HOUSEHOLD AND STRUCTURAL INSECTS

Liquid Boric Acid Bait for Control of Structural Infestations of Pharaoh Ants (Hymenoptera: Formicidae)

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ABSTRACT A 1% boric acid–sucrose water bait was evaluated for efficacy in reducing structural infestations of Pharaoh ants, *Monomorium pharaonis* (L.), at 2 sites. One of the sites was an apartment complex with a natural infestation of Pharaoh ants. The other site consisted of a group of small buildings that were purposely infested with Pharaoh ants. Treated and untreated (control) bait stations were replaced once a week for 3 wk at each site, then removed from the study site. Significant reductions in the number of foraging ants at both sites were attained in the 1st week after exposure to the boric acid bait and was maintained thereafter for 7 wk in the apartment complex and for 8 wk in the small-building complex.

KEY WORDS *Monomorium pharaonis,* ant baits, boric acid

RECENT RESEARCH HAS demonstrated the efficacy of boron compounds against several household pests, including house flies, *Musca domestica* L. (Mullens and Rodriguez 1992, Hogsette and Koehler 1994); cat fleas, *Ctenocephalides felis felis* Bouché (Klotz et al. 1994, Hinkle et al. 1995); German cockroaches, *Blatella germanica* (L.) (Strong et al. 1993, Cochran 1995); and eastern and Formosan subterranean termites, *Reticulitermes flavipes* (Kollar) and *Coptotermes formosanus* Shiraki, respectively (Grace 1991, Grace and Yamamoto 1994). For ant control, boric acid has been used as a toxicant in a liquid bait against workers of *Camponotus floridanus* (Buckley) (Klotz and Moss 1996), small queenright colonies of *Monomorium pharaonis* (L.) (Pharaoh ant), *Linepithema humile* (Mayr), and *Tapinoma melanocephalum* (F.) (Klotz et al. 1996), and large queenright colonies of *Solenopsis invicta* Buren (Klotz et al. 1997). For *C. floridanus,* the effective concentration of boric acid was found to be much lower than what is currently being used in ant baits (Klotz and Moss 1996). Over the dosage range from 0.13 to 3.13% boric acid, median lethal times (LT_{50}s) (95% CL) ranged from 9.7 (8.1–13.3) d to 1.5 (1.2–1.7) d. Based on the aforementioned toxicity studies in the laboratory with carpenter ants, a 1% boric acid in a 10% solution of sucrose water was used as a bait in laboratory studies with colonies of several species of urban pest ants (Klotz et al. 1996, 1997). In tests with alternative food and water available, small colonies of *M. pharaonis, L. humile,* and *T. melanocephalum* were eliminated when exposed continuously to this bait.

A liquid carrier in an ant bait is ideal because many species of pest ants naturally feed on honeydew and therefore are adapted to collecting, transporting, and sharing a liquid diet. For example, 99% of the food coming into a nest of *L. humile* is in a liquid state (Markin 1970). Boric acid is a good toxicant for a liquid ant bait because it is soluble in water, slow-acting (Klotz and Moss 1996), and has low mammalian toxicity (Quarles 1992). It has been used in pest control for at least a century (Quarles 1993) and is an active ingredient in several commercially available ant baits. However, our recent research has suggested that excessively high rates (≥5%) of boric acid are being used in ant baits, and that much lower concentrations would actually be more effective.

Except for the termites and work of Grace and Yamamoto (1994), all of the boric acid studies listed above were conducted under controlled laboratory conditions. The efficacy of any treatment strategy in pest control also should be determined under natural conditions. Therefore, the objective of this study was to evaluate a 1% boric acid sucrose–water bait in the field against structural infestations of Pharaoh ants.

Materials and Methods

Study site 1 was an apartment complex located in Gainesville, FL. Six single-story buildings (≈176 m^2 interior area per building), each consisting of 4 one-bedroom apartments were used. The experimental design was adopted from another bait study conducted at the same location by Oi

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et al. (1994). The size of Pharaoh ant foraging populations was estimated by placing white index cards (7.5 by 6.5 cm) baited with honey (≈1 g) at 6 locations inside and 6 locations outside each 1-bedroom apartment. Interior card placements were in the living room on the window sill; in the kitchen on the sink counter, and on the wall near the fuse box; in the bathroom on the basin counter and on the wall in the vicinity of the toilet; and in the bedroom on the window sill. Exterior locations included the bottom of the front door, the top of the courtyard gate, the top of the courtyard wall at the intersection of the courtyard and apartment walls, and the courtyard window sill. The remaining exterior locations were the water spigot, the wall air-conditioning hose junction, or the electric meters.

The honey-baited index cards were positioned at the apartment complex on 12 October 1995. Index cards were placed on vertical wall surfaces by using poster putty. Cards were set in place between 0930 and 1200 hours EDST and were checked ≈2 h later. Pharaoh ants were counted on each index card, then shaken off at the same location. The normal pest control service was suspended for the duration of the study. From this pretreatment survey, 6 buildings infested with Pharaoh ants were chosen for the study.

