# Evaluation of Liquid Baits Against Field Populations of the Longlegged Ant (Hymenoptera: Formicidae)

KIM-FUNG CHONG AND CHOW-YANG LEE[1]

Urban Entomology Laboratory, Vector Control Research Unit, School of Biological Sciences, Universiti Sains Malaysia, 11800 Penang, Malaysia

J. Econ. Entomol. 102(4): 1586–1590 (2009)

**ABSTRACT** An evaluation of several insecticides, namely, 0.01% fipronil, 0.05% indoxacarb, and 2% boric acid in liquid bait formulations were carried out against field populations of the longlegged ant, *Anoplolepis gracilipes* (Fr. Smith) (Hymenoptera: Formicidae). The baits were formulated in brown cane sugar solution (50%, wt:wt) and placed in an experimental bait station. Each bait was evaluated against populations of *A. gracilipes* at four buildings. Fipronil, indoxacarb, and boric acid were effective against *A. gracilipes*, with >90% reduction of workers within 3 d posttreatment. Total reduction (100%) was achieved within 7 d for fipronil, 14 d for indoxacarb, and 56 d for boric acid. The performance of fipronil and indoxacarb baits did not differ significantly ($P > 0.05$) in all postbaiting sampling intervals. Reduction of *A. gracilipes* resulted in an increase in other ant species [*Monomorium pharaonis* (L.), *Monomorium floricola* (Jerdon), *Monomorium orientale* Mayr, *Monomorium destructor* (Jerdon), *Tapinoma indicum* Forel, *Pheidole* sp., and *Camponotus* sp.] at the baited locations.

**KEY WORDS** *Anoplolepis gracilipes*, baiting, fipronil, indoxacarb, boric acid

The longlegged ant, *Anoplolepis gracilipes* (Fr. Smith) (Hymenoptera: Formicidae), is one of the world's top 20 worst land invertebrate invaders (ISSG 2001). Formerly known as *Anoplolepis longipes*, it is a primary species of the moist tropical lowlands (Wetterer 2005). The native range of *A. gracilipes* is still unknown, but it was proposed to be Africa or Asia (Wetterer 2005). This species has successfully spread throughout the world through a variety of pathways, such as with sea cargo involving that timber trading; in soil, machinery, and road vehicles; and within horticulture and material packaging.

*A. gracilipes* causes a negative impact to the environment especially in its introduced regions, e.g., replacing native ant species (O'Dowd et al. 2003, Lester and Tavite 2004). *A. gracilipes* also attacks endemic crabs on Christmas Island; birds, and reptiles, and newborn animals, such as pigs, dogs, cats, rabbits, and rats (Haines et al. 1994, O'Dowd et al. 2003, Abbott 2006). In addition, *A. gracilipes* is a severe household pest and nuisance in public buildings, hotels, hospitals, and food and drink processing establishments (Lewis et al. 1976).

Residual spray and baiting are common methods of ant management (Lee 2007). However, baiting has become a popular method for managing ants because this method is safe, target-specific, and able to suppress or eliminate the entire ant colony without the need to locate the nest (Suiter et al. 1997). The bait should be formulated with a slow-acting and nonrepellent insecticide. It can be a neurotoxic insecticide, stomach poison, insect growth regulator or metabolic inhibitor (Lee 2007). According to Warner and Scheffrahn (2005), residual products are not as effective as bait products against the whitefooted ant, *Technomyrmex albipes* (Fr. Smith).

In the Seychelles in the 1970s, toxic baits formulated with chlorinated hydrocarbons (aldrin) were developed for the control of *A. gracilipes* and proved to be more effective than chemical spray treatments (Lewis et al. 1976; Haines and Haines 1979a,b; Haines et al. 1994). However, due to safety reasons, many of these products have been banned. Many newer insecticide candidates that are safer and more target-specific are increasingly being used in urban pest management. In this study, we evaluated three insecticides, namely, fipronil, indoxacarb, and boric acid, in liquid brown cane sugar solution against field populations of *A. gracilipes.*

## Materials and Methods

This study was carried out on the Universiti Sains Malaysia's Minden campus in Penang Island, Malaysia. In total, 16 sites with high foraging activities of *A. gracilipes* were chosen for this study. The sites were various building blocks of selected academic departments (B1–4, C1–4, F, H1–2, and TI), university main event hall (DTSP1–3), and BK (campus newspaper building). The distance between the sites of different

[1] Corresponding author, e-mail: chowyang@usm.my.

