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Calcium silicate and organic mineral fertilizer increase the resistance of tomato plants to *Frankliniella schultzei*

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Abstract *Frankliniella schultzei* Trybon (Thysanoptera: Thripidae) is an important pest of tomato plants. The need for more healthful foods is stimulating the development of techniques to increase plant resistance to phytophagous insects. The objective of this research was to evaluate the effect of calcium silicate and an organic mineral fertilizer, alone or in combination, on the resistance of tomato plants to *F. schultzei*. The treatments consisted of: control (T1), calcium silicate (T2), organic mineral fertilizer (T3), and calcium silicate with organic mineral fertilizer (T4). The mortality of nymphs of this thrips and the number of lesions on tomato leaves were evaluated after three, six, nine and 12 applications of these products. The number of *F. schultzei* individuals and of lesions on tomato leaves was lower in treatments T2 and T4 than in T1 and T3, showing a possible increase in tomato resistance to this pest. The increase in the number of applications of calcium silicate and the organic mineral fertilizer increased the mortality of nymphs and reduced the damage by this insect on tomato leaves, mainly after nine applications.

Keywords *Frankliniella schultzei* · *Lycopersicon esculentum* · Protected cultivation · Resistance induction · Silicon

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Introduction

Tomato (*Lycopersicon esculentum* Mill.) is extensively cultivated in the world and is one of the most important vegetables grown in Brazil, which stands among the ten largest world producers (Washington et al. 2001). Tomato culture in Brazil is expanding and modernizing with better productivity, quality and regularity to meet the market demand, the main concern being control of pests and diseases (Leite et al. 2001; Vivan et al. 2002). This is necessary, because a large group of pests can cause substantial reductions in the quantity and quality of tomato production (Kennedy 2003; Mahanil et al. 2008; Miranda et al. 1998).

Frankliniella schultzei Trybon (Thysanoptera: Thripidae) is an insect that causes direct damage by feeding on leaves and indirect damage due to its capacity to transmit the *Groundnut ring spot virus* (GRSV) (Borbón et al. 2006) and *Tomato spotted wilt virus* (TSWV) (Coutts and Jones 2005), which can make tomato production unviable (Tedeschi et al. 2001).

The control of *F. schultzei* is accomplished, traditionally, with chemical insecticides (Cox et al. 2006), but the use of these products above recommended rates reduces the beneficial fauna, which in turn increases problems with pests (Atakan 2006; Gusmão et al. 2006; Leite et al. 2006).

Control methods used in pest management programs aim to reduce or to use insecticides compatible with natural enemies (Zanuncio et al. 2003). Silicate application has increased plant resistance to pests mainly by its capacity to accumulate in the cellular walls (Costa and Moraes 2006), which increases the synthesis of phenol compounds and lignin (Chérif et al. 1992; Ghanmi et al. 2004) and activates endogenous chemical plant defenses (Gomes et al. 2005), although this mineral is not essential for most of them (Epstein 1999; Savant et al. 1999). This suggests that application of silicate could increase resistance of tomato plants to *F. schultzei*.

Calcium silicate ($CaSiO_3$) is present in most silicate commercial products (Snyder et al. 2005) and the organic mineral fertilizer has silicon, essential nutrients, organic acids and proteins. The application of these two compounds to eggplant (*Solanum melongena* L.) caused high mortality of nymphs of *Thrips palmi* Karny (Thysanoptera: Thripidae) and reduced injuries caused by this insect (Almeida et al. 2008b). When administered alone it reduced the oviposition of *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) on bean plants (*Phaseolus vulgaris* L.), in choice and no-choice tests (Almeida et al. 2008a).

The objective of this study was to evaluate the effect of calcium silicate and an organic mineral fertilizer, alone or in combination, on resistance of tomato plants to the thrips *F. schultzei*.

Materials and methods

The experiment was conducted in the Laboratory of Entomology, Centro de Ciências Agrárias, Universidade Federal do Espírito Santo (CCA-UFES), in Alegre, Espírito Santo State, Brazil. Adult *F. schultzei* were collected in commercial tomato plantations and taken to the laboratory, where they were maintained on leaves of *Canavalia ensiformis* L. beans. These plants were cultivated in a greenhouse with anti-aphid screening to block the entrance of other species of arthropods. Leaves of this plant with *F. schultzei* were placed in plastic pots (15 cm×10 cm×5 cm) with the pot's upper side covered with paper filter and their lateral ones lined with paper towel and filter to avoid water accumulation. *C. ensiformis* leaves were changed when they lost their turgidity and nutritional quality. Their petioles were wrapped in moistened cotton wads to reduce water loss. Grains of pollen of *C. ensiformis* flowers were put on those leaves to increase their nutritional quality for *F. schultzei.*

