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by

J. Kenneth Grace

Department of Entomology
3050 Maile Way, Room 310
University of Hawaii
Honolulu, Hawaii 96822
USA

Abdullah Abdallay and John M. Sisson

Faculty of Forestry
Earth Sciences Centre
University of Toronto
Toronto, Ontario M5S 3B3
Canada

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Preliminary Evaluation of Borate Baits and Dusts for Eastern Subterranean Termite Control

J. Kenneth Grace[1], Abdullah Abdallay[2], and John M. Sisson[2]

ABSTRACT
Borates are of potential use in the development of baiting systems for subterranean termite control. In the 15-day laboratory assays reported here, the oral toxicity of disodium octaborate tetrahydrate to *Reticulitermes flavipes* (Kollar) was evaluated under choice and no-choice conditions. These assays suggest a range of 2500 ppm to 5000 ppm to be applicable in developing baits, and that concentrations greater than 5000 ppm may deter feeding. Laboratory assays with borate dusts (disodium octaborate tetrahydrate, zinc borate, and a fine-grain zinc borate) are also reported. In a toxic variation of mark-release methodology, these materials are passed among the test group by grooming foragers exposed to the dust. In these assays, 10% of the test group was exposed to the borate dust, then released placed in contact with unexposed workers in a simulation of a field release. Zinc borate treatment elicited the greatest mortality (99-100%), although disodium octaborate tetrahydrate also elicited mortality significantly greater than that in the control groups. These results suggest that less soluble borates may be more efficient dust toxicants, and that capture and dust-treatment of a portion of the foraging termite population could elicit high mortality among termites contacting the treated individuals after their release back into the colony.

KEYWORDS: *Reticulitermes*, termite control, borate, disodium octaborate tetrahydrate, zinc borate, Rhinotermitidae, Isoptera

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1 INTRODUCTION

Interest in the development of toxic baits to control subterranean termites (Isoptera: Rhinotermitidae) has continued to increase over the past twenty years since Esenther and Gray (1968) reported successful control of the eastern subterranean termite, *Reticulitermes flavipes* (Kollar), with mirex-impregnated baits. Mark-release-recapture studies with *R. flavipes* (Grace *et al.* 1989) and with the Formosan subterranean termite, *Coptotermes formosanus* Shiraki (Su and Scheffrahn 1988), have demonstrated that colonies of these important pest species forage over areas exceeding 1,000 m^2. Theoretically, therefore, a small number of baits could effectively control termite infestation over a large area. However, suitable nonrepellent and slow-acting alternatives to mirex have proved difficult to identify (French 1988; La Fage 1984).

Borates are slow-acting insecticides of low mammalian toxicity with demonstrated toxicity to wood-boring insects and application in wood preservation (Randall *et al.* 1934; Williams and Amburgey 1987; Barnes *et al.* 1989). Grace (1990) demonstrated that concentrations $\geq$ 20,000 ppm of barium metaborate monohydrate (Busan 11-M1[R]), applied as a slurry to filter papers, elicited high mortality and greatly reduced *R. flavipes* feeding on the treated papers. Concentrations $\leq$ 5,000 ppm did not significantly reduce

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[1]*Correspondence author, current address:* Department of Entomology, 3050 Maile Way, Room 310, University of Hawaii, Honolulu, Hawaii 96822, USA

[2]Faculty of Forestry, Earth Sciences Centre, University of Toronto, Toronto, Ontario M5S 3B3, Canada

termite feeding on the treated papers (in no-choice assays), but resulted in high termite mortality over a 30 day period, suggesting that such concentrations might be appropriate for bait development.

An alternative to the use of a bait-toxicant in termite control is the application of insecticidal dusts, in a toxic variation of mark-release-recapture methodology. Termite foragers collected in traps such as those described by Grace (1989) or Su and Scheffrahn (1986) could be coated with an insecticidal dust and released back into the foraging galleries to poison other colony members through mutual grooming behavior. In a recent symposium paper, French (1989) described the use of arsenic trioxide dust to control *Coptotermes* spp. in buildings. In laboratory assays, Grace and Abdallay (1990) found that coating 5% of the individuals in groups of 40 *R. flavipes* workers with boric acid resulted in 65.8 ± 30.2% mortality (vs. 14.2 ± 3.8% in the control groups) within 16 days.

