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A New Method of Applying Imidacloprid to Potted Plants for Controlling Aphids and Whiteflies

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Summary. The effectiveness of two application methods of the insecticide imidacloprid in controlling 1) melon aphids (*Aphis gossypii* Glover) on 'Nob Hill' chrysanthemum (*Dendranthema* ×*grandiflora* Ramat) plants and 2) silverleaf whitefly (*Bemisia argentifolii* Bellows & Perring) on 'Freedom Red' poinsettia (*Euphorbia pulcherrima* Wild.) were compared. Plants were grown in containers with their interior covered by a mixture of flat latex paint plus several concentrations of imidacloprid (0, 10, 21, 42, and 88 mg·L^{-1}), or treated with a granular application of the insecticide (1% a.i.) according to label recommendations. All imidacloprid treatments effectively reduced aphid survival for at least 8 weeks. The two most effective treatments were the granular application (10 mg a.i.) and the 88-mg·L^{-1} treatment (0.26 mg a.i). All imidacloprid treatments effectively reduced whitefly nymph survival. The 42- and 88-mg·L^{-1} treatment and the granular application (1% a.i.) were equally effective in reducing nymph numbers in lower poinsettia leaves. None of the plants given treatments with paint exhibited any phytotoxicity symptoms. These results suggest the possibility of a new application method for systemic chemicals with the potential of reducing the release of chemicals to the environment. Paint and imidacloprid mixes are not described in any product label and cannot be legally used by growers. Chemical name used: 1-[(6-chloro-3-pyrimidil)-*N*-nitro-2-imidazolidinimine (imidacloprid)

As with other crops, pest management on greenhouse floricultural crops requires chemical, biological, physical and environmental tactics. However, the greenhouse environment is unique in that it is controllable to a relatively high degree: plants are grown at quasi-optimal temperatures most of the time. As a consequence, pest populations can be very high, because optimal plant production temperatures are not very different from optimal pest development temperatures. With greenhouse ornamental crop production, pest populations must be kept at very low levels to prevent feeding injury that will weaken or kill plants, decreased aesthetics, and consumer reluctance to purchase plants infested with insects or mites.

Most pesticides registered for use in greenhouses are applied as high- or low-volume sprays. Frequent high-volume sprays of nonsystemic pesticides are labor-intensive and may affect plant growth and quality. Low-volume sprays can be applied more quickly. However, spray coverage and deposition with either method may be poor, depending on the application technique used (Lindquist et al, 1993).

When available, granular systemic insecticides can be very effective against certain pest groups (particularly piercing–sucking pests), but applying granular products to potted plants also is labor-intensive. The systemic insecticide imidacloprid (Marathon 1%G) was registered for use on greenhouse ornamental plants in 1994. This product has generally provided good to excellent long-term (6 to 10 weeks) control of whiteflies, aphids, and other pest groups (Elbert et al., 1990, 1991).

The main problems with the using the granular formulation of imidacloprid on greenhouse crops are high labor costs and proper timing (Sanderson, 1995). We wished to determine whether there were more efficient ways of applying this material using the same amount or less active ingredient per container as the granular formulation. There is evidence that reduced dosages may effectively control insects. For example, Baker and Bailey (1994) calculated that there would be a wide range of active ingredient applied by following label directions for different application methods (broadcast vs. incorporation; containers vs. plug trays).

The concept of using coated interior containers surfaces to deliver copper hydroxide has been described by Struve et al., (1994). Pasian and Struve (1996) successfully applied the growth regulator paclobutrazol to chrysanthemum plants by mixing it into flat latex paint and painting the interior surface of the containers. Based on the previous information, we hypothesized that other systemic pesticides could be delivered using coated interior containers, although not a labeled use. The objective of this work was to test whether a liquid imidacloprid formulation applied in a paint mix would control aphids on chrysanthemums (*Dendranthema grandiflora*) and whiteflies on poinsettias (*Euphorbia*

