# Practical Pest Management Strategies to Reduce Pesticide Runoff for Argentine Ant (Hymenoptera: Formicidae) Control

LES GREENBERG,[1,2] MICHAEL K. RUST,[1] JABEN RICHARDS,[3] XIAOQIN WU,[3] JOHN KABASHIMA,[4] CHERYL WILEN,[5] JAY GAN,[3] AND DONG-HWAN CHOE[1]

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**ABSTRACT** The purpose of this study was to involve pest management professionals in the design of application techniques and strategies that would be efficacious and also reduce insecticide runoff. Our study involved measuring both the efficacy of treatments for the Argentine ant, *Linepithema humile* (Mayr), and the concurrent runoff of fipronil and pyrethroids. Two collaborating companies used low-impact protocols for controlling ants while minimizing runoff. Protocol 1 involved bimonthly treatments, while Protocol 2 was monthly. Both protocols involved an initial treatment with a fipronil spray around the foundation. At the garage door– driveway interface, the fipronil application was done as a pin stream for Protocol 1, and as a crack and crevice application in the expansion joint near the garage for Protocol 2. Protocol 1 replaced most pyrethroid sprays with bifenthrin granules placed around bushes and away from the driveway. For the next treatment on day 63, Protocol 1 also included cyfluthrin spray treatments around the house foundation and crack and crevice applications around the edge of the driveway. For the first treatment in Protocol 2, the fipronil spray was supplemented with spot treatments of cyfluthrin. For subsequent Protocol 2 treatments, botanical insecticides were applied. For weeks 1 and 2 posttreatment combined, Protocol 1 had significantly higher reductions in ant numbers compared with Protocol 2. Thereafter there were no significant differences between the protocols. Runoff of bifenthrin from the granules used with Protocol 1 was much lower than in previous trials involving bifenthrin sprays. Day 1 fipronil runoff for Protocol 2 was significantly lower than that for Protocol 1. This difference may be because of the crack and crevice application applied in Protocol 2. Cyfluthrin runoff was minimal for Protocol 2, which involved spot treatments to supplement the fipronil on day 1, or the botanical insecticides for subsequent treatments. Protocol 1 had a large peak of cyfluthrin runoff at day 63 corresponding to their house and driveway treatments.

**KEY WORDS** pyrethroid, fipronil, *Linepithema humile*, integrated pest management

An unanticipated consequence of controlling ants around homes in southern California (as well as other U.S. locales) with insecticides is the runoff of these materials into the streets, drains, and urban waterways, where they are toxic to aquatic organisms. In southern California, much of this runoff is owing to efforts to control the Argentine ant, *Linepithema humile* (Mayr). Field et al. (2007) reported that >90% of service calls to one professional pest management company in San Diego were to control ants, 85% of which were for Argentine ants. This observation is probably representative of what most pest control companies in urban southern California are confronting with respect to their general pest management services.

The use of pyrethroid insecticides such as bifenthrin, cypermethrin, cyfluthrin, and permethrin by pest management professionals (PMPs) has dramatically increased since the use of organophosphates chlorpyrifos and diazinon by PMPs was discontinued in 2001. They are widely found in urban and agricultural streams across the United States (Amweg et al. 2006, Hintzen et al. 2009, Ding et al. 2010, Hladik and Kuivila 2012) and California (Weston et al. 2005; Holmes et al. 2008; Phillips et al. 2010, 2012; TDC 2010; Weston and Lydy 2010; Delgado-Moreno et al. 2011; California Stormwater Quality Association [CASQA] 2013; Ensminger et al. 2013). Likewise, a phenylpyrazole insecticide, fipronil, has been found in urban surface streams in at least 10 states, including California (Hladik and Orlando 2008, Holmes et al. 2008, Lin et al. 2008, Ryberg et al. 2010, Weston and Lydy 2010, Delgado-Moreno et al. 2011, Gan et al. 2012, Ensminger et al. 2013). The fact that pyrethroids and fipronil are appearing nationwide in urban waterways at levels toxic to keynote species in the food chain is

