Application Technique and Irrigation Method Affect Imidacloprid Control of Silverleaf Whiteflies (Homoptera: Aleyrodidae) on Poinsettias

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ABSTRACT Subirrigation systems are increasingly used to water and fertilize greenhouse crops. They also appear to be well suited for the application of systemic pesticides. We conducted two studies to look at interactive effects of imidacloprid application technique and irrigation method on plant uptake of imidacloprid and whitefly control. Drench applications of imidacloprid resulted in much higher concentrations in the leaves than applications to the bottom of pots after 14 d. However, imidacloprid efficacy in subirrigated plants was better if the imidacloprid was applied to the bottom of the pot than when an equal amount was applied as a drench. In drip-irrigated plants, imidacloprid efficacy was greater after a drench than after an application to the bottom of the pots. A second study showed that drench applications to drip-irrigated plants result in high imidacloprid concentrations in the bottom of the canopy, whereas bottom applications to subirrigated plants result in a more even distribution of imidacloprid throughout the plant. Surprisingly, the high leaf imidacloprid concentrations in the bottom layer of drip-irrigated plants did not result in improved whitefly control. Imidacloprid efficacy was better in subirrigated, bottom-treated plants than in drip-irrigated, drenched plants. Overall, results from these studies indicate that imidacloprid is very effective when applied to the bottom of subirrigated pots.

KEY WORDS *Bemisia argentifolii*, *Euphorbia pulcherrima*, irrigation method, insecticide efficacy

SILVERLEAF WHITEFLY (*Bemisia argentifolii* Bellows & Perring, Homoptera: Aleyrodidae) is an important pest on poinsettia (*Euphorbia pulcherrima* Willdenow ex Klotsch) (Brown et al. 1995). Imidacloprid (1-[6-chloro-3-pyridinyl)-methyl]-N-nitro-2-imidazolidinimine) is a relatively new, systemic chloronicotinyl insecticide (Mullins 1993), which can provide long-lasting control for whiteflies on poinsettia (Natwick et al. 1996). A single application at a high rate (0.12 g [AI]/pot) causes significant mortality of adult and immature whiteflies on poinsettia for as long as 5 mo (Bethke and Redak 1997). Because of its efficacy and lasting residual, imidacloprid currently is the standard insecticide for whitefly control in greenhouses. Imidacloprid is normally applied as a drench to the top of the growing medium.

The use of zero-runoff irrigation systems, such as flood floors, ebb-and-flow benches, and troughs, is increasing in the United States. In these irrigation systems, a fertilizer solution normally is applied to the bottom of the pots, where the growing medium absorbs it. Thus, if pesticides are applied using subirrigation systems, they would be applied to the bottom of the pots, instead of the top, resulting in a different distribution of the pesticide within the growing medium. This may affect pesticide efficacy and uptake by the plants, but little information is available about the application of pesticides with subirrigation systems.

Previous research (van Iersel et al. 2000) showed that imidacloprid application to the bottom of subirrigated pots resulted in better whitefly control than drench application to top-irrigated poinsettias. Top-watered, drenched plants took up most of the imidacloprid early in the growing season, whereas subirrigated plants, with imidacloprid applied to the bottom of the pots, had higher leaf imidacloprid concentrations near the end of the growing season (van Iersel et al. 2000). This suggests that drenched, top-watered plants have higher imidacloprid concentrations in the lower, older leaves, whereas bottom applications to subirrigated plants may result in a more even distribution of imidacloprid throughout the plant. If this is the case, concentration of imidacloprid in leaves and its efficacy might be dependent on the position of leaves on the plant. However, van Iersel et al. (2000) only measured whitefly survival and reproduction on leaves near the top of the canopy. In addition, van Iersel et al. (2000) did not determine whether the differences in whitefly control between bottom-treated, subirrigated plants and drenched, top-watered plants were due to the different imidacloprid

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application technique, or the different irrigation methods.

