BARRIER EFFICACY of ORGANOPHOSPHATE, PYRETHROID, PHENYLPYRAZOL, and CHLORONICOTINYL FORMULATIONS against *HETEROTERMES AUREUS* (ISOPTERA: RHINOTERMITIDAE)

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Abstract A modified test-tube bioassay was developed for *Heterotermes aureus* using Arizona soil samples from covered and exposed weathered termiticide plots. An organophosphate, a pyrethroid, a phenylpyrazol, and a nicotinoid were evaluated at 4 hours and 12 months post-application. Termites were placed in bioassays and checked after 7 days for survival and soil penetration. Bioassays conducted at 12 months showed statistical differences ($P<0.05$) among termiticides tested in terms of survival and penetration.

Key Words Termiticides bioassay weathered soil

INTRODUCTION

Application of liquid termiticides continues to be a primary tool in the prevention of termite structural invasions. Chemical stability of termiticides in soil is required for long-term protection. Evaluation of residual toxicity and termiticide degradation has been reported from Florida to Hawaii by Su and Scheffrahn (1990), Gold et al. (1996), and Grace et al. (1993). The testing of termiticide efficacy is on-going, because termiticides respond differently in different regions, and under different physical and environmental conditions. In Arizona the use of Aggregate Base Course (ABC) in construction fill is increasing. This gravel and rock mixture contains low organic matter and is used to establish a solid base for concrete foundation slabs. Termiticide availability under these conditions has never been reported. Therefore, candidate termiticides need to be continually evaluated not only for residuals but their bioavailability to prevent termites from penetrating treated soil.

The U.S. Environmental Protection Agency (USEPA) has delegated to USDA Forest Service the responsibility to evaluate termiticide effectiveness. Evaluations are made with ground board or concrete slab tests, as described by Kard et al. (1989). Based on these tests, a termiticide concentration fails when >5 of the 10 replications have been breached by subterranean termites (Kard et al., 1989). The goal is 5 years of protection of the pinewood exposed to treated soil. If protection is maintained for 5 years, the registration process can move forward. However, it has become more apparent that a lack of termite penetration in the treated soil can not always be attributed to the effectiveness of the termiticide, due to the possibility that termite foraging is random. This characteristic has been demonstrated by Su et al. (1999) for the Formosan subterranean termite *Coptotermes formosana* Shiraki, and by Delaphane and La Fage (1989) for the eastern subterranean termite *Reticultermes flavipes* (Kollar). The desert subterranean termite *Heterotermes aureus* (Snyder) probably has a similar foraging pattern. Bioassays were designed to evaluate tunneling of this species into insecticide-treated soil under concrete and exposed ground board (Su et al., 1993; Tamashiro et al.,1987; Baker, 2001).

In this study, we selected 4 classes of termiticides and applied them at labeled rates following standard pre-construction procedures to exposed or covered small concrete slabs. A bioassay was used to evaluate the barrier efficacy of the treated soils against *H. aureus.*

MATERIALS and METHODS

Insecticides

Termiticides tested were: Premise 2 (imidacloprid, 0.1%: Bayer, Kansas City, Mo.); Talstar T/I (bifenthrin 0.12%, FMC Corporation, Princeton, N.J.), Talstar T/I (bifenthrin 0.12% plus cellulose, FMC Corporation, Princeton, N.J.), Termidor 80WG (fipronil 0.125%, Aventis Environmental Sciences, Inc., Montvale, N.J.), Termiticide DSB-1 formulation (Arizona Chemical Group, Inc., Mesa, Ariz.), and Termiticide DSB-2 formulation (Arizona Chemical Group, Inc., Mesa, Ariz.). Premise, Talstar, and Termidor are commercially registered termiticides. Termiticide DSB-1 and DSB-2 are currently being registered as a termiticide. Termiticide DSB-1 and DSB-2 are organophosphates, bifenthrin is a pyrethroid, fipronil is a phenyl pyrazole, and imidacloprid is a chloronicotinyl.

Termiticide solutions were prepared following label instructions and applied as previously described degradation studies (Baker, 2001). Native soil composition was: 71.6% sand, 25.8% silt, 2.6% clay, 1.8% gravel, and 8.1 pH. It was excavated from each 0.46 m by 0.46 m by 0.3 m plot, and replaced with white construction sand. Either native soil or Aggregate Base Course (ABC) fill was refilled in each plot. The composition of ABC fill is: 84.6% sand, 14.1% silt, 1.4% clay, 27.3% gravel, and 7.89 pH. The course fill consists of 79.4% sand, 15.1% silt, 5.5% clay, 62.4% gravel, and 8.0 pH. In order to sample these plots, all ABC fill was passed through a 1.3 cm screen because it can contain upward of 35% by volume of 2.54 cm rocks and above. Exposed 0.46 m by 0.46 m plots had pine-wood frames (2.5 cm by 10 cm by 1.25 cm) placed at ground level. Covered concrete slabs had pine-wood frames (2.5 cm by 10 cm by 2.5 cm) placed on the ground at each plot.

