Pest Management of Argentine Ants (Hymenoptera: Formicidae)[1]

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Abstract Control of Argentine ants, *Linepithema humile* (Mayr), around structures in urban settings requires an extensive and thorough use of existing registered sprays and baits. Barrier sprays must be thoroughly applied at maximum label rates to prevent ants from accessing structures. Although insecticides with systemic activity such as imidacloprid and thiamethoxam may ultimately reduce homopteran food sources for *L. humile,* quantifying the impact of such reductions has been difficult. Applications of bifenthrin and deltamethrin granules provide short-term reductions. Most commercial baits available for *L. humile* are not readily consumed by foragers, or they provide too rapid kill of workers. Consequently, none of the baits are consistently effective. Potential new active ingredients for baits such as fipronil, imidacloprid, and thiamethoxam provide about 50% kill within 3 days and are readily accepted by foragers. These toxicants are extremely promising in liquid bait formulations. No single control strategy or treatment has been consistently effective.

Key Words Argentine ant, *Linepithema humile,* ants, Formicidae, IPM, baits, sprays, granules

The Argentine ant, *Linepithema humile* (Mayr), is one of the most important ant pest species in agricultural, natural and urban settings, especially in Mediterranean and semitropical climates worldwide (Vega and Rust 2001). In agriculture, it is an important secondary pest because *L. humile* actively tends homopteran insects that produce honeydew that it feeds on and simultaneously interferes with predators and parasites of mealybugs, soft scales, and mites (DeBach et al. 1951, Flanders 1951, Haney et al. 1987). In natural environments, *L. humile* displaces many native ant species (Tremper 1976), especially those with similar foraging and feeding preferences such as the velvety tree ant, *Liometopum occidentale* Emery, and the odorous house ant, *Tapinoma sessile* (Say) (Ward 1987), and disrupts native plant and animal communities (Bond and Slingsby 1984, Cole et al. 1992). In urban settings, *L. humile* becomes a nuisance when it forages around and invades homes (Klotz et al. 1995, Knight and Rust 1990b).

Linepithema humile is an important invasive tramp species because it is polygynous and unicolonial, reproduces by budding, disperses by human commerce, and lives in close association with humans (Hölldobler and Wilson 1990). Argentine ants prefer to nest in areas modified by human activities (Passera 1994), but will readily

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relocate with the slightest disturbance or with change in weather. The amount of disturbance and the presence of a permanent water source are important parameters for their successful establishment (Ward 1987). Colonies may extend over areas as large as 15 ha (Passera 1994). In certain parts of their range, several colonies will fuse with the onset of winter and seek out nest sites exposed to sunlight (Markin 1967). These mega-colonies become extremely mobile in spring and summer. Foragers marked with dyes have been collected more than 51 m from feeding stations (Ripa et al. 1999). It is these biotic characteristics that make this species so difficult to control.

Control strategies have been primarily focused on the use of baits and the application of contact and barrier sprays and granules. Insecticides applied as sprays or granules typically kill or repel foraging ants and do not affect the queen or workers in the nest (Knight and Rust 1990a). Pyrethroids such as cypermethrin and cyfluthrin are highly repellent and provide rapid kill when ants contact barriers. However, some repellent barriers occasionally trap ants indoors, requiring additional treatments (Gulmahamad 1997, Rust et al. 1996, Suoja et al. 2000). Chlorpyrifos and fipronil barriers are less repellent and provide excellent kill of workers. When applied around homes, the thoroughness of coverage and the amount of active ingredient applied are important to providing long-term control (Rust and Knight 1990, Rust et al. 1996). Factors likely to contribute to decreased performance of barrier treatments against ants include heavy irrigation, dense ground cover, exposure to direct sunlight, alkaline nature of stucco and concrete surfaces, and exposure to high temperatures. Another important reason that barrier applications fail to provide long-term control is that pest control professionals are not willing to apply barriers at maximum label rates because of the cost.

