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Hydrogel baits with low-dose thiamethoxam for sustainable Argentine ant management in commercial orchards

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Abstract

Argentine ants, *Linepithema humile* (Mayr) (Hymenoptera: Formicidae), are a significant pest in various agricultural systems around the world, and are often associated with outbreaks of phloem-feeding hemipteran insects. Previous research has evaluated a number of active ingredients and management approaches for controlling Argentine ant populations in agricultural systems, but various regulatory and economic issues have limited the development of effective management tools. Current chemical controls rely on residual sprays or toxic baits, each one posing unique disadvantages that limit their usefulness and efficacy. This study evaluated the potential of water-storing crystals to effectively deliver liquid baits to Argentine ants. The efficacy of bait crystals containing 0.007% thiamethoxam was first evaluated in laboratory colonies. In addition, field studies were performed in a commercial plum orchard to determine the efficacy of the bait crystals. Protein marking was used within the orchard to examine the distribution of the bait in Argentine ant populations when delivered via water-storing crystals. Results of laboratory tests showed that water-storing crystals containing 0.007% thiamethoxam are highly attractive and effective against Argentine ants and require ca. 3–5 days to kill all castes and life stages. Results of the protein-marking study demonstrated that the percentage of ants carrying protein-labeled sugar water decreases sharply with increasing distance from the bait station. Bait movement was limited to within 17 m of the bait dispenser. Furthermore, bait efficacy tests in the field showed that Argentine ants can be effectively controlled using liquid thiamethoxam baits deployed via water-storing crystals. The bait was highly effective and ant densities throughout the baited plots declined by 94 ± 2% within 14 days. The results of this study demonstrate that (1) thiamethoxam is highly effective for Argentine ant control in fruit orchards when used in low concentrations (0.007%), and (2) water-storing crystals are an effective tool for delivering liquid baits to Argentine ants in agricultural settings.

Introduction

The Argentine ant, *Linepithema humile* (Mayr) (Hymenoptera: Formicidae), is an invasive species that has successfully spread around the world with damaging ecological and economic consequences (Suarez et al., 2001; Holway et al., 2002; Roura-Pascual et al., 2004). Although mainly recognized as an urban pest (Knight & Rust, 1990), the Argentine ant can also have severe negative impacts on natural (Holway et al., 2002) and agricultural environments (Vega & Rust, 2001). In agricultural systems, Argentine ants are often associated with outbreaks of phloem-feeding hemipteran insects such as aphids, scales, mealybugs, and others (Daane et al., 2007). Argentine ants tend Hemiptera in return for honeydew, protect them from natural enemies, and consequently interfere with

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biological control of honeydew-producing pests (Prins et al., 1990; Buckley & Gullan, 1991).

Despite Argentine ant presence in agricultural systems, relatively little work has been done on management approaches. Chemical control of ants is mainly accomplished with residual sprays or toxic baits. Residual sprays may be effective, but suffer a number of disadvantages that make them unattractive to growers. The main disadvantage is that residual sprays provide temporary control, but have little long-term impact. This is because sprays only kill the foraging workers, but have little effect on reproductives and workers in the nest (Knight & Rust, 1990, 1991). This necessitates frequent re-applications which are labor-intensive and cost-ineffective. Another drawback of residual insecticides is that they kill a significant proportion of non-target, beneficial organisms (Smith et al., 1996). Finally, the relatively long residual activity of some sprays is a concern with regard to re-application intervals, environmental pollution, and pesticide residues in crops. An alternative to residual sprays is toxic baits which exploit the recruitment and food-sharing behavior of ants to maximize efficacy. Baits also reduce non-target and environmental effects because they require relatively small amounts of insecticide. Previous studies show that a variety of insecticides including boric acid, fipronil, imidacloprid, and thiamethoxam may be used in liquid baits for Argentine ant control (Hooper-Bui & Rust, 2000; Klotz et al., 2003; Daane et al., 2008). In agricultural situations, liquid insecticide baits have proven effective for managing Argentine ants in vineyards and citrus groves (Klotz et al., 2003; Daane et al., 2006, 2008). Despite these advantages, liquid baits are not ideal. One disadvantage is the lack of commercially available bait dispensers that are effective, inexpensive, and easy to service. Second, bait stations are very labor-intensive because they need to be put out in fairly large densities (hundreds per ha), require periodic cleaning to prevent sugar fermentation, and need to be frequently monitored and refilled. For these reasons, bait manufactures have been reluctant to register bait products that would be suitable for large-scale agricultural settings.

