FINAL REPORT 2009

FIELD EVALUATIONS OF LOCALIZED TREATMENTS FOR CONTROL OF DRYWOOD TERMITE INFESTATIONS IN CALIFORNIA

STRUCTURAL PEST CONTROL BOARD, STRUCTURAL PEST

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By

Vernard Lewis, Sara Moore, Robin Tabuchi, and Gail Getty

University of California, Berkeley

EXECUTIVE SUMMARY

Six insecticides were tested for their effectiveness against natural field infestations of *Incisitermes minor* (Hagen) found in homes and commercial structures from fourteen cities. A joint University and pest control industry team inspected dozens of homes and structures as possible candidates for the study. Those chosen, presented a diverse assortment of garages, attics, decks, infestations behind drywall, and crawlspace locations; all presenting a robust set of conditions to demonstrate product performance. Boards were determined as infested by drywood termites using a portable acoustic emission (AE) device that detects termite feeding. The active ingredients included in the field tests were disodium octaborate tetrahydrate (DOT, two products), *d*-limonene, fipronil, imidacloprid, and thiamethoxam. In addition, two untreated checks were included: treatment with water only and no treatment. In total there were eight treatments, replicated at least four times, and all were randomly assigned. Label instructions were followed and a State licensed structural pest control company conducted all applications. All boards receiving chemical treatments were drilled and treated. This process included drilling a diamond pattern of four holes spaced 3” to 5” inches apart, down the entire length of the board for board dimensional sizes of 2 by 8 or less. For board dimensional sizes 4 by 4 and larger and if accessible, the opposite side was drilled in similar fashion and treated.

Four of the above insecticides were injected as liquid; only imidacloprid and thiamethoxam was applied as pressurized foam. Pre- and post-treatment AE counts per minute were compared for all treatments. At the end of three months, although most product treatments had reduced termite-feeding activity, the reduction was not significantly different from untreated checks. The limitations when using local treatments, improvements needed in active ingredient (AI) and detection equipment, highly variable field conditions, and challenges in scientifically documenting product field performance are discussed and presented.

INTRODUCTION

Localized treatments to control infestations of the western drywood termite, *Incisitermes minor*, have had a long history of use in California. The earliest published reports mention the use of arsenic dusts and chlorinated hydrocarbons (Randall and Doody 1934, Hennessy 1993). Over the last seven decades, at least 52 different chemical AIs have been tested for localized control of drywood termites (including species of *Incisitermes* and *Cryptotermes*) (Randall and Doody 1934; Randall et al. 1934; Mallis 1945; Snyder 1950; Lewis and Haverty 1996; Moein and Farrag 1997; Scheffrahn et al. 1979, 1997, 1998, 2001; Lewis and Power 2004; Potter 2004; Lewis et al. 2005; Woodrow et al. 2006; Woodrow and Grace 2007; Lewis and Rust 2009; Lewis 2009). Most of these AIs have been phased out or banned. Currently, there are 10 AIs available for use in California and they include cyfluthrin, bifenthrin, *d*-limonene, disodium octaborate tetrahydrate, fipronil, imidacloprid, permethrin, pyrethrum, silica gel, and thiamethoxam. By some estimates, localized treatments for drywood termites account for at least 70% of the marketplace in California (Potter 2004).

Some confusion, in the Industry and by consumers, exists over advertising claims of local treatments for drywood termites being equivalent to whole structure treatments using fumigation and heat. For some of the products commercially available in California, there are gaps in our understanding or no published papers that pertain to California conditions and species of drywood termites. The pest management professional's (PMP) decision-making process is hampered without reliable efficacy information substantiating product performance claims. Additionally, consumers' confidence in the PMP may suffer.

In 2007, the California Structural Pest Control Board (SPCB) awarded two contracts to the University of California to conduct evaluations on the effectiveness of the six most commonly used products for drywood termite control. The first contract called for Dr. Michael Rust, Department of Entomology, UC Riverside, to conduct the laboratory component, and the second, for Dr. Vernard Lewis, Department of Environmental Science, Policy & Management, UC Berkeley, to direct the field component.