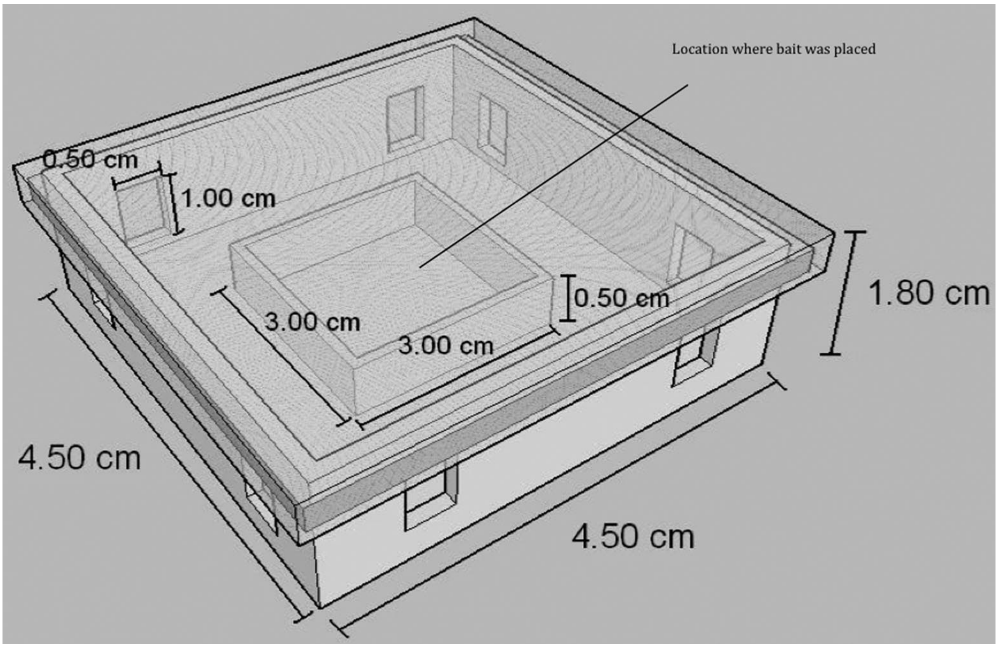


**Fig. 1.** Experimental bait station used in this study.

treatment ranged between 200 and 600 m. Treatment locations were building perimeters with plants and shrubs, and stone walks. Three technical grade insecticides were used, namely fipronil (PESTANAL, Sigma-Aldrich Laborchemikalien GmbH, Munchen, Germany), indoxacarb (DuPont Professional Products, Wilmington, DE), and boric acid (Sigma-Aldrich, St Louis, MO). They were first diluted in analytical grade ethanol and then formulated in the following bait concentrations by mixing 1 ml of analytical grade ethanol-diluted insecticide with brown cane sugar solution (50%, wt:wt) as foraging stimulant: fipronil (0.01%, wt:wt), indoxacarb (0.05% wt:wt), and boric acid (2%, wt:wt). These concentrations were chosen because an earlier laboratory evaluation showed that they were the minimal concentrations required to eliminate laboratory colonies of *A. gracilipes* within 30 d postbaiting (C.-Y.L., unpublished). Each bait was evaluated at four sites. The control sites were baited with blank brown cane sugar solution (added with 1 ml of analytical grade ethanol).

