CROP PROTECTION

Effect of Sodium Silicate Application on the Resistance of Wheat Plants to the Green-Aphids S*chizaphis graminum* (Rond.) (Hemiptera: Aphididae)

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Efeito da Aplicação de Silicato de Sódio na Resistência de Plantas de Trigo ao Pulgão-Verde *Schizaphis graminum* (Rond.) (Hemiptera: Aphididae)

RESUMO - O pulgão-verde *Schizaphis graminum* (Rond.) é importante praga do trigo, causando danos às plantas em todos os estágios fenológicos da cultura. Este trabalho teve como objetivo avaliar o efeito da aplicação de silício na resistência de plantas de trigo a esta praga. Foram conduzidos ensaios em casa-de-vegetação e em laboratório. O experimento em casa de vegetação foi conduzido em delineamento experimental completamente casualizado com dois tratamentos, que consistiram na aplicação de silício e testemunha (sem aplicação), e dez repetições, sem controle ambiental. Os bioensaios em laboratório foram realizados em câmara climatizada, à temperatura de 25 ± 1°C, umidade relativa de 70 ± 10% e fotofase de 12h, com delineamento experimental de blocos ao acaso, em esquema de parcelas subdivididas. O silício, na forma de solução de silicato de sódio a 0,4% de SiO_2 foi aplicado na dose de 50 ml/vaso, por seis vezes, em intervalos de cinco dias, sendo a primeira realizada cinco dias após a emergência das plantas de trigo. A partir do 35º dia após a emergência das plantas foram realizadas as seguintes avaliações: a) preferência em teste com chance de escolha em laboratório; b) preferência em teste com chance de escolha em casa-de-vegetação; e c) reprodução e desenvolvimento do pulgão-verde em laboratório. A aplicação de silicato de sódio reduziu a preferência, a longevidade e a produção de ninfas do pulgão-verde *S. graminum*, conferindo, portanto, resistência as plantas de trigo a este inseto-praga.

PALAVRAS-CHAVE: Insecta, silício, resistência induzida, preferência alimentar

ABSTRACT - The green-aphid *Schizaphis graminum* (Rond.) is considered the major important pest of wheat plant, for causing severe injuries to the plants in all phenological crop stages, being able even to cause plant death. The objective of this study was to evaluate the effects of the application of silicon on the resistance of wheat plants to this pest. The experiments were carried out under greenhouse and laboratory conditions. The greenhouse experiment was conducted in a completely randomized experimental design with two treatments, consisting on silicon application and a control (without silicon application) with 10 replications and without environmental control. The laboratory bioassays were conducted under controlled environmental conditions (25 ± 1°C temperature; 70 ± 10% RH; and 12h photophase), in a randomized block experimental design, with a sub-divided plot scheme. The silicon, in the form of sodium silicate solution at 0.4% SiO_2 was applied in six doses of 50 ml/pot each, at five-day intervals, being the first application performed five days after emergence of the wheat plats. Thirty-five days after plants emergence the following evaluations were performed: a) feeding preference in the laboratory; b) feeding preference in the greenhouse; and c) reproduction and development of the green-aphid. Application of sodium silicate reduced preference, longevity, and production of nymphs of the green-aphids *S. graminum*, thus conferring a resistance to wheat plants against this insect-pest.

KEY WORDS: Insecta, silicon, induced resistance, feeding preference

Among the insect-pests affecting the wheat crop, the green-aphid *Schizaphis graminum* (Rond.) is considered of major importance for causing severe injuries to plants in all phenological crop stages, being able even to cause death of plants. This pest is prejudicial to the plant either due to the large quantity of sap it extracts, causing water and nutrients depletion, or due to the injection of toxins and viruses transmission (Penna-Martinez 1985, Cruz *et al.* 1988).

The damage caused by the green-aphid on wheat depends upon its population density, growth stage and vigor of plants, moisture conditions and predation by natural enemies. Chemical control is used in the management of the green-aphid on the wheat crop. Wide-spectrum insecticides, however, are mostly used, thus increasing the probability of harmfulness to non-target insects (Penna-Martinez 1985, Salvadori 1999).

The induced resistance of plants to insects is a potential strategy in the integrated pest management aiming the reduction of deleterious effects of chemical compounds. Therefore, although not being considered an essential nutritional element to the plants, the addition of silicon has induced resistance in many plant species, specially grasses. Besides, this procedure jointly with the plant genotype has determined the potential of production as well as the tolerance to insect-pests and diseases.

