research

Silicon-Based Fertilizers and Insect Pests

Some have suggested that silicon-based fertilizers can prevent insect outbreaks in greenhouse plants — but is there any basis for those claims?

By Ray Cloyd

Greenhouse producers are continually seeking alternative means of dealing with insect and mite pest populations, instead of relying solely on insecticides or miticides, to avoid resistance. A "potential pest management strategy" is the application of silicon-based fertilizers to improve plant tolerance to insect feeding, thus reducing damage. A number of articles have promoted claims that silicon applications may avoid insect outbreaks; however, there is minimal quantitative research to support these claims. The protective role of silicon associated with disease resistance is well documented, but there is relatively little documentation concerning silicon's association with resistance to insect pests. Most of the previous research with silicon has been conducted with agricultural crops such as rice and sugar cane (monocots). How silicon "protects" plants from insect feeding is still being disputed. It has been suggested that silicon increases the epidermal toughness and strengthens leaves' cell walls, which makes it difficult for insects to feed and obtain required nutrients (proteins, amino acids and sugars). However, it is still uncertain whether horticultural plants (mostly dicots) will respond similarly to silicon applications as monocot plants.

Silicon is the second most abundant element comprising 25.7 percent of the earth's crust, a relatively inert element that is considered important to plant and animal life. Silicon is present mainly as silica or silicates, and can be synthesized into other substances, such as silicones and organosilicones. Silicon is classified as a "beneficial element" but the function of silicon in plants is not well understood despite its association with structural, physiological and protective properties. Silicon is commonly referred to as silica (SiO_2). Monosilicic acid [$Si(OH)_4$] is a soluble hydrated form of silica, and the primary form of silicon absorbed and utilized by plants.

Although most plants that accumulate silicon are monocots, such as rice and sugar cane, there are some dicots that do form silica deposits in plant tissues, including avocado, banana, pineapple and squash. However, in general, monocots tend to accumulate substantially more silicon in plant tissues than dicots. As such, plants may be categorized based on their ability to absorb silicon from a standard solution. The first category includes plants designated as silicon accumulators, which possess the ability to absorb silicon directly from soil solutions more rapidly than water. Silicon accumulators contain less than or equal to 1.5 percent silicon by weight. In the second category are silicon-neutral plants, containing between 0.5 and 1.5 percent silicon by weight. Cucumber is an example of a silicon-neutral plant because of its passive absorption of silicon from soil solutions. The third category includes silicon rejectors because they either eliminate or exclude silicon from plant tissues. These plants do not absorb silicon into tissues and typically contain less than or equal to 0.5 percent silicon by weight. Many dicots, especially horticultural crops, are considered silicon rejectors.

Alternative pest control methods can help reduce insect resistance.

Currently, there is relatively minimal information to substantiate silicon's role associated with resistance to insect pests. As such, we decided to investigate the effects of silicon-based fertilizer applications (as potassium silicate) on the life-history parameters of two phloem-feeding insects: citrus mealybug (*Planococcus citri*) and greenhouse whitefly (*Trialeurodes vaporariorum*). For the sake of brevity, in this article, we will discuss the results from three experiments with citrus mealybug. We will present the results of the whitefly experiments in a future article.

To avoid providing extraneous information associated with the procedures used during the study, we will briefly highlight the relevant points associated with the materials and methods. Furthermore, we have developed a determination procedure that allowed us to quantify the silicon concentration in plants. The description associated with the procedure is too complex to address in this article, although several of the figures indicate the silicon concentration in plants.

Experiment 1

***Effects of silicon-based fertilizer applications on life-history parameters of the citrus mealybug feeding on green coleus* (Solenstemon scutellarioides)**

Green coleus plants were grown from cuttings prior to artificial inoculation with citrus mealybug.

Plants were subject to constant liquid feed fertilization program (200-ppm nitrogen).

The silicon application treatments, at a rate of 50 ppm, were: spray, drench, spray + drench combination and control. Plants were inoculated with first instar nymphs of citrus mealybug using a leaf disk transport procedure. Two weeks after inoculation, we inspected coleus plants daily.