Here we report the results of two additional studies designed to obtain a better understanding of how imidacloprid can be used with different irrigation systems. The goal of the first study was to determine whether the efficacy of imidacloprid depends on the method of imidacloprid application (bottom-application versus drench) or irrigation method (drip versus ebb-and-flow subirrigation). The objective of the second study was to compare imidacloprid concentrations and efficacy in different canopy layers as the result of bottom-applications to subirrigated plants and drench-applications to drip-watered plants.

Materials and Methods

Study 1: Application Technique by Watering Method Interactions. *Plant Material.* Rooted poinsettia 'Peter Jacobsen's Peterstar Red' cuttings were received from Paul Ecke Ranch (Encinitas, CA) on 17 March 1999. Immediately after arrival, cuttings were planted in 15-cm-diameter pots filled with a peat-based growing medium (10–25% sphagnum peat, 25–40% vermiculite, 5–15% perlite, 0–10% bark ash, and 25–45% pine bark; Metro-Mix 300, The Scotts Company, Marysville, OH).

Treatments. Plants were placed on ebb-and-flow benches (1.2 by 2.4 m^2, MidWest Gromaster, St. Charles, IL), where they were either subirrigated or top-watered with low-flow drip tubing (30 ml/min; Netafim, Fresno, CA). Plants were watered with a fertilizer solution containing 200 mg/liter N and made with a 20:4.3:16.6 (N:P:K) water-soluble fertilizer (20-10-20 Peat-Lite Special, The Scotts Company). Plants were watered twice daily during the first week after transplanting, after which they were watered once daily until 9 June. From then on, plants were watered twice daily again. Drip-irrigated plants were not watered for several days before 14 June, because the drip system malfunctioned.

Imidacloprid treatments were started on 1 April, when plants in both irrigation treatments had roots distributed throughout the pots. One hundred milliliters of imidacloprid solution (132 mg (AI)/liter) (Marathon 60 WP, Olympic Horticultural Products, Bradenton, FL) was either applied to the top of the growing medium as a drench application, or to the bottom of the pots by pouring the solution into a 15-cm saucer and placing the pots in these saucers. To assure that the growing medium absorbed practically all of the imidacloprid solution in the saucers, 60 ml of fertilizer solution was added to the saucers after most of the imidacloprid solution had been taken up. A third treatment did not receive any imidacloprid and was watered the same as during the rest of the experiment. This resulted in a total of six treatments [2 irrigation methods (subirrigation versus drip irrigation) × 3 imidacloprid treatments (drench, bottom application, and untreated control)]. To improve growing medium uptake of the imidacloprid solution, plants were not watered during the day before the treatments were applied.

Data Collection and Analysis. Leaf blade samples were collected from 10 plants per experimental unit at 14 d (15 April) and from three plants at 82 d after application of the imidacloprid (22 June). More plants were harvested at the first sample date, because 100 g of leaf tissue was needed for analysis. Samples were frozen until they were analyzed for imidacloprid concentration.

For analysis, imidacloprid and metabolites were extracted from the plant material following Weber (1994) using methanol/1% sulfuric acid (3:1), partitioned against hexane, and the aqueous solution was passed through a XAD-4 column (Amberlite XAD-4 nonionic polymeric adsorbent, Sigma, St. Louis, MO). The methanol eluate was concentrated and the imidacloprid plus metabolites were oxidized to 6-chloronicotinic acid. The 6-chloronicotinic acid was converted to its methyl ester using diazomethane. Residues were then quantified by gas chromatography with an electron capture detector (Weber 1994). The chromatography conditions were a silinized glass column (2 m by 4 mm i.d. packed with GP 1.5% SP2250/1.95% SP2401 on 100/120 Supelcoport; Supelco, Belfonte, PA); an injection port temperature of 260°C, an oven temperature of 130°C; a detector temperature of 350°C; a mixture of argon/methane (95/5%, vol:vol) as carrier gas at 45 ml/min; and on column injection (silinized glass wool plug changed daily). Residues were quantified by external standardization (retention time ≈4 min) (Weber 1994). Analyses were performed at The University of Georgia's Pesticide and Hazardous Waste Laboratory (Athens, GA).

