

EFFICACY OF SELECTED LOCALIZED INJECTABLE CHEMICAL TREATMENTS AGAINST *CRYPTOTERMES BREVIS* (ISOPTERA: KALOTERMITIDAE) IN NATURALLY INFESTED LUMBER

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Abstract A number of previous studies have reported superior levels of efficacy for slow-acting, non-repellent toxicants in laboratory simulations against drywood termites, but very little research has been conducted in naturally infested wood. We utilized boards naturally infested with *Cryptotermes brevis* (Walker), extracted from hardwood shipping pallets. We sought to compare the efficacy of various experimental treatments: untreated (nothing), solvent control (distilled water), 0.05% imidacloprid suspension concentrate (Premise 0.5 SC), 0.05% imidacloprid water soluble packets (Premise 75), 15% disodium octaborate tetrahydrate (DOT, Tim-Bor 98 SP), and 0.05% spinosad SC (Tracer). These treatments were randomly assigned to boards within size class blocks and two duration blocks, 28 and 56 days. Injections were limited to a single point on each board, which had the highest degree of visible drywood termite activity. Upon breakdown, boards were first cut into sections and split apart to extract termites. The numbers of living and dead termites extracted from individual sections were summed over boards and percent dead was calculated; treatment effects were analyzed with an ANOVA model. There was no effect of post-treatment duration, board-size, or the injection quantity on percent dead. Pooled mean (n=12) percent dead ranged from 17.1 % for Premise 0.5 SC to 60.2% for DOT, among the chemical treatments, while the water and non-treatment controls produced 32.4% and 4.5% dead, respectively. There were overall significant treatment effects. While individual mean comparisons indicated that DOT was significantly different from the untreated control, the remaining treatments were intermediate in their effects. None of the toxicants was significantly different from the solvent (water) control. Although the experimental conditions were highly constrained, the results demonstrate that spot-treatment is a hit-or-miss proposition. Interestingly, there was a relatively high degree of mortality (mean = 32% dead) resulting from the injection of water alone; a phenomenon known as “water poisoning” that may indicate that highly desiccation-tolerant species cannot tolerate emersion in liquid water, as has been observed by other authors.

Key Words *Cryptotermes brevis*, localized treatments, drywood termite

INTRODUCTION

Damage due to drywood termites is often overshadowed by that of subterranean termites, especially in Hawaii. However, throughout the tropics and subtropics, drywood termites are actually far more common in structures than subterranean termites (Rust et al., 1998; Scheffrahn et al., 1988). The ubiquitous nature of these structural pests dictates the need for safe and effective alternatives to whole-structure fumigation, currently the most common form of drywood termite treatment in Hawaii. Various localized treatments have been investigated (Lewis and Haverty, 1996), but injectible chemical treatments remain the most practical and economically feasible.

Localized treatments, because they treat only the infested portion of the structure, are dependent on clearly defining the infestation to ensure complete efficacy. Typically, drywood termite infestations are defined by a visual assessment (inspection) of the structure. However, such inspections are complicated by the fact that drywood termites are cryptic and do not necessarily leave visual clues. Additionally, even if it were possible to define an infestation, not all areas of a structure are accessible to localized treatments. Thus, long-term control of drywood termites using locally injected insecticides is dependent on whether those drywood termites not immediately affected by the treatment, will be impacted by the residual activity of the pesticide. Scheffrahn et al. (1997) showed that drywood termites would forage from untreated areas into areas treated with a slow acting and nonrepellent toxicant (spinosad), at least in an artificial gallery system, and hypothesized that spinosad residues might actually enhance foraging through the treated area. Ferster et al. (2001) further showed that nymphs transferred the material between nest mates leading to mortality of non-foraging termites.