[1] Department of Entomology, University of California, Riverside 92521.
[2] Corresponding author, e-mail: Les.greenberg@ucr.edu.
[3] Department of Environmental Sciences, University of California, Riverside 92521.
[4] Environmental Horticulture Advisor, UC Cooperative Extension, 7601 Irvine Blvd., Irvine, CA 92618.
[5] Area IPM Advisor, UC Cooperative Extension, 9335 Hazard Way, Ste. 201, San Diego, CA 92123.

an urgent issue for all states where these pesticides are used for the management of urban pest ants. A recent report (CASQA 2013) reviews the past decade of reports from California and found that bifenthrin was found in 69% of sediment samples and 64% of water samples (total of 9,200 samples), while fipronil was found in 39% of water samples and 19% of sediment samples (total of 3,200 samples).

Recent studies have focused on the means by which these urban pesticides enter waterways. One likely source is overwatering of residential lawns that have been treated with pyrethroids (Hanzas et al. 2011). Another source may be treatments around houses that contact impervious surfaces such as concrete, allowing easy runoff (Jiang et al. 2010, 2011; Jorgenson et al. 2012; Thuyet et al. 2012; Luo et al. 2013). The chemical characteristics of pesticide formulation, such as the presence of surfactants, may also increase runoff with water (Jorgenson and Young 2010). Finally, the methods by which pesticides are applied around houses can significantly alter runoff to the street (Greenberg et al. 2010). We have previously reported on the efficacy of Argentine ant treatment strategies around homes using our monitoring methods (Klotz et al. 2007, 2008, 2009, 2010). Our present goal is to develop effective strategies for ant management that will reduce the amount of pyrethroids and fipronil used around homes and avoid their runoff to the street. To achieve this goal, we monitored the efficacy of ant treatments around homes and also collected samples from water moving off the driveway to measure how much insecticide ran off.

## Materials and Methods

**Estimating Ant Numbers.** To evaluate ant populations, the numbers of ants around homes were monitored using vials containing 13 ml of 25% sucrose water. Ten vials were placed on the ground around the exterior foundation ("house"), and 10 additional vials were placed out in the yard ≈5 m from the structure ("yard"). Each vial was covered with a plastic flowerpot to minimize disturbance and ambient light and protect the vials from irrigation. The vials were preweighed and then were left in place on the ground for 24 h. The vials were then reweighed to measure the amount of sucrose water consumed by the ants. Five vials were hung by a string to a tree where ants could not reach them and were used as evaporative controls. Reierson et al. (1998) determined that on average an Argentine ant consumes 0.3 $\mu$l of sucrose water per visit, which along with the total consumption can be used to calculate the number of ant visits per vial over the 24-h monitoring period. Therefore, each milliliter of solution consumed by ants represents ≈3,300 ant visits. Posttreatment evaluations of ant numbers were done at 1, 2, 4, 8, 10, and 14 wk. The reductions were summarized separately for house and yard data because most of the treatments concentrated on the house foundation, with less emphasis on the yard and fence lines.

**Treatment Protocols.** We collaborated with two large pest control companies in the development of effective insect pest management techniques for ant control around houses. The goal for each company was to minimize runoff of fipronil and pyrethroids (bifenthrin and cyfluthrin). Ten home owners, 5 for each company, volunteered their homes for these summer trials. The houses were treated by each company for ant infestations from July through October 2012. Current regulations pertinent to pyrethroid applications around homes include the following limitation: broadcast sprays cannot be applied closer than 60 cm from horizontal impervious surfaces. Within the 60-cm barrier from impervious surfaces, applicators can do spot, crack, and crevice, and 2.54-cm-wide pin stream applications where ants are seen. A pin stream can also be done on the driveway or other horizontal impervious surfaces where there are ants. (New California restrictions on the use of pyrethroids can be found here: http://www.cdpr.ca.gov/docs/legbills/rulepkgs/11-004/text_final.pdf).