Two to 3 d before baiting, a pretreatment ant count in each site was conducted by counting the number of foraging ants inside five petri dishes (diameter, 9 cm) containing 5 ml of brown cane sugar (on cotton bung). The distance between two petri dishes was set at 2 m. The total number of ants found inside the dishes was recorded by taking digital photograph, and the number of ants was counted later on a computer. On the baiting day, 5 ml of the liquid bait was introduced onto a cotton bung and placed inside an experimental bait station (Fig. 1). The bait station was constructed from thin Plexiglas with a thickness of 2 mm. Ten experimental bait stations were placed at each site, next to the ant trails. The distances between the stations ranged between 40 cm and 4.5 m. The bait was replenished three times a week to ensure the bait did not dry out and to allow continuous feeding of the ants on the bait. The effectiveness of the treatment was determined by using the same method as in pretreatment count. Sampling was carried out at 1, 3, 7, 14, 21, 28, 56, and 84 d postbaiting. When other ant species were found inside petri dishes, they also were counted according to the same procedure described above.

Data on percentage of reduction of foraging ants were subjected to Kruskal–Wallis (KW) analysis of variance, and means were separated with KW multiple range test by using Statistix 7.0 (Analytical Software, Tallahassee, FL).

## Results and Discussion

The 2% boric acid, 0.05% indoxacarb, and 0.01% fipronil experimental baits were effective against foraging *A. gracilipes*, with >90% reduction within 3 d posttreatment. Control treatment showed increase in forager numbers throughout the 84-d evaluation period (Table 1). Although complete reduction (100%) of worker ants was achieved within 7 d for fipronil, 14 d for indoxacarb, and 56 d for boric acid, there seemed to be no significant difference ($P > 0.05$) between the performance of indoxacarb and fipronil baits throughout the entire evaluation (Table 1). Fipronil has been shown as an effective insecticide against many structural insect pests, including ants, termites, and cockroaches (Tingle et al., 2000). It is a nonrepellent insecticide that can act as both a stomach and contact poison (Soeprono and Rust 2004, Klotz et al. 2007). In laboratory studies, colonies of *Tapinoma melanocephalum* (F.) that fed on 0.05% fipronil in 10% sugar

**Table 1. Mean percentage of reduction of foraging *A. gracilipes* after baiting**

| Days after treatment | Mean % reduction of workers ± SEM | | | |
|---|---|---|---|---|
| | Control | 2% Boric acid | 0.05% Indoxacarb | 0.01% Fipronil |
| Prebaiting mean no. ants ± SE | 391.5 ± 66.2a | 336.0 ± 40.6a | 357.5 ± 70.8a | 344.5 ± 51.8a |
| 1 | −64.62 ± 49.25b | 92.07 ± 2.40ab | 96.14 ± 1.60a | 99.40 ± 0.10a |
| 3 | −65.66 ± 49.00b | 94.21 ± 0.45ab | 99.17 ± 0.47a | 99.41 ± 0.59a |
| 7 | −52.86 ± 57.31b | 83.73 ± 3.05ab | 99.11 ± 0.66a | 100.00 ± 0.00a |
| 14 | −120.67 ± 103.82b | 95.56 ± 0.84ab | 100.00 ± 0.00a | 100.00 ± 0.00a |
| 21 | −71.49 ± 95.11b | 96.48 ± 0.45ab | 100.00 ± 0.00a | 100.00 ± 0.00a |
| 28 | −163.98 ± 119.24b | 99.46 ± 0.40a | 100.00 ± 0.00a | 100.00 ± 0.00a |
| 56 | −47.90 ± 74.80b | 100.00 ± 0.00a | 100.00 ± 0.00a | 100.00 ± 0.00a |
| 84 | −27.93 ± 36.46b | 100.00 ± 0.00a | 100.00 ± 0.00a | 100.00 ± 0.00a |

Means followed by different letters within the same row are significantly different ($P < 0.05$; Kruskal–Wallis multiple range test).

solution were eliminated within 1 wk (Ulloa-Chacón and Jaramillo 2003), and Hooper-Bùi and Rust (2000) showed with *L. humile* that as low as $1 \times 10^{-5}$ fipronil in 25% sucrose water killed 100% of workers and queens in 14 d.