Insecticidal baits have been recommended for Argentine ant control for at least a century (Rust 1986). As noted by Suiter et al. (1997), there has been a dramatic evolution of ant baits over the last 60 yrs and the realization of the need to exploit ant foraging and feeding behavior. Ideal toxicants for ant baits exhibit delayed toxicity over a 10- to 100-fold range, are readily transferred between ants, and are not repellent when combined with the bait base (Stringer et al. 1964). Baits containing sodium arsenite, chlorpyrifos, hydramethylnon, and sulfuramid do not have delayed toxic action and do not kill queens (Knight and Rust 1991). In contrast, sucrose solutions containing 1×10^{-4} and 1×10^{-5} % (w/v) fipronil and 0.5% boric acid provide worker and queen kill within 14 d (Hooper-Bui and Rust 2000). Workers ingest more sucrose or hydramethylnon suspension per feeding bout than do queens, suggesting that multiple feedings must occur in order to increase mortality of queens (Hooper-Bui and Rust 2001). The lethal time of borate baits is a function of the concentration of boron (Klotz et al. 2000), but there is a significant reduction in consumption of baits containing >1% boric acid. Applications of a solid bait consisting of silkworm pupae and hydramethylnon have provided good control of *Iridmomyrmex rufoniger* (Lowne) and *I. purpureus* (Smith) (James et al. 1996) and *L. humile* (Krushelnycky and Reimer 1998, Rust and Knight 1990). However, after initial reductions, the populations typically recovered suggesting that queens were not killed (Krushelnycky and Reimer 1998, Rust and Knight 1990).

Alternative control strategies such as ant repellents have been reviewed by Klotz et al. (1997). Sticky bands on the trunks effectively prevented ants from foraging in trees and vines providing the plants were pruned to prevent the canopy from contacting the ground or other objects (Phillips et al. 1987). Shorey et al. (1996) found that sticky barriers (Stickem Special, Seabright Enterprises, Emeryville, CA) containing farnesol were effective for 2 to 3 months in preventing ants from ascending citrus trees. Close-fitting elastic bands containing a slow-release formulation of chlorpyrifos prevented *I. rufoniger* from ascending citrus trees for more than 27 months (James et al. 1995). However, this strategy has never been adopted in agriculture because of the extensive labor of maintaining the barriers. It is unlikely that sticky barriers would be practical or effective around residences.

It has been proposed by professional pest control technicians that ants around structures might be controlled by reducing the number of honeydew-producing homopterans from plants surrounding structures. In citrus, Markin (1970) found that about 99% of *L. humile* workers returning to the colony carried honeydew and nectar, and only on a rare occasion small insects. Rust et al. (2000) found that sucrose solutions were preferred year round, while protein demand was greatest during the spring. Unfortunately, similar feeding studies have not been conducted in urban and residential areas. Although Argentine ants are extremely opportunistic feeders, having been observed feeding at garbage receptacles, pet food dishes, on dead insects and animals, and at hummingbird feeders, a primary food source has not been identified.