In this report we present results on the field performance of six currently used products in California for local treatment of drywood termite infestations. It is hoped that this study will provide the industry, regulatory, scientific, and consumers with a better sense on the effectiveness of local treatments and their advertising claims.

METHODS AND MATERIALS

Six insecticides were tested for their effectiveness as localized treatments against *I. minor* field infestations in homes and structures and included the following: Bora-Care® (disodium octaborate tetrahydrate (DOT) 40%, Nisus

Corp., Rockford, TN), Optigard™ ZT (thiamethoxam 21.6%, Syngenta Crop Protection, Inc., Greensboro, NC), Premise Foam® (imidacloprid 0.01 oz/lb, Bayer Environmental Science, Research Triangle Park, NC), Termidor SC (fipronil 9.1%, BASF Corp., Research Triangle Park, NC), Tim-Bor® (DOT 98%, Nisus Corp., Rockford, TN), and XT-2000 (92% *d*-limenone, Xtermite, Inc., San Diego, CA and bottled by Speer in Memphis, TN). Bora-Care was donated to the Lewis Laboratory by the Nisus Corporation for an earlier study and was maintained in chemical inventory. Tim-bor, Optigard ZT foam and Premise Foam were provided by Clark Pest Control, Lodi, CA, and a collaborator to the field study. Termidor was donated to the project by BASF Corporation, and Newport Beach Exterminators, Newport Beach, CA, also a project collaborator, donated XT-2000®.

To ensure a robust test for all products, we felt it was necessary to include a variety of conditions found in the field when encountering infestations and while conducting treatments. The conditions include geographic location, accessible and inaccessible areas of infestations in structures, and presence of wall coverings. Candidate homes to be included in the study were provided by several licensed pest control companies from around the state (Fig. 1). Homeowners were given written notice on the objectives of the research. The criteria we used for inclusion in the study included having an active infestation (boards that averaged 4 or more AE counts/min are considered active with drywood termite infestations; Lewis et al. 2004), accessible (able to be touched by human hands), and willingness of participating homeowner or tenant to treatment and follow-up inspections. The final list of candidate homes included in the study was selected from fourteen cities in the state, stretching from Sonoma to the north and as far south as La Jolla.

The presence or absence of termite activity in boards in structures was determined with a portable acoustic emission (AE) detection device (Termite Tracker, Dunegan Engineering, Midland, TX)(Fig. 2). Boards were determined to contain active drywood termites by drilling a 1/8″ diameter hole and inserting the sensor probe roughly ¾″ deep and taking three one-min readings of termite feeding activity. This process was repeated every 24″down the length of the board. For thicker boards (> 4″ in cross-section), additional AE monitoring holes were drilled for both sides undergoing treatment.

The same state licensed structural pest control applicator (from Clark Pest Control, Stockton, CA) conducted all drilling of holes and product applications. Prior to treatment, all chemically treated and water only boards had four holes drilled in a diamond pattern (1/8″ diameter) spaced 3″-5″ inches apart, down the entire length of the board for board dimensional sizes of 2 by 8 or less (Fig. 3. For board dimensional sizes 4 by 4 and larger and if accessible, the opposite side was drilled in similar fashion and treated. Label instructions were followed and maximum product rates were used. All chemical treatments assignments were randomized prior to application. The Bora-Care was diluted 1:1 with water to a 23% final solution DOT and was injected as a liquid into drilled holes. The Optigard ZT was prepared according to the label directions at a 15:1 foam ratio, for a final thiamethoxam concentration of 0.1%, and injected into drilled holes with the Optigard ZT Foamer Kit (Fig. 4). The Premise foam came as ready-to-use foam in a pressurized aerosol can that was equipped with an applicator tip and was injected into drilled holes. The Termidor SC was injected into drilled holes as an aqueous preparation at 0.125% final solution. The Tim-bor was mixed in water to a final 15% DOT solution. The XT-2000 was injected without dilution into treated boards. In addition, two untreated checks were included in the study: treatments with water only and no treatment. In total there were eight treatments, replicated at least four times. Post-treatment evaluations included visual searches of boards for signs of re-infestations (pellets, termites, and wings) and use of AE equipment to take three one-minute recordings from the same boards that underwent pre-treatment investigations. All pre- and post-AE counts was transformed using a square root function to meet testing assumptions of normal distribution and equal variance (ANOVA, SAS Institute 2008). Differences before treatment and at 3 months post-treatment, mean number of holes drilled and mean volume of pesticides injected among treatment were conducted using ANOVA and pair-wise comparisons among treatment means using Tukey's test (SAS Institute 2008 and R Development Core Team 2009). The benchmark in demonstrating successful field performance included the reduction in post-treatment AE levels that were significantly lower compared to the untreated checks.

