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Biological aspects and feeding behavior of cotton aphid in watermelon cultivars submitted to silicon application

Aspectos biológicos e comportamento alimentar do pulgão-do-algodoeiro em cultivares de melancia submetidas à aplicação de silício

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ABSTRACT: This research aimed to evaluate the biological aspects and the feeding behavior of *Aphis gossypii* in watermelon cultivars submitted to silicon application. The experiment was conducted at the Institute of Education, Agriculture and Environment of the Federal University of Amazonas, Humaitá, Brazil. The experimental design was completely randomized in a 2×3 factorial (with and without silicon; cultivars Crimson Sweet, Fairfax and Charleston), with ten replications. The application of silicic acid (1%) was carried out directly on the substrate using dose equivalent to 1 ton $SiO_2 \cdot ha^{-1}$, 25 days after sowing. The rearing of aphids was kept in cucumber plants, cultivar Caipira. Insect biology tests were conducted to evaluate the duration of the prereproductive, reproductive and postreproductive periods, longevity, number of nymphs, and feeding behavior using the honeydew secretion technique. Analysis of variance was performed using the statistical program SISVAR and the means were compared by the F and Scott–Knott test ($p \leq 0.05$). The silicon application to watermelon plants affects the reproduction and feeding of *A. gossypii*. The watermelon plants cultivar Crimson Sweet treated with silicon has high resistance to feeding by *A. gossypii*.

KEYWORDS: silicon acid; aphids; cucurbitaceous; constitutive resistance; *Aphis gossypii.*

RESUMO: Nesta pesquisa objetivou-se avaliar os aspectos biológicos e o comportamento alimentar de *Aphis gossypii* em cultivares de melancia submetidas à aplicação de silício. O experimento foi conduzido no Instituto de Educação, Agricultura e Ambiente da Universidade Federal do Amazonas, Humaitá, Brasil. Utilizaram-se o delineamento experimental inteiramente ao acaso e o esquema fatorial 2×3 (sem silício e com silício; cultivares Crimson Sweet, Fairfax e Charleston), com dez repetições. A aplicação do ácido silícico (1%) foi realizada diretamente no substrato, com dose equivalente a 1 ton $SiO_2 \cdot ha^{-1}$, 25 dias após a semeadura. Os pulgões da criação foram mantidos em plantas de pepino, cultivar Caipira. Foram conduzidos ensaios de biologia do inseto para avaliação da duração dos períodos pré-reprodutivo, reprodutivo e pós-reprodutivo, longevidade, número de ninfas e comportamento alimentar por meio da técnica de secreção de *honeydew*. Realizou-se a análise de variância dos dados utilizando-se o programa estatístico SISVAR e as médias foram comparadas pelo teste de F e Scott–Knott ($p \leq 0,05$). A aplicação de silício em plantas de melancia afeta a reprodução e a alimentação de *A. gossypii*. Plantas de melancia do cultivar Crimson Sweet tratadas com silício apresentam alta resistência à alimentação por *A. gossypii*.

PALAVRAS-CHAVE: ácido silícico; afídeos; cucurbitácea; resistência constitutiva; *Aphis gossypii*.

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INTRODUCTION

Watermelon, *Citrullus lanatus* (Thunb.) Matsum & Nakai, is a Cucurbitaceae with a worldwide production of 118 million tons, and Brazil is the world's fifth largest producer with 2.240 million tons (FAO, 2018). In the state of Amazonas, Brazil, watermelon planted area covers 3068 hectares, involves 8415 family farmers (IBGE, 2017), and is a crop of great importance, especially for small farmers.

Pest insects can infest watermelon plantations and reduce production and fruit quality. The aphid *Aphis gossypii* Glover (Hemiptera: Aphididae) is one of the main pests of this crop (SILVA et al., 2002). This species can feed on different cultures and is widely distributed around the world (BLACKMAN; EASTOP, 1984). It sucks the plant sap, causes deformities in the leaves and branches, reduces the plant photosynthetic capacity, as well as facilitates transmission of viruses from the genus *Potyvirus* (PINTO et al., 2008).

Application of chemical products is still the most used method to control *A. gossypii* in watermelon plants. However, there are many reasons to invest in alternative control methods to replace or decrease the use of insecticides, such as development of pest resistance to the active principle (PALUMBO et al., 2001) and consequently increased dosage and applications, the high cost of chemical control and persistence on vegetal products and ecotoxicological problems. Thus, alternative methods of pest control are increasingly being studied.