We treated trees and shrubs around homes with systemic insecticides (imidacloprid and thiamethoxam) to kill homopertan pests. *Linepithema humile* populations were monitored to determine if the reduction of homopterans ultimately affected the number of ants around homes. Approximately 25 liters of 0.004% imidacloprid (Merit 75WP, Bayer Corp., Kansas City, MO) or 0.004% thiamethoxam (25WG, Syngenta Crop Protection, Richmond, CA) were applied to foliage in yards with a gasoline engine-powered 193-L FMC spray rig. In some yards, cyhalothrin (Demand CS, Syngenta Crop Protection, Richmond, CA) or cyfluthrin (Tempo SC Ultra, Bayer Corp., Kansas City, MO) was added to the systemic insecticide to also serve as a barrier treatment. Ant foraging activity around structures was monitored before and after spraying by determining the amount of sucrose water consumed in 24 h (Reierson et al. 1998). Barrier sprays of cyhalothrin and cyfluthrin provided statistically significant reductions up to wk 4, but failed to provide meaningful reductions in the number of ants visiting monitoring stations (Table 1). The number of ants visiting monitoring stations significantly decreased by wk 4 at residences treated with thiamethoxam or a combination of imidacloprid + cyfluthrin. Even though the reductions were statistically significant, none of the treatments provided acceptable control at wk 8. In fact, the number of ants, as indicated by sucrose water consumption, began to increase. It was difficult and it may be impossible to quantify the effect of the systemic insecticides on the homopteran pests because we could not locate specific sites where the ants were feeding and, therefore, could not evaluate the effect of the sprays on them. In addition, many properties with substantial ant populations were not heavily landscaped. At other heavily landscaped residences, there were few homopterans on the plants. At some residences, fruit trees and tall Eucalyptus trees with homopterans and ant trails were difficult to thoroughly inspect and treat. In urban settings, two other factors that may also contribute to the marginal efficacy of foliar sprays are that *L. humile* forages as far as 51 m into neighboring yards and feeds on a variety of alternate food sources including trash, pet foods, and dead animals.

Habitat modification. Flanders (1943) reported that powdered talc applied to the trunks of trees prevented *L. humile* from ascending. In California, outdoor campers successfully prevent ants from invading recreational vehicles by surrounding the tires

Table 1. The efficacy of foliar and perimeter sprays around residences (n = 5) for control of *L. humile*

Toxicants	Site*	Avg. no. ant visits/vial	Avg. no. ant visits (% reduction)**			
			1 wk	2 wk	4 wk	8 wk
cyhalothrin CS, 0.03%	B	23,522	17,619 (25.1%)†	23,571 (0.0%) n.s.	18,065 (32.2%)†	disc.
thiamethoxam 25WG, 0.004%	F	23,147	15,524 (32.9%)†	16,596 (63.8%)†	6,576 (71.6%)†	disc.
cyhalothrin 0.03% + thiamethoxam 0.004%	B + F	27,054	6,779 (64.9%)†	5,883 (78.3%)†	6,529 (75.9%)†	12,285 (54.6%)†
cyfluthrin SC Ultra, 0.0056%	B	27,214	9,094 (66.6%)†	7,938 (70.8%)†	16,347 (39.9%)†	14,981 (45.0%)†
imidacloprid 75 WP, 0.004%	F	21,257	24,323 (0.0%) n.s.	28,650 (0.0%) n.s.	disc.	
cyfluthrin 0.0056% + imidacloprid 0.004%	B + F	22,036	7,659 (65.2%)†	8,388 (61.9%)†	14,497 (34.2%)†	14,063 (36.2%)†

* Sprays applied during July 2001. Five residences were treated per treatment. Sites monitored with 20 sucrose water vials. B = barrier sprays; F = foliar sprays.

** Disc. = discontinued. Percent reductions followed by an "†" are significantly different from the pre-treatment count ($P < 0.05$; Wilcoxon signed-ranks test). n.s. = not significant.

with a barrier of powdered household cleanser. The cleanser is not highly toxic to the ants, but it does repel them.

To determine if the particle size of a substrate influences the foraging activity of *L. humile*, sand particles were separated into various sizes ranging from 20 to >300 mesh with sieve screens. Plastic Petri dishes (8.5 cm diam) were filled with the sand particles and a 1.5-cm diam screw cap was inverted in the center to serve as a platform for a feeding station containing sucrose water. The Petri dish and sand were placed in a plastic box with a laboratory colony of Argentine ants. The number of ants drinking at the screw cap was counted every 30 min for 2 h. The number of ants feeding at the cap dramatically decreased when the sand particles were smaller than 200 mesh (Table 2). One possible explanation is that the workers cannot lay a recruitment pheromone trial on these finely divided powders. A common field ant *Formica pilicornis* Emery in southern California avoids finely divided sand particles, and the use of fine beach sand significantly reduced the number of *F. pilicornis* nests on an endangered seabird's nesting site in San Diego (D. A. Reierson, unpubl. data). Finely divided sand of specific sizes may prevent the ants from constructing their nests and tunnels. It may also be possible to reduce ant foraging and nesting in sites likely to be inhabited by *L. humile* nests, especially at the bases of trees and around structures.