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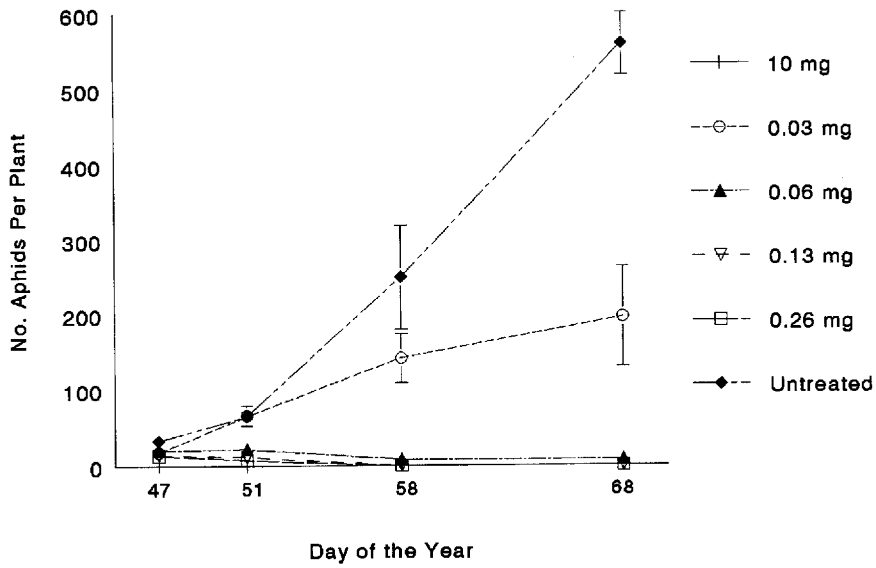

Fig. 1. Mean number of live melon aphids per chrysanthemum plant. Aphids were sampled from five plants per replicate. Vertical bars represent the standard error of the mean.

pulcherrima). If successful, the method would solve the application labor and timing problem. The pesticide dosage would also be the same in each pot and be evenly distributed. More efficient pesticide distribution might also make it possible to use lower application rates.

Materials and methods

CONTAINER PAINTING TECHNIQUE. Imidacloprid 240 g·L^{-1} flowable (Bayer Corp., Kansas City, Mo.) was stirred into white interior flat latex paint (water solution of butyl acrylate–vinyl acetate copolymer, titanium dioxide, aluminum silicate, and amorphous silicate). The paint and imidacloprid mixtures were applied to the internal surfaces of 10.2- and 15.3-cm-diameter standard plastic containers. After painting, the containers dried for 24 hours before use. On average, 3.0 and 6.4 mL of paint–imidacloprid mixture were used to paint 10.2 and 15.3-cm-diameter containers, respectively. With these volumes, the active ingredient applied in the different treatments were 0.03, 0.06, 0.13, and 0.26 mg for the 10.2-cm-diameter pots and 0.07, 0.14, 0.27, and 0.56 mg for the 15.3-cm-diameter pots. The 1% granular formulation was applied at rates near the maximum labeled rate for the smaller pot diameter, and minimum labeled rate for the larger pot diameter (10 mg to the 10.2-cm-diameter pots and 5 mg to the 15.3-cm-diameter pots). The imidacloprid plus paint mixtures applied much less active ingredient per container compared with the granular applications. Preliminary observations indicated that lower imidacloprid rates could be used when applied in paint.

The objectives of these experiments were to 1) determine the effectiveness of the paint–imidacloprid mixture in controlling aphids on chrysanthemum and silverleaf whiteflies on poinsettia and 2) compare the effects of two different application techniques and different paint–imidacloprid concentrations.

EXPERIMENT 1: MELON APHID CONTROL ON CHRYSANTHEMUMS. One rooted 'Nob Hill' chrysanthemum cutting was planted in each of ninety 10.2-cm-diameter painted (imidacloprid incorporation or paint only) and unpainted (for granular application) plastic containers filled with Ball Mix II (Ball Seed Co., West Chicago, Ill.), a commercial bark-based media. Twenty-four hours after potting, all plants were infested with five adult aphids. Plants were irrigated as needed using 20N–8.3P–16.7K fertilizer solution (250 mg·L^{-1} N two out of every three irrigations). Plants were placed on benches in a double layer of polyethylene over glass-covered greenhouse compartment in a 5 × 6 randomized complete block (RBC) design, with three plants making up each replication (15 plants per treatment). Plants were not pinched, and, 2 weeks after potting, lights were turned off leaving plants under natural (February), long-night conditions.

Treatments were paint only, four paint plus imidacloprid treatments (0.03, 0.06, 0.13, and 0.26 mg·L^{-1}), and a 1% granular formulation application at 10 mg/pot. The granular application was made 48 hours after potting the chrysanthemum cuttings.

Plant height was measured at the beginning of the experiment (5 Feb. 1995—day 36) and again when the experiment was terminated (5 Apr. 1995—day 95). Live aphids per plant were recorded at weekly intervals beginning 14 days after potting and continued until aphids were observed in substantial numbers on lower leaves of the 0.03-mg treatment (8 Mar. 1995—day 67). Eight weeks after potting, additional aphid efficacy data were obtained by caging aphids using small plastic clip-on cages. Ten aphids were applied on each of one upper and one lower leaf per plant. The number of live aphids per leaf at 2, 3, 6, and 7 days after caging was recorded.