The effect of the different treatments on survival of mature whiteflies and the emergence and survival of immatures was tested weekly. A culture of silverleaf whiteflies was maintained on poinsettias grown on greenhouse benches. Adults were aspirated at random from these plants and used in the experiments. Approximately 10 adult whiteflies were placed in clip-on leaf cages without selecting for sex. These cages were constructed of thick foam (2 by 2 cm and 3 mm) with a 1-cm hole in the center. This hole was covered with 180-mesh silk screening material and the cage held on the leaf with a modified hair clip. A cage was placed on a fully expanded, subapical leaf (no bracts) on two plants per experimental unit. Survival percentage of the adult whiteflies was determined 2 d after they had been placed on the plants. After this count, leaf cages and the surviving whiteflies were removed from the plants, and the position of the cages was marked on the leaves with a permanent marker. After 3 wk, the number of living, immature whiteflies in this same spot on the leaf was counted.

Experimental Design. The experiment was designed as a randomized complete block with a split-plot and six replications. Irrigation method (subirrigation versus drip irrigation) was the main blocking factor and imidacloprid treatment (drench, bottom application, and untreated control) was the split. The experimental unit was a group of 25 plants used for collecting tissue samples at two occasions and for the whitefly-efficacy studies. Leaf tissue imidacloprid levels were analyzed by analysis of variance (ANOVA) after square-root transformation of the data to stabilize the variance.

Survival of adult whiteflies and the number of immature whiteflies could not be analyzed by standard statistical techniques. These data were not normally distributed and because of the large number of zeros in these data sets, the data could not be transformed to approximate a normal distribution. Instead, we used zero-inflated Poisson and zero-inflated binomial regression models to analyze these data sets (Hall 2000, Lambert 1992). This approach has been used previously for data from a similar experiment (van Iersel et al. 2000). Treatment comparisons were performed using Wald tests (Wald 1943). The Wald test is a general test appropriate in many situations in which maximum likelihood is used as the method of estimation. Wald test statistics (W) follow chi-square distributions, with number of degrees of freedom that depends on the nature of the hypothesis being tested.

Study 2: Effects on Imidacloprid Distribution and Efficacy. *Plant Material.* Three hundred rooted cuttings of 'Festival Red' were received from Oglevee (McDonough, GA) on 13 August 1999. These cuttings had not been treated with imidacloprid. Cuttings were planted in 15-cm pots filled with a peat-based growing medium (Metro-Mix 300, The Scotts Company) immediately after arrival. Plants were then placed on 0.9 by 1.5-m^2 ebb and flow benches (15 benches with 18 plants each). All branches were pruned weekly, so only a single (main) stem remained. Plants were watered daily with a fertilizer solution containing 225 mg/liter N (20-10-20 Peat-Lite Special, The Scotts Company).

Treatments. Plants were grown for 2 wk before imidacloprid treatments were applied on 27 August. The three different treatments were as follows: (1) an untreated, subirrigated control, (2) 100 ml of imidacloprid solution (132 mg (AI) / liter; 4.4 g Marathon/20 liter; Marathon contains 60% [AI]) applied to the bottom of the pots, using a saucer (these plants were subirrigated during the rest of the experiment), and (3) a 100-ml drench applied to the top of the growing medium of drip-irrigated plants. After the growing medium of the plants that received the bottom application had absorbed most of the imidacloprid solution, 100 ml of fertilizer solution was applied to the saucers to help facilitate the absorption of the imidacloprid that remained in the bottom of the saucer. Drip-irrigated plants were not leached during the first 2 wk after the imidacloprid application. To facilitate imidacloprid absorption by the growing medium, plants were not watered the day before the imidacloprid applications.