The silicon deposition on leaves epidermis prevents penetration and chewing by insects once the cells become hardened (Yoshida 1975). Larvae of the stem-borer *Chilo supressalis* (Walker) (Lepidoptera: Pyralidae) fed on plants with high silicon content had their mandibles damaged (Djamin & Pathak 1967). Rice nurseries fertilized with silicon, using ashes of rice husk as source of this element, showed lower number of plants with "dead heart" diseases caused by the stem-borer on the cultivar Jaya, after transplantation (Savant *et al.* 1997). The resistance of 11 rice cultivars to the stem-borer *Chilo agamemnon* Bles. and to the leaf miner *Hydrellia prosternalis* Deeming (Diptera: Ephydridae) was correlated with higher silicon content (Soliman *et al.* 1997). Goussain *et al.* (2002) reported the wearing out in the incisory region of the mandibles of the caterpillar *Spodoptera frugiperda* (J.E. Smith) (Noctuidae) when fed on corn leaves, which had received applications of sodium silicate.

In feeding preference tests carried out with the green-aphid *S. graminum* on silicon-treated sorghum plants Carvalho *et al.* (1999) observed almost half the number probably of aphids on the leaf sections of plants that had received silicon application. This was due to a mechanic barrier provided by the deposition of this element on the cell wall. The deposition and the increased solubility of the silicon in wheat plants have already been reported as a resistance-inducer to two important aphids *Metopolophium dirhodum* (Walk) and *Sitobion avenae* (Fabricius), after foliar sprays of this element with a 1% Na_2SiO_2 solution (Hanisch 1980).

The objective of this study was to evaluate the effect of the application of sodium silicate on the resistance of wheat plants to the green-aphid *S. graminum*, aiming at providing relevant imputs to the management of aphids on this crop.

Materials and Methods

The experiments were installed within the period of April 26th to July 29th 2000 and were carried out in two steps, under greenhouse and laboratory conditions at the Departamento de Entomologia da Universidade Federal de Lavras, MG, Southeast Brazil.

Under greenhouse conditions, 20 wheat seeds, variety Embrapa-21 (dry-land rice) were sown in each 4 kg capacity plastic pot filled with a substrate composed of sieved trench soil, which was amended with 2.5 g of NPK (4-14-8) per pot. Each pot was daily irrigated with 200 ml distilled and de-ionized H_2O. After emergence, the plants in each pot were thinned, selecting the most vigorous ones and **keeping(?)** only four plants per pot. The silicon, in the form of a sodium silicate solution with 0.4% SiO_2, was applied in six doses of 50 ml/pot each with five-day intervals. The first application was performed five days after emergence of the wheat plants. The experiment was conducted in a completely randomized experimental design with two treatments (with sodium silicate application and a control without sodium silicate) and 10 replications, without environmental control.

Thirty-five days after emergence of plants, the following evaluations were performed: a) feeding preference in the laboratory; b) feeding preference under greenhouse conditions; and c) reproduction and development of the green-aphid.

Feeding Preference in the Laboratory. A free-choice test was performed in the laboratory. Two sections of silicone-treated wheat leaves and two non-treated ones were collected on plants from pots corresponding to each treatment and placed into plastic cups 5.5 cm heigh and 6.5 cm diameter at the top. The 5-cm long leaf sections were vertically placed into the cups, attached to a Styrofoam circle, which completely filled the upper diameter of the container, forming a 90º angle with the walls of the cup. The Styrofoam circle was placed in the upper third of each cup and the space below it was filled with water. In the center of each Styrofoam circle, 10 *S. graminum* adult aphids were released totaling 10 cups per treatment. These cups were then placed into two rectangular trays measuring 50 cm x 30 cm, containing water and detergent to avoid escape of aphids. These trays were maintained in environmental chambers at 25 ± 1°C temperature, 70 ± 10% RH and 12h photophase. Evaluations were carried out 24h, 48h and 72h after releasing the aphids, by counting and removing the nymphs present in the leaves of each treatment.

Feeding Preference under Greenhouse Conditions. In the free-choice test conducted in the greenhouse, each experimental plot was a round plastic micro-cage 5.4 cm diameter and 1.2 cm high, with the side walls covered with black insulating tape (Goussain *et al.* 2002). The bottom of the cage had two 2.4-cm diameter orifices, with the external wall covered with a 0.2-cm thick synthetic foam. On top of that foam, a 2.5-cm in diameter plastic ring was placed. The ring was welded to the metal stick of a clipper-type of hair holder and the other clipper stem was attached to the micro-cage. This micro-cage was then arranged in such a way that could hold a leaf between the ring and the orifice. A control-leaf (without silicon) was placed in one of the orifices; in the other, a leaf with each one of the silicon treatments was placed. After attaching the micro-cages, 10 adult aphids were released in each one. The micro-cages were then covered with an organza-type cloth and placed at the apical third of the 5th totally developed leaf of the plant. The evaluations were performed at 24h, 48h and 72h after aphids release by counting and removing the nymphs on the leaves of each treatment.