Tomato plants var. 'Santa Clara' with an average height of 14±3.25 cm were transplanted to 5-liter plastic containers. The substrate consisted of a mixture of soil and humus (4:1), 7.1 kg dolomitic limestone, 2.0 kg P_2O_5 per m^3, and fertilizer in accordance with the recommendation for this culture. Before transplanting, the leaves of the tomato seedlings were immersed for 30 s in the solutions of calcium silicate and organic mineral fertilizer, alone or together. This research was conducted in a greenhouse with temperatures ranging between 15ºC and 30ºC and mean photophase of 12.5:11.5 h (L:D).

Every 5 days after transplanting, the young tomato plants were sprayed from the bottom to the top, with 50 ml of the following solutions: (T1) water, (T2) calcium silicate at a concentration of 15 g l^{-1} water, (T3) organic mineral fertilizer (Ergofito®, Tecnobiol S.A. Fertilizantes do Brasil) at a concentration of 2 ml l^{-1} water and (T4) a combination of these products at 4 g of calcium silicate and 2 ml of the organic mineral fertilizer per liter of water. The surfactant Hi Ten™ (200 g l^{-1} polyoxyethylene alkyl phenol ether; Arysta LifeScience-South America, Sao Paulo City, Brazil) was used in all treatments and control.

The calcium silicate originated from clay silicate and contained: 17.45% Si_2O; 20.56% Al_2O_3; 9.82% S; 1.31% CaO; 0.34% TiO_2; 0.18% MgO; 0.36% Fe_2O_3. The organic mineral fertilizer is a liquid with:

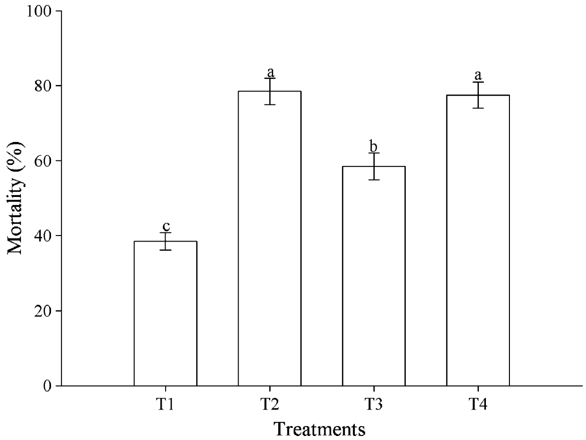

Fig. 1 Mortality (mean±S.D.) of *Frankliniella schultzei* nymphs on tomato leaves in the treatments: control (T1), calcium silicate (T2), organic mineral fertilizer (T3), and calcium silicate plus organic mineral fertilizer (T4). Bars with the same letter do not differ statistically by Tukey's test ($P<0.05$)

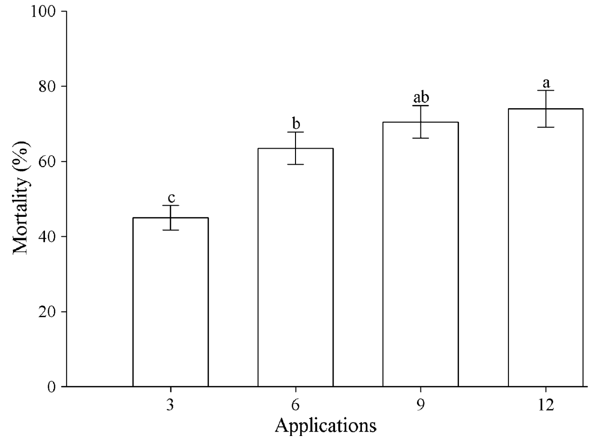

Fig. 3 Mortality (mean±S.D.) of *Frankliniella schultzei* nymphs on tomato leaves after three, six, nine and 12 applications of calcium silicate and organic mineral fertilizer. Bars with a common letter do not differ statistically by Tukey's test ($P<0.05$)

15 ppm Si_2O; 100 ppm N; 25 ppm P_2O_5; 50 ppm K_2O; 13.75 ppm S; 0.069 ppm Zn; 0.475 ppm B; 11.25 ppm Fe; 0.375 ppm Mn; 2.75 ppm Cl; 0.75 ppm Cu; 0.075 ppm Mo; 0.875 ppm Co; and 87.5 ppm organic carbon.