To separate leaves into different age groups, the uppermost leaves (>2.5 cm wide) were marked with a jeweler's tag on the day of imidacloprid application (27 August) and 4 October. Thus, the age groups of the leaves consisted of the bottom canopy layer (below the lowest tag), middle canopy layer (between the two tags), and top canopy layer (above the upper tag).

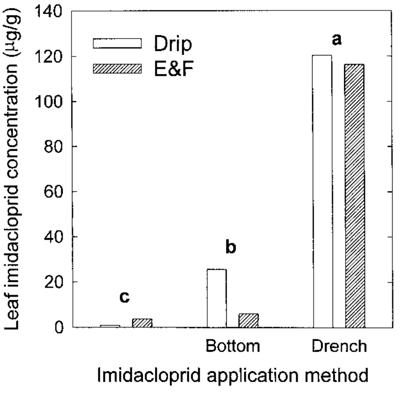

Fig. 1. Effect of imidacloprid application technique (untreated control, application to the bottom of the pot, and drench application) and irrigation method (drip-irrigation or ebb-and-flow [E&F] subirrigation) on leaf concentrations of imidacloprid. Tissue concentrations ($n = 6$) were determined 14 d after the application. Application methods with the same letter are not significantly different ($P > 0.05$). Irrigation method did not affect leaf concentrations of imidacloprid.

Data Collection and Analysis. Stomatal conductance and transpiration rate of fully expanded subapical leaves were measured weekly with a steady-state porometer (LI-1600, LI-COR, Lincoln, NE), from 27 August until 15 October. At 63 d after application (29 October), leaves of the different age groups were sampled from 10 plants in every experimental unit and frozen until they could be analyzed for imidacloprid content as described above.

On 12 October, weekly measurements of whitefly survival and reproduction were started. Approximately 10 whiteflies were placed on one of the lower leaves (below the lower tag) and the uppermost green leaf. Adult survival percent and number of immatures were determined as described above. Two plants from each experimental unit were selected randomly for these measurements on each measurement date.

The experimental design was a randomized complete block with three treatments and five replications. The experimental unit was a group of 15 plants on one bench. Leaf imidacloprid levels were analyzed by ANOVA after square-root transformation of the data to stabilize the variance. Whitefly data were analyzed with zero-inflated Poisson and zero-inflated binomial regression models, as described above.

Results and Discussion

Study 1: Application Technique by Watering Method Interactions. *Leaf Imidacloprid Concentrations.* At 14 d after the imidacloprid application, leaf imidacloprid concentrations were much higher in plants that received a drench application than in plants where imidacloprid was applied from the bottom (Fig. 1; $F = 87.2$; df = 2, 20; $P < 0.0001$). Traces

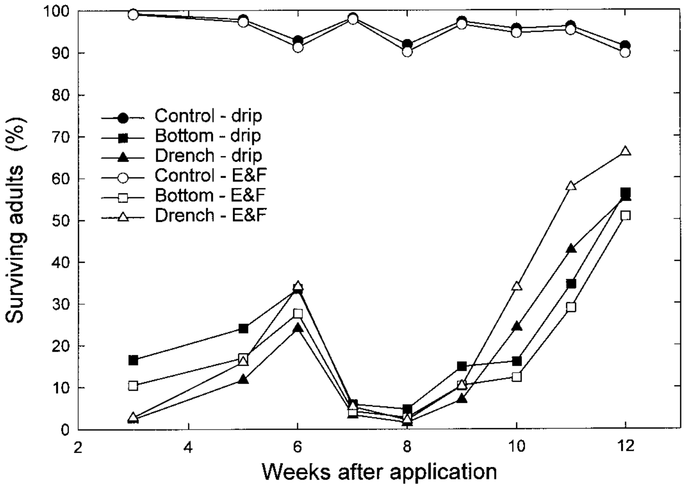

Fig. 2. Effect of imidacloprid application technique (untreated control, application to the bottom of the pot, and drench application) and irrigation method (drip-irrigation or ebb-and-flow [E&F] subirrigation) on survival of adults whiteflies (n = 6). Survival percentage was determined after whiteflies had been on the plants for 2 d.