Baits. The active ingredient (AI) in a bait must provide delayed toxicity to give workers time to transfer the bait to other members of the colony and recruit additional foragers. Secondly, the bait must also be readily consumed by foragers. Fig. 1 illustrates the relationship between a bait's speed of kill (LT_{50}, the time required to kill 50% of the workers) and its acceptance. The broader the range of concentrations that permits delayed toxicity and is still acceptable (Fig. 1, the area within the rectangle), the more likely the bait will be effective. For example, in 25% sucrose water, as the concentration of imidacloprid increased from 0.001% to 0.005%, the time required to kill 50% of the ants decreased from 1.8 to 0.7 days, and the amount collected decreased from 0.617 to 0.384 g. In a similar manner, the overall reduction in ant numbers around structures declined from 62.8 to 33.5%. The faster the bait kills, the faster recruitment and trophallaxis are negatively affected. Ripa et al (1999) found that after 24 h workers of *L. humile* consumed 85% less bait containing 0.001%

Table 2. Effect of sand particle size on the foraging activity of *L. humile*

Particle size*	Avg. no. ants at min			Avg. no. ant visits (SEM)/hour**
	30	60	90	
30-40	25.0	30.7	29.3	241 ± 40.7 a
40-100	27.0	14.0	25.0	252 ± 28.7 a
120-200	8.0	11.0	7.5	134 ± 91.8 ab
230-270	5.3	3.7	4.0	15 ± 5.5 b
>325	0.0	0.7	0.7	15 ± 0.3 b

* Particles retained by U.S. Standard sieves screens.

** Means followed by the same letter are not significantly different ($P < 0.05$, Tukey's hsd).

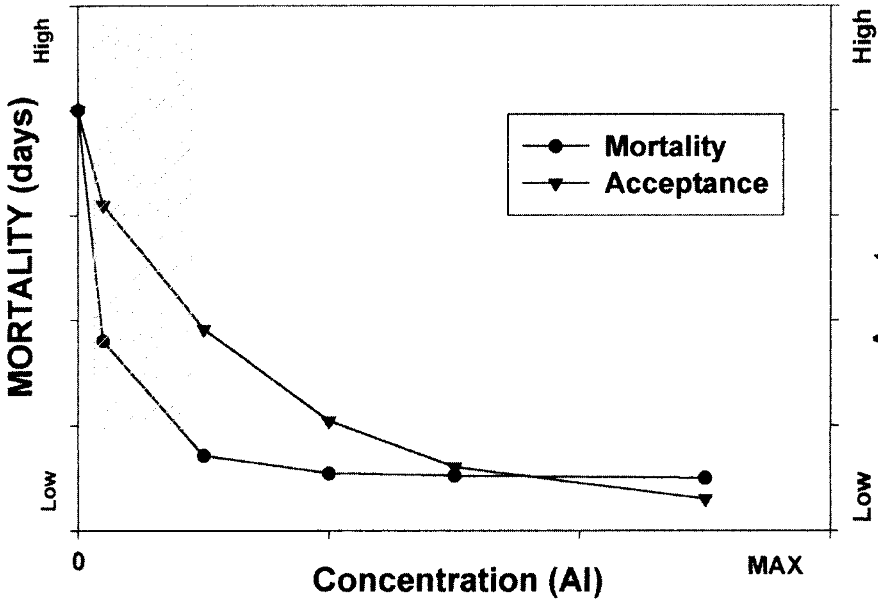

Fig. 1. The relationship between inherent toxicity (LT_{50}) and bait acceptance.

compared to 0.0001% fipronil and the distance it spread among workers decreased by about 50%.