To determine the effectiveness of a 1% boric acid–sucrose water solution in reducing Pharaoh ant populations, treated and untreated bait stations were randomly assigned to the 6 buildings so that 3 buildings were used per treatment and control, respectively. Bait stations were positioned adjacent to the index card locations by using double-sided tape and the ants shaken onto the bait station, immediately after counts were made. Stations consisted of small Gelman petri dishes (50 mm diameter, 9 mm high, Fisher Scientific, Ann Arbor, MI), each supplied with a wad of cotton soaked in 7 ml of either 1% crystalline boric acid (Sigma Chemical, St. Louis, MO; 99% [AI]) dissolved in 10% (wt:vol) sucrose-deionized water solution or 10% sucrose–water solution alone. The lid of the petri dish had 9 small holes (≈3 mm diameter) to allow ant entry and prevent evaporation of the solution. For the first 3 wk, stations were replaced each week with new, fresh bait stations. Any live ants remaining in the old bait station were removed and released at the station site. After the 3rd week of treatment, the baits were removed for the remainder of the study. Posttreatment populations were monitored weekly for the 1st month after treatment and then every other week for the 2nd month (19 October through 15 December 1995) using a monitoring procedure similar to the pretreatment survey except that ants were counted on honey-baited index cards after the stations were removed. This ensured that the cards would intercept ants that were visiting the bait stations. Outdoor temperatures during the population monitoring ranged from 19.0 to 34.5°C.

The boric acid bait and control also were evaluated simultaneously with the field test described above at a 2nd site. Study site 2 is a building complex constructed specifically for Pharaoh ant research located at the Center for Medical, Agricultural, and Veterinary Entomology, USDA–ARS in Gainesville, FL. The complex consists of 9 wooden building units (2.4 m wide, 3.0 m long, 2.4 m high) constructed on solid concrete slabs. Building units are arranged in a 3 x 3 units square grid with 15.2 m separating each unit. The central unit, which contained electronic equipment, was not used in this study. Building specifications for each of the other 8 units (Vail 1996) provided for temperature and ventilation control. A hygrothermograph placed in the corner of each building recorded air temperature and humidity.

Unlike in study site 1, large colonies of Pharaoh ants consisting of 100–200 queens, ≈10 g of brood, and 10,000–15,000 workers were introduced into each unit (4 units control, 4 units treatment). Water was provided for ants in test tubes with cotton plugs; the tubes were placed on each of the 2 inside window sills. A food cup, containing crickets and cotton wicks saturated with 25% honeywater (vol:vol), also was placed on the window sills once a week.

Populations of Pharaoh ants were estimated on the same dates and following the same procedure as described for study site 1, except only 4 locations inside and 4 locations outside each unit were monitored. Interior card placements were on the 2 window sills, next to the air conditioner, and along the door frame. Exterior card locations were on the 2 window sills, next to the electrical conduit, and along the outside door frame.

Statistical Analysis. The mean number of ants per card for the control and treated buildings was evaluated by the general linear model (GLM) procedures (SAS Institute 1993) for each sample date. Means were transformed with the log(x+1) to reduce variation and to generate a more normal distribution.

Results and Discussion

In both the apartment and small-building research complex, the 1% boric acid sucrose–water bait reduced populations of Pharaoh ants (based on number of workers collected at pretreatment survey cards) within the 1st week after bait application (Tables 1 and 2). A reduction in Pharaoh ant numbers was maintained for the duration of the test in both study sites, except for the final week in the apartment complex when the the number of workers collected in the treated buildings was not significantly different from that in the control buildings ($P = 0.0538$). In treated buildings at both study sites, foraging activity, albeit very light, continued. Therefore, the 1% boric acid bait maintained population suppression of foraging workers but not elimination of Pharaoh ant colonies. Ef-

Table 1. Number of Pharaoh ants per honey-baited card obtained inside and outside apartment buildings (site 1), 1–8 wk following placement of bait stations (boric acid–sucrose water solution)

Treatment	Mean no. (± SEM) ants per card						
	Wk 0[a]	Wk 1	Wk 2	Wk 3	Wk 4[b]	Wk 6	Wk 8
1% boric acid	19.24 ± 10.40	0.80 ± 0.21*	0.05 ± 0.03*	0.08 ± 0.03*	0.01 ± 0.01*	0.82 ± 0.22*	2.16 ± 0.86
Control	28.53 ± 11.73	74.96 ± 26.58	28.73 ± 12.64	21.07 ± 11.34	6.65 ± 3.82	32.22 ± 2.29	24.64 ± 14.78
P	0.6281	0.0217	0.0478	0.0401	0.0189	0.0044	0.0538
df; *F*	1, 4; 0.27	1, 4; 13.35	1, 4; 7.95	1, 4; 8.98	1, 4; 14.56	1, 4; 33.45	1, 4; 7.32

Means followed by an asterisk in each column are significantly different ($P < 0.05$) from the control by using GLM on $\log_{10}(x + 1)$ transformed data. Untransformed means are presented.