RESULTS AND DISCUSSION

Before presenting the results, there are several disclaimers to discuss. First, the statements that follow only pertain to remedial treatments. We did not include variables related to the prevention of drywood termite infestations. Second, the discussions that follow apply only to the 3-month, post-treatment check. We do not know what could have happened at later post-treatment evaluations.

In the original State contract, five replicates were promised for each product tested. This condition was met for all products, except Premise (4) and Tim-bor (4). The fifth replicate for each of these products was conducted; however, at the time of writing this report, the 3-month post-treatment inspection for the fifth replicates were not recorded, and will not be available until later in September.

All five replicates for all products will be available at the Structural Pest Control Board meeting to be held on October 21, 2009 in Riverside, CA.

We felt that we were successful in achieving a robust test. In total, we visited 17 cities and examined at least 164 separate infestations. Among those infestations, 48 (29%) contained in 14 cities were acceptable for field-testing and included in the study. The average number of infested boards among field sites was 3.5 and ranged from 1 to 9. Most sites 10 of 17 used in the study had multiple infestations. Field sites used were predominately residential. Infestations were primarily exposed wood, contained mostly in garages, decks, deck railings, and attics. However, four sites involved inaccessible areas, one site involved an infestation behind drywall, and two infestations involved the use of extension ladders to reach and treat locations in excess of 10 feet (3 m) above the ground (Fig. 5). Two field sites were commercial and included an equipment storage area; one large wooden condominium complex in La Jolla was also included. Most of the infestations were accessible (90%), meaning exposed wood in garages, porches, decks, eves, and deck hand rails. Seventy-nine percent (117, 79%) of the infestations were not included in the study for a variety of reasons including: the infestation was not currently active, inaccessible areas (high vaulted ceilings and wall coverings), and homeowners unwilling to participate. Overall, we felt that the range of infestations included in the study was varied and diverse and presented a challenge for all products to demonstrate effectiveness in controlling drywood termite infestations.

The results of this study are presented in Table 1. All six products tested and two untreated checks (injected with water, and no treatment) are represented. The average number of drilled holes varied from 34 to 91 among chemical treatments. The fewest number of holes (Tim-bor, 34) was significantly different from the greatest number of holes (Optigard ZT, 91) ($F = 3.4$; $df = 6, 16$; $P < 0.01$). The number of drilled holes for Tim-bor was nearly three-fold less than for other products. This is to be expected when conducting a field study. The conditions encountered by inspectors and applicators in the field are highly variable. Other researchers have reported similar field variance in the number and intensity of infestations when conducting AE monitoring (Scheffrahn et al. 1997, Thoms 2000, Lewis et al. 2005).

The amount of pesticide applied also varied among products used (Table 1). The volume of product applied under field conditions ranged from 6 to 12 ounces, roughly two-fold difference. However, there were no significant differences in the amount of material applied. The untreated checks, which did not receive any treatment, liquid, or foam, were not analyzed with the other treatments.