From 80 tomato plants, each group of 20 was exposed to ten *F. schultzei* nymphs that were transferred to the plants 2 days after the third, sixth, ninth and twelfth applications of Treatments 1, 2, 3 and 4. Thrips were contained in a circular arena consisting of a rubber ring (diam, 1 cm) glued on the leaves of the plants. Only one arena per replication was placed onto the abaxial side of the terminal leaflet present in the leaves located in the median third of the plant. The mortality of the nymphs of *F. schultzei* and the number of lesions on tomato leaves were evaluated with a stereomicroscope 5 days after the insect nymph release.

The experiment was performed in a randomized factorial design with 4×4 ×5 in split-plots; number of

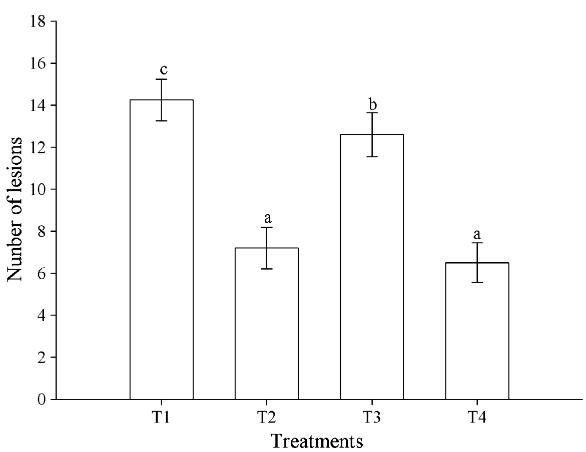

Fig. 2 Number of lesions (mean±S.D.) caused by *Frankliniella schultzei* per 1-cm-diam circular area on tomato leaves in the treatments: control (T1), calcium silicate (T2), organic mineral fertilizer (T3), and calcium silicate plus organic mineral fertilizer (T4). Bars with the same letter do not differ statistically by Tukey's test ($P<0.05$)

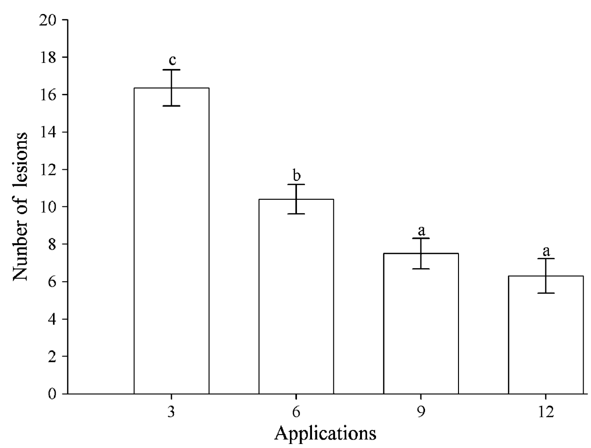

Fig. 4 Number of lesions (mean±S.D.) caused by *Frankliniella schultzei* on tomato leaves after three, six, nine and 12 applications of calcium silicate and organic mineral fertilizer. Bars with the same letter do not differ statistically by Tukey's test ($P<0.05$)

applications as plots; and treatments with calcium silicate and an organic mineral fertilizer, alone or in combination, as sub-plots. The number of applications was the first factor and the induction source the other one. Five replications were used with a tomato plant representing each one. The means were compared by the Tukey test at 5% probability level with the System for Statistical Analyses program (SAEG 9.1).

Results and discussion

The variation sources, applications and treatments had no significant interactions for mortality (F=1.65, df=9, 48; P>0.05) and number of lesions (F=1.25, df=9, 48; P> 0.05). However the number of applications affected nymphal mortality increase (F=51.91, df=3, 48; P< 0.001) and lesions decrease (F=85.40, df=3, 48; P< 0.001) and the treatments affected nymphal mortality increase (F=91.86, df=3, 48; P<0.001) and lesions decrease (F=80.36, df=3, 48; P<0.001) performed by *F. schultzei* nymphs.

