Laboratory Evaluation of a Boric Acid Liquid Bait on Colonies of *Tapinoma melanocephalum* Argentine Ants and Pharaoh Ants (Hymenoptera: Formicidae)

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ABSTRACT A 1% boric acid–sucrose water bait and 0.9% hydramethylnon granular bait were evaluated for efficacy against small laboratory colonies of *Tapinoma melanocephalum* (F.); Argentine ants, *Linepithema humile* (Mayr); and Pharaoh ants, *Monomorium pharaonis* (L.). *T. melanocephalum* workers were reduced by 97% in the 1st wk and brood reduced by 96% in the 3rd wk when colonies were exposed to boric acid bait for as few as 3 d. The hydramethylnon bait did not significantly affect colony growth. *L. humile* colonies exposed to boric acid bait for 3 d resulted in reductions of 75 and 88% for workers and brood, respectively, by the 3rd wk. *L. humile* colonies exposed continuously caused a 90% reduction of workers and brood by the 3rd wk. Workers and brood in colonies exposed to hydramethylnon bait were reduced 86 and 77%, respectively, after 3 wk. After exposure to boric acid bait for 3 d, *M. pharaonis* workers and brood were reduced 73 and 50%, respectively, by 8 wk. A continuous exposure of boric acid or hydramethylnon baits caused reductions of 90 and 60% for workers and brood, respectively, by 3 wk.

KEY WORDS *Linepithema humile, Monomorium pharaonis, Tapinoma melanocephalum,* baits

BORIC ACID BAITS were used for ant control in the late 1800s and early 1900s (Riley 1889, Rust 1986) and they continue to play an important role. Given this long-term usage, it is surprising that there is little information on the efficacy of boric acid in controlling species of urban pest ants. For example, there is no information on the use of boric acid for *T. melanocephalum.*

In laboratory tests with Argentine ants, *Linepithema humile* (Mayr), Rust and Knight (1990) found that a commercial 5% boric acid gel bait was unsuccessful in controlling colonies of this species. For Argentine ant control, Olkowski et al. (1991) recommend the application of a 2.7% boric acid in sucrose water bait. In laboratory and field tests with Pharaoh ants, *Monomorium pharaonis* (L.), Newton (1980) successfully controlled this species with bait formulations of 5 and 7% boric acid. For Pharaoh ant control, Wright and Stout (1978) recommend 2% boric acid in either a liquid or solid bait. In laboratory tests with the Florida carpenter ant, *Camponotus abdominalis floridanus* (Buckley), Klotz and Moss (1996) showed that 0.13–3.13% concentrations of boric acid were effective at killing ants.

The varied efficacy of boric acid ant baits may be the result of the amount of bait ingested by a colony. Because baits with lower percentage of boric acid result in slower mortality (Klotz and Moss 1996), we formulated a 1% boric acid in sucrose water, and tested the effectiveness of a limited versus continuous availability against colonies of urban pest ants under controlled laboratory conditions.

Materials and Methods

Test Insects. Evaluations were conducted with small laboratory colonies reared and maintained as described by Williams (1990) at 49% RH and 25°C at the USDA-ARS Medical and Veterinary Entomology Research Laboratory. All *T. melanocephalum* and Argentine ant colonies were collected in either Orange or Alachua counties, Florida, and were reared in the laboratory for 10–20 mo. For *T. melanocephalum* and Argentine ants each replicate consisted of 7–10 and 3 queens, respectively, 250–300 workers, and 100–500 mm^2 of brood. Pharaoh ant colonies were made from existing colonies maintained in the laboratory for at least 4 yr.