of imidacloprid were detected in untreated control plants and may have been present in the stock plants at the time that cuttings were taken, or could have leached out of pots treated with imidacloprid and transferred to control plants through the recirculating fertilizer solution. Irrigation method did not have an effect on imidacloprid concentrations in leaves at 14 d after treatment ($F = 1.05$; df = 1, 5; $P = 0.35$), and there was no interactive effect of irrigation method and application technique on leaf imidacloprid concentration ($F = 1.72$; df = 2, 20; $P = 0.20$). Only trace amounts (<2.1 μg/g) of imidacloprid were detected in leaves 82 d after treatment, and there were no significant differences among the treatments. Other studies have reported that imidacloprid residues are persistent in plants. For example, Westwood et al. (1998) found significant amounts of imidacloprid in leaves of sugar beet (*Beta vulgaris altissima* Doell.) 97 d after application to seed, although most of the imidacloprid had been metabolized at this time. Bethke and Redak (1997) found that imidacloprid can cause significant mortality of silverleaf whiteflies on poinsettia for >160 d. Similarly, imidacloprid reduces whitefly populations on cauliflower (*Brassica oleracea* L. variety *botrytis*), tomato (*Lycopersicon esculentum* Miller), and eggplant (*Solanum melongena* L.) for 3 mo or more (Natwick et al. 1996, Stansley et al. 1998). However, it is not clear whether this long-lasting activity was caused by the presence of imidacloprid itself or its metabolites, which can be more insecticidal than the parent compound (Nauen et al. 1998). Rapid growth of the plants in our experiments may have contributed to the low imidacloprid concentrations in the leaves at 82 d after application, because it would result in a dilution of the imidacloprid in the leaves. However, it seems unlikely that this can account completely for the low concentration of imidacloprid, because leaf concentrations in drenched plants were ≈50 times lower at 82 d than at 14 d after treatment. Metabolism of the imidacloprid probably also contributed to the low concentrations at 82 d after the application.

Whitefly Survival. Survival of adult whiteflies in the two control treatments ranged from 90 to 100% throughout this experiment (Fig. 2), indicating that environmental conditions were favorable for whitefly survival. Control of adult whiteflies on drip-irrigated plants was better with a drench application than with a bottom application of imidacloprid ($W = 16.1$, df = 2, $P = 0.0006$); whereas for subirrigated plants, bottom application was more effective than drench application ($W = 6.14$, df = 2, $P = 0.046$). Control of adult whiteflies on drip-irrigated plants with drench application was similar to control on subirrigated plants with bottom application of imidacloprid. Only at 3 wk after application was there a significant difference ($W = 13.2$, df = 2, $P = 0.0013$) between these two treatments, with drench application to drip-irrigated plants resulting in better control of adult whiteflies than bottom application to subirrigated plants. These results differ from our previous finding that bottom applications to subirrigated plants are more effective than drench applications to top-watered plants (van Iersel et al. 2000). All imidacloprid treatments started losing efficacy 10 wk after application, and 12 wk after the application survival of adults was close to 60% on the imidacloprid treated plants. This is consistent with our finding that leaf imidacloprid levels were very low at 82 d after treatment (Fig. 1).

Whitefly Reproduction. Subirrigated control plants had fewer immature whiteflies than drip-irrigated control plants (Fig. 3; $W = 39.0$, df = 2, $P < 0.0001$). The reason for this difference is not clear, but apparently the subirrigation resulted in changes in environmental conditions or host plants that made them less favorable for production of immatures. All imidacloprid treatments resulted in reduction in the number of immatures ($W > 967$, df = 2, $P < 0.0001$) and differ-

