Impacts of Residual Insecticide Barriers on Perimeter-Invading Ants, with Particular Reference to the Odorous House Ant, *Tapinoma sessile*

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J. Econ. Entomol. 97(2): 601–605 (2004)

ABSTRACT Three liquid insecticide formulations were evaluated as barrier treatments against perimeter-invading ants at a multifamily housing complex in West Lafayette, IN. Several ant species were present at the study site, including (in order of abundance) pavement ant, *Tetramorium caespitum* (L.); honey ant, *Prenolepis imparis* (Say); odorous house ant, *Tapinoma sessile* (Say); thief ant, *Solenopsis molesta* (Say); acrobat ant, *Crematogaster ashmeadi* (Mayr); crazy ant, *Paratrechina longicornis* (Latrielle), field ants, *Formica* spp.; and carpenter ant *Camponotus pennsylvanicus* (DeGeer). Studies began in May 2001 and concluded 8 wk later in July. Individual replicate treatments were placed 0.61 m (2 feet) up and 0.92 m (3 feet) out from the ends of 46.1 by 10.1-m (151 by 33-foot) apartment buildings. Ant sampling was performed with 10 placements of moist cat food for 1 h within treatment zones, followed by capture and removal of recruited ants for later counting. All treatments led to substantial reductions in ant numbers relative to untreated controls. The most effective treatment was fipronil, where 2% of before-treatment ant numbers were present at 8 wk after treatment. Both imidacloprid and cyfluthrin barrier treatments had efficacy comparative with fipronil, but to 4 and 2 wk, respectively. Odorous house ants were not sampled before treatment. Comparisons of ant species composition between treatments and controls revealed an increase in odorous house ant frequencies at 1–8 wk after treatment in treated locations only. These results demonstrate efficacy for both nonrepellent and repellent liquid insecticides as perimeter treatments for pest ants. In addition, our findings with odorous house ant highlight an apparent invasive-like characteristic of this species that may contribute to its dramatic increase in structural infestation rates in many areas of the United States.

Structure-infesting ants are the cause of frequent pest problems in urban environments because of their violation of esthetic and economic thresholds, and their potential influences on human health (Hölldobler and Wilson 1990, Lee 2002). Recent advances have provided new tools to more effectively manage urban pest ants. These tools include liquid baits (Higgins et al. 2002, Vail and Bailey 2002), residual perimeter sprays that evolved from termiticide products (Potter and Hillery 2002), and approaches that involve a combination of these two tools (Vail and Bailey 2002). New nonrepellent insecticides also offer promise as bait ingredients because of their lack of detection by foraging ants, slow action, and resulting high degrees of horizontal transmission in ant colonies via trophallaxis (Ratliff 2003, Rust et al. 2003).

A current challenge to effective urban ant control is the spread of invasive ant species and native ant species that are undergoing apparent range expansions (Hedges 2000). Two major invasive ant species are the Argentine ant, *Linepithema humile* (Mayr), and fire ants, *Solenopsis* spp., both of which occur in the eastern and western United States (Hölldobler and Wilson 1990). The odorous house ant (Smith 1928), a native pest ant species, is being increasingly encountered in a number of areas of the United States (Hedges 2000, Barbani and Fell 2002). The odorous house ant is thought by many to be undergoing a range expansion. As noted by Higgins et al. (2002), the odorous house ant shares many features in common with invasive ant species such as Argentine and fire ants. These features include polygyny, supercolony behaviors, large colony size, and high degrees of colony mobility (Smith 1928).