To overcome the problems associated with traditional baits, we evaluated a novel bait delivery technology which relies on water-storing crystals. Water-storing crystals, also known as hydrogels, are superabsorbent polymers that are widely used in forestry, horticulture, and landscaping as a means of conserving water. The crystals are a cross-linked polyacrylamide copolymer gel and are able to absorb ca. 300× their weight in water. Dry granules resemble salt crystals and when immersed in water swell up and turn into a gel-like substance that resembles chunks of ice. The hydrated granules, called water crystals, slowly release water over time. The crystals may also be used to absorb liquid insecticide baits and serve as a novel bait delivery technology. The saturated water crystals combine the advantages of both sprays and liquid baits because they are easy to apply, do not require a dispenser, do not need to be serviced or refilled, are relatively inexpensive, and offer environmental benefits because they require a relatively small amount of insecticide. Bait crystals saturated in 25% sucrose solution containing 0.007% thiamethoxam have been shown to be highly attractive to laboratory colonies of Argentine ants and highly effective against all castes and life stages (Buczkowski et al., 2014).

Although baits offer great promise for managing ant populations in agricultural settings, the efficacy of baits is linked to the understanding of ant foraging patterns and ant movement. A major challenge is to know how many bait placements are necessary for effective control. Specifically, it is important to determine the optimal bait density to maximize efficacy while minimizing material and labor costs. Previous studies show that incremental increases in bait station density have an increasingly suppressive effect on both ant activity and mealybug abundance in vineyards (Nelson & Daane, 2007). Optimal bait density may depend on many factors including the size of the ant populations, time of year, cropping system type and design, and the presence of alternative food sources. Another important factor is the distance and direction that the ants carry the bait once a bait station is located. In row crops, such as vineyards and orchards, the bait may be carried along rows, across rows, or both.

This study had three main objectives: (1) to evaluate the efficacy of bait crystals with thiamethoxam under laboratory conditions; (2) to use protein marking and sandwich enzyme-linked immunosorbent assay (ELISA) to examine the distribution of sucrose in Argentine ant populations within a commercial plum orchard when delivered via water-storing crystals; and (3) to test the efficacy of 0.007% thiamethoxam in a commercial plum orchard delivered via water-storing crystals. Taken together, the results advance our understanding of Argentine ant foraging and movement patterns within commercial agriculture and contribute to the development of sustainable management tools for Argentine ants in natural and managed ecosystems.

Materials and methods

Laboratory study on efficacy of water crystals containing thiamethoxam

Colonies of *L. humile* were collected from a large polydomous supercolony in Winston-Salem, NC, USA (36°04′06.46″N, 80°16′31.95″W) and were maintained under laboratory conditions on 25% (wt/vol) sucrose solution and artificial Bhatkar diet ad libitum, and hard-boiled egg and freshly killed *Nauphoeta cinerea* (Olivier) cockroaches once a week. Colonies were maintained and all experiments conducted at 25 ± 2 °C, 60 ± 10% r.h., and L14:D10 photoperiod.

To prepare the bait, water-storing crystals (100% polyacrylamide; Miracle Gro Lawn Products, The Scotts Company, Marysville, OH, USA) were saturated in liquid ant bait containing 0.007% thiamethoxam. To make 1 l of bait, 500 ml of water was placed in a measuring container and 250 g of sucrose was added. When the sugar dissolved, water was added to bring it up to 1 l to achieve 25% g ml^{-1} sucrose solution. To add the thiamethoxam, 1 ml of Optigard Flex (21.6% thiamethoxam; Syngenta Crop Protection, Greensboro, NC, USA) was diluted in 100 ml water, and 3.12 ml of the 1:100 dilution was then added to 1 l of sucrose solution to achieve 0.007% thiamethoxam. Preliminary tests showed that the crystals reached maximum size and optimal saturation when 20 g dry crystals were mixed with 1 l bait. Hence, 1 l of bait to 20 g crystal ratio was employed and the crystals were allowed at least 1 h to saturate.