Oviposition (egg-laying) by mealybug females was determined by the presence of a white, cottony egg mass underneath the abdomen. Egg masses and ovipositing citrus mealybug females were collected with a microspatula and placed into vials containing 70 percent isopropyl alcohol (rubbing alcohol). Citrus mealybug ovipositing females were measured, and the eggs in the abdomen and external egg mass were dissected and counted.

There were three harvest dates to assess the total silicon content in the coleus leaves and stems. The first harvest was 15 days after inoculating coleus with citrus mealybugs, second harvest was 38 days after inoculation and third harvest was 60 days after.

We evaluated the following citrus mealybug life history parameters: egg load of females and development time from first instar to egg-laying adult.

Experiment 2

Effect of different silicon-based fertilizer rates applied as a growing medium drench on the life history parameters of the citrus mealybug feeding on green coleus

The experiment was similar to the first one, but we evaluated citrus mealybug life-history parameters (egg load of females and development time from first instar to egg-laying adult) feeding on green coleus plants treated with different rates of the silicon-based fertilizer (potassium silicate): 0, 100, 400, 800 and 1,600 ppm.

As in the first experiment, we evaluated the following citrus mealybug life-history parameters: egg load of females and development time from first instar to egg-laying adult.

Experiment 3

***Effect of silicon-based fertilizer applications on the life history parameters of the citrus mealybug feeding on fiddle-leaf fig* (Ficus lyrata)**

Seventy-five fiddle-leaf fig plants (ficus 'Little Fiddle') were established from oasis plugs for 35 days before they were treated with different rates of the silicon-based fertilizer: 0, 100, 400, 800 and 1,600 ppm. They also were subject to a constant liquid feed fertilization program (200-ppm nitrogen).

There were two harvest dates to assess the silicon content in the leaves and stems of the fiddle-leaf fig plants. The first harvest was 45 days after plants had received the first silicon treatment. This was used to establish a silicon concentration baseline, and the final harvest was at the conclusion of the experiment.

As in the first and second experiment, we evaluated the following citrus mealybug life-history parameters: egg load of females and development time from first instar to egg-laying adult.

Results and Discussion

Select results from the three experiments are presented in the figures. None of the silicon-based fertilizer application treatments (spray, drench or combination) at 50 ppm affected the mean number of eggs laid (egg load) by citrus mealybug females (Figure 1) and development time, in days, from first instar to egg-laying adult (Figure 2). For example, the mean egg load ranged from 199.5 to

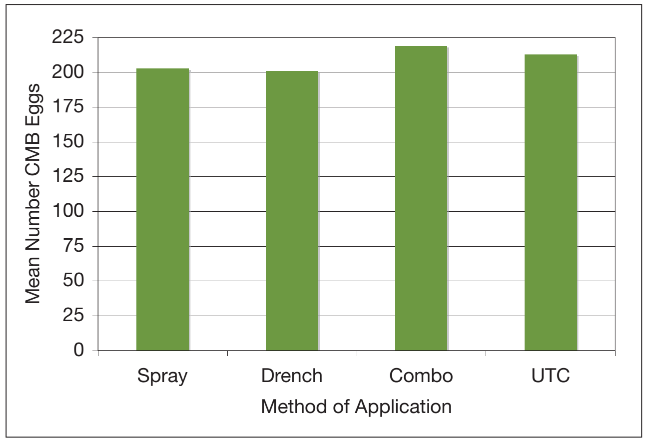

Figure 1. Mean number of citrus mealybug (CMB) eggs laid by females associated with each method of application (spray, drench, combination and untreated check [UTC]) on coleus plants receiving 50-ppm potassium silicate.