Insecticide applications were made using a stainless steel 18.5 l watering can. Rates were at the industry standards of 1 gallon / 10 sq ft (852 ml / 0.47 m) for all native soils and 1.5 gallons / 10 sq ft (1.23l / 0.47 m) for the ABC fill. In all cases they were applied as pre-treatment to the native soil and ABC fill. After plots were treated, concrete was applied. The plots were protected from direct sun with cover. Covers were constructed of 1.25 cm plywood cut to 0.6 m by 0.6 m. Approximately 20.3 cm from the corners, four hole were drilled to enable 15.2 cm bolts to be placed through the holes and fastened with 0.6 cm nuts. Once the bolts were in place, 5 cm plastic spacers were bolted to the covers with a 1.3 cm washer and nut. To increase the holding in the concrete, construction wire was woven about the 4 posts in the shape of a figure 8.

Test Site

Tucson averages more than 360 days per year of sun, with soil temperatures in the summer in excess of 60ºC, and the day temperatures exceeded 37ºC seventy-five times. During the 12-month testing period, there was 3.9 cm of rain near the plots.

Sampling

Soil samples were taken at 4 and 12 months post-treatment by using a 2.54 cm by 19 cm stainless steel core sampler to a depth of approximately 5 cm. Samples were either directly taken in the exposed plots or by gently tilting the covered mini-slab to one side. Attempts to maintain the soil profile integrity failed in all the samples, primarily because the soil was dry; thus samples were composite. After samples were taken, white construction sand was used to fill the hole, and covered slabs were repositioned over the plot. Two soil samples were taken, composited, and split between residue testing and bioassay. All samples were held in their plastic sleeves or plastic bags and frozen at 0°C until shipped for analysis or used in the bioassay.

Bioassay

A bioassay procedure similar to that described by Su et al. (1993) and modified by Baker (2001) was used to test the barrier efficacy against *H. aureus*. At 24 hours prior to the bioassay screening, soil samples were removed from the freezer and left to air dry. All soil samples were packed into 15 cm by 15 mm glass tubes to a depth of 5 cm. Agar plugs (0.5 cm) were sandwiched above and below each sample. Located below and in contact with the soil sample were 3.5 cm by 5.5 cm rolled cardboard and a sliver of wood to provide food and harborage for the termites. A plastic cap was forced over the bottom to prevent termites from escaping and to hold the sample in place.

Twenty-three undifferentiated workers and 2 soldiers were placed into the top of each glass tube. All termites used in this study were field collected and held in complete darkness at 29°C and 90% RH for less than 3 months. For the initial bioassay there were 3 replicates, but in the 12-month test, there were 3 separate bioassays of each sample for a total of 9 replicates, in an attempt to evaluate the bioassay method. All test units were held vertically at 29°C and 90% RH for 7 days. Attempts were made to hold the imidacloprid samples for 14 days but survival in the checks was low.

Data Analysis

Significant differences ($P<0.05$) among means in percentage survival and centimeters of penetration were separated by Duncan's multiple range test (SAS Institute, 2000).

RESULTS and DISCUSSION

Soil Samples 4 Hours Post-Termiticide Application

Mean distance penetrated in treated soils by termites and mean percent survival is summarized in Table 1. All treatments, except bifenthrin plus cellulose, had no survival or penetration. None of the 3 soil substrate had any influence on survival or penetration at least initially.

Soil Samples 12 Months Post-Termiticide Application

One year after application all the treatments — except fipronil, bifenthrin, and bifenthrin plus cellulose — had increased survival and penetration (Table 2). Exposed plots in general had greater survival and the most penetration due in part to exposure to environmental elements, particularly sun and heat.