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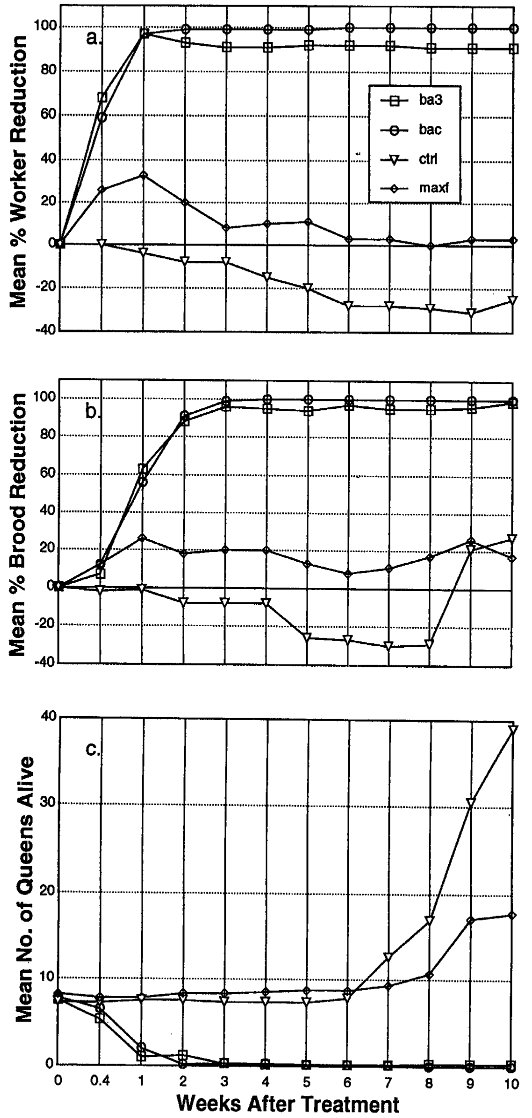

Fig. 1. Mortality (mean) in *T. melanocephalum* (a) workers (b) brood and (c) queens for colonies exposed for 3 d (ba3) or continuously (bac) to a boric acid bait or a hydramethylnon bait (maxf), or a 10% sucrose-water control (ctrl).

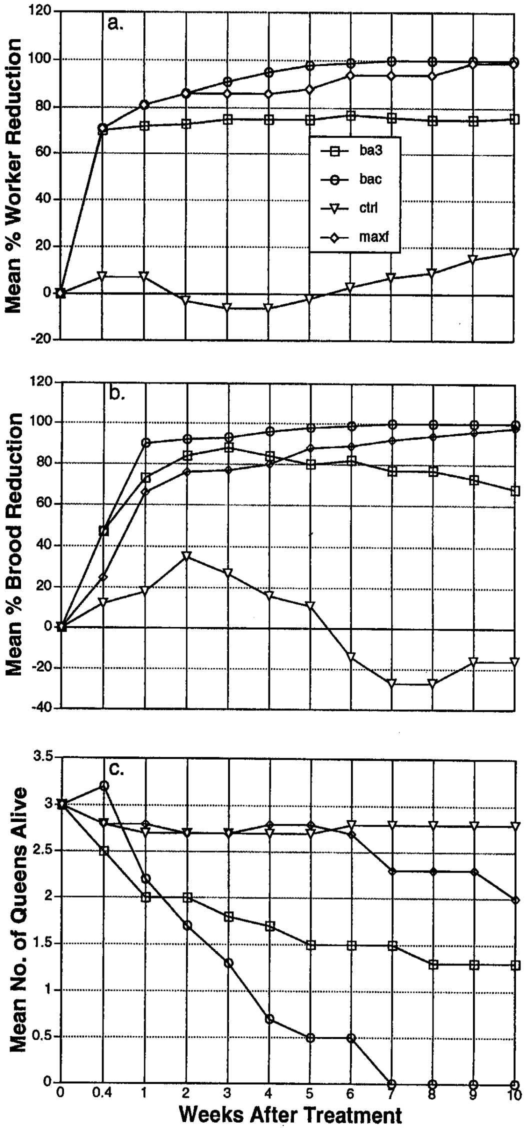

Fig. 2. Mortality (mean) in *L. humile* (a) workers (b) brood and (c) queens for colonies exposed for 3 d (ba3) or continuously (bac) to a boric acid bait or a hydramethylnon bait (maxf), or a 10% sucrose-water control (ctrl).