Sucrose solutions are highly preferred by Argentine ants (Baker et al. 1985, Rust et al. 2000). The addition of up to 2% carboxymethyl cellulose and ethanol to sucrose solutions did not affect acceptance by *L. humile* (Baker et al. 1985). However, the inclusion of preservatives or other additives may drastically reduce the amount of bait taken. For example, three different commercial baits containing 5.4% borax (Ant-B-Gon™ Le Groupe Solaris, Mississauga, Canada, Antex™ Wilson Laboratories Inc., Dundas, Ontario, and Terro Ant Killer II™ Senoret Chemical Inc., Kirkwood, MO) were tested in choice feeding arenas and their acceptance differed dramatically (Rust et al. 2000). The arenas, made from aluminum cake pans, have four holes punched through the sides above the bottom of the pan. The holes are placed 90° apart. Sections of glass tubing (10 cm long) are inserted through the holes so that the end of the tube is flush with the outer edge of the pan. Ten hexagonal weighing pans cemented to floor of the pan serve to hold the 1.5-mL microcentrifuge tubes. About 1.5 g of bait was placed in each microcentrifuge tube. The arenas were covered with a piece of plywood and placed near *L. humile* nests. After 24 h, the baits were returned to the laboratory and weighed. The Ant-B-Gon bait was highly preferred. Antex and Terro Ant Killer II were not as preferred as Ant-B-Gon (Table 3). Two other baits containing boric acid were also not preferred by foraging workers, demonstrating that formulations may greatly affect consumption by workers.

Granular protein baits containing hydramethylnon have been shown to be effective against Argentine ant workers, especially early in the season (Knight and Rust 1991, Krushelnycky 1998). Similarly, Forschler and Evans (1994) found that macerated

Table 3. Bait preferences in choice tests with field colonies of *L. humile**

Bait	A.I. (%)	Avg. consumed (g)**	Preference rank	Rank total
Ant-B-Gon	borax (5.4)	0.6441 a	2, 2, 1, 2, 2, 1	10
Antex	borax (5.4)	0.0534 b	4, 6, 8.5, 7, 6, 8	39.5
Terro Ant Killer II	borax (5.4)	0.2892 b	3, 3, 3, 4, 5, 4	22
Outsmart	boric acid (6.25)	0.0566 b	6, 7, 7, 6, 7, 6	39
Drax	boric acid (1)	0.2106 b	7, 4, 4, 3, 3, 5	26

* Tests conducted 4 October 2000. Six arenas were placed near ant trails for 24 h.

** Means followed by the same letter are not significantly different at $P < 0.05$ (Tukey's hsd; $F_{5,40} = 14.946$, $P < 0.001$).

silkworm pupae/ fish meal bait containing hydramethylnon provided good control. However, Knight and Rust (1991) found that these baits did not have delayed toxicity and failed to kill the queens. Alternation of solid protein baits and liquid baits may provide another approach to baiting extensive colonies of *L. humile.*

Finding acceptable bait bases and active ingredients that provide delayed toxicity are two of the major challenges to developing effective baits for Argentine ant control. For example, soybean oil baits that effectively control red imported fire ants, *Solenopsis invicta* Buren, are not acceptable to Argentine ants (Rust, unpubl. data). Silverman and Roulston (2001) have shown that *L. humile* prefers liquid formulations over gel sucrose baits. Additional research on formulating baits is needed.

Barrier sprays and granular treatments. The application of granular insecticides has been recommended to reduce chemical costs and yet provide effective barrier treatments around structures. To evaluate the efficacy of granular treatments, yards, flower beds and areas surrounding five homes were treated with either bifenthrin or deltamethrin granules. Some residences were treated with both barrier sprays and granular insecticides. Residences were monitored outside with sucrose-water vials to determine the extent of *L. humile* infestations (Reierson et al. 1998).