Penetration was nearly complete with imidacloprid and the DSB compounds 1 and 2, implying significant degradation and the inability to provide protection. This is in disagreement with USDA trials in Arizona in which most of the non-repellent termiticides had not failed to provide protection after 12 months (Kard, 1999). Native covered plots had the lowest survival and penetration. Fipronil and bifenthrin plus cellulose had the lowest survival and almost no penetration of the treated soil over all three soil types. Covered ABC fill gave mixed results with some products, imidacloprid and DSB-1 plus having greater survival than the untreated soil. In part, this result could be attributed to the 27% gravel in which the termiticides had no adsorption capacity. However, bifenthrin, fipronil, and bifenthrin plus had no penetration and a small percentage survival**.**

Imidacloprid performance was best under native soils both in mortality and distance penetrated. It would appear based on time of application; in August during our most intense rainy period (July-September) the exposed imidacloprid plots could have leached. Felsot et al. (2000) reported non-termiticide residues of imidacloprid 90 cm deep. The pyrethroid bifenthrin treat-

Table 1. Vertical distance of termiticide-treated soil penetrated by *H. aureus* and the associated mortality after 7-day laboratory bioassay in which termites were exposed to a 5 cm core sample 4 h post treatment

		Exposed 4 Hours				Covered Native 4 Hours				Covered ABC Fill 4 Hours			
Treatment	Rate	X % Surv.	SE	X Pen.(cm)	SE	X % Surv.	SE	X Pen. (cm)	SE	X % Surv.	SE	X Pen.(cm)	SE
Check	0	70.6	7.6 a	5	0 a	70.6	9.5 a	5	0 a	62.6	10.3 a	5 a	0
Talstar Plus	0.12	17.3	11.3 b	0	0 b	8	7.9 b	0	0 b	0	0 b	0 b	0
Talstar	0.12	0	0 c	0	0 b	0	0 b	0	0 b	0	0 b	0 b	0
DSB-1	0.25	0	0 c	0	0 b	0	0 b	0	0 b	0	0 b	0 b	0
DSB-2	0.5	0	0 c	0	0 b	0	0 b	0	0 b	0	0 b	0 b	0
Premise	0.1	0	0 c	0	0 b	0	0 b	0	0 b	8	7.9 b	0 b	0
Termidor	0.125	0	0 c	0	0 b	0	0 b	0	0 b	0	0 b	0 b	0

Values are means of 3 reps/treatment. Means followed by the same letter within a column are not significantly different (P <. 05; Duncan's Multiple Range Test (SAS Institute 2000).

Table 2. Vertical distance of termiticide-treated soil penetrated by *H. aureus* and the associated mortality after 7-day laboratory bioassay in which termites were exposed to a 5 cm core sample 12 months post treatment

		Exposed 12 Months				Covered Native 12 Months				Covered ABC Fill 12 Months			
Treatment	Rate	X % Surv.	SE	X Pen.(cm)	SE	X % Surv.	SE	X Pen.(cm)	SE	X % Surv.	SE	X Pen.(cm)	SE
Check	0	64.4	10.8 a	5	0 a	59.1	7.9 a	5	0 a	60	10.5 a	4.4	0.6 a
Premise	0.1	55.1	8.2 abc	3.6	0.5 ab	20.9	10.5 bc	0.4	0.3 cd	76.4	4.6 a	3.9	0.7 ab
DSB-2	0.5	44.4	11.8 abc	3.3	0.8 ab	9.3	9.3 c	0.7	0.5 cd	38.9	10.5 b	2.9	0.8 bc
DSB-1	0.25	30.6	14 cd	3.7	0.7 ab	9.3	7.5 c	1.9	0.8 bc	75.6	6.3 a	4.7	0.3 a
Talstar	0.12	17.8	10.3 cd	0.5	0.4 c	24	10.4 bc	0.4	0.5 cd	3.6	3.6 c	0	0 d
Talstar Plus	0.12	12	6.9 d	0.4	0.3 c	12.9	9.2 c	1.2	0.6 cd	2.7	1.8	c 0	0 d
Termidor	0.125	0.4	0.4 d	0.7	0.5 c	6.1	6.1 c	0	0 d	0	0 c	0	0 d

Values are means of 9 reps/treatment. Means followed by the same letter within a column are not significantly different (P<. 05; Duncan' Multiple Range Test (SAS Institute 2000).

Proceedings of the 4th International Conference on Urban Pests.
Susan C. Jones, Jing Zhai, and Wm H. Robinson editors. (2002)

ments, with and without the cellulose, were consistent across treatments. Baskaran et al. (1999) reported that bifenthrin was more stable, at least initially, than chloropyrifos. Fipronil continued to limit survival and low penetration from the initial 4 hours. Ramesh and Balasubramanian (1999) reported fipronil appeared more susceptible to hydrolysis than other organophosphate compounds such as chloropyrifos; however, after 12 months fipronil still has bioavailability.

In conclusion, it appears that some of the selected termiticides are breaking at year 1, with soil influencing the termiticide's ability to maintain the barrier. More information will be forthcoming in the next few years.

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Proceedings of the 4th International Conference on Urban Pests.
Susan C. Jones, Jing Zhai, and Wm H. Robinson editors. (2002)