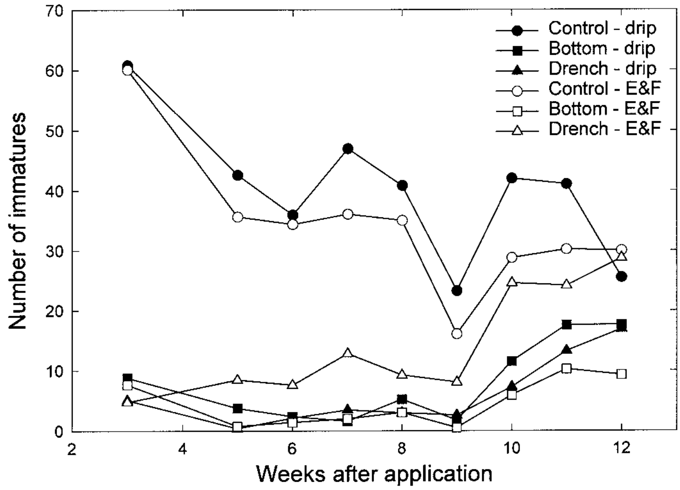

Fig. 3. Effect of imidacloprid application technique (untreated control, application to the bottom of the pot, and drench application) and irrigation method (drip-irrigation or ebb-and-flow [E&F] subirrigation) on reproduction of whiteflies (n = 6). The number of immatures was determined 3 wk after approximately ten adults had been placed on a leaf for 2 d.

ences in reproduction were similar to differences in the survival of adults. Drip-irrigated plants that were drenched with imidacloprid had fewer immatures than those that were treated from the bottom (W = 7.98, df = 2, P = 0.018). The opposite was true for subirrigated plants, where treatment to the bottom of pots resulted in fewer immatures than drench treatment (W = 185.8, df = 2, $P < 0.0001$). However, there were no consistent differences between the number of immature whiteflies on drenched plants with drip-irrigation and bottom-treated plants with subirrigation. Only in week 9 (W = 12.3, df = 2, $P < 0.0021$) and week 12 (W = 23.5, df = 2, $P < 0.0001$) did the application of imidacloprid to the bottom of subirrigated plants watered result in fewer immature whiteflies than drench application to drip-irrigated plants. In contrast, both a previous study (van Iersel et al. 2000) and the second study reported in this article indicated that application of imidacloprid to the bottom of subirrigated plants is more effective than drench application to top-watered plants.

Drench applications have the highest efficacy for drip-irrigated plants, whereas bottom applications are more effective for subirrigated plants. This is probably due to movement of imidacloprid in the growing medium. When imidacloprid is applied to the bottom of drip-irrigated plants, imidacloprid can easily be leached out of the bottom of the pots. This is much less likely to happen when plants receive a drench treatment, because the imidacloprid has to move through the entire pot, before it can be leached out.

With subirrigation, leaching from pots is minimal. The fertilizer solution is absorbed by the growing medium through holes in the bottom of the pots and the water moves upward through the growing medium because of evaporation from the growing medium surface. This causes fertilizer salts to accumulate at the surface of the growing medium (Argo and Biernbaum 1996), where they are less available to the plants (Argo and Biernbaum 1995). It seems likely that imidacloprid movement and availability to the plant would be affected similarly. Accumulation of imidacloprid at the surface of a subirrigated growing medium is probably faster after a drench application than after a bottom application. When the application is made to the bottom of the pot, the imidacloprid needs to be transported throughout the entire height of pot before reaching the surface of the growing medium, whereas imidacloprid is already near the surface of the growing medium after a drench application. Thus, when plants are subirrigated, the imidacloprid likely will be available longer for plant uptake after a bottom than after a drench application.