Indoxacarb is an oxadiazine that is highly toxic to insects (McCann et al. 2001). It was classified by the U.S. Environmental Protection Agency as a reduced risk active ingredient and must be metabolized by the insect into an *N*-decarbomethoxyllated metabolite to become an acute toxicant (Furman and Gold 2006b). Furman and Gold (2006e) showed that both larvae and workers of *Solenopsis invicta* (Buren) were able to metabolize indoxacarb into this acute toxic metabolite. To control field colonies of *S. invicta,* 0.045% indoxacarb on defatted corn grit was placed within 0.5–3.0 m of their mounds (Furman and Gold 2006a,b,c). Fuman and Gold (2006b) also reported that 0.045% indoxacarb was effective against *M. pharaonis, Pogonomyrmex barbatus* (Smith), and *Dorymyrmex pyramicus* Forel, with 92–100% population decrease within 24 h posttreatment in the field. Our results also showed that 0.05% indoxacarb reduced *A. gracilipes* activity by 96% within 24 h posttreatment. Barr (2003) reported that 0.045% indoxacarb bait reduced *S. invicta* activity in >90% of the mounds within 9 d during the summer, and it took 10 wk to reach similar reduction in the fall. Ant foraging was suppressed by <10% of the untreated plots 2 d posttreatment.

According to Knight and Rust (1991), boric acid is an excellent toxicant for ant bait because it is water-soluble, slow-acting, nonrepellent and low mammalian toxicity. Boric acid disrupts water balance and digestion of insects (BP 2007); thus, they die from dehydration and starvation. In tests around structures infested with *M. pharaonis*, a dual-bait formulation (5.3% boric acid and 4.3% sodium borate) reduced population by >90% after 2 wk (Lee and Lee 2002), and a 1% boric acid in 10% sucrose solution significantly reduced activity after 1 wk (Klotz et al. 1997a). Sweetened liquid baits containing 0.5–1% borate provided significant and continuous reduction of *L. humile* around structures for >6 wk (Klotz et al. 1998, 2007). In laboratory studies, colonies of *T. melanocephalum* fed 0.5% boric acid in 10% sucrose water had 100% mortality in 3 wk (Ulloa-Chacón and Jaramillo 2003), and *L. humile* were eliminated in 14 d after feeding on 0.5% boric acid in 25% sucrose water (Hooper-Bùi and Rust 2000). Klotz and Moss (1996) stated that low concentration of boric acid is appro-

**Table 2. Occurrence of other ant species at the test sites after baiting[a]**

| Bait | Site | Day 0 | Day 1 | Day 3 | Day 7 | Day 14 | Day 21 | Day 28 | Day 56 | Day 84 |
|---|---|---|---|---|---|---|---|---|---|---|
| Control | B1 | | | | | | | | | |
| | B2 | | | Mf | Mf | | Mf | | Mf | |
| | B3 | | | | | | | | | |
| | B4 | | | | Mo | Mo | Mo | | | |
| 2% Boric acid | C1 | | | | | | | | | |
| | C2 | | | | | | | | | |
| | C3 | | | | | Ca | | | | |
| | C4 | | | | | Ti | Ti | | | |
| 0.05% Indoxacarb | DTSP1 | | Md | Md | | | | | | |
| | DTSP2 | | Ph, Ti | | | | | | | |
| | DTSP3 | | Ph, Ti | | | | | | | |
| | TI | | Ca, Ti | | | | | | | |
| 0.01% Fipronil | H1 | | Ti, Mf | | | | | | | |
| | H2 | | Ti | Ti | | | | | | |
| | F | | Ca | | | | | | | |
| | BK | | Ca, Ti, Mp | | | | | | | |

[a] B1–4, School of Biological Sciences; BK, Campus newspaper building; C1–4, School of Chemical Sciences; Ca, *Camponotus* sp.; DTSP1–3, Dewan Tuanku Syed Putra complex; F, School of Physical Sciences; H1–2, School of Humanities; Md, *Monomorium destructor;* Mf, *Monomorium floricola;* Mo, *Monomorium orientale* 1; Mp, *Monomorium pharaonis;* Ph, *Pheidole* sp.; Ti, *Tapinoma indicum;* TI, School of Industrial Technology.