For Pharaoh ants, each replicate consisted of 3 queens, 0.2 g brood, and ≈500 workers. All colonies were starved for food, but not water, 1 d before bait exposure.

Baits. Crystalline boric acid (99%, Sigma, St. Louis, MO) was dissolved in a 10% (wt:vol) sucrose-deionized water solution to produce a 1% solution. A solid formulation of 0.9% hydramethylnon in silkworm pupae, *Bombyx mori* (L.), (Maxforce Ant Killer Granular Bait, American Cyanamid, Wayne, NJ) was included as a standard because of the numerous ant species on its label.

Baiting Procedure. The boric acid bait solution was force-fed to each colony from a liquid bait dispenser (cotton-plugged, 100-by 16-mm test tube) for 3 d. Colonies were then returned to the regular laboratory diet of crickets and honey-water.

For continuous feeding tests, after the initial 3 d force-feeding, each bait and the regular lab diet remained available for the duration of the test. All colonies were provided water, which was continuously available from a cotton-plugged test tube. For both exposure periods, there were n = 6, 6, and 4 replicate colonies for *T. melanocephalum*, Argentine ants, and Pharaoh ants, respectively. Control colonies (n = 4 or 6) were provided 10% sucrose solution ad libitum.

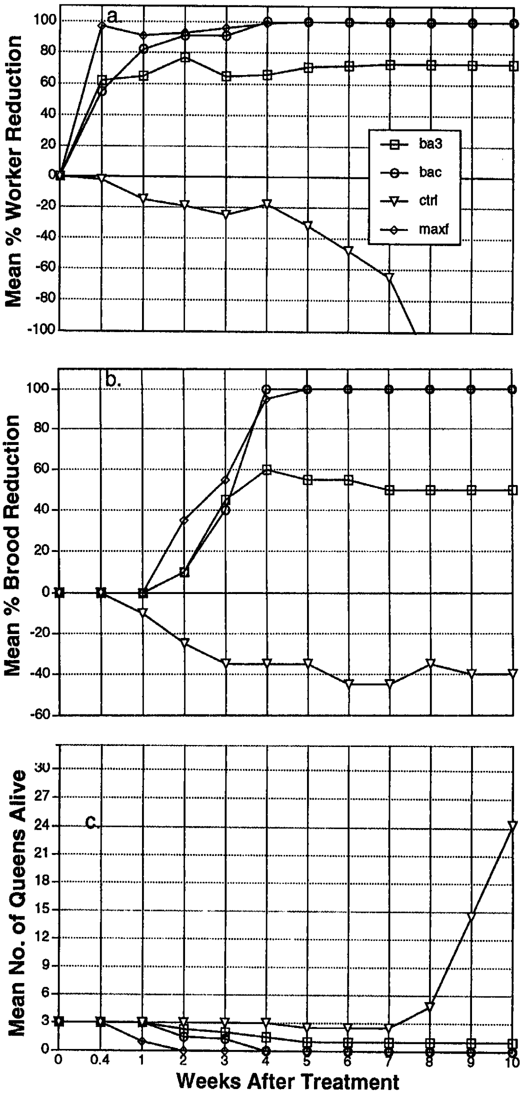

Fig. 3. Mortality (mean) in *M. pharaonis* (a) workers (b) brood and (c) queens for colonies exposed for 3 d (ba3) or continuously (bac) to a boric acid bait or a hydramethylnon bait (maxf), or a 10% sucrose-water control (ctrl).

Responses. Queen number, type and quantity of brood, and estimated worker numbers (Williams and Vail 1993, Vail and Williams 1995) were recorded on day 3 and then weekly for 10 wk or until colony death. For *T. melanocephalum* and Argentine ants, brood quantity was determined by measuring the surface area of a given brood using a 5- by 5-mm grid; for Pharaoh ants, brood quantity was determined by visually comparing a photograph of known quantities of brood with the brood present in a replicate (Vail and Williams 1995).