In this study, our objectives were two-fold. First, we sought to evaluate the efficacy of nonrepellent and repellent insecticides against perimeter-invading ants at a sight containing a diverse number of ant species (primarily pavement ants). Second, we compared ant species composition between treatments and controls to determine whether treatments had any influence on the proportions of pest ant species in treatment zones. We found that barrier treatments of both repellent and nonrepellent insecticides are effective against a number of perimeter-invading ant species, and further, that odorous house ants occurred exclu-

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Table 1. Efficacy of barrier insecticide treatments against perimeter-invading ants

Treatment	Before treatment	After treatment				GLM
	Wk 0*	Wk 1	Wk 2	Wk 4	Wk 8	α, df, MSE
Fipronil (0.06%)	141.7 ± 41.9 *a	0.0 ± 0.0b	0.0 ± 0.0b	0.0 ± 0.0b	3.3 ± 3.3b	0.05, 10, 1058.3
Imidacloprid (0.06%)	151.7 ± 76.2 *a	3.3 ± 0.3b	8.3 ± 8.3b	2.7 ± 2.2b	190.3 ± 60.9a	0.05, 10, 3531.5
Cyfluthrin (0.05%)	121.0 ± 30.2 *b	1.0 ± 0.8d	26.0 ± 12.5c	156.3 ± 37.6b	999.0 ± 114.3a	0.05, 10, 6709.7
Control	77.0 ± 25.0 *c	130.3 ± 33.1c	269.7 ± 14.1b	155.7 ± 72.7c	605.0 ± 109.4a	0.05, 10, 11506.0

Before and after treatment data represent the total average number of ants at each sampling time ± SE (n = 2–3). Values followed by the same letters within rows are not significantly different by the LSD t-test. Data in the GLM column represents α, degrees of freedom, and mean square error (MSE) associated with each t-test.

* Wk 0 means within the same column followed by an asterisk (*) are not significantly different by the LSD t-test ($\alpha = 0.05$, df = 7, MSE = 9123.33).

sively in treated areas after insecticide treatments began to loose efficacy. The latter result is suggestive that odorous house ants will readily invade habitat zones in response to the elimination of competing species such as the pavement ant.

Materials and Methods

The study site was the Purdue Village apartment complex in West Lafayette, IN. All buildings in the complex have identical dimensions of 46.1 by 10.1 m (151 by 33 feet). The complex consists of 65 uniformly spaced buildings situated mostly in north-south and east-west orientations. Building construction consists of wood and block frames with brick exteriors and full basements. Landscaping consists of open grassy areas (mowed weekly) with sparse shrubbery and trees around buildings. All treatments were performed on north-south–oriented buildings (six buildings located at the North end of the complex).

Ants were sampled 1 d before treatment and then at 1, 2, 4, and 8 wk after treatment. Sampling was performed by monitoring ant recruitment to 10 2-cm-diameter placements of wet cat food (9-Lives, Tuna in Sauce) per replicate. The cat food consisted of fish-based protein (tuna, 16%), with 2% fat content and 0% carbohydrate. Cat food was distributed on caps of commercially available laboratory cups (25 ml in volume) and placed at evenly spaced intervals throughout treated areas. After 1 h, cups were snapped onto caps, which facilitated the capture of ants that had recruited to the cat food. Ants were returned to the laboratory, frozen, and later counted. All sampling was done between 7:00 a.m. and 10:00 a.m.

Spray treatments were placed around either the north or south ends of apartment buildings, with one end serving as a replicated unit (treatment area 121 m^2 [400 $feet^2$]). All treatments and controls were placed between 46 and 122 m apart. All treatments were replicated three times with the exception of cyfluthrin, which had two replicates. Insecticide dilutions were applied using 11.4 liters (3-gal) polypropylene home and garden sprayers (Hudson Eliminator, Hastings, MN) with adjustable nozzles. Flat fan settings were used to place treatments 0.92 m (3 feet) out from and 0.61 m (2 feet) up walls. One gallon of finished spray was applied per replicate. Insecticide rates were 0.06% (fipronil and imidacloprid) or 0.05% (cyfluthrin) active ingredient. Formulated materials consisted of Termidor SC (fipronil, Aventis Inc., Research Triangle Park, NC), Premise SC (imidacloprid, Bayer Environmental Science, Kansas City, MO), and Tempo SC Ultra (cyfluthrin, Bayer Environmental Science). Statistical analyses consisted of analysis of variance (PROC GLM) on mean ant numbers over time by treatment, or between treatment locations before treatment, followed by least significant difference (LSD) t-tests to test for significant differences between means (SAS Institute 2000).

