) (Farshidi et al., 2012). This also induces an increase in transpiration since it favored an increase in the absorption of K in the denseflower cordgrass *Spartina densiflora* Brongn. (Poaceae) under salt stress (Mateos-Naranjo et al., 2013). All of the above is explained because Si actively participates in the closure and opening of the stomata (Prado, 2008).

The highest level of accumulated N was observed in the interactions with the doses of 200, 400 and 600 kg/ha of N with 240 kg/ha of K, with 200 kg/ha of N and with 0 kg/ha of K; furthermore, also with the lower interactions of 0 kg/ha of K and the lowest and highest doses of N (0, 400 and 600 kg/ha) and at the doses of 240 kg/ha of K and 0 kg/ha of N (table 3).

Table 3. Comparison of the means of the accumulated N, K, and Si, the AUDPC, and the intensity of *Bipolaris maydis* for the K x N interaction

Treatments		Accumulated (mg per pot)			*Bipolaris maydis*	
Doses of K (kg/ha)	Doses of N (kg/ha)	N	K	Si	AUDPC	Severity (%/)
0	0	41.60 d	1330.41 c	84.07 c	11.52 a	69.3 a
0	200	67.16 abc	1680.27 bc	199.58 ab	10.83 a	66.1 a
0	400	59.32 bcd	2319.63 ab	214.67 ab	9.44 b	56.2 bc
0	600	60.01 bcd	1671.14 bc	171.36 b	10.69 a	63.8 ab
0	800	50.59 cd	1005.40 c	108.27 c	11.66 a	70.8 a
240	0	56.11 cd	2918.76 a	184.29 b	7.91 c	47.0 d
240	200	60.47 bc	2969.09 a	208.90 ab	7.91 c	47.5 d
240	400	76.27 ab	2617.06 a	236.70 a	8.47 c	50.5 cd
240	600	81.32 a	2528.69 a	179.35 b	10.83 a	64.5 a
240	800	66.88 abc	2496.42 a	173.87 b	11.66 a	70.5 a
Typical error*		3. 99	159.34	10.23	0.26	

* Different letters in the columns differ for $p \leq 0.05$.

Source: Elaborated by the authors

The accumulation of K was favored when fertilized with K, regardless of the dose of N, as well as with an intermediate dose of N (400 kg/ha) compared to the absence of K.

The highest accumulated Si was observed in the doses of 200 and 400 kg/ha of N with or without the application of K. On the other hand, the lowest values were found in the treatments where K was not applied at the highest and lowest doses of N (0 and 800 kg/ha). At low and high doses of N, we verified that the Si is absorbed less by the corn plant, and fertilization with K increases the absorption efficiency.

These results agree with those of Mauad et al. (2013), who found an interaction of the Si content with the combinations of the doses of this element with N in the aerial part of the rice plants.

Castellanos et al. (2015a) also observed the influence of Si accumulation in the corn plant under hydroponic conditions as a function of the K x N interaction for both low and high doses of K. In both cases, the maximum accumulated values were found in intermediate concentrations of N between 10 and 15 mmol/L.

The lower AUDPC and the attack severity of *B. maydis* occurred in treatments with 240 kg/ha of Si and N doses of 0, 200 and 400 kg/ha, although this last variable did not differ statistically between treatments with and without application of K and 400 kg/ha of N. The highest AUDPC were found in the treatments without the application of K (0 kg/ha) and in the lowest and highest doses of N (0, 200, 600 and 800 kg/ha), as well as before the application of K (240 kg/ha) and in the highest doses of N (600 and 800 kg/

ha). On the other hand, the severity was higher when K was not applied compared to the low and high doses of N (0, 600, and 800 kg/ha) and when K was applied compared to the highest doses of N (600 and 800 kg/ha).

When the four fertilization doses under study included N, a high accumulation of N was achieved in the corn plant before fertilization with Si, and intermediate doses of N were only achieved when plants were not fertilized with silicon. The highest level of accumulated N was observed when treated with Si in interactions with doses of 200, 400, 600, and 800 kg/ha of N, and when Si was not applied at doses of 200, 400 kg/ha of N. However, the last interaction (0 kg/ha of Si x 400 kg/ha of N) did not differ statistically from other treatments, including those that received 0 kg/ha of N (table 4).

Table 4. Comparison of means for the accumulated values of N, K, and Si, in addition to the AUDPC and the intensity of *Bipolaris maydis* for the Si x N interaction

Treatments		Accumulated (mg per pot)			*Bipolaris maydis*	
Doses of Si (kg/ha)	Doses of N (kg/ha)	N	K	Si	AUDPC	Severity (%/)
0	0	45.46 c	1706.33 cd	113.98 e	12.22 ab	73.9 ab
0	200	72.92 a	1856.02 bcd	160.47 cde	11.94 b	72.8 b
0	400	58.89 abc	2241.59 abcd	181.12 bc	10.55 cd	63.5 cd
0	600	52.45 bc	1751.96 cd	122.87 de	11.52 bc	69.4 bc
0	800	53.31 bc	1886.67 bcd	114.17 e	13.19 a	79.3 a
380	0	52.26 bc	2542.84 ab	154.37 cde	7.22 e	43.1 e
380	200	68.88 ab	2793.34 a	248.02 a	6.80 e	40.3 e
380	400	76.71 a	2695.11 a	270.24 a	7.36 e	44.0 e
380	600	73.58 a	2447.87 ab	227.84 ab	10.00 d	60.1 d
380	800	65.31 ab	1615.16 d	167.97 cd	10.13 d	60.3 d
Typical error*		3.99	159.34	10.23	0.26	

* Different letters in the columns differ for $p \leq 0.05$.