The plants resistance to insect attack can collaborate to maintain the aphid population density below the level of economic damage, consequently, reducing losses in production. Therefore, the use of variety resistant to aphids can be a good alternative. The induced resistance is another promising method in the management of *A. gossypii*. This method causes changes in the quality and quantity of secondary substances and nutrients, as well as cellular and histological changes which affect the behavior, physiology, biology and ecology of insects and pathogens (PANIZZI; PARRA, 1991).

In this way, the constitutive resistance of watermelon cultivars and the induction of resistance to pests through silicate fertilization can contribute to the integrated management of *A. gossypii* in watermelon culture, alone or synergistically. Thus, the objective of this research was to evaluate the biological aspects and feeding behavior of *A. gossypii* in watermelon cultivars submitted to silicon application.

MATERIAL AND METHODS

The experiment was carried out in a greenhouse and air-conditioned room at the Plant Health Laboratory in the Institute of Education, Agriculture and Environment (IEAA) of the Federal University of Amazonas (UFAM), Humaitá, Amazonas, Brazil. The experimental design was completely randomized in a factorial scheme 2×3 (with and without silicon; cultivars Crimson Sweet, Fairfax and Charleston), with ten replications.

Four watermelon seeds were sown in each pot containing 10 kg of substrate soil/cattle manure at the ratio 3:1. The pots were placed on a bench in greenhouse. Twenty days after sowing, thinning was conducted leaving only one plant in each pot. The application of silicic acid (1%) was carried out directly on the substrate, with a dose equivalent to 1 ton $SiO_2 \cdot ha^{-1}$, 25 days after sowing. Each pot was used as a replication.

The aphids *A. gossypii* were collected in commercial watermelon crops next to Humaitá, Amazonas, Brazil, and were kept in climatized chambers at 25 ± 2 °C and photophase of 12 h. Cucumber plants, cultivar Caipira, were grown in pots with 5 kg of substrate, in greenhouse, to provide food for creation of *A. gossypii*.

Aphids remained in leaf sections of cucumber with 8 cm diameter, washed and immersed in hypochlorite solution (1%) for 5 min. These leaves were fixed in Petri dishes using agar-water (1%) and closed with voile fabric and rubber ties. When the leaves turned yellow, they were replaced.

Biological aspects of *A. gossypii*

A cage of transparent material of 0.5 cm height and 0.8 cm diameter was fixed in each plant with metal clip, five days after the silicon application. Two adult females of *A. gossypii* beginning reproductive period were kept in each cage for 24 h. After this period, adult females were removed, and a newborn nymph was left. The duration of the prereproductive, reproductive and postreproductive periods, longevity and number of nymphs were evaluated. During the reproductive period, the nymphs were counted and removed from the cages daily.

Feeding behavior of *A. gossypii*

This test was conducted 10 days after silicon application in laboratory at 25 ± 4 °C. A plastic cylinder 12 cm in diameter and 2.5 cm wide was covered with a filter paper strip impregnated with solution of 0.3 g of ninhydrin, 3 mL of glacial acetic acid and 10 mL of n-butanol. This cylinder was fixed on an analog clock with 12 h rotation supported by an iron rod. An aphid kept without feeding for 1 h before the start of the test was placed on abaxial side of watermelon leaf, for each treatment and replication, that was placed 1 cm above the filter paper strip. The droplets of honeydew, secreted by the insects, colored the paper strip of purple, due to the ninhydrin. The number of droplets of honeydew, the time for the first droplet and the time for the last droplet were evaluated.

Statistic

Analysis of variance was performed using the statistical program Sisvar, version 4.0 (FERREIRA, 2014). The means of the silicon treatment were compared using the F-test ($p \leq 0.05$) and the cultivars using the test of SCOTT; KNOTT (1974) at the level of 5% probability. The transformation $\sqrt{(X + 0.5)}$ was made for the number of honeydew droplets.

RESULTS AND DISCUSSION

Biology of *A. gossypii*

It was found, through analysis of variance, significant effects on the number of nymphs for the application of silicon, however no significant differences were observed for the other sources of variation. There were no significant differences for longevity and for prereproductive, reproductive and postreproductive periods for the sources of variation studied (Table 1).

The number of nymphs in the watermelon plants was higher when silicon was not applied (control) compared to the plants treated with this element, independent of cultivar effect (Table 2). Similarly, it was observed that the number of nymphs of *Schizaphis graminium* (Rondani) was higher when not treated with silicon in sorghum plants (CARVALHO et al., 1999; COSTA; MORAES, 2006) and in wheat plants (BASAGLI et al., 2003). ALCANTRA et al. (2019) observed no effects of silicon application on any biological parameters of *A. gossypii* feeding plants of cotton genotypes with silicon.