EXPERIMENT 2: SILVERLEAF WHITEFLY CONTROL ON POINSETTIA. One rooted 'Freedom Red' poinsettia cutting was planted in each of ninety 15.3-cm-diameter painted or unpainted plastic containers filled with Ball Mix II on 29 June 1995—day 180. Plants were placed on benches in a double-wall polycarbonate covered and shaded greenhouse in a 5 × 6 RCB design, with three plants per replication (15 plants per treatment). Plants were infested with silverleaf whiteflies using infested leaf pieces removed from plants in another greenhouse compartment. Plants were irrigated as needed and fertilized with a slow release 14N–6.2P–11.6K Osmocote (Sierra Chemical Co. Milpitas, Calif.) formulation, 6 g/pot. Containers were painted as described previously.

Treatments were paint only, four paint plus imidacloprid treatments (0.07, 0.14, 0.27, and 0.56 mg/pot), and a 1% granular formulation application at 5 mg/pot. The granular application was made 6 days after potting poinsettia cuttings.

Whitefly control was evaluated as follows. Adults were counted six times at 1- or 2-week intervals (between days 198 and 261) on two leaves from the lower, middle, and upper portions of each plant, and healthy eggs and early and late instar immatures were counted once near the termination of the experiment (day 255) on 2.5-cm leaf discs taken from upper, middle, and lower foliage.

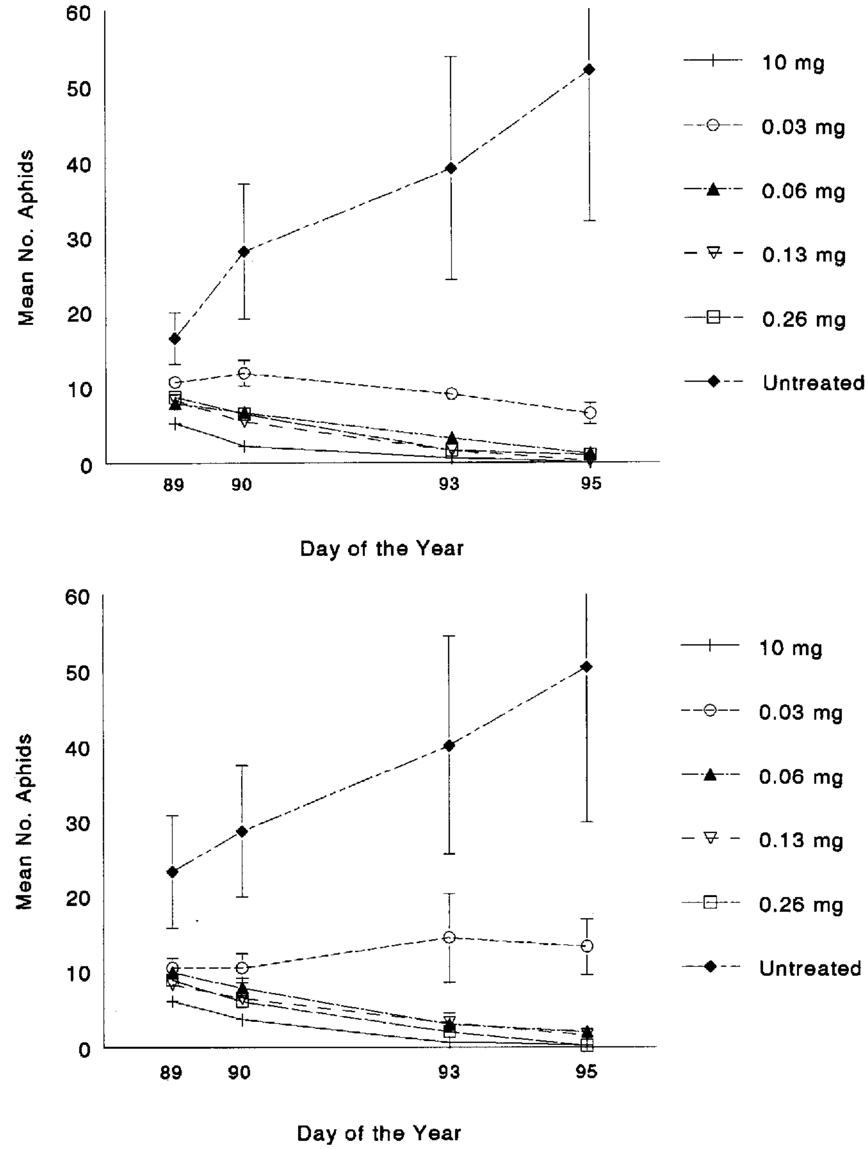

Fig. 2. Mean number of live melon aphids after caging on upper (top) and lower (bottom) chrysanthemum leaves for 6 days, 8 weeks after potting the cuttings. Each cage contained 10 adult aphids on day 88. Vertical bars represent thestandard error of the mean.