Scheffrahn et al. (1997) also evaluated the long-term efficacy of localized injections of spinosad in comparison to that of various conventional fast-acting toxicants against drywood termites, *Cryptotermes brevis* (Walker) and *Incisitermes snyderi* (Light), in both lab simulations and under field conditions. Mortality data in the lab indicated significant mortality with spinosad suspension concentrate (SC) while disodium octaborate tetrahydrate (DOT) (dust and 10% aqueous), calcium arsenate (35% dust), and chlorpyrifos (aerosol) resulted in only marginal levels of mortality. Field studies based on detection of acoustic emissions (AE) (Scheffrahn et al., 1993) also indicated that spinosad SC was the only material tested that resulted in significant long-term reductions in acoustic evidence (Scheffrahn et al., 1997).

Imidacloprid (Premise) is a relatively slow-acting toxicant that has been investigated extensively for use against subterranean termites (Thorn and Breisch, 2001; Kard, 1998), but has not been widely investigated for use against drywood termites. Scheffrahn et al. (2001) recently studied the efficacy of imidacloprid for the prevention of colony formation of *C. brevis* and found that it prevented colony establishment, although not as consistently as DOT or silica dusts.

The goal of the study described here was to evaluate the efficacy of imidacloprid in comparison to spinosad and DOT in wood naturally infested by *C. brevis*. We also sought to limit the insecticide applications in order to simulate a scenario of limited access to the infestation; i.e., only treating a portion of the infested area in the naturally infested wood. We chose to evaluate mortality over a relatively short duration (28, 56 days), as in previous work (Scheffrahn et al., 1997, 1998). We utilized naturally infested shipping pallets because they were representative of structural infestations, but could be destroyed at the end of the trial (unlike structures) and termite mortality directly assessed.

MATERIALS AND METHODS

Infested hardwood shipping pallets were selected from a pool of infested pallets from a warehouse at the Pearl Harbor Naval Base, Honolulu, HI. Pallets were preselected based on the presence of fecal pellets, kick-out holes (holes from which fecal pellets were expelled) and living termites. The pallets were cut into individual boards and then sorted according to the level of infestation and dimension (nominal 1 x 4 in (2 x 8.9 cm), 2 x 4 in (3.8 x 8.9 cm), 1 x 6 in (2 x 14 cm), or remaining odd sizes). Boards without evidence of infestation were discarded, and the areas of highest activity were identified on each of the remaining boards. Boards were assigned to blocks based on size class (1 x 4 in, 2 x 4 in, 1 x 6 in).

Six treatments were included: untreated (blank control), solvent control (distilled water), 0.05% imidacloprid suspension concentrate (Premise 0.5 SC, Bayer Corporation, Kansas City, MO), 0.05% imidacloprid water soluble packets (Premise 75, Bayer Corporation, Kansas City, MO), 15% disodium octaborate tetrahydrate (DOT) (Tim-bor 98 SP, Nisus Corporation, Rockford, TN), and 0.05% spinosad suspension concentrate (Tracer, Dow Agrosciences, Indianapolis, IN). All insecticides were supplied by Bayer Corporation (Kansas City, MO). Treatments were randomly assigned to the boards within size class blocks and two duration blocks, 28 and 56 days. There were 2 replicates per treatment for each board size class and test duration block, with 72 total boards in the study, ranging in length from 102 to 122 cm. Treatment injections were made at the single point of highest termite activity on each board, either directly in kick-out holes or via holes drilled with a 3/32 in (2.3 mm) drill bit. Pre-assigned materials were injected into galleries using a 50-ml glass syringe tipped with a 18.5 gauge x 5 cm hypodermic needle affixed with a small rubber stopper to prevent back-flow. The materials were injected until failure or until 30 ml had been reached.