The present paper describes laboratory evaluation of the oral toxicity of disodium octaborate tetrahydrate to *R. flavipes* in no-choice and two-choice assays, and evaluation of several borate dusts in laboratory assays simulating field conditions.

2 MATERIALS AND METHODS

2.1 Termite collection

Eastern subterranean termites, *R. flavipes*, were collected in traps consisting of plastic pipe (ABS) containing rolled corrugated cardboard (Grace 1989). These traps were buried just below the soil surface at a site in downtown Toronto and a second site in the City of Scarborough. Termite populations at these two sites have been described by Grace *et al.* (1989). Termites collected while feeding on the corrugated cardboard were kept in plastic boxes in unlighted incubators at 27 ± 0.5°C and 90 ± 5% relative humidity. Bioassays using termite workers (undifferentiated individuals older than the third instar, as determined by size) were also performed in these incubators.

2.2 Disodium octaborate tetrahydrate bait evaluation

Both no-choice (force-feeding) and two-choice feeding assays were performed, using methodology similar to that described by Grace (1990). Tim-Bor[R] (US Borax & Chemical Corporation, Anaheim, California),[3] a commercial formulation of disodium octaborate tetrahydrate, was mixed in deionized water and equivalent amounts of the resulting solutions pipetted onto both sides of weighed (oven-dried) 9-cm Whatman No. 1 filter papers to achieve precise deposits by weight. Expressed as the weight of compound on the papers, concentrations of 0 ppm (control), 500, 1000, 2500, 5000, and 10000 ppm were evaluated in the no-choice assays; and 0, 1000, 2500, and 5000 ppm in the two-choice assays.

In the no-choice assays, treated papers were cut into 2 X 6-cm strips (ca. 69-mg), and a single strip placed along one side of a polystyrene vial (44.8-ml, 60 X 35-mm diameter) containing 15-g sand, 3-ml deionized water, and 30 *R. flavipes* workers. Each vial was capped with a polyurethane foam plug and placed in the incubator. After 15 days, termite feeding and mortality were evaluated by counting surviving termites and weighing the oven-dried papers. Papers were brushed free of sand, oven-dried (2 hours, 75°C), placed in

[3]Mention of a company or trade name in this publication is for identification purposes only and does not constitute an endorsement by the University of Toronto or the University of Hawaii, or signify approval of any product to the exclusion of other comparable products.

a desiccator for 1 hour to equilibrate to room temperature, then removed singly and rapidly weighed at a precision of 0.1-mg. Each treatment was repeated with three experimental units (vials) from each of the two colonies, and results subjected to analysis of variance (ANOVA, blocked by colony) and means significantly different at the 0.05 level separated by the Ryan-Einot-Gabriel-Welsch (REGW) Multiple F Test (SAS 1987b).

Two-choice feeding assays were identical to the no-choice assays, except that each borate-treated filter paper strip was paired with an untreated (water only) strip on the opposite side of the same vial. As in the no-choice assays, each treatment was repeated with six experimental units (2 colonies X 3 vials per treatment), and feeding and mortality were evaluated after 15 days. To test for feeding deterrence, weight losses from treated and untreated papers within each treatment were compared (paired comparisons *t* test, $\alpha \leq 0.05$) (SAS 1987a). Percentage mortality among treatments was subjected to ANOVA blocked by colony, and the REGW Multiple F Test, $\alpha \leq 0.05$ (SAS 1987b).