Statistical Analysis. Data from the colony evaluations were analyzed by analysis of variance and means separated by the Tukey honestly significant difference (HSD) test (SAS Institute 1993).

Results and Discussion

The 3 d and continuous exposure to the 1% boric acid bait were effective in reducing colony size of *T. melanocephalum* (Fig. 1), *L. humile* (Fig. 2), and *M. pharaonis* (Fig. 3). At 10 wk, the 3 main criteria for efficacy (worker mortality, brood reduction, and number of queens) were all significantly different from the control (Tables 1–3). For *T. melanocephalum* colonies (Fig. 1) exposed to boric acid bait continuously or for 3 d, the number of workers was reduced by 97% in the 1st wk and brood reduced by 96% in the 3rd wk. Queens were eliminated by the 8th wk in colonies exposed continuously and by the 12th wk in those colonies which were exposed for 3 d to boric acid bait. A 90% reduction of workers and brood occurred by the third wk in *L. humile* colonies (Fig. 2) exposed continuously to boric acid bait. In colonies exposed for only 3 d, workers and brood were reduced 75 and 88% respectively by the 3rd wk. Queens were eliminated by the 7th wk in colonies exposed continuously, but only reduced in number in those colonies exposed for 3 d. For *M. pharaonis* (Fig. 3) colonies exposed continuously to boric acid bait, a 90% reduction of workers and a 40% reduction of brood occurred by the 3rd wk. In colonies exposed to boric acid bait for 3 d, worker and brood reductions were 73 and 50%, respectively, by the 8th

Table 1. Comparison of mean ± SEM percent reduction of workers, percent reduction of brood, and the number of live queens for *T. melanocephalum* colonies 10 wk after exposure to boric acid and hydramethylnon baits

Bait treatment	*n*	% reduction of workers	% reduction of brood	No. live queens
Boric acid (continued exposure)	6	100a	100a	0a
Boric acid (3 d exposure)	6	91 ± 4a	99 ± 1a	0.3 ± 0.2a
Hydramethylnon	6	3 ± 7b	17 ± 11b	17.8 ± 7.0a,b
Control[a]	6	−25 ± 19b	27 ± 20b	39.0 ± 19.8b
P		0.0001	0.0001	0.0327
df; *F*		3, 15; 37.97	3, 15; 15.65	3, 15; 3.81

Analysis of variance and Tukey HSD analysis performed on mean percentage of worker mortality and brood reduction and number of live queens; Means within columns followed by the same letter are not significantly different ($P < 0.05$, Tukey HSD test [SAS Institute 1993]).

[a] Negative values in control indicate growth of the colony parameter.

Table 2. Comparison of mean ± SEM percent mortality of workers, percent reduction of brood, and the number of live queens for *L. humile* colonies 10 wk after exposure to boric acid and hydramethylnon baits

Bait treatment	*n*	% reduction of workers	% reduction of brood	No. live queens
Boric acid (continued exposure)	6	100a	100a	0a
Boric acid (3 d exposure)	6	76 ± 11a	68 ± 16a	1.3 ± 0.3b
Hydramethylnon	6	99 ± 1a	98 ± 1a	2.0 ± 0.5b,c
Control[a]	6	18 ± 13b	−16 ± 31b	2.8 ± 0.3c
P		0.0001	0.0004	0.0001
df; *F*		3, 15; 19.66	3, 15; 11.16	3, 15; 14.40

Analysis of variance and Tukey HSD analysis performed on mean percentage of worker mortality and brood reduction and number of live queens; Means within columns followed by the same letter are not significantly different ($P < 0.05$, Tukey HSD test [SAS Institute 1993]).

[a] Negative values in the control indicate growth of the colony parameter.

wk. Queens were eliminated by the 4th wk in colonies exposed continuously to boric acid bait but, queens were never eliminated in colonies exposed for 3 d.