The effect of thiamethoxam was tested on each of three colony fragments, consisting of (1) 500 workers, one queen, 0.5 g brood; (2) 1 000 workers, two queens, 1 g brood; or (3) 5 000 workers, 10 queens, 5 g brood. The colony fragments were placed inside 17 × 12 × 9-cm fluon-coated plastic boxes and allowed to colonize a moist plaster nest (5 cm diameter). The ants were provided with drinking water and allowed to acclimate to the nest for 48 h. No food was provided during the acclimation period. At the end of the acclimation period, the bait (3 g saturated crystals, 0.007% thiamethoxam) was introduced. Five replications for each colony size were performed and the assay was run for 7 days. Following exposure to the bait, daily observations were made of worker mortality, queen mortality, and brood condition. Brood condition was assessed visually and rated according to the following scale: 5 = no change from the original or more brood present, 4 = 70–90% brood present, 3 = 50% brood present, 2 = little brood present, and 1 = no brood present. Control tests (n = 5 for each colony size) consisted of colonies provisioned with 3 g crystals saturated in sugar water containing no insecticide.

Field study site

The field experiments were conducted at the Vergelegen Wine Estate, a wine and fruit farm in the vicinity of Somerset West, Western Cape, South Africa (34°04′47.0″S, 18°53′12.3″E). All tests were conducted in a plum orchard during early fall (March), at the end of the harvest season. The tree beds are 3 m wide with trees planted 1.5 m apart and are bare soil. Rows between tree beds are also 3 m wide and consist of grass and weedy vegetation that is periodically mowed. Each tree row is irrigated via above-ground plastic pipes and sprinklers. Preliminary observations indicated Argentine ant presence along all rows of the orchard. The ants were mainly active in the tree beds, where the lack of ground vegetation and the presence of irrigation pipes facilitated ant movement along rows.

Protein-marking study in an orchard

A section of the orchard consisting of ca. 45 rows was selected for the protein marking study. The goal was to examine the distance and direction that Argentine ants travel after feeding on the bait and subsequently determine bait station density necessary for effective control. The study was initiated at the end of the harvest season, after the fruit had just been picked. A large amount of rotting fruit fall was present on the ground and all rotting fruit was removed from the study site 1 week prior to initiating the study to limit the natural food sources for the Argentine ants. Preliminary observation of Argentine ant feeding behavior showed that the ants readily fed on plum juice from damaged fruit and preyed upon fruit fly larvae developing in rotting fruit. A test plot was ca. 15 m wide × 34 m long and consisted of three rows of 21 trees each. Therefore, each center row was flanked by two side rows. Four test plots were utilized for replicating the study and all test plots were separated by at least three rows (ca. 15 m) where no baiting occurred.

On the basis of preliminary observations of ant foraging behavior in the orchard, we hypothesized that most of the ant movement would be along rows, and not between rows. This is because the ants appeared to nest at the base of trees and foraged mostly along the irrigation pipes and tree trellises and rarely crossed the grassy medians separating the rows. To estimate the distance sucrose solution is carried in the orchard and the extent of worker movement within the plots, we used protein marking coupled with double-antibody sandwich enzyme-linked immunosorbent assay (DAS-ELISA) (Buczkowski, 2012).

Water-storing crystals were saturated with 25% sucrose solution (as above) containing technical grade rabbit immunoglobin (IgG) protein (Sigma Chemical, St. Louis, MO, USA) at a concentration of 1.0 mg IgG ml^{-1} bait. At each plot, a single feeding station containing 10 g of crystals was placed on the ground next to the first tree in the middle row. The crystals were dispensed from a plastic weight boat and were left in place for 24 h. After 24 h, the distribution of the protein marker throughout each plot was estimated by randomly sampling 10 workers from five equidistant points along each of the three rows: the baited center row and the two un-baited side rows. The ants were sampled at every fourth tree equivalent to 0 (beginning of row), 8, 17, 25, and 34 m from the first tree. In total, 150 ants were sampled from each of the four plots. All individuals were frozen at −20 °C and later analyzed by DAS-ELISA using previously described methodology (Buczkowski & Bennett, 2009; Buczkowski, 2012). Four test plots (replicates) were used. The percentage of workers scoring positive for rabbit IgG protein was determined. The samples were scored positive if the ELISA optical density value exceeded the mean negative control value by three standard deviations (Sutula et al., 1986; Buczkowski, 2012).