**Protocol 1.** The first company scheduled bimonthly treatments (July and September). Each house was treated with 1.9 liters of 0.06% fipronil spray (Termidor SC, BASF, Research Triangle Park, NC), 3.8 ± 0.52 liters (range, 2.8–5.7 liters) of 0.1% cyfluthrin (Cy-Kick CS, Whitmire Micro-Gen, St. Louis, MO), and 408 ± 57.8 g (range, 227–567 g) of 0.2% bifenthrin granules (Talstar PL, FMC, Philadelphia, PA). In July, the PMP applied the fipronil spray with a Birchmeier Flox 10-liter backpack sprayer (Birchmeier, Stetten, Switzerland) with an adjustable cone nozzle. It was applied as a narrow band ≈5.1 cm up and 5.1 cm out from the house foundation at the grade–wall junction. At the garage door–driveway interface (but not specifically into the expansion joint), the PMP did a pin stream application with the applicator tip ≈0.6 m from the surface. The PMP supplemented the fipronil with bifenthrin granules applied with a 14 oz CentroBulb Duster (Centro Company, South Salem, NY) around landscaped areas such as bushes and trees and decorative walls and borders. The applicator swept off the driveway and sidewalk any granules that landed there. On the second treatment on day 63, the PMP applied the granular bifenthrin as described above and a 20-cm band of cyfluthrin around the house foundation, not including the driveway or other impervious surfaces in the backyard. A pin stream of cyfluthrin was applied to the driveway at the garage door, as well as the edges of the lawn next to the driveway. Call backs from homeowners complaining about ant problems received an additional treatment with cyfluthrin sprays and bifenthrin granules.

**Protocol 2.** The second company scheduled monthly home service from July through October. Each house was treated with 1.9 liters of 0.06% fipronil (see above), 2.1 ± 0.19 liters of 0.1% cyfluthrin (see above), and 11.4 liters of a botanical pesticide, 0.025% EcoPCO WP-X WP (Prentiss Inc., Alpharetta, GA; the active ingredients of the powder are 0.05% pyrethrins, 5% thyme oil, and 3% 2-phenethyl propionate). Using a B&G 2-gal handheld tank sprayer and adjustable cone tip (B&G Equipment Co., Jackson, GA), the PMP sprayed the fipronil band 30 cm up and 30 cm out from the grade–wall junction. At the garage door–driveway expansion joint the PMP used a crack and crevice application with the applicator tip right up against the expansion joint. On the first visit, the fipronil was supplemented with an application of the cyfluthrin spray, using a 1-gal B&G handheld tank sprayer. It was used as a spot treatment around the edge of the lawn and around fence lines. The PMP also used the cyfluthrin along the edge of the lawn next to the driveway as a crack and crevice or spot treatment. Monthly, after the initial visit and for all callbacks, the PMP used a 10-cm fan spray of the EcoPCO WP-X (using the 2-gal B&G applicator), around all areas of the house foundation, driveway, tree trunks, fence lines, and shrubs.

Because of the fact that the companies could not always schedule treatments for their five homes for the same day, we have grouped the treatments and monitoring dates for the five houses of each protocol into weekly categories so that meaningful comparisons of the protocols could be done at similar time intervals. Treatments at the houses began the week of 18 July 2012, and the last monitoring for ant numbers was the week of 22 October 2012.

**Measurement of Insecticide Runoff.** A previous study showed that after house treatments, significant amounts of insecticide ran off down the driveway to the street (Greenberg et al. 2010). For the current study, we flushed the driveway from the garage door to the street with 76 liters of water as measured by a water meter (AbsolutelyNew Water Saver Usage Meter, San Francisco, CA) attached to a hose nozzle. At the curb, 1 liter of water was collected by making a dam consisting of a U-shaped block of Styrofoam inside a plastic bag. Water collected in the dam was collected with a glass pipette and put into a 1-liter amber glass bottle. These samples were kept at 4°C until analyzed for insecticide residues. Samples were collected 1, 28, 65, and 98 d after the initial treatments, and usually within a couple of days of a treatment. There were no significant rain events during this period. Samples were analyzed for bifenthrin, cyfluthrin, and fipronil. Techniques for analyzing botanicals are not readily available at this time and were therefore not measured.