GOUSSAIN et al. (2005) observed a lower rate of sap intake in individuals of *S. graminium* when they are feeding on wheat plants fertilized with silicon. Thus, the fertility of aphids can be reduced due to energetic substances deficiency in the organism. The reproductive potential of aphids is influenced by the host plant (physiological state, morphology and natural resistance) and by climatic conditions, such as temperature and other factors (KOCOUREK et al., 1994; BETHKE et al., 1998).

COSTA; MORAES (2006) found that the prereproductive and reproductive periods of *S. graminium* were not affected by the application of silicon in wheat plants. Also, GOUSSAIN et al. (2005) found no influence on the prereproductive and postreproductive periods of this same aphid. GOMES et al. (2005) did not observe effect of Si in the prereproductive, reproductive periods and longevity of *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) in potato plants. In addition, NERI et al. (2009) found that the prereproductive and postreproductive periods of the caterpillar *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) feeding corn plants did not differ when plants were fertilized with silicon or not treated.

MICHELOTTO; BUSOLI (2003) found that the average longevity, reproductive and postreproductive period of *A. gossypii* were 14, 6 and 21 days, respectively, in different cotton cultivars. ALCANTRA et al. (2019), studying these same parameters and insect species in other cotton cultivars, found values of 12, 1.2 and 13 days. For the three watermelon cultivars evaluated in the present study the periods of 22, 0.65 and 27 days were observed for these parameters for *A. gossypii*.

Feeding behavior of *A. gossypii*

Table 3 shows the analysis of variance and significant effects are observed for the number of droplets of honeydew when

Table 1. Mean squares of the number of nymphs (NN), prereproductive (PRE), reproductive (RP) and postreproductive (POS) period and longevity (LON) of *A. gossypii* in different watermelon cultivars submitted to the silicon application.

SV	DF	Mean Squares				
		NN	PRE	RP	POS	LON
Silicon	1	6080.267**	0.067^{ns}	117.600^{ns}	0.817^{ns}	112.067^{ns}
Cultivars	2	674.817^{ns}	0.117^{ns}	17.150^{ns}	1.850^{ns}	17.717^{ns}
Silicon × cultivars	2	1205.117^{ns}	0.117^{ns}	35.150^{ns}	0.317^{ns}	48.017^{ns}
Error	54	581.552	0.063	32.663	0.639	41.174
CV (%)	-	28.16	5.05	25.98	122.97	23.31

**Significant at 1% probability level; $^{ns:}$ not significant; SV: source of variation; DF: degrees of freedom; CV: coefficient of variation.

Table 2. Mean values of the number of nymphs (NN), prereproductive (PRE), reproductive (RP) and postreproductive (POS) periods and longevity (LON) of *A. gossypii* in watermelon plants submitted to silicon application in greenhouse.

Silicon	NN	PRE	RP	POS	LON
Without Si	95.70 ± 3.51a	5.0 ± 0.05a	23.4 ± 0.62a	0.53 ± 0.13a	28.93 ± 0.66a
With Si	75.57 ± 5.30b	4.9 ± 0.05a	20.6 ± 1.33a	0.77 ± 0.16a	26.13 ± 1.50a

Means followed by the same vertical letter are not significantly different by the F-test ($p \leq 0.05$).

Table 3. Mean squares of the number of droplets (NG), time to first droplet (TFD) and time to last droplet (TLD) of *A. gossypii* honeydew in different watermelon cultivars subjected to the silicon application.

SV	DF	Mean squares		
		NG	TFD	TLD
Silicon	1	10.548**	41.631**	147.320**
Cultivars	2	0.505^{ns}	105.555**	60.749**
Silicon × cultivars	2	0.493^{ns}	75.224**	94.225**
Error	24	0.194	0.376	7.140
CV (%)	-	-	25.12	33.74

**Significant at 1% probability level; ^{ns}Not significant; SV: source of variation; DF: degrees of freedom; CV: coefficient of variation. NG was transformed into √(X + 0.5).

silicon was applied, independent of the cultivar effect. It also shows significant interaction between cultivars and silicon application to time for first droplet and the time for last droplet.