Results and Discussion

Barrier Treatment Efficacy. No significant differences in ant numbers occurred between treatment locations before treatment (Table 1). Relative to controls, all treatments were effective at eliminating perimeter-invading ants throughout the 8-wk study (Table 1; Fig. 1). Fipronil was the most effective

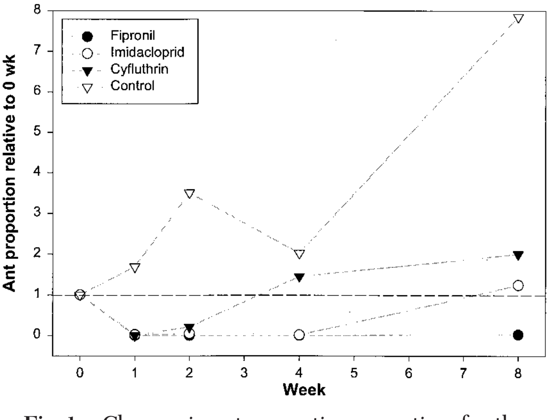

Fig. 1. Changes in ant proportions over time for three insecticide treatments versus water-treated controls. Data points represent average differences in sampled ant numbers relative to before treatment samples taken at week 0 (n = 2–3). Numbers greater than 1 represent fold increases in ant numbers, whereas numbers less than 1 represent percentage reduction.

treatment, with 2% of ants remaining relative to before treatment levels after 8 wk. Imidacloprid performed similarly to fipronil to 4 wk after treatment (5% of before-treatment numbers), and cyfluthrin to 2 wk after treatment (0% of before treatment). Of these three insecticides, only cyfluthrin (a pyrethroid) is considered to be repellent. In addition, it should be emphasized that imidacloprid presently has a label that only permits its use for carpenter ant control. The efficacy demonstrated for imidacloprid suggests that it has potential for labeling that permits its use as a residual insecticide barrier treatment for general ant control.

Clearly, however, the nonrepellent insecticide fipronil shows the best relative efficacy as a residual perimeter barrier treatment for numerous ant species. Fipronil was initially developed for the urban pest control market as a termiticide (Potter and Hillery 2002); however, because of its exceptional persistence and high-level toxicity to insects (Scharf et al. 2000), fipronil also has efficacy as a residual perimeter insecticide for general ant control.

Ant Species Sampled. Pavement ants were the dominant ant species at the study site (80.1% of sampled ants), followed by honey ants (14.1%), and then odorous house ants (2.6%). Several other species occurred at levels below 1.5% (thief, acrobat, crazy, field, and carpenter). The abundance of pavement items (e.g., sidewalks, porches, and parking lots) and open grassed areas likely supports the presence of a large pavement ant population at our study site (Mallis 1982, King and Green 1995, Scharf et al. 2002). Likewise, the lack of established tree stands at the site probably is associated with lower numbers of the less abundant species (e.g., carpenter ants). Interestingly, odorous house ants were not sampled before treatment, and only in treated areas at 1 wk after treatment and later (see below). The species proportions observed in the current study were somewhat different from a survey of ants occurring in underground termite monitoring stations in the same general area of Indiana (Scharf et al. 2002), indicating differences in terrestrial versus subterranean behaviors by these species.