Plant height was measured on day 198 and again on day 219. Plants were pinched following this, and no further height measurements were taken. Data from the plants in painted pots were analyzed by using Wadley's Problem (Finny, 1971) to estimate a lethal doses 99 (the dose or concentration necessary to kill 99% of the test animals, LD99). The LD99 or above painted-pot treatment rates were then compared with the 1% granular applicationtreatment.

Results

Melon aphid on chrysanthemum. Aphid control was good to excellent in all but the lowest paint incorporation treatment (0.03 mg/pot) (Fig. 1). On the last sample date (day 68, 8 Mar. 1995), the granular treatment and the two highest painted-pot rates (0.13 and 0.26 mg/pot) provided 100% control. The LD99 painted-pot rate was 0.06 mg/pot, but aphid control was significantly ($p = 0.05$) less than on plants in the 0.13- and 0.26-mg/pot treatments.

After 8 weeks, when aphids were caged on leaves, results were similar (Fig. 2 A and B). Aphid control was best, and statistically equal, among the granular treatment and the two highest painted-pot rates (0.13 and 0.26 mg/pot). Again, the LD99 painted-pot rate was 0.06 mg/pot, but aphid control was significantly less than on plants in the 0.13- and 0.26-mg/pot treatments. At this point in the crop, it took about 7 days for complete control to occur. Aphid control was about equal on apical and subapical leaves, but there was slightly greater survival on lower leaves of plants in pots treated with the two lowest rates of paint incorporation.

Untreated plants were significantly shorter than all imidacloprid-treated plants (Table 1), indicating that aphid numbers were high enough to affect growth. Plants treated with the 0.03-mg/pot paint incorporation were shorter than the other treatments, but differences were slight. This showed that there were no plant growth effects from any of the imidacloprid treatments.

Silverleaf whitefly on poinsettia. Adult whitefly numbers remained low on plants in all treatments, including controls, for about 4 weeks (days 199 to 220) (Fig. 3). At this time, adult numbers on untreated control plants began to increase rapidly. Adult numbers began to increase markedly on plants in pots treated with 0.07 mg imidacloprid after about 6 weeks and more slowly on the other imidacloprid-treated plants. There were essentially no differences in adult numbers on plants in pots treated with 0.14, 0.27, and 0.56 mg a.i. or the 1% granular formulation, although numbers of adults steadily increased on all plants treated with these rates from day 234 to 261. Adult numbers began to decline on untreated control plants and plants in pots treated with the 0.07-mg paint incorporation between days 249 and 261. This probably can be attributed to a decline in overall plant quality.

After sampling eggs and other immature stages on day 256, several differences were apparent (Fig. 4). The painted pot rate providing the LD99 was 0.27 mg/pot. This application rate, the 0.56-mg/pot paint incorporation and the 1% granular application (5 mg/pot), were statistically equal and had significantly fewer eggs and other immature stages than either the untreated plants or plants in painted pots treated with 0.07 mg imidacloprid.

There were early instar immatures and eggs present on all foliage sampled in all treatments on day 256, indicating that whitefly control in all treatments was beginning to break down. Based on age distribution of the white-

Table 1. Mean chrysanthemum plant height on day 95, following imidacloprid applications in latex paint or as granules.

Treatment	Application method	Mean ht ± SE (cm)
Untreated	---	26.8 ± 1.1
10 mg/pot	1% Granular	39.5 ± 0.1
0.03 mg/pot	Paint mix	37.1 ± 1.0
0.06 mg/pot	Paint mix	40.3 ± 0.9
0.13 mg/pot	Paint mix	39.0 ± 1.2
0.26 mg/pot	Paint mix	39.6 ± 1.2

fly immature stages on the plants when sampled, control probably began to break down about 45 days after potting the cuttings.

There were no significant differences in plant height between 17 July and 7 Aug. 1995 (data not shown) among any of the treatments, indicating that the pesticide treatments had no effect on plant growth of poinsettia and that whitefly numbers were not large enough before and during this period to affect the plants.