priate in ants control because it allows ample time for the ants to recruit and pass the toxin to other members of the colony. Hooper-Bùi and Rust (2000) also showed that low concentration of fipronil and boric acid were promising candidates for *L. humile* control. It is important to allow the ants to feed on the low concentration baits longer than 3 d because the toxicant's effect is delayed and cumulative (Klotz et al. 1996, 1997b). In this study, boric acid took 2 mo to achieve 100% reduction of *A. gracilipes.*

One of the challenges in ant management in the tropics is the emergence of another species upon suppression or elimination of the more dominant species (Lee 2007). The problem may be worsen when these species do not respond to the initial baits, and new control strategies are required to solve the problem. Lee (2002) demonstrated that when *Monomorium* populations were eliminated by using imidacloprid bait, the numbers of *Paratrechina longicornis* (Latreille) and *T. melanocephalum* increased because they were now able to forage in a wider area that was formerly dominated by *Monomorium* spp., but they were not affected by the bait. Several peridomestic species, such as *Phedole megacephala* (F.), *T. melanocephalum,* and *P. longicornis,* also increased in numbers after the more dominant *M. pharaonis* was suppressed by baits (Lee et al. 2003). Scharf et al. (2004) also documented in their studies on fipronil perimeter treatment against several perimeter-invading ant species [such as pavement ant, *Tetramorium caespitum* (L.) and honey ant *Prenolepis imparis* (Say)] that the odorous house ant, *Tapinoma sessile* (Say), became dominant after the other ants were eliminated. A similar observation was recorded in this study. When the number of *A. gracilipes* decreased, other ant species were found on the baits, especially at the locations where *A. gracilipes* was baited with indoxacarb and fipronil (Table 2). These species include *Camponotus* sp., *Tapinoma indicum* Forel, *M. destructor, Pheidole* sp., and *M. pharaonis.* However, these species also were eliminated after feeding on the baits. At the boric acid sites, *Camponotus* sp. and *T. indicum* were found when *A. gracilipes* workers were reduced by >95% (Table 2). Among the many species that showed up after the elimination of *A. gracilipes, T. indicum* was the most frequent species. *M. floricola* also was found at control sites and was found feeding with *A. gracilipes* without any sign of aggression toward one another. *Monomorium orientale* Mayr also was found feeding together with *A. gracilipes* (Table 2, B4).

In summary, brown cane sugar-based liquid bait containing fipronil, indoxacarb, and boric acid were highly effective against field populations of the longlegged ant. Reduction in *A. gracilipes* numbers may result in the occurrence of other pest ant species in the baited locations.

## Acknowledgments

We thank Nellie S.-C. Wong (Universiti Sains Malaysia) and Mark A. Coffelt and Clay W. Scherer (DuPont Professional Products) for reviewing the early manuscript draft, and the two anonymous reviewers whose comments significantly improved the manuscript. This study was supported in part by DuPont Professional Products. K.-F.C. was supported under a postgraduate fellowship from Universiti Sains Malaysia.

## References Cited

**Abbott, K. L. 2006.** Spatial dynamics of supercolonies of the invasive yellow crazy ant, *Anoplolepis gracilipes*, on Christmas Island, India Ocean. Divers. Distrib. 12: 101–110.

**Barr, C. 2003.** Fire ant mound and foraging suppression by indoxacarb bait. J. Agric. Urban. Entomol. 20: 143–150.

**[BP] Beyond Pesticide. 2007.** Chemical WATCH factsheet: boric acid. (http://www.beyondpesticides.org/pesticides/factsheets/Boric%20Acid.pdf).

**Furman, B. D., and R. E. Gold. 2006a.** Determination of the most effective chemical form and concentration of indoxacarb, as well as the most appropriate grit size, for use in Advion™. Sociobiology 48: 309–334.