Ant Species Composition before and after Treatment. Odorous house ants were not sampled before treatment in any of the treatment or control locations (Fig. 2B). After treatments, odorous house ants were sampled in all treatment locations, but not in controls (Fig. 2C). Foraging odorous house ant numbers were highest in the fourth week after treatment sampling, a time when foraging pavement ant numbers were the lowest. Although a decrease in daily temperature between the third and fourth week after treatment samples (Fig. 2A) was associated with a decrease in control ant numbers sampled at the fourth week after treatment (Table 1; Fig. 1), ant numbers sampled over the entire study do not correlate with temperature. Somewhat similar increases in the occurrence of another *Tapinoma* ant (the ghost ant, *Tapinoma melaoncephalum* F.) were noted by Lee et al. (2003) after baiting with methoprene or hydramethylnon at sites dominated by the Pharaoh ant, *Monomorium pharaonis* (L.). However, because similar increases in *T. melaoncephalum* were observed in controls, other environmental factors cannot be ruled out with respect to changes in species composition in this particular study. Together, our observations suggest that the elevated incidence of odorous house ants after treatment is related to a release from competition with nearby colonies of competing ant species, and is not influenced by environmental temperature.

Although the odorous house ant has been increasing in pest status in recent years (Hedges 2000, Barbani and Fell 2002), it was first documented as a pest more than 75 yr ago (Smith 1928). The odorous house ant and its cogeneric relatives *T. melanocephalum* and *Tapinoma indicum* Forel have also been noted as major household pests in Asia (Lee et al. 2003). The reasons for the increase in odorous house ant infestation rates across the United States are not presently known. Several aspects of their biology are known, two of which help to validate our conclusions. First, even though odorous house ants prefer warmer temperatures (Smith 1928) and have been observed as being most active above 21°C (70°F) (Barbani and Fell 2002), sampled odorous house ant numbers did not correlate with daily high temperature when compared over the length of our entire study.

Second, and apparently more importantly, odorous house ants show low interspecific aggression and are easily displaced by competing ant species (Smith 1928, Barbani and Fell 2002). We observed odorous house ants only in treatment zones, and not in untreated controls. This suggests an impact of barrier insecticide treatments on releasing odorous house ants from competition with other ant species in treatment zones, rather than an influence by ambient temperature on odorous house ant activity. Based on this conclusion, three approaches seem realistic for control of odorous house ants in similar situations when less persistent liquid insecticide sprays are used: 1) retreating with liquid insecticides, 2) implementation of a baiting program 4–8 wk after treatment, or 3) a combination of both approaches (Vail and Bailey 2002) either initially or as a follow-up to residual sprays. With respect to liquid baits, formulations containing both boric acid and imidacloprid at low concentrations (i.e., ≤50 ppm) have shown reasonable efficacy against odorous house ants (Higgins et al. 2002).

With respect to explaining the growing pest status of the odorous house ant, no answers are presently available. Based on our observations, one potential explanation could be the increasing use of perimeter insecticide treatments for general ant control, both by homeowners and pest management professionals. As suggested by our findings, such widespread insecticide use could be releasing odorous house ant populations from competition with other ant species, thus enabling their proliferation.

Odorous house ants are opportunistic nesters and their use of mulch as a nesting medium is well documented (Meissner and Silverman 2001; M.E.S. and C.R.R., unpublished data). Therefore, a second potential explanation relates to increased urbanization