Reproduction and Development of the Green-Aphid. Twenty plastic cups (ten per treatment) were prepared as described for the feeding preference test in the laboratory. Each cup was infested with 10 less than 24h-old green-aphid nymphs and then placed in a 50 cm x 30 cm rectangular tray containing water and detergent to avoid escape of aphids. These trays were placed into environmental chamber at 25 ± 1°C temperature, 70 ± 10% RH and 12h photophase. The following observations were performed: time-span of the pre-reproductive and reproductive periods, survival of the nymph phase, longevity and total production of nymphs.

Statistical Analyses. For the first experiment, a completely randomized experimental design, with two treatments (silicon application and non-treated control) and ten replications was used. However, in the feeding preference test with choice chance, due to the special characteristics of this type of test, the treatments were arranged in a randomized block experimental design, with a sub-divided plot scheme; the variable "silicon application" was allocated to the plots and the variable "time of evaluation" was allocated to the sub-plots. Data were submitted to ANOVA, and the means were compared by the means-grouping test of Scott & Knott (1974) at P ≤ 0.05.

Results and Discussion

Feeding Preference in the Laboratory. The differences among treatments were not statistically significant for the evaluations performed at 24h, 48h and 72h after aphids release. However, the mean of **all(?)** evaluations in each treatment were significantly different (P ≤ 0.05). On the foliar sections of the silicon-treated wheat plants the number of nymphs was 85% lower than on the control ones. On the other hand the total production of nymphs at 72h after infestation was practically twofold in the control treatment (Table 1). Theses results clearly demonstrate the preference of the green-aphids for leaves detached from plants that did not receive sodium silicate solution.

Feeding Preference under Greenhouse Conditions. When the feeding preference test was carried out directly on the plants in the greenhouse, statistically significant differences among treatment were observed (Table 2). In the evaluation performed 72h after infestation, the number of green-aphid nymphs on the leaves corresponding to the sodium silicate-treated plants was less than half the number observed on the leaves of the control plants. After 48h and 72h of green-aphids release, a significant increase on production of nymphs occurred on the control plants as opposed to a significant decrease occurring on the silicon-treated ones. Thus, 72h after green-aphids release, the total production of nymphs was more than twofold higher than the number of nymphs present on leaves of sodium silicate-treated plants (Table 2).

Reproduction and Development of the Green-Aphid. Statistically significant differences (P > 0.05) were not detected neither for the biological characteristics related to pre-reproductive and reproductive periods nor for survival of the nymph phase (Table 3). For the biological aspects related to longevity, however, statistically significant differences (P ≤ 0.05) did occur (Table 3). On the other hand, the total number of nymphs produced within the reproductive period was affected by silicon application (Fig. 1). Females that developed on leaf sections of silicon-free plants (control) produced 80% more nymphs than those reared on leaf sections of silicon-treated wheat plants (Fig. 1).

The non-preference of the green-aphid for sodium silicate-treated wheat plants was demonstrated in the free-choice tests performed either in the laboratory with detached leaves or in the greenhouse with whole plants. In both tests, 72h after green-aphids release there was a reduction of practically half the number of nymphs when the aphids were maintained on silicon-treated plants. The 72h interval has already been recommended by Cruz *et al.* (1998) as an adequate time for evaluating resistance to aphids on sorghum genotypes.

Table 1. Number of nymphs (mean ± se) of the green-aphid *S. graminum* on two wheat leaf sections, detached from treated and non-treated wheat plants, evaluated 24h, 48h and 72h after release of 10 adult aphids. Temperature: 25 ± 1ºC., RH: 70 ± 10%, photophase:12h

Treatments	Number of nymphs			Mean
	24h	48h	72h	
Silicon-free (control)	16.1 ± 0.71	15.7 ± 0.90	15.5 ± 0.76	15.8 a
Silicon-treated	8.4 ± 0.43	8.9 ± 0.43	8.2 ± 0.52	8.5 b
Mean	12.2 A	1.3 A	11.8 A	-

Means followed by the same capital letter in the columns and small letter in the lines are not statistically different by the Scott & Knott test (P ≤ 0.05).

Table 2. Number of nymphs (mean ± se) of *S. graminum* in leaf sections of treated and non-treated wheat plants, at 24h, 48h and 72h after their release, in a greenhouse.