**Furman, B. D., and R. E. Gold. 2006b.** Trophallactic transmission and metabolism of the active ingredient indoxacarb in Advion™ (Hymenoptera: Formicidae). Sociobiology 48: 335–353.

**Furman, B. D., and R. E. Gold. 2006c.** Comparison of the effectiveness of a label-rate broadcast treatment with Advion™, a label-rate broadcast treatment with Amdro®, and a pre-baiting broadcast treatment with Advion™ at controlling *Solenopsis invicta* (Hymenoptera: Formicidae). Sociobiology 48: 479–491.

**Furman, B. D., and R. E. Gold. 2006d.** Determination of the most effective concentration and quantity of Advion™, as well as the most effective placement of the bait for individual *Solenopsis invicta* mound treatments (Hymenoptera: Formicidae). Sociobiology 48: 101–116.

**Furman, B. D., and R. E. Gold. 2006e.** The effectiveness of label-rate broadcast treatment with Advion™ at controlling multiple ant species (Hymenoptera: Formicidae). Sociobiology 48: 559–570.

**Haines, I. H., and J. B. Haines. 1979a.** Toxic bait for the control of *Anoplolepis longipes* (Jerdon) (Hymenoptera: Formicidae) in the Seychelles. II. Effectiveness, specificity and cost of baiting in field applications. Bull. Entomol. Res. 69: 77–85.

**Haines, I. H., and J. B. Haines. 1979b.** Toxic bait for the control of *Anoplolepis longipes* (Jerdon) (Hymenoptera: Formicidae) in the Seychelles. III. Selection of toxicants. Bull. Entomol. Res. 69: 203–211.

**Haines, I. H., J. B. Haines, and J. M. Cherrett. 1994.** The impact and control of the crazy ant, *Anoplolepis longipes* (Jerd.), in the Seychelles, pp. 206–218. *In* D. F. Williams [ed.], Exotic ants—biology, impact and control of introduced species., Westview Press, Boulder, CO.

**Hooper-Bùi, L. M., and M. K. Rust. 2000.** Oral toxicity of abamectin, boric acid, fipronil and hydramethlynon to laboratory colonies of Argentine ants (Hymenoptera: Formicidae). J. Econ. Entomol. 93: 858–864.

**[ISSG] Invasive Species Specialist Group. 2001.** 100 of the world's worst invasive alien species. A selection from the global invasive species database. (http://www.issg.org/database).

**Klotz, J. H., and J. Moss. 1996.** Oral toxicity of a boric acid-sucrose water bait to Florida carpenter ants (Hymenoptera: Formicidae). J. Entomol. Sci. 31: 9–12.

**Klotz, J. H., D. H. Oi, K. M. Vail, and D. F. Williams. 1996.** Laboratory evaluation of a boric acid liquid bait on colonies of *Tapinoma melanocephalum,* Argentine ants and

Pharaoh ants (Hymenoptera: Formicidae). J. Econ. Entomol. 89: 673–677.

**Klotz, J. H., K. M. Vail, and D. F. Williams. 1997a.** Liquid boric acid for control of structural infestations of Pharaoh ants (Hymenoptera: Formicidae). J. Econ. Entomol. 90: 523–526.

**Klotz, J. H., K. M. Vail, and D. F. Williams. 1997b.** Toxicity of a boric acid-sucrose water bait to *Solenopsis invicta* (Hymenoptera: Formicidae). J. Econ. Entomol. 90: 488–491.

**Klotz, J., L. Greenberg, and E. C. Venn. 1998.** Liquid boric acid bait for control of the Argentine ant (Hymenoptera: Formicidae). J. Econ. Entomol. 91: 910–914.

**Klotz, J. H., M. K. Rust, L. Greenberg, H. C. Field, and K. Kupfer. 2007.** An evaluation of several urban pest management strategies to control Argentine ants (Hymenoptera: Formicidae). Sociobiology 50: 391–398.