**Chemical Analysis.** Pyrethroids and fipronil in the runoff water were solvent extracted following modified EPA Method 3510C, and analyzed by gas chromatography–electron capture detector (GC-ECD). Briefly, the water sample was transferred to a 2-liter glass separatory funnel preloaded with 40 g of sodium chloride and spiked with 1 ml of 40 ppb decachlorobiphenol as a surrogate. Pyrethroids were extracted for three consecutive times using 60 ml of methylene chloride each time. The extracts from the three extractions were combined and then passed through 40 g of anhydrous sodium sulfate to remove the residual water, followed by concentration to near dryness, and then reconstituted in hexane/acetone (9:1, vol:vol). This fraction was further concentrated to near dryness under nitrogen, and then reconstituted to 1 ml with hexane. An aliquot of the final extract was injected for GC-ECD analysis. For quality assurance and quality control purposes, one blank sample consisting of deionized water was extracted and analyzed for every 10 samples.

**Statistics.** For each protocol and for each monitoring period, we computed the percent reduction in ant numbers compared with the pretreatment numbers as determined by our sugar water monitoring (Figs. 1 and 2). For statistical comparisons, the proportional data were arcsine-transformed to improve nor-

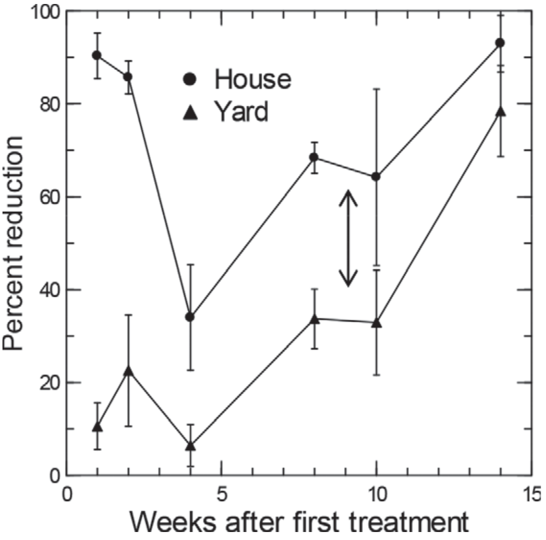


**Fig. 1.** Ant reductions for Protocol 1. These houses were treated bimonthly at weeks 0 and 8 (arrow). Data points show the means ± SE; $N = 5$ houses. After week 0, treatments consisted of cyfluthrin and bifenthrin granules, when necessary.

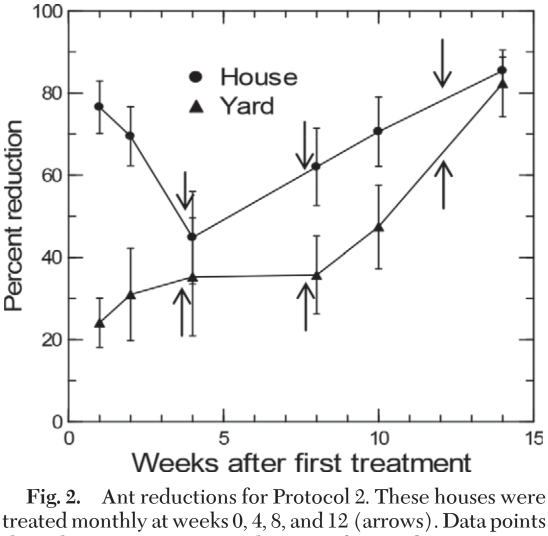


**Fig. 2.** Ant reductions for Protocol 2. These houses were treated monthly at weeks 0, 4, 8, and 12 (arrows). Data points show the means ± SE; $N = 5$ houses. After week 0, treatments consisted of botanicals and cyfluthrin, if necessary.