Efficacy of thiamethoxam bait in an orchard

The four plots utilized for the protein-marking study were subsequently used for estimating the efficacy of 0.007% thiamathoxam bait when delivered via water-storing crystals saturated in sugar water containing the insecticide. The initial ant abundance within the plots was estimated by using bait cards baited with a blend of canned tuna and maize sirup (50/50, vol/vol). The cards were placed on the ground and along irrigation pipes that the ants used as trailing guidelines. Ten cards were used for each row (30 cards per plot) with a card at every other tree (every 3 m). The number of ants feeding on the bait cards was recorded after 2 h. The following day, the insecticide bait crystals (prepared as above) were placed directly on the ground at the base of trees. Five equidistant bait placements of 10 g each were made for each row. Therefore, the baits were placed at 0 m (beginning of row), and then 8, 17, 25, and 34 m (every fourth tree). All plots were re-baited on day 7. The efficacy of the thiamethoxam bait was determined by re-sampling ant activity in each plot at 1, 3, 7, and 14 days after the initial treatment and comparing counts at each time point to the initial counts. Ant activity in control plots (n = 4) was estimated as above except that the plots received bait crystals saturated in sugar water containing no insecticide.

Statistical analysis

All data analyses were performed using SAS 9.2 statistical software (SAS, 2008). For all assays, analysis of variance (ANOVA) tests used Proc GLM on mean cumulative percent mortality. A CLASS statement was used to specify dependent classification variables used in the model. These variables included time, caste, treatment, and replicate.

Results

Laboratory study on efficacy of water crystals containing thiamethoxam

Bait crystals saturated in sugar water were highly attractive to Argentine ant workers. Overall, the effect of treatment (thiamethoxam crystals vs. control) was highly significant (ANOVA: $F_{1,38} = 375.43$, $P<0.0001$) indicating that 0.007% thiamthoxam is highly effective against Argentine ants when delivered via bait crystals. The effect of caste (workers vs. queens vs. brood) was also highly significant ($F_{2,123} = 8.23$, $P = 0.0004$) with workers dying significantly faster than either queens or brood (based on post hoc mean comparisons by Tukey's honestly significant difference test). The effect of colony size was not significant ($F_{2,123} = 0.01$, $P = 0.99$). The majority of workers (>90%) died within 2 days of feeding and complete worker mortality was achieved in 3 days (Table 1). The effect of time was not significant ($F_{6,119} = 1.59$, $P = 0.16$); the majority of the workers died within the first 24–48 h and worker mortality on days 3–7 was 100% across replicates and colony sizes (Table 1). Mortality in the queens was slightly slower during the first 2 days, but complete mortality was observed within 5 days. Mortality in the brood was somewhat delayed and a gradual deterioration of brood condition was observed with complete mortality achieved by day 5.

Protein-marking study in orchard

The percentage of ants testing positive for the protein marker declined sharply as distance from the bait station increased (Figures 1 and 2A–C). Distance from the bait station was a highly significant factor (ANOVA: $F_{1,55} = 13.81$, $P<0.001$) suggesting that the movement of sugar water is highly localized. At 24 h, bait movement was limited to within 17 m of the bait station. At 24 h, 70 ± 8% (mean ± SE) of the workers sampled at the bait station tested positive for the protein marker and the percentage of workers testing positive declined to 33 ± 10% at 8 m and 8 ± 5% at 17 m along the baited (center) row. Not surprisingly, the highest proportion of ants testing positive was detected along the baited center row with row position also a significant factor ($F_{2,57} = 15.31$, $P<0.0001$). However, the effect of plot was not significant, suggesting comparable bait distribution across the different plots ($F_{3,56} = 0.08$, $P = 0.96$). No protein-marked workers were detected beyond the 17-m mark in any of the rows even though *L. humile* were observed foraging along the whole length of all rows.

Linepithema humile normally travel along rows and fewer ant trails were observed between rows. Therefore, we expected trellising and water pipes along rows to facilitate food movement, and row middles to impede food movement. The results largely support this, but some food movement between rows was observed, extending to 8 m away from the bait placement (Figures 1 and 2A–C).