[a] Pretreatment survey to determine size of foraging ant populations.

[b] Boric acid bait removed.

fective pest control with this bait, then, would entail monitoring for ants and retreating problem areas where foraging populations existed.

In the apartment complex, ant foraging activity was primarily outdoors with 88% of the total number of ants counted in the pretreatment survey located outside. This predominance of outdoor activity in Pharaoh ants was noted in a previous study conducted at this same site (Oi et al. 1994), and control was attained by bait placements soley on the outside of the apartments. In the small buildings at the research complex, 63% of the total number of ants counted in the pretreatment survey was located indoors. This difference in location of ant activity between the 2 sites may have occurred because Pharaoh ant colonies at site 2 were purposely released in the interior of the small buildings where food and water were provided. Also, interior temperature was controlled to optimize ant survival. The most important reason for decreased outdoor foraging at site 2 was caused by the presence of another ant species, *Dorymyrmex bureni* (Trager), which quickly dominated and displaced the Pharaoh ant.

Outdoor temperatures had a profound effect on activity levels. For example, on wk 4 at the apartment complex, when the temperature dropped in the afternoon to 19.0°C, there was almost no activity in either the control or treated buildings (Table 1). The following week, when the temperature rose to 24.0°C in the afternoon, foraging activity in the controls resumed to previous levels. At site 2, activity remained high in the control buildings throughout the study (Table 2) primarily because of the optimal conditions provided for the ants' foraging. Results of this study validate the use of these buildings for evaluating ant baits. Even though the number of baits per square foot was different at the 2 study sites, the trends in bait efficacy were similar. The tests were terminated after 8 wk because of cold weather. With higher temperatures again in spring, a resurgence of Pharaoh ants is likely, making another treatment with the boric acid bait necessary.

Boric acid baits have been used extensively for Pharaoh ant control, but the concentration of active ingredient used has been much higher than 1%. In laboratory and field tests, Newton (1980) successfully controlled Pharaoh ants with bait formulations of 5 and 7% boric acid. Wright and Stout (1978) recommended 2% boric acid in either a liquid or solid bait. And several of the currently available baits range from 5 to 17% boric acid. The high doses used are probably designed to eliminate ants quickly. However, at higher doses, the ants tend to die too quickly, therefore not allowing enough time for the bait to be passed around to the entire colony through trophallaxis (Klotz and Moss 1996). Additionally, it is important for the ants to feed on a boric acid bait for longer than a 3-d period because the effects are delayed and cumulative (Klotz et al. 1996, 1997).

Some of the advantages of using boric acid as a bait toxicant for Pharaoh ants include its delayed activity and its solubility in water. At low concentrations, boric acid is slow-acting and less likely to

Table 2. Number of Pharaoh ants per honey-baited card obtained inside and outside research units (site 2), 1–8 wk following placement of bait stations (boric acid–sucrose water solution)

Treatment	Mean (± SEM) no. ants per card						
	Wk 0[a]	Wk 1	Wk 2	Wk 3	Wk 4[b]	Wk 6	Wk 8
1% boric acid	33.00 ± 9.83	0.88 ± 0.31*	0.28 ± 0.16*	0.06 ± 0.06*	0.06 ± 0.04*	0.25 ± 0.09*	0.19 ± 0.06*
Control	30.00 ± 13.20	9.06 ± 1.11	7.22 ± 2.08	31.91 ± 8.86	129.06 ± 16.19	194.69 ± 23.37	100.09 ± 16.53
P	0.7722	0.0002	0.0001	0.0004	0.0002	0.0001	0.0001
df; *F*	1, 6; 0.09	1, 6; 61.99	1, 6; 138.02	1, 6; 51.49	1, 6; 61.36	1, 6; 335.62	1, 6; 82.20

Means followed by an asterisk in each column are significantly different ($P < 0.05$) from the control by using GLM on $\log_{10}(x + 1)$ transformed data. Untransformed means are presented.

[a] Pretreatment survey to determine size of foraging ant populations.

[b] Boric acid bait removed.

be repellent. For example, in consumption tests with *Solenopsis invicta* (Klotz et al. 1997), the amount of boric acid–sucrose water consumed was inversely related to the concentration of active ingredient. High concentrations of boric acid bait (5%) were consumed at a significantly lower rate than the control (10% sucrose water).

The effective concentration of boric acid in this bait is much lower than what is currently being used or recommended. Commercially available bait formulations for ants include syrups, gels, granules, and solids for bait stations. A new possibility is a water-based liquid formulation which offers sugar as a food attractant to initiate recruitment and water as a carrier to provide moisture.

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