After the predetermined duration (28 or 56 days), the boards were cut into 10 – 12 inch sections using a band saw, and these individual pieces were split apart to extract termite. Numbers of both living and dead termites were counted. The numbers of dead and living termites extracted from individual sections were summed over boards and percent dead was calculated as dead termites divided by the numbers of living plus dead termites, which was then transformed using the arcsine-square root transformation prior to statistical analysis. The nuisance variable board-size was first analyzed followed by duration and treatment effects using an ANOVA model (Proc GLM, SAS Institute 1997). Given a significant model at $\alpha = 0.05$, individual treatment effects were resolved using Tukey-Kramer mean comparisons (SAS Institute, 1997) in order to test the hypotheses that the active ingredients had a significantly greater effect on percent dead than control treatments and that more mortality would be found at 56 days than at 28 days.

RESULTS AND DISCUSSION

Upon breakdown of the study boards, a total of 8442 living and 3375 dead termites were collected. The living termites consisted of 8044 nymphs, 254 soldiers, and 144 reproductives; while the dead termites included 3277, 71, and 27, nymphs, soldiers and reproductives, respectively. Thirteen of the boards did not contain any termites, living or dead at the termination of the trial. Total living and dead termites collected per board ranged from 1 to 1129, with an average of 207.3 per board (standard error of the mean = 32.5). Analysis of block effects revealed that there was no significant effect of the board-size blocks on percent mortality or the numbers of living and dead termites; further ANOVA analyses revealed no significance of the amount of material (solution quantity) injected.

It was initially hypothesized that these nonrepellent insecticides would have successively greater mortality between the 28 and 56 days post-treatment durations. A summary of percent dead by post-treatment duration length is presented in Table 1. There was no significant effect of the post-treatment duration on percent dead ($F = 1.66$; 5, 23 d.f.; $P = 0.1855$). Scheffrahn et al. (1997) observed that termite acoustic emissions (AE) activity in structures treated with spinosad gradually decreased over an 8-month period following treatment. These authors were evaluating structural infestations which could extend over larger areas; whereas we were studying single boards which had been removed from previously infested shipping pallets. The lack of difference between our two time durations is probably due to most mortality occurring prior to the first month, as observed in the laboratory simulations of Scheffrahn et al. (1997) and the naturally infested wood studied by Scheffrahn et al. (1998).

Table 1. Percentage mortality by test duration of all castes of *Cryptotermes brevis* from injections of insecticides.

Treatment	Mean \pm Standard Error ¹	
	28 days	56 days
non-treated control	4.8 \pm 3.7	4.0 \pm 3.4
water	51.0 \pm 26.2	19.9 \pm 16.1
imidacloprid SC ²	30.5 \pm 29.0	3.7 \pm 2.3
imidacloprid WSP ³	32.8 \pm 16.3	40.3 \pm 19.3
DOT ⁴	62.7 \pm 13.5	58.3 \pm 16.3
spinosad SC ⁵	39.8 \pm 13.2	50.9 \pm 21.1

¹Mean and standard error of 6 treated boards;

²Premise 0.5 SC, 0.05% solution;

³Premise 75 water soluble packet, 0.05% solution;

⁴Disodium octaborate tetrahydrate, Tim-bor, 15% solution;

⁵Tracer, 0.05% solution

After pooling durations for the sample boards, there were overall significant treatment effects ($F = 3.0$, 5, 52 d.f., $P = 0.0186$). In pair-wise comparisons, a single treatment, DOT, produced a level of mortality significantly greater than the untreated control, while the remaining treatments were intermediate in their effects (Table 2). DOT had the highest level of percent dead at 60.2%, with spinosad SC producing 44.2% dead. Percent dead levels ranged from 17.1%, for the suspension concentrate to 36.5% water soluble packet formulations of imidacloprid, which were both intermediate in the effects, not significantly different from either DOT or the non-treatment controls.

Table 2. Pooled total living, dead and percent dead of all castes of *Cryptotermes brevis* from injections of insecticides after 28 and 56 days.