According to MITTLER (1958), the rate of sap ingested by the insect can be measured by the secretion of honeydew. So, when silicon was applied, independent of the cultivar, insects secreted less than a quarter of the number of droplets compared to plants not treated with Si (Table 4). Probably, the insects in plants that received silicon application had difficulties in feeding and reduced the volume of secretion due to the mechanical barrier formed in the plants by Si. In addition to this barrier, silicon can induce an increase in the production of compounds with harmful effects on the insect (MARSCHNER, 1995). PEREIRA et al. (2010) found that the Si applied to wheat plants affected the production of droplets of honeydew from *Schizaphis graminum*.

Aphids did not feed on the plants of the cultivar Crimson Sweet when they received silicon application; there was no production of droplets, indicating a possible high-grade antixenosis (Table 4). This type of resistance is related to plant secondary metabolism and comes from physical, morphological and chemical changes (LARA, 1991). Silicon may have induced the plant to produce defense compounds and/or changed the thickness of the plant epidermis. According to AGARIE et al. (1998), the cell wall becomes thick due to deposition of silicon in the epidermal cells. In addition, its application probably acted synergistically to the cultivar constitutive resistance.

The time to produce the first droplet in the cultivar Fairfax treated with silicon was 10.54 h; aphids showed difficulty to start feeding on these plants. On the other hand, there was no significant difference between cultivars when silicon was not applied.

There was no aphid feeding on the cultivar Crimson Sweet when silicon was applied. However, when silicon was not applied, the insects started to feed less than 1 h after the start of the test. There was also difference for the cultivar Fairfax between treatments with and without application of silicon. The treatment of plants with silicon increased the time for the first droplet by almost 9 h, indicating difficulty in insects feeding in this treatment. For the cultivar Charleston, there was no significant response to the silicon application in relation to the time for the first droplet.

Table 4. Time, in hours, for secretion of the first droplet and number of droplets of honeydew of *A. gossypii* in watermelon cultivars submitted or not to the silicon application.

Cultivars	Time for the first droplet (hours)	
	With silicon	Without silicon
Crimson Sweet	0.00 ± 0.00bB*	0.95 ± 0.42aA
Fairfax	10.54 ± 0.25aA	1.85 ± 0.30aB
Charleston	0.32 ± 0.15bA	1.00 ± 0.31aA
Silicon	**Number of droplets**	
Without silicon	5.40 ± 0.41B	
With silicon	1.27 ± 0.50A	

Means followed by the same lowercase letters comparing cultivars and capital letters comparing silicon do not differ statistically by Scott–Knott and F-test, respectively (p ≤ 0.05). *There was no feeding by *A. gossypii*.

These results corroborate with GOUSSAIN et al. (2005), who found that secretion of honeydew droplets from *S. graminum* was reduced when these aphids feed with wheat plants treated with Si. This reduction and the increase of time to start feeding indicates that silicon may be producing a barrier in these plants, causing a decrease in feeding. COSTA et al. (2011) found that the silicon application combined or not with imidacloprid reduced the feeding time of *S. graminum* in wheat plants. According to GOUSSAIN et al. (2002), silicon accumulates in plants and provide a mechanical barrier to pest attack and/or induce the synthesis of phenolic compounds, which decrease palatability to pest insects.

The time for the secretion of the last droplet showed significant difference between cultivars only when the plants were treated with silicon (Table 5). In this condition, there was no feeding of the insects for the cultivar Crimson Sweet, while the cultivar Fairfax showed a longer time for the secretion of the last droplet.

For the cultivars Crimson Sweet and Charleston, the application of silicon in the honeydew test reduced the time for secretion of the last droplet compared to the untreated plants of these cultivars; thus, silicon showed a positive interaction with these cultivars. In integrated pest management, it is recommended to combine control methods to maintain crop

Table 5. Time, in hours, for honeydew last droplet secretion from *A. gossypii* in watermelon cultivars submitted to the silicon application.

Cultivars	Time for honeydew last droplet (hours)	
	With silicon	Without silicon
Crimson Sweet	0.00 ± 0.00cB*	10.39 ± 0.63aA
Fairfax	10.93 ± 0.34aA	9.06 ± 1.25aA
Charleston	6.18 ± 2.54bB	10.96 ± 0.23aA

Means followed by the same lowercase letter in the column and capital letters in the rows are not different statistically by Scott–Knott and F test, respectively ($p \leq 0.05$). *There was no feeding by *A. gossypii*.

health. Thus, associating constitutive and induced resistance may be a good tactic for the management of *A. gossypii* in watermelon.

CONCLUSIONS

Silicon applied to watermelon plants affects the reproduction and feeding of *A. gossypii*. The cultivar Crimson Sweet has high resistance to feeding by *A. gossypii* when treated with silicon.

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