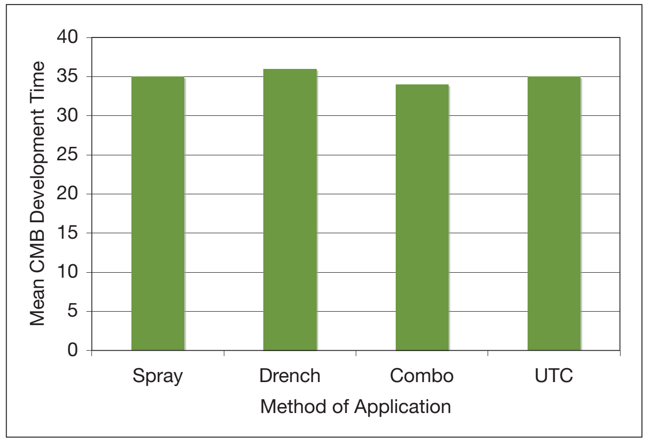

Figure 2. Mean citrus mealybug (CMB) development time, in days, from first instar to egg-laying adult associated with each method of application (spray, drench, combination and untreated check [UTC]) on coleus plants receiving 50-ppm potassium silicate.

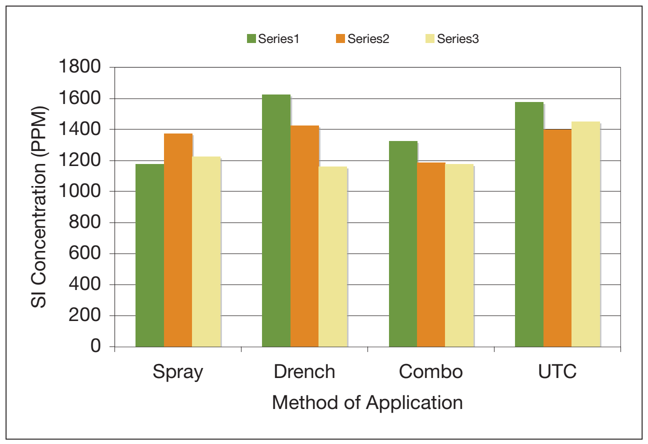

Figure 3. Mean silicon concentration (SI CONC) in green coleus plant tissue by harvest day associated with each method of application (spray, drench, combination and untreated check [UTC]) on coleus plants receiving 50-ppm potassium silicate. Day 1 is 15 days after inoculating plants with citrus mealybugs, Day 2 is 38 days after inoculating plants with citrus mealybugs and Day 3 is 60 days after inoculating plants with citrus mealybugs.

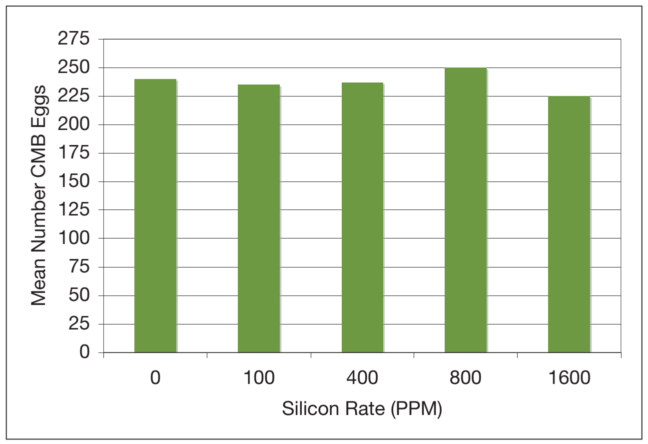

Figure 4. Mean number of citrus mealybug (CMB) eggs laid by females associated with the different silicon-based fertilizer treatment rates (0-, 100-, 400-, 800- and 1,600-ppm silicon) applied to green coleus plants.

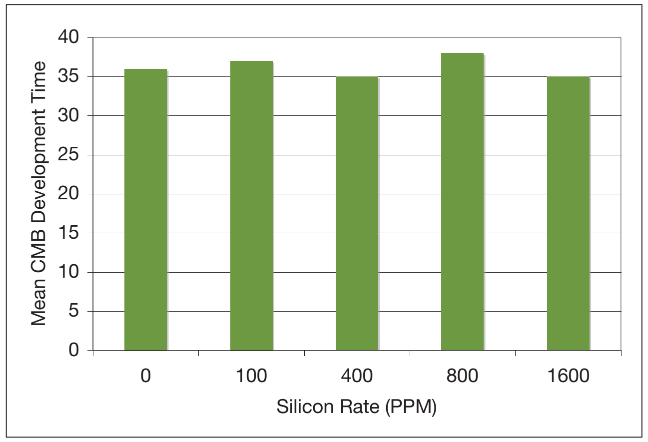

Figure 5. *Mean citrus mealybug (CMB) development time, in days, from first instar to egg-laying adult associated with the different silicon-based fertilizer treatment rates (0-, 100-, 400-, 800- and 1,600-ppm silicon) applied to green coleus plants.*