Treatment	Mean \pm Standard Error ¹		
	Living termite	Dead Termites	Percentage dead ²
untreated	165.8 \pm 53.4	23.3 \pm 15.2	4.5 \pm 2.4B
water	160.3 \pm 83.6	51.8 \pm 30.2	32.3 \pm 14.3AB
imidacloprid sc	103.1 \pm 54.5	67.3 \pm 63.7	17.1 \pm 14.3AB
imidacloprid wsp	114.7 \pm 44.4	13.1 \pm 4.7	36.5 \pm 12.1AB
DOT	39.8 \pm 13.8	56.3 \pm 24.2	60.2 \pm 10.2 A
spinosad sc	119.9 \pm 54.2	69.5 \pm 38.9	44.2 \pm 10.9AB

¹Mean and standard error of 12 treated boards

²Grouped by letters according to Tukey-Kramer mean comparisons (SAS Institute 1997).

Scheffrahn et al. (1997, 1998) found that spinosad had the highest degree of mortality in both laboratory and field evaluations, with DOT only having minor insignificant effects. In our study none of toxicant treatments was truly outstanding, although it must be noted that we applied an 0.05% spinosad solution, in contrast to the 0.5% solution used by Sheffrahn et al. (1997, 1998).

It appears that the main difficulty with treating a small portion of an infestation is that it is a hit-or-miss proposition. Within a single board there can be many incipient colonies, and it is difficult if not impossible to treat all of them when a limited number of injections are made. Evidence of this is the high variance (SEM) apparent in the results presented in Tables 1 and 2. Percent dead per board ranged from 0-88.5% for imidacloprid SC, 0.72 to 100% for imidacloprid WSP, 0-95.7% for DOT, and 0-100% for spinosad SC. The high variances and wide ranges indicate that some areas in the boards were treated, while others that also contained termites were not. Scheffrahn et al. (1998), although observing consistently high rates of mortality in their field simulations with *C. brevis*, commented that in those samples where there was a lack of efficacy injections had been made into inactive galleries. This factor alone may be responsible for the limited efficacy of imidacloprid and other localized treatments in naturally infested wood, when the number of injection points is highly constrained.

Interestingly, there was a high mean percentage dead (32%) resulted from the injection of water in some boards. This phenomenon was termed "water poisoning" by Steward (1982), and may indicate that there are simply too few escape routes for termites when galleries in an isolated board are flooded with any liquid. In similar studies utilizing water as a solvent control (unpublished data), we did not observe the same degree of mortality from water. However, a key difference between the present study and our unpublished study is the size of the study sample. In the unpublished work, we utilized entire hardwood shipping pallets as structural microcosms, as compared to treating single isolated boards. Upon breaking down the pallets, we observed numerous connections between sections and boards. Thus, the toxicity evident with water alone in the present study could be the result of an absence of these natural escape routes.

CONCLUSION

The limited efficacy that we observed with all toxicants tested may have largely resulted from constraining the number of injection points; i.e., we probably could have achieved more significant and consistent results with numerous injections along the width and length of each board. However the purpose of this study was to evaluate these materials under less-than-ideal (real world) conditions. In a recent review of drywood termite management, Lewis (2003) stated that most drywood termite strategies are 100% effective under ideal conditions. He differentiated the various treatment strategies in terms of their ability to overcome the myriad of variables involved in treating drywood termite infestations in the field, which he termed robustness. While whole-structure treatments are very robust because they minimize most variables involved, localized treatments are limited by the most profound variable, which is the cryptic nature of drywood termites. Previous studies have indicated that non-repellant, slow-acting toxicants are superior to conventional toxicants; i.e., more robust because one can treat a portion of a colony and termites will forage through the treatment residue and distribute

the toxin to nestmates. Our results also indicate that in some replicates within treatments, a high degree of mortality was indeed achieved, presumably because the toxicant was injected directly into the gallery system where most of the termites existed. What no toxicant can do is penetrate from one galley to another in situations where there are multiple and separate gallery systems in a single board, especially when access to the infestation for treatment may be limited. Thus localized chemical injections, no matter how effective the active ingredient may be, are inherently limited by the cryptic nature of drywood termites.

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