Granular insecticides provided >70% reductions in ant counts at wk 1 (Table 4). Even though the numbers of ants at sites treated with granules were significantly lower at wk 4, the treatments provided less than 50% reductions. Costa et al. (2001) found that bifenthrin granules provided excellent control of *L. humile* in containerized nursery operations for 12 wks. One major difference between the two studies was the nature of substrate to which the granules were applied. In the nursery study, the granules were applied to the surface of plastic weed guard and hard compacted soil. Around structures, the granules were applied to mulch, grass, crushed rock, stones, and loose soil thus reducing the likelihood that ants will contact them.

Better control might have been achieved if the granular applications could have been directed to potential nesting sites in urban settings. However, this is time consuming and it is difficult to locate all of the possible nesting sites around structures. In addition, nesting sites might also be located in neighboring yards.

Biological control. Natural enemies of Argentine ants have been sought as early as 1918 without much success (Vega and Rust 2001). Two dipteran parasitoids, *Pseudodacteon pusillum* Borgmeier and *Apocephalus silvestrii* Borgmeier, attack for-

Table 4. The efficacy of granular and spray applications of bifenthrin and deltamethrin around residences (n = 5) for control of *L. humile**

Toxicant	G. A.I. g/92.9 m^2	Spray vol. (liters)	Avg. no. ant visits/vial	Avg. no. ant visits/vial (% reduction)**		
				1 wk	4 wks	8 wks
bifenthrin	4.2	—	28,245	3,735 (86.8)†	17,221 (39.0)†	21,175 (25.0) n.s.
bifenthrin	2.1	—	29,495	7,928 (73.1)†	18,868 (36.0)†	16,004 (45.7)†
bifenthrin	2.1	29.7	19,994	3,908 (80.5)†	14,559 (27.2)†	5,144 (74.3)†
bifenthrin	—	51.7	24,959	3,227 (87.1)†	9,977 (60.0)†	12,476 (50.0)†
deltamethrin	1.3	—	22,912	5,063 (77.9)†	12,002 (47.6)†	17,860 (22.0) n.s.

* bifenthrin = Talstar SC and G, treated July 2000; deltamethrin = Deltagard 0.1 G, treated July 1998. Sites monitored with 20 sucrose water vials.
** Percent reductions followed by an "†" are significantly different ($P < 0.05$, Wilcoxon signed-ranks).

aging ants affecting the ability of Argentine ants to forage above ground (Borgmeier 1938, Disney 1994, Orr and Seike 1997). Argentine ants were absent in areas where *P. pusillum* was present. This resulted in increased ant diversity in these areas. Possible these parasitoids might decrease the competitive advantage of Argentine ants and thereby might also increase the native ant diversity in urban areas.

Summary

The management of Argentine ants remains an extremely difficult task for structural pest control professionals and homeowners. Most toxic or repellent barriers fail to provide long-term control because of quickly deteriorating residual activity coupled with the reluctance of applicators to apply maximum label rates. Maximum rates tend to be prohibitively expensive. Unfortunately, most commercial ant baits are not readily accepted by foragers and not suited for Argentine ant control. If accepted, currently available baits typically provide too rapid of kill of workers and fail to kill the queens, thereby only temporarily suppressing ant populations and giving the false impression of good control.

Additional research and development of bait-bases and toxicants with delayed toxicity are necessary. Treatment strategies incorporating a combination of barrier sprays and baits may provide an economical solution, but additional research is needed so that repellent sprays do not adversely affect the baits. An integrated approach will be necessary to control this formidable pest, but additional research will need to be conducted on areas such as habitat modification, biological control, and the use of multiple tactics. Some consideration to establishing quarantines and reducing *L. humile's* spread by commerce might also be considered. No single approach will probably provide satisfactory Argentine ant control in urban settings.

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