Study 2: Effects on Imidacloprid Distribution and Efficacy. *Leaf Imidacloprid Concentrations.* There were large differences in leaf tissue imidacloprid concentrations in the different canopy layers of drip- and subirrigated plants (F = 36.6; df = 5, 20; $P < 0.0001$). The bottom canopy layer of drip-irrigated plants had the highest imidacloprid concentration, and imidacloprid concentration was much lower in the middle and top canopy layers of drip-irrigated plants (Fig. 4). The bottom canopy layer of subirrigated plants also had a much lower imidacloprid concentration than the bottom layer of drip-irrigated plants, but the differences in imidacloprid concentration among the different canopy layers of subirrigated plants were smaller than in drip-irrigated plants. There were no significant differences in the leaf imidacloprid concentration between the bottom and middle, or middle and top canopy layers of subirrigated plants. This suggests that imidacloprid uptake in drip-watered plants occurred mainly in the early part of the growing season, whereas the imidacloprid uptake of subirrigated plants was more steady throughout the growing season. These differences in imidacloprid uptake by the plants were not related to the transpiration rate of the plants, because there were no significant differences in sto-

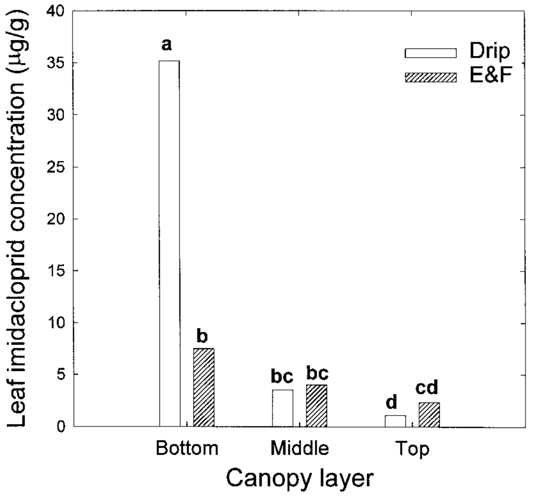

Fig. 4. Leaf imidacloprid concentrations in the bottom, middle, and top part of the canopy of drip-irrigated, drenched plants and ebb-and-flow subirrigated [E&F], bottom-treated plants ($n = 5$). Bars with the same letter are not significantly different ($P > 0.05$).

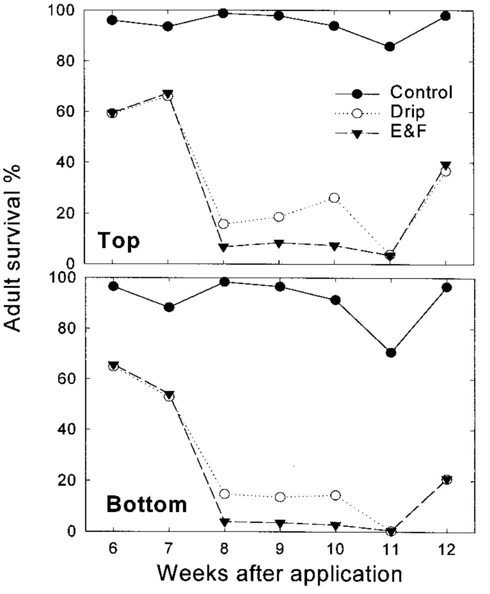

Fig. 5. Survival of adult whiteflies in the top and bottom of the canopy on ebb-and-flow subirrigated, bottom-treated plants and drip-irrigated, drenched plants ($n = 5$). Control plants were subirrigated by ebb-and-flow and did not receive an imidacloprid application. Survival percentage was determined after adults had been on the plants for 2 d.

matal conductance ($F = 0.94$; df = 2, 8; $P = 0.43$) or transpiration ($F = 0.91$; df = 2, 8; $P = 0.44$) among the treatments at any of the eight measurement times (results not shown). A very small amount of imidacloprid (0.36 μg/g) was present in the bottom layer of the canopy of control plants, whereas the middle and upper layers did not contain any imidacloprid. The imidacloprid in the bottom canopy layer of the control plants may have been the result of imidacloprid applications to the stock plants from which the cuttings were taken.