The reduction of colony growth for all 3 species after a 3 d exposure to boric acid bait was unexpected, because preliminary tests had indicated that ants might need to feed on boric acid bait >3 d for the cumulative effects of this toxicant to be manifested. However, the 3 d exposure did not allow sufficient time for the elimination of colonies. Based on these laboratory results, boric acid baits need to be available for >3 d to be effective. Continuous feeding on the boric acid bait resulted in elimination of all colonies of the 3 species tested. Continuous feeding on the hydramethylnon bait showed varied results. None of the *T. melanocephalum*, some of the Argentine ant, and all of the Pharaoh ant colonies were eliminated. The variable response of the 3 species to the hydramethylnon bait is probably caused by differences in dietary preference.

At 10 wk for *T. melanocephalum*, the 3 colony parameters were not significantly different between the control colonies and those provided hydramethylnon bait (Table 1). At 10 wk, *L. humile* colonies (Fig. 2) exposed to hydramethylnon bait resulted in reductions of 99 and 98% for workers and brood, respectively. Queens were not eliminated after 10 wk. For *M. pharaonis* colonies (Fig. 3) exposed to hydramethylnon, there was >90% reduction of workers and brood by the 3rd and 4th wk, respectively. Queens were eliminated by the end of the 2nd wk.

The lack of efficacy with hydramethylnon bait may be caused by differences in feeding preferences among these species of ants. For example, a protein-based solid bait, such as Maxforce, might not be as preferred to *T. melanocephalum* as the carbohydrate-based liquid bait. More information is needed on the natural feeding habits of this species which is becoming a more prevalent urban pest ant in Florida (Klotz et al. 1995).

Also, the concentration of hydramethylnon may have deterred feeding. Red imported fire ant colonies subjected to high concentrations (20% [AI]) of hydramethylnon were probably deterred from feeding; lower concentrations (0.1–10% [AI]) caused colony elimination. The colonies returned to normal in the 20% treatment (Williams et al. 1980).

Successful control of *T. melanocephalum* with boric acid-sucrose water bait suggests a direction for future bait development for this species. In the case of Argentine ants, which in some geographic areas (Knight and Rust 1990) are large-scale urban pests, this bait might provide an inexpensive control measure for use in urban or agricultural situ-

Table 3. A comparison of mean ± SEM percent mortality of workers, percent reduction of brood, and the number of live queens for *M. pharaonis* colonies 10 wk after exposure to boric acid and hydramethylnon baits

Bait treatment	*n*	% reduction of workers	% reduction of brood	No. live queens
Boric acid (continued exposure)	4	100a	100a	0a
Boric acid (3 d exposure)	4	73 ± 11a	50 ± 24a	1.0 ± 0.6a
Hydramethylnon	4	100a	100a	0a
Control[a]	4	−218 ± 73b	−40 ± 8b	24.3 ± 8.6b
P		0.0006	0.0001	0.0067
df; *F*		3, 9; 15.92	3, 9; 23.42	3, 9; 7.94

Analysis of variance and Tukey HSD analysis performed on mean percentage of worker mortality and brood reduction and number of live queens; Means within columns followed by the same letter are not significantly different ($P < 0.05$, Tukey HSD test [SAS Institute 1993]).

[a] Negative values in the control indicated growth of the colony parameter.

ations. For Pharaoh ants, in which rapid changes in food preference occur (Edwards and Abraham 1990), boric acid–sucrose water bait may be an alternative to the currently available Pharaoh ant baits like Maxforce.

There are several advantages to boric acid-based water baits. First, they provide moisture and also exploit the natural feeding habits of honeydew-collecting ants. Additionally, Klotz and Moss (1996) noted that there was possible disruption of water regulation by boric acid, causing ants to ingest more of the bait to counterbalance dehydration.

In comparison with boric acid baits used in the past for ant control, this bait has a much lower concentration. The low concentration may enhance long-term ingestion of the bait, thus allowing thorough distribution of the boric acid and subsequent death of the colony. In addition, there is a reduction in pesticide usage, thus lowering the cost for the active ingredient, but more importantly, enhancing the safety of other organisms and minimizing potential negative environmental effects. The next step is to determine whether these results are consistent with bait tests on large colonies both in the laboratory and in the field.

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