Treatments	Number of nymphs			Mean
	24h	48h	72h	
Silicon-free (control)	12.4 ± 0.44 aA	13.3 ± 0.53 aA	13.7 ± 0.47 aA	13.1
Silicon-treated	7.1 ± 0.50 bB	6.4 ± 0.62 bB	6.1 ± 0.61 bB	6.5
Mean	9.8	9.8	9.9	-

Means followed by the same small letter in the columns and capital letter in the lines are not statistically different by the Scott Knott test (P ≤ 0.05).

Table 3. Duration of the pre-reproductive and reproductive periods (days), nymph survival (%) and adult longevity (days) (mean ± se) of *S. graminum* adults in leaves sections of treated and non-treated wheat plants. Temperature: 25 ± 1ºC., RH: 70 ± 10%, photophase: 12h

Treatments	Periods		Survival (%)	Longevity
	Pre-reproductive	Reproductive		
Silicon-free (control)	5.2 ± 0.20 a	21.1 ± 0.73 a	71.0 ± 3.84 a	24.1 ± 0.91 a
Silicon-treated	5.40 ± 0.31 a	17.0 ± 1.51 a	68.0 ± 9.30 a	19.0 ± 1.82 b

Means followed by the same small letter in the column and capital letter in the lines are not statistically different by the Scott Knott test (P ≤ 0.05).

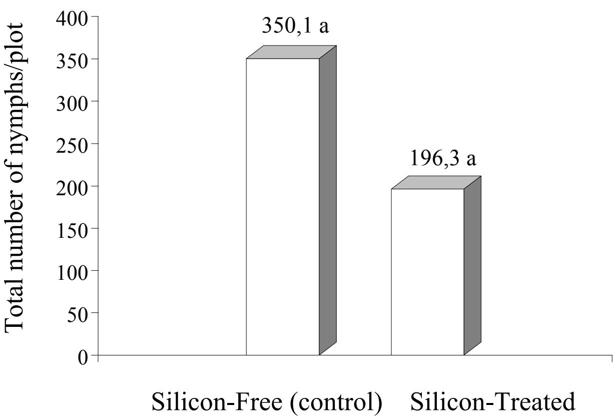

Figure 1. Total number of *S. graminum* nymphs, in leaf sections of wheat treated and non-treated plants. Temperature: 25 ± 1ºC., RH: 70 ± 10%, photophase:12h. Means followed by the same letter don't differ statistically within them, by the F test (P ≤ 0.05).

Similar observations had already been reported by other authors for different species of insects and/or host plants. In feeding preference tests conducted with the green-aphid *S. graminum* on silicon-treated and non-treated sorghum plants, Carvalho *et al.* (1999) observed almost twice the number of aphids on leaf sections, which did not receive silicon treatment. These researchers concluded that the non-preference of aphids for silicon-treated leaves was due to a mechanical barrier provided by the deposition of this element on the cell wall. Analogous conclusions have also been drawn from other crops and for other insects (Djamin & Pathak 1967, Tayabi & Azizi 1984, Salim & Saxena 1992, Sawant *et al.* 1994, Goussain *et al.* 2002). Wheat leaves that received silicon sprays were more turgid than those silicon-free ones (control). Research results have indicated that the silicon, once absorbed by the xylem veins, is deposited on the wall of the plant tissues, forming a mechanical barrier (Blum 1968). This banier could have turned difficult or prevented penetration of the stylets of the aphids, impairing their feeding behavior.

The reproductive capacity of the green-aphid was also affected by the sodium silicate application, as well as the biological cycle, and longevity. According to Hanisch (1980), the deposition and the increased solubility of the silicon in the leaves of wheat plants after foliar sprays of this element as a 1% Na_2SiO_2 solution were pointed out as the cause of the resistance of this cereal crop to the aphids *M. dirhodum* and *S. avenae*. Some studies conducted on cucumber plants have suggested that silicon can also act in the faster activation of defense mechanisms in plants against aggressor organisms (Samuels *et al.* 1991, Chérif *et al.* 1992).

The application of silicon to the wheat crop may minimize the problems caused by *S. graminum*. It provides a moderate degree of resistance, but presents the advantage of being feasibly integrated to other management tactics in controlling this pest. On the other hand, silicon sprays affect the feeding preference of the green aphid *S. graminum*, thus increasing the resistance of wheat plants. Concomitantly it affects biological parameters of the insect such as longevity and nymph production, thus reducing the reproductive potential of females on wheat plants and therefore reducing the insect population density, damages and yield losses to the crop.

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