Source: elaborated by the authors

In the absence of Si, there was no difference in the accumulated K for the interactions with the different doses of N. The accumulated K increased in the presence of treatment with Si and the doses of 0, 200, 400 and 600 kg/ha of N, in relation to the dose of 800 kg/ha, but did not differ concerning the interaction without Si x 400 kg/ha of N.

The highest accumulated Si were observed at the N doses of 200, 400, and 600 kg/ha, without statistical difference with the interaction without silicon and the intermediate dose of N (400 kg/ha). At low and high doses of N, Si is less absorbed by the corn plant, and the fertilization with Si increases the absorption efficiency.

These results confirm that the Si accumulation in plants is affected with the nutritional disequilibrium that is produced with high doses of N. This has been raised as well by Mauad et al. (2013), who informed the decrease in silica deposition in rice plant leaves compared to the highest dose of N, and by Castellanos al. (2015a), in their observations of corn under hydroponic conditions.

The lower AUDPC and attack severity of *B. maydis* were presented with the application of Si and low levels of N, which is confirmed in the treatments with 380 kg/ha of Si and doses of 0, 200, and 400 kg/ha of N. The highest AUDPC and attack severity occurred in the treatments with 0 kg/ha of Si, and with the lowest and highest doses of N (0 and 800 kg/ha). In general, the application of Si had an impact on the development of the disease since the values of the disease variables were similar for the treatments 380 kg/ha of Si x 600 and 800 kg/ha of N, and 0 kg/ha of Si x 400 kg/ha of N. This last treatment stands out for the low levels of attack severity and AUDPC when Si was not applied.

In the consulted literature, results were obtained related to the positive effect of silicon on other corn diseases that affect the stem, such as those caused by *Pythium aphanidermatum* (Edson) Fitzp, *Fusarium graminearum* Schwabe (*Gibberella zeae*), and *F. moniliforme* (Sawada) Wollenw (*G. fujikuroi*) (Sun et al., 1994).

Regarding foliar diseases in other grasses, Santos et al. (2003) reported higher severity of blight caused by *Magnaporthe grisea* (T.T. Hebert) M.E. Barr in the leaves of rice plants, where Si was not applied, in relation to the treatment where the highest dose was applied.

Zanão et al. (2009) observed that the application of Si in rice was reflected in a higher concentration of Si in the leaves and higher resistance to helmintosporiosis by *Bipolaris oryzae* (Breda de Haan) Shoemaker. Furthermore, Zanão et al. (2010) reported having verified a lower content of N in the leaves of the rice when they showed higher affectation by *B. oryzae.*

Pereira et al. (2010) also verified differences in the severity and AUDPC of *Bipolaris sorokiniana* Shoemaker in plants of two wheat varieties that had received Si fertilization compared to others that did not receive it. These authors verified a higher concentration of Si in the leaves of the plants that were fertilized with this element.

The increase in resistance of plants by silicon applications has been associated with the higher density of silicate cells in the epidermis of the leaves, which act as a physical barrier to the penetration of fungi. Although Si is a bioactive element in different biological systems, the mode of action in plants is not fully known (Romero et al., 2011). Furthermore, these authors suggest the existence of results that show that Si can also act locally inducing defense reactions and that it can also contribute to systemic resistance through stress hormones, although the exact mechanism in which silicon operates is not yet clear.

For this reason, the current results, although they explain the role that Si can play in the resistance of corn to *B. maydis*, especially when there is balanced fertilization of N in the plant, must be taken as a starting point to carry out other research that delves into the mechanisms of action of Si that generates this beneficial response. On the other hand, the role of K in disease resistance at low concentrations of N should be further explored in future research, due to the significant decrease observed in the severity of the southern corn leaf blight with high potassium fertilization at doses of 0, 200 and 400 kg/ha of N.

Conclusions

The southern corn leaf blight was present in all treatments, but the disease variables were always influenced by fertilization with nitrogen, potassium, and silicon, which induced higher severities and AUDPC in the interaction of dose 0 of Si and dose 0 of K, and lower disease severities at the dose 380 kg/ha of Si with 240 kg/ha of K.

In the treatments that received fertilization with Si and K combined with the intermediate dose of N, there were higher accumulations of N, K, and Si and lower levels of severity and AUDPC.

The accumulations of N, K, and Si showed variations compared to the interactions of K and N fertilization since they showed lower levels of the disease variables in fertilization with K and N, with doses between 0 and 400 kg/ha. In contrast, the accumulations of N, K, and Si also varied compared to the different combinations of Si and N fertilization. With these, lower severities and AUDPC are observed in fertilization with Si and N, with doses between 0 and 400 kg/ha.

Finally, high doses of N did not favor the absorption of Si, which prevented its beneficial role. Therefore, higher disease indicators were observed.

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Disclaimers

All the authors made significant contributions to the document, so they all agree with its publication and declare that there are no conflicts of interest in this study.

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