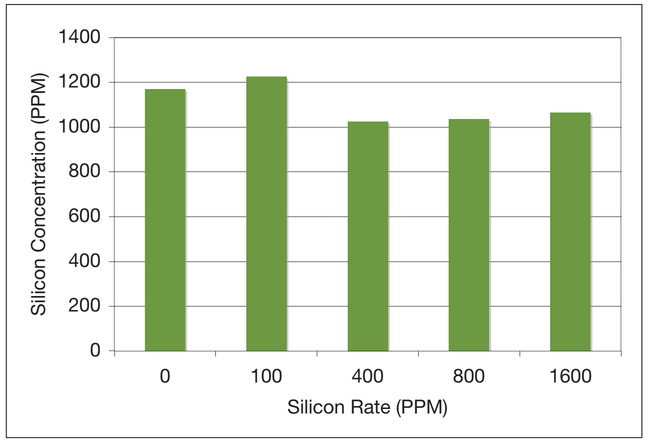

Figure 6. *Mean silicon concentration (ppm) in green coleus associated with the different silicon-based fertilizer treatment rates (0-, 100-, 400-, 800- and 1,600-ppm silicon).*

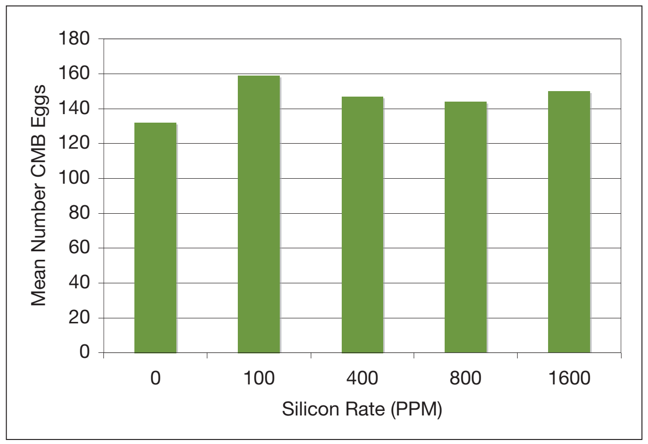

Figure 7. *Mean citrus mealybug (CMB) eggs laid by females associated with the different silicon-based fertilizer treatment rates (0-, 100-, 400-, 800- and 1,600-ppm silicon) applied to fiddle-leaf fig plants.*

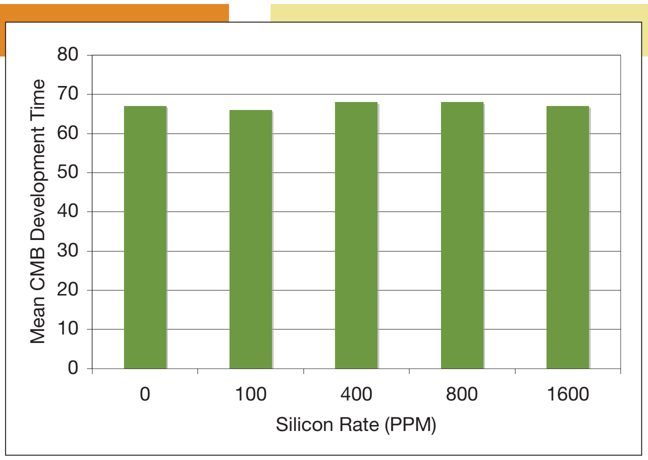

Figure 8. Mean citrus mealybug (CMB) development time, in days, from first instar to egg-laying adult associated with the different silicon-based fertilizer treatment rates (0-, 100-, 400-, 800- and 1,600-ppm silicon) applied to fiddle-leaf fig plants.