Whitefly Survival. Environmental conditions during the experiment were favorable for whiteflies, because survival on control plants ranged from 70 to 98% during the experiment (Fig. 5). Survival of adult whiteflies was lower in the bottom than in the top of the canopy at 7, 11, and 12 wk after imidacloprid application ($W > 11.9$, df = 2, $P < 0.026$). Survival was surprisingly high at 6 and 7 wk after the imidacloprid application. It is possible that whitefly feeding was limited during the 2 d that the adults were placed on the leaves, thus limiting the exposure of the whiteflies to imidacloprid; however, it is unclear why this would have been the case. Generally, whitefly survival was lower on subirrigated than on drip-irrigated plants ($W = 8.45$, df = 2, $P = 0.0146$). Differences in adult whitefly survival were most evident from 8 to 10 wk after the imidacloprid application.

Treatment differences in adult whitefly survival were similar in the bottom and top layer of the canopy. Although drip-irrigated plants had much higher imidacloprid concentrations in the bottom canopy layer than subirrigated plants, this did not result in better control of adult whiteflies. The reason for this is not clear, but it is possible that the imidacloprid in leaves of drip-irrigated plants accumulated in a part of the leaf where it was not effective. Xylem-mobile compounds, such as imidacloprid, tend to accumulate in leaf margins (Canny 1990). Because the leaf cages were placed away from the leaf margins, the whiteflies may not have been exposed to the part of the leaves with the highest imidacloprid concentration. These results indicate that imidacloprid concentration in leaves may not accurately reflect its efficacy.

Whitefly Reproduction. Environmental conditions were suitable for the development of immature whiteflies, because the number of immatures in the control treatment ranged from 16 to 39 in the upper and from 8 to 26 in the lower canopy layer (Fig. 6). The number of immatures in the lower canopy layer of the control treatment increased throughout the experiment, possibly because these leaves contained low concentrations of imidacloprid (0.36 μg/g at 63 d after application). No imidacloprid was detected in the upper canopy layer of control plants, and there was no apparent trend in the number of immatures on those leaves during this experiment. Imidacloprid greatly decreased the number of immatures ($W = 338.1$, df = 2, $P < 0.0001$). The imidacloprid treatments started to loose their efficacy at 9 wk after the applications, when the number of immatures started to increase on both drip- and subirrigated plants. Subirrigated plants generally had fewer immatures than drip-irrigated plants ($W = 9.46$, df = 2, $P = 0.0088$).

The number of immature whiteflies is probably a more important measure of imidacloprid efficacy than survival percentage of adults, because it determines how rapidly the population can build up. Results from this study show that imidacloprid applications to the

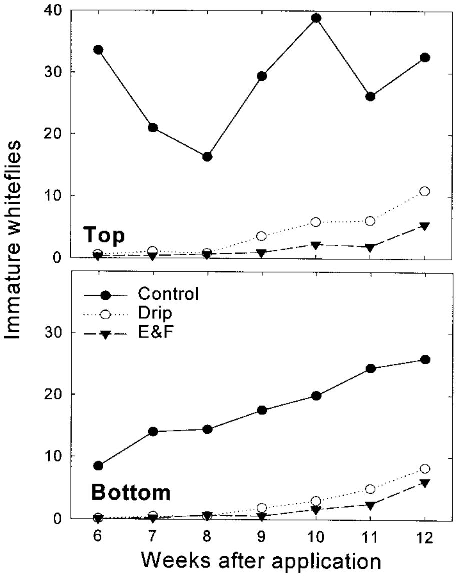

Fig. 6. Reproduction of whiteflies in the top and bottom of the canopy on ebb-and-flow subirrigated, bottom-treated plants and drip-irrigated, drenched plants ($n = 5$). Control plants were subirrigated by ebb-and-flow and did not receive an imidacloprid application. The number of immatures was determined 3 wk after approximately 10 adults had been placed on the leaf for 2 d.

bottom of subirrigated pots result in better whitefly control than drench applications to drip-irrigated plants, when equal amounts of imidacloprid are applied. Thus, applying imidacloprid by subirrigation appears to be a viable alternative to the standard drench treatment.

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