**Knight, R. L., and M. K. Rust. 1991.** Efficacy of formulated baits for control of Argentine ant (Hymenoptera: Formicidae). J. Econ. Entomol. 84: 510–514.

**Lee, C. Y. 2002.** Tropical household ants: pest status, species diversity, foraging behavior and baiting studies, pp. 3–18. *In* S. C. Jones, J. Zhai, and W. H. Robinson [eds.], Proceeding of the 4th International Conference on Urban Pests. Pocahantas Press, Blackburg, VI.

**Lee, C. Y. 2007.** Perspective in urban insect pest management in Malaysia. Vector Control Research Unit, School of Biological Sciences, Universiti Sains Malaysia, Penang, Malaysia.

**Lee, C. Y., and L. C. Lee. 2002.** Field and laboratory evaluation of a boron-based containerized dual-bait formulation against the Pharaoh ant, *Monomorium pharaonis* (Hymenoptera: Formicidae). Sociobiology 40: 655–665.

**Lee, C. Y., L. C. Lee, J.P.S. Na, P. Y. Loke, K. T. Lim, and E.H.H. Teo. 2003.** Evaluation of methoprene granular baits against foraging Pharaoh ants, *Monomorium pharaonis* (Hymenoptera: Formicidae). Sociobiology 41: 717–723.

**Lester, P. J., and A. Tavite. 2004.** Long-legged ants, *Anoplolepis gracilipes* (Hymenoptera: Formicidae), have invaded Tokelau, changing composition and dynamics of ant and invertebrate communities. Pac. Sci. 58: 391–401.

**Lewis, T., J. M. Cherrett, I. Haines, J. B. Haines, and P. L. Mathias. 1976.** The crazy ant (*Anoplolepis longipes* (Jerd.) (Hymenoptera: Formicidae)) in Seychelles and its chemical control. Bull. Entomol. Res. 66: 97–111.

**McCann, S. F., G. D. Annis, R. Shapiro, D. W. Piotrowski, G. P. Lahm, J. K. Long, K. C. Lee, M. M. Hughes, B. J. Myers, S. M. Griswold, et al. 2001.** The discovery of indoxacarb: oxadiazines as a new class of pyrazoline-type insecticides. Pest Manag. Sci. 57: 153–164.

**O'Dowd, D. J., P. T. Green, and P. S. Lake. 2003.** Invasional 'meltdown' on an oceanic island. Ecol. Lett. 6: 812–817.

**Scharf, M. E., C. R. Ratliff, and G. W. Bennett. 2004.** Impacts of residual insecticide barriers on perimeter-invading ants, with particular reference to the odorous house ant, *Tapinoma sessile.* J. Econ. Entomol. 97: 601–605.

**Soeprono, A. M., and M. K. Rust. 2004.** Effect of delayed toxicity of chemical barriers to control Argentine ants (Hymenoptera: Formicidae). J. Econ. Entomol. 97: 2021–2028.

**Suiter, D., D. Wu, and G. Bennett. 1997.** The evolution of ant control. Pest. Control 65: 46–51.

**Tingle, C.C.D., J. A. Rother, C. F. Dewhurst, S. Lauer,and W. J. King. 2000.** Health and environmental effects of fipronil. Pesticide Action Network UK, London, United Kingdom.

**Ulloa-Chacón, P., and G. I. Jaramillo. 2003.** Effects of boric acid, fipronil, hydramethylnon and diflubenzuron baits on colonies of ghost ants (Hymenoptera: Formicidae). J. Econ. Entomol. 96: 856–862.

**Warner, J., and R. H. Scheffrahn. 2005.** Laboratory evaluation of baits, residual insecticides and an ultrasonic device for control of white-footed ants, *Technomyrmex albipes* (Hymenoptera: Formicidae). Sociobiology 45: 317–330.

**Wetterer, J. K. 2005.** Worldwide distribution and potential spread of the long-legged ant, *Anoplolepis gracilipes* (Hymenoptera: Formicidae). Sociobiology 45: 77–97.

*Received 18 November 2008; accepted 23 April 2009.*