mality (Figures show nontransformed results). Repeated measure (RM) analyses of variance (ANOVAs) were done on the arcsine-transformed proportions, where "subjects" were houses sampled over time. Our real interest was a comparison of the houses in the two protocols, the "between subjects" part of a RM ANOVA, and is equivalent to comparing the grand means over time of the two protocols. Although we show week 14 in the figures, we did not include those data in the statistical analysis because they are end of season ant numbers (see Discussion). We did the RM ANOVA over the first 10 wks, as well as for each consecutive shorter time period down to weeks 1 and 2. As a follow-up to RM ANOVAs, we did simple ANOVAs at each monitoring date to compare the two protocols. Similar RM ANOVAs were done on the log-transformed runoff data for fipronil to compare Protocols 1 and 2. A simple ANOVA was done with log-transformed data to compare the two protocols for cyfluthrin runoff at day 63. All analyses were done with Systat (2009).

## Results

**Ant Numbers.** The RM ANOVAs between the two protocols over 10 wk did not show any significant differences either at the house foundation or yard ($F = 2.5$; df = 1,8; $P = 0.15$; and $F = 3.3$; df = 1,8; $P = 0.10$, respectively; Figs. 1 and 2). A RM ANOVA for weeks 1 and 2 at the house foundation over time, however, was significant ($F = 5.8$; df = 1,8; $P = 0.04$), with Protocol 1 reductions slightly higher during this period. For the same 2-wk period, the yard reductions were not significantly different ($F = 3.2$; df = 1,8; $P = 0.11$). Protocol 2 yard reductions for weeks 1 through 3 were slightly better than those for Protocol 1, although the results were not significant ($F = 4.5$; df = 1,8; $P = 0.07$). For both house and yard, there were no significant $F$ values for the ANOVAs for single week periods or for other groupings of the consecutive week data. For weeks 2 through 10, there were significantly more ants in the yard than at the house foundation for both Protocols 1 and 2 (RM ANOVA, $F = 51.3$; df = 1,8; $P < 0.001$; and $F = 13.1$; df = 1,8; $P = 0.007$, respectively). During the study there was one homeowner callback (a complaint to the company) for ants indoors from a Protocol 1 house, and two callbacks to the houses receiving Protocol 2 treatments. The companies left liquid boric acid baits for homeowners, who were instructed to place them near ant trails indoors.

**Insecticide Runoff.** For each insecticide measured in the runoff, the graphs show a horizontal dashed line, which represents the $EC_{50}$ (the concentration required to kill or immobilize half of the *Ceriodaphnia*), a keynote fresh water aquatic crustacean, to that insecticide.

**Protocol 1.** The concentration of bifenthrin from driveway runoff from the granules was near or at the *Ceriodaphnia* $EC_{50}$ (Fig. 3). The use of spot treatments of cyfluthrin for an August callback and for the September bimonthly treatments resulted in runoff levels above the $EC_{50}$ for cyfluthrin for days 65 and 98 (Fig. 4). The concentration of fipronil in the runoff (Fig. 5) was orders of magnitude below the fipronil $EC_{50}$, except for day 1, when it slightly exceeded it.

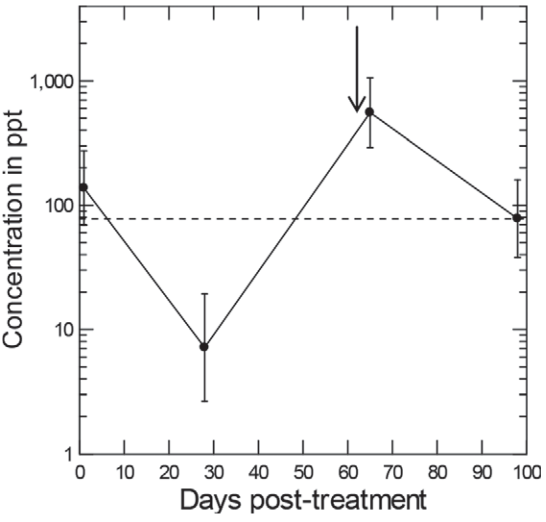


**Fig. 3.** Protocol 1 bifenthrin runoff. The horizontal dashed line shows the *Ceriodaphnia* $EC_{50}$ (78 ppt). Treatments were done at days 0 and 63. Data points show the means ± SE. The arrow shows the second application before day 63. $N = 5$ houses.

