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

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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 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

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).

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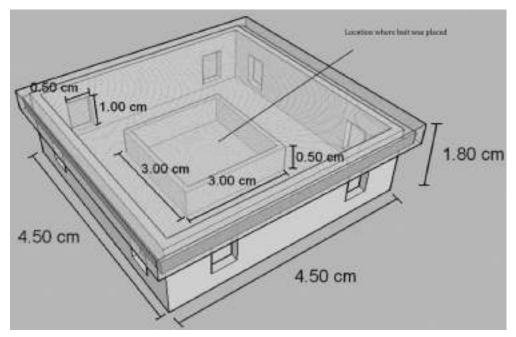


Fig. 1. Experimental bait station used in this study.

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

	Mean % reduction of workers ± SEM							
Days after treatment	Control	2% Boric acid	0.05% Indoxacarb	0.01% Fipronil				
Prebaiting mean no. ants ± SE	$391.5 \pm 66.2a$	336.0 ± 40.6a	357.5 ± 70.8a	$344.5 \pm 51.8a$				
1	$-64.62 \pm 49.25$ b	$92.07 \pm 2.40ab$	$96.14 \pm 1.60a$	$99.40 \pm 0.10a$				
3	$-65.66 \pm 49.00$ b	$94.21 \pm 0.45ab$	$99.17 \pm 0.47a$	$99.41 \pm 0.59a$				
7	$-52.86 \pm 57.31$ b	$83.73 \pm 3.05ab$	$99.11 \pm 0.66a$	$100.00 \pm 0.00a$				
14	$-120.67 \pm 103.82b$	$95.56 \pm 0.84ab$	$100.00 \pm 0.00a$	$100.00 \pm 0.00a$				
21	$-71.49 \pm 95.11$ b	$96.48 \pm 0.45ab$	$100.00 \pm 0.00a$	$100.00 \pm 0.00a$				
28	$-163.98 \pm 119.24b$	$99.46 \pm 0.40a$	$100.00 \pm 0.00a$	$100.00 \pm 0.00a$				
56	$-47.90 \pm 74.80$ b	$100.00 \pm 0.00a$	$100.00 \pm 0.00a$	$100.00 \pm 0.00a$				
84	$-27.93 \pm 36.46$ b	$100.00\pm0.00a$	$100.00 \pm 0.00a$	$100.00 \pm 0.00a$				

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  $1\times10^{-5}$  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 watersoluble, 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

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	
	<b>B</b> 3									
	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						
	$\mathbf{F}$		Ca							
	BK		Ca, Ti, Mp							

<sup>&</sup>lt;sup>a</sup> 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.

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Received 18 November 2008; accepted 23 April 2009.