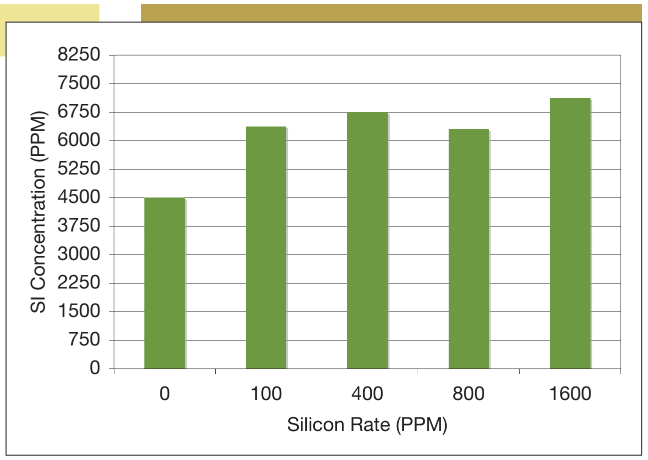

Figure 9. Mean silicon concentration (ppm) in fiddle-leaf fig plants associated with the different silicon-based fertilizer treatment rates (0-, 100-, 400-, 800- and 1,600-ppm silicon).

219.5 eggs and the mean development time ranged from 34.2 to 35.7 days. This suggests that applications of the silicon-based fertilizer, as 50-ppm potassium silicate, did not inhibit citrus mealybug feeding on green coleus, and subsequently does not negatively affect any of the citrus mealybug life-history parameters measured. It is possible that the manufacturers' label rate of 50-ppm silicon is too conservative for substantial quantities of silica to accumulate in coleus tissues. Furthermore, the coleus plants did not appear to absorb and translocate supplemental silicon into plant tissues to exhibit a response, which is common among many dicots. What was interesting to note was that the untreated check plants had higher concentrations of silicon than most of the plants that did receive silicon (Figure 3, page 35).

In the second experiment, none of the

different rates of the silicon-based fertilizer (0, 100, 400, 800 and 1,600 ppm) negatively affected either the mean number of eggs laid by citrus mealybug females (Figure 4, page 35), with egg loads ranging from 223 to 249 eggs across all the silicon rates or the mean development time from first instar to egg-laying adult, which ranged from 35.0 to 36.6 days (Figure 5, page 36). Although there were statistically significant differences in citrus mealybug female egg load and development time (days), the differences were neither consistent nor additive with the increasing silicon-based fertilizer rates. Again, there was no correlation between the silicon-based fertilizer rate and concentration of silicon in the plant tissue with concentrations ranging between 1,000- and 1,235-ppm silicon (Figure 6, page 36).

As with the citrus mealybug and coleus experiments, the different silicon-based fertilizer rates (0-, 100-, 400-, 800- and 1,600-ppm silicon) did not dramatically impact the mean number of eggs laid by the citrus mealybug females (Figure 7, page 36) or development time from first instar to egg-laying adult (Figure 8, page 37) when feeding on fiddle-leaf fig plants. The mean egg load ranged from 132.3 to 159.2 eggs, while the development time from first instar to egg-laying adult ranged from 66.9 to 68.7 days. The silicon concentrations present in fiddle-leaf fig plants was between 6,000- and 7,500-ppm silicon (Figure 9, page 37), substantially higher than concentrations in coleus plant tissue, which would classify fiddle-leaf fig as a silicon-neutral plant. In fact, the fiddle-leaf fig plants that received the higher silicon-based fertilizer rates appeared to absorb and accumulate more silicon than plants that did not receive any silicon. However, these elevated concentrations of silicon did not negatively affect any of the citrus mealybug life-history parameters measured.

In conclusion, none of the silicon-based fertilizer application rates evaluated in our study negatively affected the life-history parameters of citrus mealybug feeding on coleus and fiddle-leaf fig, which may be associated with the preferred feeding location of citrus mealybug, such as plant stems, although this is dependent on plant type. In our study, few citrus mealybugs were harvested from fully expanded leaves and petioles.

We have demonstrated that silicon was not absorbed or translocated into either coleus or fiddle-leaf fig tissues at concentrations harmful to citrus mealybug; both plants may be considered silicon rejectors. It appears, based on our results, that applications of silicon-based fertilizers may not inhibit insect pest feeding or prevent insect outbreaks. GPN

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