**Protocol 2.** The concentration of cyfluthrin in the runoff was below the *Ceriodaphnia* $EC_{50}$ except for the day 1 sample (Fig. 4). The concentration of fipronil in the runoff was orders of magnitude below the *Ceriodaphnia* $EC_{50}$ for all samples, including day 1 (Fig. 5).

Both companies used the same volume of 0.06% fipronil for treatments on day 0. Analysis of the water

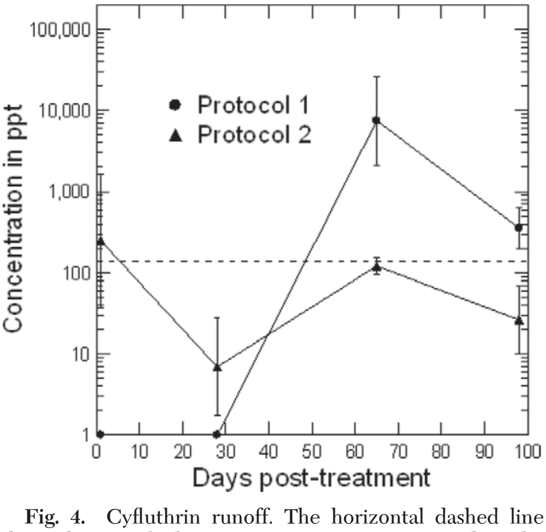


**Fig. 4.** Cyfluthrin runoff. The horizontal dashed line shows the *Ceriodaphnia* $EC_{50}$ (140 ppt). Data points show the means ± SE. Protocol 1 treatments were at days 0 and 63. Protocol 2 only received the treatment on day 0. $N = 5$ houses.

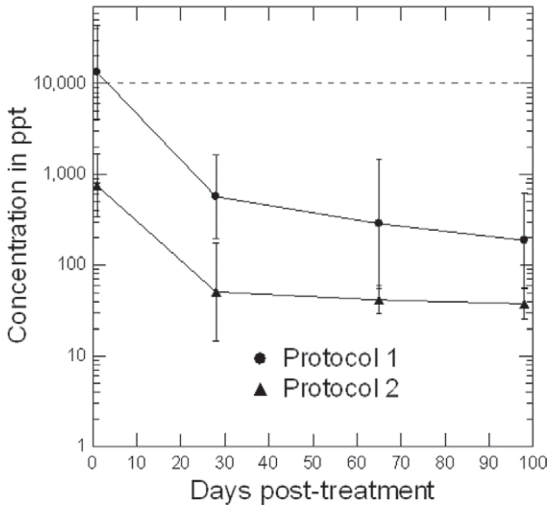


**Fig. 5.** Fipronil runoff. Treatments for both protocols were done once at day 0. Data points show the means ± SE. The horizontal dashed line shows the *Ceriodaphnia* $EC_{50}$ (10,000 ppt). $N$ = 5 houses.

samples showed that Protocol 1 had higher concentration of fipronil in the runoff than Protocol 2, but not significantly so over the entire time period (RM ANOVA, $F$ = 4.3; df = 1,8; $P$ = 0.07). An ANOVA of the day 1 runoff of the two protocols was significant ($F$ = 5.31, df = 1,8, $P$ = 0.05), with Protocol 1 showing more runoff.

## Discussion

Our estimation of ant numbers relies on the number of foraging ants that feed on sucrose water baits. In southern California, we know that this measure gives an accurate representation of ant numbers during the peak ant season of early June to early October. Of course, these dates would differ for other climates and localities. Week 14 ant numbers shown in our figures were measured in mid-October; the drop-off in ant numbers visible there is largely seasonal and therefore we have not included those numbers in our statistical analyses.