The mortality of *F. schultzei* nymphs was significantly higher in the calcium silicate only (T2) and calcium silicate plus organic mineral fertilizer (T4) treatments than in the control (T1), with an increase of 50% in insect mortality in T2 and T4 compared with T1 (Fig. 1). These results agree with the reduction in the number of species of thrips of the genera *Frankliniella* and *Thrips* (Thysanoptera) on tomato plants that received application of acibenzolar-*S*-methyl (BTH) (Momol et al. 2004). The foliar applications of calcium silicate alone or associated with BTH on cucumber plants (*Cucumis sativus* L.) increased the nymphal mortality of nymphs and the duration of the development period between nymphs and adults of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae), which was attributed to the increase in defense substances of these plants (Correa et al. 2005). Applications of silicon can activate enzymes such as chitinase, peroxidase, 1,3-glucanase, polyphenoloxidase, phenylalanine ammonia-lyase proteinase and lipoxygenases in cotton, tomato and wheat plants (Correa et al. 2005; Inbar et al. 2001). These enzymes play a role in the metabolism of phenolic compounds, such as lignin, which decreases the nutritional quality and digestibility of the cell tissues (Aguirre et al. 2007), resulting in low population growth of insects on plants (Gomes et al. 2005).

The high mortality of *F. schultzei* nymphs in treatments T2 and T4 may also be related to their difficulty in feeding, by not being able to scrape nutrients from leaves covered with calcium silicate or the organic mineral fertilizer. This may be due to a physical barrier. Silicon is deposited beneath the cuticle to form a cuticle–silicon double layer (Ma and Yamaji 2006; Massey et al. 2007), which will make leaf tissues more rigid, thus hindering feeding by the insects. The application of silicon on corn plants reduced the longevity of *Schizaphis graminum* (Rond.) (Hemiptera: Aphididae), suggesting the physical effect of silica (Goussain et al. 2005). Feeding and larval growth of *Eldana saccharina* Walker (Lepidoptera: Pyralidae) caterpillars were lower on sugarcane plants with larger silica levels on their stems (Kvedaras and Keeping 2007).

The number of lesions on tomato leaves caused by *F. schultzei* was reduced by approximately 50% in treatments T2 and T4 (Fig. 2), which may be due to silicon deposition in the epicuticular layer of tomato leaves, but with lower reduction in the T3 treatment (11.60%), probably due to the lower silicon level in the organic mineral fertilizer (15 ppm Si_2O). The increased tissue hardness can wear out the mandibles of *F. schultzei* nymphs, because its mandibular apparatus is of the scratching-sucking type. For this reason they can feed only after scratching the tissue surface, and thus the damage caused by this insect on plants treated with calcium silicate and the organic mineral fertilizer is reduced. The application of calcium silicate reduced the damage by *E. saccharina* on sugarcane plants (Kvedaras et al. 2007). Corn plants (*Zea mays* L.) treated with silicon resulted in higher mortalities of *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) caterpillars due to the wear and accentuated tear of their mandibles during all instars (Goussain et al. 2002). Silicon treatment may induce mechanical barriers to insect feeding and growth on plants (Massey et al. 2006).

An increase in number of applications of calcium silicate and organic mineral fertilizer increased the mortality of *F. schultzei* nymphs (Fig. 3) and reduced the number of lesions on tomato leaves (Fig. 4). This may be because the foliar applications of calcium silicate and organic mineral fertilizer, alone or in combination, on tomato plants, may have caused the accumulation of silicon on the leaf surface, thereby forming a mechanical barrier on the tomato plant leaf surface. The severity of the damage caused by *Blumeria graminis* f.sp. *tritici* was lower on wheat plants exposed to silicon root applications than to foliar spray, possibly due to the low accumulation of this element in plant tissue following silicon spray (Guével et al. 2007). However, tomato plants accumulate a low level of silicon absorbed from the soil (Lana et al. 2003; Ma and Yamaji 2006) and the increase in the silicon level in tomato leaves is not proportional to the availability of this element in the soil (Pereira et al. 2003). On the basis of the low translocation capacity of silicon by tomato plants and the hypothesis that silicon can stimulate physical barriers on leaf tissues, the calcium silicate and organic mineral fertilizer were applied on leaves of this plant.

An increase in plant resistance can reduce the use of chemical products in agricultural production. The mortality of *F. schultzei* nymphs was significantly higher in the treatment with the organic mineral fertilizer only (T3) than in the control (T1) (Fig. 1). This indicates the effect of calcium silicate, because nymphal mortality was similar in treatments T2 and T4. A source of silicate can be an alternative for the control of *F. schultzei* in tomato plants.

Nine or more applications of calcium silicate, alone or in combination with the mineral organic fertilizer, can reduce feeding and damage by, and increase mortality of *F. schultzei* in tomato cultivation.

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