2.2 Borate dust evaluation

A laboratory assay was developed to simulate the introduction of dust-treated termites into collection traps (Grace 1989) leading into subterranean termite galleries in the soil. This was a modification of the three-compartment bioassay apparatus employed by Grace and Abdallay (1990) to evaluate the effects of boric acid and barium metaborate monohydrate dusts on *R. flavipes*. In the modified assay apparatus, three polystyrene vials (44.8-ml, 60 X 35-mm diameter) were connected to each other by 6-cm lengths of tygon tubing. Each vial thus represented one point of an equilateral triangle. Holes were drilled in the sides of each vial, immediately above the base to permit the termites to walk easily in and out of an empty vial, and the tubing held in place by silicone caulking. One vial was left empty, while the other two vials each contained 15-g sand, a 2 X 6-cm strip of Whatman No. 1 filter paper as food, and 3-ml deionized water. Twenty-seven (27) *R. flavipes* workers were placed in each of the two vials containing sand, and allowed to equilibrate for 24 hours in the unlighted incubator. Extensive tunneling during this period insured access from the empty vial through the tubing into the termite galleries within the vials containing sand.

Three borate powders were provided by the US Borax & Chemical Corporation (Anaheim, California): disodium octaborate tetrahydrate (Tim-Bor^{R}), zinc borate (Firebrake ZB^{R}), fine-grain zinc borate (Firebrake ZB-Fine^{R}). Termite workers were placed in a small petri dish containing a thin layer of powder, and the dish shaken once to coat the insect. After one minute, the dish was shaken once more, and the workers transferred by brush to the empty vial in the assay apparatus. Six dust-treated *R. flavipes* workers (10% of the total population of 60 termites in the assay apparatus) were placed in each empty vial. The vials were capped with polyurethane foam plugs, and placed in the incubator for 15 days. Termites used in control assays were treated similarly, but without powder.

Six 15-day assays (each with 60 termites - 54 untreated and 6 treated) were conducted with each treatment, using workers collected from the Toronto site. Percentage mortality was subjected to analysis of variance (ANOVA), and means significantly different at the 0.05 level separated by the REGW Multiple F Test (SAS 1987b).

3. RESULTS AND DISCUSSION

3.1 Bait toxicity and feeding deterrence

Concentrations of disodium octaborate tetrahydrate greater than 2500 ppm were necessary to elicit significant mortality during the 15-day assay period. In the no-choice assays, high mortality among the control groups due to problems in maintaining high humidity throughout the incubator interfered with the mortality analysis (Table 1). However, 100% *R. flavipes* mortality resulted from feeding on papers impregnated with 10000 ppm. In the two-choice assays, with high humidity maintained throughout the incubator, feeding on 2500 and 5000 ppm elicited significant termite mortality (Table 2). In these latter assays, there were no significant differences at the 0.05 level in feeding on borate-treated and untreated papers. However, the p-value of 0.094 (paired-comparisons t test) obtained in comparing feeding on treated and untreated papers at 5000 ppm and the significant reduction in feeding noted on papers impregnated with 5000 and 10000 ppm in the no-choice assays suggest that feeding deterrence may occur with concentrations of disodium octaborate tetrahydrate greater than 5000 ppm. Termite avoidance of cellulosic baits containing more than 5000 ppm disodium octaborate tetrahydrate is also indicated in field studies with *Heterotermes aureus* (Snyder) (S.C. Jones, personal communication).

Grace (1990) determined that concentrations $\leq$ 5000 ppm of barium metaborate monohydrate were appropriate for bait development, with 1500 ppm eliciting 100% mortality within 30 days. The present results suggest the applicability of similar concentrations of disodium octaborate tetrahydrate, with the optimum concentration falling between 2500 and 5000 ppm.

3.2 Mortality following dust exposure

Treatment of 10% of the *R. flavipes* test population with each borate dust resulted in mortality significantly greater than that of the control groups by the end of the 15-day assay interval (Table 3). Treatment with zinc borate elicited greater mortality than treatment with disodium octaborate tetrahydrate, despite the reduced solubility and lower boron content of zinc borate. Grace and Abdallay (1990) found that exposure to zinc borate and disodium tetraborate decahydrate dusts elicited equivalent mortality in exposed *R. flavipes* workers. It is possible that low solubility of the compound may be advantageous in passing the toxicant to unexposed workers through mutual grooming behavior, since less would be leached from the insect's cuticle into the damp sand. Mortality from exposure to the uniform small particles (mean size = 3 microns) of Firebrake ZB-Fine^{R} was equivalent to that resulting from exposure to the coarser Firebrake ZB^{R} (size range = 2-10 microns).