Table 1 Cumulative mean (± SD) mortality (%) in Argentine ant workers, queens, and brood. Control mortality did not exceed 5% in any of the tests and is not shown

		Time since treatment (days)						
Caste	Colony size	1	2	3	4	5	6	7
Workers	500	71 ± 14	98 ± 3	100	100	100	100	100
	1000	66 ± 16	96 ± 6	100	100	100	100	100
	5000	49 ± 7	95 ± 5	100	100	100	100	100
Queens	500	20 ± 45	60 ± 55	100	100	100	100	100
	1000	10 ± 22	50 ± 35	100	100	100	100	100
	5000	14 ± 9	76 ± 11	88 ± 4	96 ± 5	100	100	100
Brood	500	0	25 ± 18	60 ± 14	85 ± 14	100	100	100
	1000	0	20 ± 21	65 ± 14	95 ± 11	100	100	100
	5000	0	35 ± 34	65 ± 29	80 ± 33	100	100	100

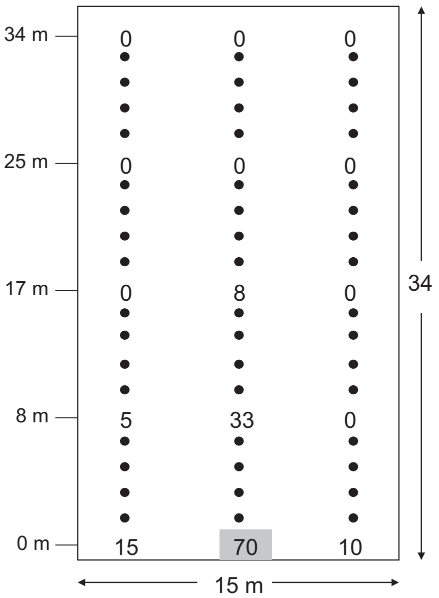

Figure 1 Distribution of protein marker in field colonies of *Linepithema humile* provisioned with water-storing crystals containing rabbit immunoglobin protein (IgG) after 24 h. The values are expressed as mean percentage (n = 4 plots) of ants testing positive for the protein marker as revealed by ELISA. Black circles represent trees. The light shaded square indicates bait station placement. Side markers indicate distance (m) from bait placement.

Efficacy of thiamethoxam bait in orchard

The results from this study show that *L. humile* can be controlled effectively using liquid thiamethoxam baits deployed via water-storing crystals (Figure 3). Within the treated plots, the number of ants detected on the monitoring stations decreased quadratically over time according to the equation: number of ants = 95.9–19.9 × [no. days] + 1.0 × [no. days]^2 ($t \geq 2.7$, $R^2 = 0.27$, $P \leq 0.009$). Within the treated plots, on average (± SD) 144 ± 67 ants per monitoring station were detected during the initial pre-treatment inspection (Figure 3). Relative to the initial counts, the ant densities throughout the baited plots declined significantly at 1 day after treatment (DAT) (mean ± SE = 85 ± 8% reduction; t = 1.78, P = 0.0004), 3 DAT (75 ± 9% reduction; t = 4.16, P = 0.001), 7 DAT (83 ± 12% reduction; t = 4.35, P = 0.0003), and 14 DAT (94 ± 2% reduction; t = 5.34, P = 0.0001; all d.f. = 12). Both, treatment (ANOVA: $F_{1,38} = 48.53$, $P<0.0001$) and day ($F_{4,35} = 3.07$, $P = 0.003$) were highly significant, whereas plot was not significant ($F_{3,36} = 0.96$, $P = 0.42$).

Discussion

Argentine ants, like many other pest ant species, frequently associate with honeydew-producing hemipterans and cause hemipteran outbreaks in urban, agricultural, and natural environments (Silverman & Brightwell, 2008). Because liquid foods such as honeydew and nectar comprise the greatest proportion of Argentine ant diet (Markin, 1970), their management is best achieved with liquid sugar baits that effectively mimic these natural food sources (Nelson & Daane, 2007; Daane et al., 2008). However, liquid bait use has been limited due to the lack of bait dispensers that are effective, inexpensive, and easy to service especially when used on a commercial scale. The current results demonstrate that bait crystals overcome many of these limitations and combined with a toxicant (thiamethoxam) are an effective tool managing Argentine ant populations.