Discussion

As shown by Pasian and Struve (1996) with the plant growth regulator paclobutrazol, paint can be used as a delivery system for systemic chemicals if incorporated in the product label. These experiments demonstrated that imidacloprid incorporated into latex paint can effectively control silverleaf whiteflies and melon aphids at application rates well below those suggested on the label for the 1% granular formulation. The effectiveness of low rates incorporated into paint may be because more roots were in contact with the insecticide, since a high proportion of roots of potted plants tend to grow close to the container wall. The 1%G formulation is normally applied by placing granules on the growing medium surface. The pesticide is moved into the root zone by irrigation. Some of the pesticide is probably lost through leaching. Additional research is required to test this hypothesis. Future experiments will include increased imidacloprid concentrations in the paint to increase the length of control. Application rates will remain below those on the labeled products.

We must point out that the duration of silverleaf whitefly control (about 6 weeks) was shorter than in some of our previous experiments with granular imidacloprid applications (R.K. Lindquist, unpublished data). This probably was due to two factors: 1) the application rate was near the minimum label rate and 2) the granules were applied 6 days after potting the cuttings, which may have been before an adequate root system was present to take up the pesticide.

The Worker Protection Standard (WPS), which is designed to protect agricultural workers from undue exposure topesticides, requires that every pesticide used in agriculture have a restricted entry interval (REI)—the time, in hours, that unprotected workers must remain out of the treated area (with some exceptions). The REI for Marathon 1%G is relatively short (12 hours). However, REIs of only 4 hours are allowed for certain products and application methods. If approved by EPA, the incorporation of this insecticide into paint may reduce the REI, because workers are not exposed to the chemical on the inside of the container. It is not yet known how much insecticide remains in the painted pot and the level of exposure experienced by consumers. This must be investigated as well. Growers should not use this application method until it is described in the labels of the mentioned products.

In addition to possibly reducing worker exposure, this application method may release less pesticide into the environment than granular applications, drenches, or high-volume sprays. Additional studies are being conducted to determine any environmental impact of this systemic insecticide application technique.

As part of a program to reduce possible pesticide contamination and delay the onset of pesticide resistance, integrated pest management (IPM) programs are being implemented by increasing numbers of greenhouse growers. The use of less-toxic biorational pesticides and biological control agents is increasing. Beneficial insects and mites for controlling most major greenhouse crop insect and mite pests are available from commercial insectaries. However, each beneficial insect or mite usually controls only one pest. Integrating biorational pesticides or application methods less harmful to beneficials is a logical approach, but this is not an easy task. Incorporating imidacloprid into paint may allow certain beneficials to help control pest groups such as thrips and spider mites while the imidacloprid controls whiteflies and aphids. So-

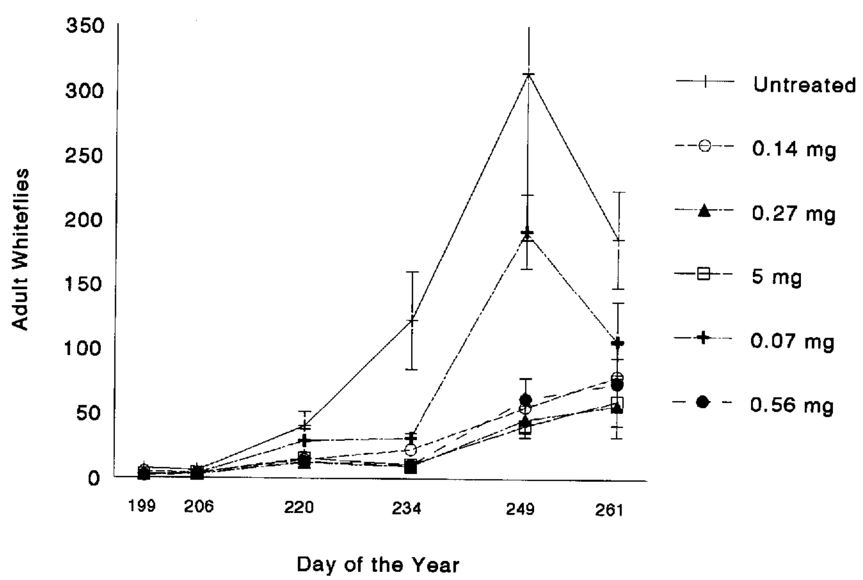

Fig. 3. Mean number of silverleaf whitefly adults sampled from lower, middle and upper poinsettia leaves on different dates after potting poinsettias. Adults were sampled from two leaves from each location. Numbers are mean totals of the means from five plants per replicate. Vertical bars represent the standard error of the mean.