Two strategies were tested in these trials. Company 1 used a more traditional approach, consisting of an initial fipronil foundation treatment supplemented by pyrethroids. However, in place of a pyrethroid spray, the company used bifenthrin granules applied away from impervious surfaces. For their second treatment, the PMP also did spot treatments with cyfluthrin sprays plus bifenthrin granules where ants were seen. To reduce the amount of insecticides used, this company treated bimonthly instead of monthly. Company 2 relied more heavily on botanicals on a monthly schedule. The PMP also did an initial treatment with fipronil and spot treatments with cyfluthrin. But for their subsequent monthly treatments, the PMP used only EcoPCO WP-X, a liquid spray containing a mixture of natural plant oils.

With respect to ant control, the bimonthly use of more traditional insecticides controlled ants at about the same level as the monthly applications of botanicals. The two callbacks from homeowners who had properties treated using Protocol 2 may reflect the fact that botanicals are repellent and might drive some ants indoors. The same is true of traditional pyrethroids applied around houses, which may have caused the callback in Protocol 1. For the first 2 wk, the Protocol 1 combination of fipronil plus granular bifenthrin gave better control than the Protocol 2 treatment of fipronil plus cyfluthrin. Thereafter, the differences were slight.

Compared with the house, control of ants in the yard was not good, likely because the treatments mostly targeted the house foundation. Most residents complain about ants when they were in or close to the house, and were less concerned about ants in the yard or at the fence. Protocol 2 showed an initial higher control rate in the yard, perhaps because the botanicals could be used in larger quantities around the house and yard without runoff concerns.

There was almost an order of magnitude difference in the fipronil runoff between the two companies (Fig. 5). An examination of photographs of the applications showed that Company 1 did a pin stream application at the garage door expansion joint, but used a backpack and held the spray wand ≈0.6 m from the crack. Company 2 used a hand-held sprayer with the wand tip directly in the crack. The lower pressure of the hand-held spray nozzle and the more localized application of the material may have accounted for the observed differences in runoff.

The initial bifenthrin runoff in Protocol 1 from the granular product was ≈150 ppt (Fig. 3). This result is similar to an earlier report of ≈300 ppt (Greenberg et al. 2010). We have seen pyrethroid runoff this low only with the granular product. By way of comparison, that same article (Greenberg et al. 2010) reported the initial runoff from bifenthrin barrier sprays at ≈9,000 ppt. Jorgenson et al. (2012) also reported that pyrethroid granule products applied to turf yielded the least runoff among the pyrethroids tested.

Company 2 used the cyfluthrin spray for spot treatments only at day 0. Company 1 first used the chemical at day 63 (Fig. 4). Both companies used the cyfluthrin along the edges of the lawn next to the driveway, as well as applications around the foundation. The runoff for Protocol 2 at day 1 was ≈350 ppt, just above the *Ceriodaphnia* $EC_{50}$ of 140 ppt (Fig. 4). At day 63, the runoff for Protocol 1 was at ≈7,000 ppt. It is likely that in both cases most of the runoff results from treatments in the cracks and crevices adjacent to the driveway, which would be in contact with water moving down the driveway. Although the new labeling for pyrethroids prohibits their use on impervious surfaces, elimination of crack and crevice treatments adjacent to the driveway and sidewalk may improve the efficacy of these new regulations.

Traditional PMP practices included widespread use of pyrethroids in the yards to control ants there. Because of sensitivities about pyrethroid runoff, both companies in this study limited the use of pyrethroids in the yards. Not surprisingly, ant control in the yards was significantly worse than at the house foundation (Figs. 1 and 2). Homeowners may be tolerant of the higher numbers in the yard, so long as the ants do not invade the structure. We may need to use alternative treatments in the yard if the ants begin to invade the structure. Other strategies, such as bait stations and botanicals, may be helpful in those locations.

The involvement of PMPs in developing alternative pest management strategies is essential if new strategies are to be widely adopted by the industry. If two of the largest pest management companies can successfully adopt these reduced risk strategies and show that they are cost effective, other companies are more likely to adopt them. These kinds of demonstration projects are essential in changing the standard practices of the industry.

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