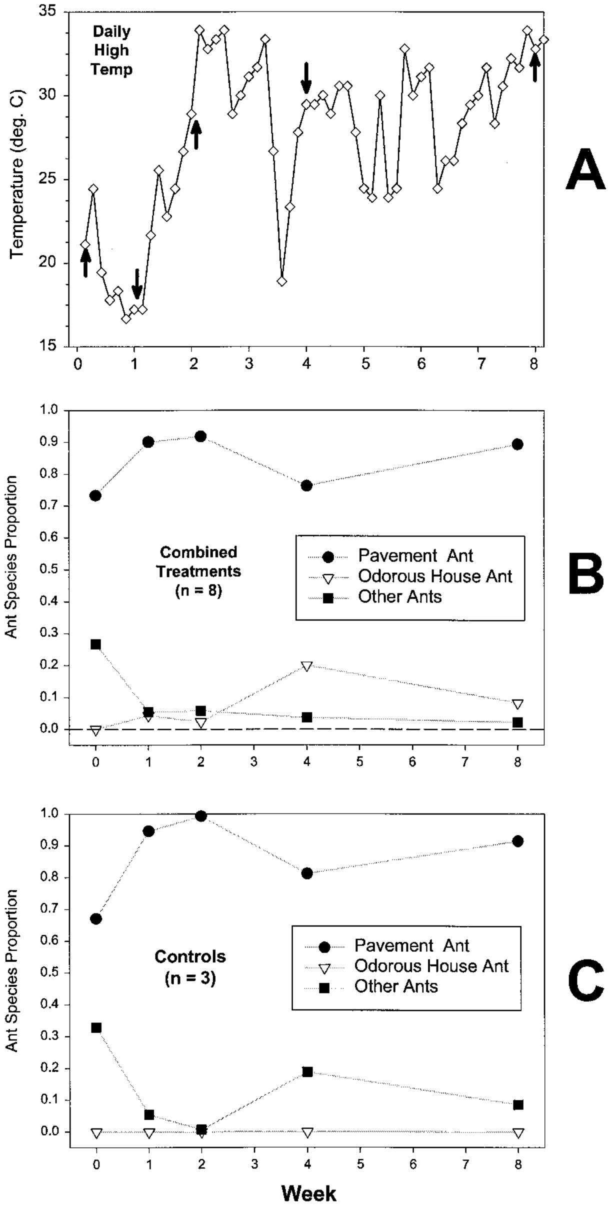

Fig. 2. Changes in ant species composition throughout the course of the current study. Shown are (A) daily high temperatures (arrows represent sampling times at week 0, 1, 2, 4, and 8); (B) pooled species composition over time for treatment locations ($n = 8$); and (C) species composition over time in water-treated controls ($n = 3$). Distance of controls from treatments was either 46 or 123 m (150 or 400 feet).

across the United States and an associated increase in the placement of landscaping mulch around structures. In this regard, the odorous house ant can be considered as an invasive species that is exploiting the newly available niche that is offered by landscape mulch. In an effort to discourage use of mulch by odorous house ants and other ant species, Meissner and Silverman (2001) have evaluated aromatic cedar mulches and found them to be highly effective for this purpose.

Finally, a third explanation for increasing odorous house ant pest problems relates to global climate change and the apparent preference of odorous house ant for warmer temperatures. If global warming proves to be a true phenomenon, it could serve to at least partially explain the recent increases in odorous house ant pest problems.

Conclusions. Here, we have demonstrated the impacts of residual liquid insecticide barrier treatments on 1) perimeter-invading ant foraging (and presumably population levels) and 2) species composition. Our study site contained buildings of uniform dimension and spacing, which permitted a highly uniform and controlled experimental testing configuration. We found that nonrepellent insecticides had greater efficacy than a repellent insecticide and that ant species composition changed most dramatically in areas treated with less persistent barrier insecticides. Specifically, we observed a noteworthy increase in odorous house ant occurrence in treatment zones as residual spray efficacy began to diminish. Our results demonstrate the potential for nonrepellent insecticide barrier treatments in general ant control and highlight an apparent invasive-like characteristic of the odorous house ant that may contribute to its increasing pest status in numerous areas of the United States. Although our results suggest interesting possibilities relating to the odorous house ant as a pest species, a better understanding of the biology of this ant will be necessary before more conclusive statements can be made.

Acknowledgments

We acknowledge Dan Suiter (University of Georgia, Griffin) for development of the sampling technique employed in this study, Tyler Janovitz for ant identification, and Aventis/BASF for partial research support. We also acknowledge the participants in a workshop entitled "Evolving Issues in Ant Control" (Purdue University, 4–5 March 2003) for discussions and ideas on odorous house ant expansion, particularly, Mike Rust, Karen Vail, and Jules Silverman. This is journal article no. 17185 of the Agriculture Research Program of Purdue University, West Lafayette, IN.

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Received 10 September 2003; accepted 4 December 2003.