4 CONCLUSIONS

Borates are potentially useful in baiting systems to control subterranean termites, both as oral bait toxicants and as dust treatments. Our results indicate that concentrations of disodium octaborate tetrahydrate greater than 5000 ppm may deter feeding by *R. flavipes*, and studies by other researchers suggest similar effects on other subterranean termite species. Therefore, concentrations $\leq$ 5000 ppm appear appropriate in bait development, unless feeding stimulants or other masking agents are used to enhance bait acceptance.

Table 1. Mean (± SE) weight loss (from feeding) of filter papers treated with disodium octaborate tetrahydrate and percentage mortality of *Reticulitermes flavipes* workers in 15-day no-choice laboratory assays.[1]

Concentration (ppm)	Paper weight loss (mg)	Percent Mortality
10,000 ppm	4.39 ± 1.44a	100.00 ± 0a
5,000	8.95 ± 2.51a	70.00 ± 12.47ab
2,500	17.00 ± 1.90b	47.78 ± 12.58b
1,000	16.99 ± 0.78b	68.50 ± 11.33ab
500	19.04 ± 1.41b	41.11 ± 6.19b
0	17.47 ± 1.16b	56.67 ± 14.50ab

[1]N = 6 (2 colonies X 3 vials per treatment). Each vial contained a single treated strip of Whatman No. 1 filter paper placed in damp sand, and 30 *R. flavipes* workers. Means in each column followed by the same letter are not significantly different (ANOVA blocked by colony, Ryan-Einot-Gabriel-Welsch Multiple F Test, $\alpha \leq 0.05$) (SAS 1987b).

Table 2. Mean (± SE) weight loss of paired disodium octaborate tetrahydrate treated and untreated filter paper strips, and percentage mortality of *Reticulitermes flavipes* workers in 15-day two-choice laboratory assays.[1]

Concentration (ppm)	Paper Weight Losses (mg)[2]		Percent Mortality[3]
	Treated	Untreated	
5,000 ppm	4.54 ± 1.21	8.82 ± 3.68	46.67 ± 5.90a
2,500	10.09 ± 2.72	6.76 ± 2.51	36.11 ± 4.34ab
1,000	7.11 ± 1.88	12.97 ± 2.91	27.22 ± 3.15b
0	7.47 ± 2.25	13.35 ± 2.89	23.89 ± 4.42b

[1]N = 6 (2 colonies X 3 vials per treatment). Each vial contained a treated and an untreated filter paper strip (0 ppm = water only) placed in damp sand, and 30 *R. flavipes* workers.

[2]Within each treatment, there were no significant differences in feeding on treated and untreated papers (paired comparisons *t* test, $\alpha \leq 0.05$) (SAS 1987a), although at 5,000 ppm $P = 0.094$.

[3]Means followed by the same letter are not significantly different (ANOVA blocked by colony, Ryan-Einot-Gabriel-Welsch Multiple F Test, $\alpha \leq 0.05$) (SAS 1987b).

Table 3. Mortality in groups of 60 *Reticulitermes flavipes* workers 15 days after treatment of 10% of each group with borate dusts.

Compound	Percent Mortality[1]
Zinc borate (Firebrake ZB[R])	100.00 ± 0.00 a
Fine-grain zinc borate (Firebrake ZB-Fine[R])	99.45 ± 0.56 a
Disodium octaborate tetrahydrate (Tim-Bor[R])	68.89 ± 6.16 b
Control	25.28 ± 2.33 c

[1]Mean (±SE) of 6 groups of 60 workers, in 3-compartment bioassays (see text). Means followed by the same letter are not significantly different (ANOVA, REGW Multiple F Test, $\alpha \leq 0.05$).

Although probably more labor intensive than the use of oral bait toxicants, treatment of termite foragers with borate dusts may also provide effective control. Multiple collection traps at a particular site or multiple capture and release cycles could be employed to treat a large proportion of the foraging population. Our successful laboratory results with zinc borate suggest that the less soluble borates may be more efficient dust toxicants.

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