Results show that under laboratory conditions bait crystals with 0.007% thiamethoxam are highly attractive and effective against Argentine ants and require ca. 2 days to

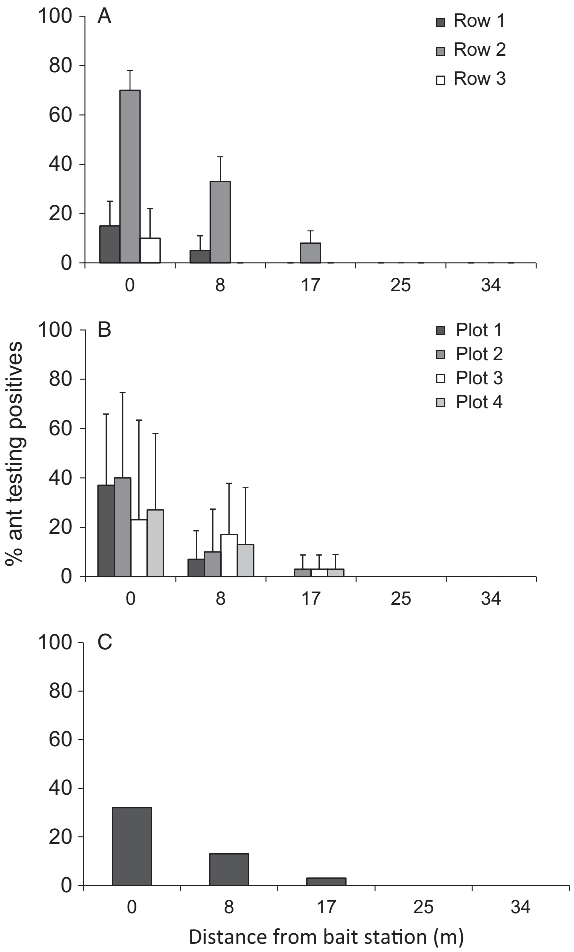

Figure 2 Distribution of protein marker in field colonies of *Linepithema humile* provisioned with water-storing crystals containing rabbit immunoglobin protein (IgG) after 24 h. The values are expressed as mean percentage (+ SD) of ants testing positive for the protein marker as revealed by ELISA. (A) Data pooled across plots and averaged across rows; (B) data pooled across rows and averaged across plots; and (C) overall percentage of ants testing positive for the protein markers at various distances from the bait placement (data averaged across rows and plots).

kill all workers and 3–5 days to kill all queens and brood. These results corroborate the results of previous laboratory tests which demonstrated that bait crystals with 0.007% thiamethoxam are highly effective against all castes and life states of Argentine ants (Buczkowski et al., 2014).

Results of the protein-marking study demonstrate that bait movement is limited to within 17 m of the bait dispenser and the percentage of ants carrying the bait decreases sharply with increasing distance from the bait station. Argentine ants normally travel along rows, because (1) the pipes and trellises provide smooth structural guidelines which greatly speed up ant movement; (2) the trees provide shade extending the foraging time into the hottest part of the day; and (3) the nests are usually located at the base of trees, in close proximity to the irrigation pipes. Therefore, we expected trellising and water pipes along rows to facilitate food movement and weedy row middles to impede food movement. The results largely support this hypothesis, but some food movement between rows was observed as well, extending ca. 8 m away from the bait placement. The results suggest that what appears to be a single long trail may actually be a number of shorter trails connected in a linear fashion. The ants maintained numerous nests along the foraging trails and these nests served as both sinks and sources for ants present on the trails. Our results suggest that *L. humile* forage locally and distribute food resources to nearby nests. Specifically, ants at the beginning of the trail do not travel the whole length of the trail, but rather forage on trees closest to the nest from which they originate and likely deliver food to that same nest. Similar results have been observed for field populations of Argentine ants in natural habitats (Heller et al., 2008) and other highly polydomous ant species such as odorous house ants, *Tapinoma sessile* (Say) (Buczkowski & Bennett, 2006).

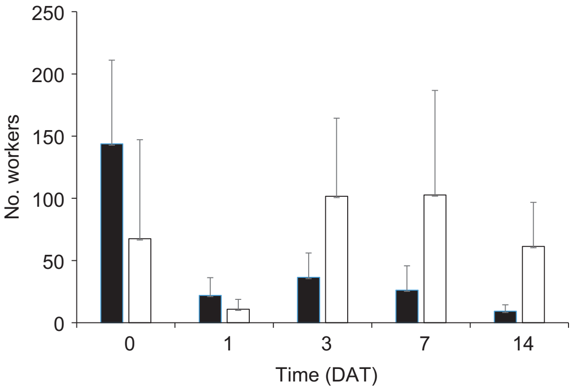

Figure 3 Mean (+ SD) number of ants present on monitoring cards in plots treated with thiamethoxam bait (solid bars) and control plots (open bars), at 0–14 days after treatment (DAT). For each time point, the value represents an average of four plots and 30 monitoring stations within each plot.

The results from the field study with bait crystals containing thiamethoxam corroborate the results of laboratory tests and demonstrate that thiamethoxam is highly effective in suppressing Argentine ants in commercial fruit production and may offer great potential in other agricultural systems and natural environments. The results of other field studies also demonstrate that thiamethoxam is highly effective against Argentine ants in agricultural environments. Liquid sugar baits containing 0.0001%

thiamethoxam effectively suppressed Argentine ants in California (USA) vineyards and effectively reduced mealybug populations on grape clusters (Nelson & Daane, 2007). Future tests should focus on evaluating bait crystals with other active ingredients in other high-value agricultural crops.

Optimal bait station density is critical for the effectiveness of ant control programs and is determined largely by the distance that the ants carry the bait and population density. In California vineyards, liquid bait stations were deployed at various densities and assessed for their impact on populations of Argentine ants and grape mealybugs (Nelson & Daane, 2007). Results showed that incremental increases in bait station density had an increasingly suppressive effect on both ant activity and mealybug abundance. However, the data did not indicate a particular bait density that maximized suppression. Rather, the results showed that all densities provide some reduction and suggested that optimal bait station density may depend on the size of the Argentine ant population. The authors concluded that higher bait densities may be needed to achieve satisfactory control within one or two seasons, especially when ant densities are particularly high. In subsequent seasons, as the ant population declined, lower bait station density may be required.

In large-scale commercial agriculture, the goal is to minimize pest management costs and maximize ant suppression. The growers seek maximum pest suppression using the lowest bait station density as liquid bait dispensers are costly to deploy and maintain. For this reason, the adoption of liquid bait stations in commercial agriculture has been rather slow (Nelson & Daane, 2007). In contrast, bait crystals do not require bait dispensers and can be deployed quickly with minimum labor allowing for a much higher density than can be achieved with liquid bait dispensers. The current study utilized 15 bait placements per 510 m^2 of orchard, equivalent to ca. 300 bait placements per ha. Such density would have been likely too costly for use with liquid bait dispensers (Nelson & Daane, 2007) suggesting that bait crystals might be an attractive economic alternative to bait dispensers. A priority for future studies is to determine whether greater ant suppression can be achieved when the crystals are uniformly scattered over the landscape rather than placed in discrete piles. The crystals could be applied directly to the ground using existing farm equipment such as granular fertilizer spreaders, seed dispensers, or even aerial applications and such applications could further reduce labor costs. Studies indicate that ants retrieve proportionally more food from dispersed rather than clumped food patches (Sanders & Gordon, 2002; Schmolke, 2009) and scattering the crystals might result in faster retrieval, greater ant suppression, reduced labor costs, and ultimately better environmental stewardship through reduced pesticide use.

The results obtained in this study may be attributed to four factors. First, all rotting fruit was removed from the test plots prior to baiting to limit the natural food sources available to the ants. Preliminary baiting experiments with fruit jelly demonstrated that the ants largely ignored the jelly baits when fruit fall was present and preferred to feed on the plums. Removing the competing food sources starved the population of carbohydrates and most likely contributed to the high attractiveness of the bait crystals. However, the growers are not likely to remove the fruit from the ground and baiting should occur when no fruit is present. Second, no honeydew-producing Hemiptera were observed on the trees during the study, which further limited the natural food sources available to the ants. It is not known if the Hemiptera were never present in the orchard, seasonally absent, or eliminated with early-season insecticide treatments. Third, the study was conducted in early fall when ant densities were beginning to decline due to cooler night temperatures. Proper timing is essential to the success of ant-baiting programs and baits should be deployed either in early spring during peak larval development and nest expansion or in the fall when there is a drop in ant activity due to climatic factors. Fourth and finally, thiamethoxam has been shown to be highly effective in bait formulations against Argentine ants (Daane et al., 2008) and has been used successfully against Argentine ants in other agricultural settings including vineyards and orchards (Klotz et al., 2003; Daane et al., 2008).

Overall, the results of this study demonstrate that (1) thiamethoxam is highly effective for Argentine ant control in fruit orchards when used in low concentration (0.007%), and (2) water-storing crystals are an effective tool for delivering liquid baits to Argentine ants in agricultural settings.

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