The efficacy of products among treatments when compared to untreated checks was unremarkable after the 3-month post-treatment inspection and the high variability masked treatment effects (Table 1). With the exception of Tim-bor and the untreated checks, most products demonstrated at least a 90% reduction in AE counts post-treatment. However, the reduction in AE counts, as measured by the change or difference between Pre- and Post-treatment AE counts, was not significantly different when compared to the water injected boards and untreated checks ($F = 1.07$, $df = 7, 35$; $P > 0.40$). Scatter plots of the mean Pre-AE and post-AE counts also showed high variability among treatments and no clear association with treatments (Figures 6 and 7). The assumptions for using ANOVA testing were met and data transformations did not change the lack of significance and it is doubtful increasing sample size alone would produce significant results. Previous published results suggest a similar finding: a reduction in termite activity, but not total elimination (Randall and Doody 1934, Lewis et al. 2004, Lewis and Power 2004, Lewis et al. 2005, Woodrow et al. 2006, Woodrow and Grace 2007). The challenges presented for local treatments in eliminating infestations are daunting and include expansive gallery systems (Harvey 1934, Grace et al. 2009), higher percentage of wood in homes being inaccessible (Lewis et al. 2004), and as few as 10 survivors being able to reestablish the same infestation (Smith 1995). For local treatments, the need for retreatment under field conditions has been previously reported (Randall and Dowdy 1934, Thoms 2000, Lewis et al. 2005).

So what can be done to improve local treatment performance? Since drywood termites are a single piece (or small group of boards) infester, at a minimum the active ingredients in products for remedial control must be non-repellent, slow acting, and have the capacity of trophallaxis passing to fellow nest mates. Of the products tested, only Termidor, Tim-bor dust, Optigard ZT, and Spinosad

(DowAgroSciences) have demonstrated these biological properties (Scheffrahn et al. 1997, Rust 2008, Lewis and Rust 2009). Additionally, for local treatments to have maximum effectiveness, infested boards need to be accessible to drilling and treatment. By some estimates, inaccessible areas in homes in the state can represent 40% of the structural members (Lewis et al 1997). Accessibility of infested boards has always been an impediment to the success of local treatments.

Drywood termite populations in boards and logs are highly variable under field conditions. Published reports show the variability in population size to range from 1 to more than 10,000 individuals (Harvey 1934; Scheffrahn et al. 1993; Lewis and Power 2004; Lewis et al. 2004, 2005; Lewis and Rust 2009). For the current study and with few exceptions, the variance met or exceeded the average Pre- and Post-AE values. The inference implied by these high standard deviation numbers is that drywood termite field populations are highly variable, and significant testing to demonstrate field performance will be challenging.

Improvements in AE performance are also needed. Improvements to consider include extending monitoring times, the use of additional sensors, monitoring during peak feeding and foraging times, increasing AE activity by heating boards, and use of attractants. The amount of time used for AE monitoring has varied, from 30 sec to five minutes (Scheffrahn et al. 1993, 1997; Thoms 2000; Lewis and Power 2004; Lewis et al. 2004, 2005; Woodrow et al. 2006). For researchers, extending AE monitoring time is inconvenient, but doable for research objectives. At the business level, increasing AE monitoring time to five minutes and beyond for each location, means additional expense for labor and could lead to higher costs for consumers and lost revenues for the pest management professional (PMP). Whatever new detection technology is ultimately developed it must be practical for companies operating at the "speed-of-business" when meeting consumers' demands for service. Adding additional sensors to aid monitoring larger areas is intriguing and technically feasible, but again cost-prohibitive for most small to medium sized companies to purchase and maintain within equipment inventory. Several other studies have reported increased AE activity can be generated by heating boards (Lemaster et al. 1997, Indrayani et al. 2006, Lewis et. 2009), but investigations are needed to verify this under field conditions. Using several detection devices/techniques in tandem has also been proposed (Thorne 1993); however, field verification on this detection technique is lacking and could also be cost-prohibitive. Lastly, laboratory work conducted in Australia suggests drywood termites (*Cryptotermes secundus*) can be attracted to wood resources using sound (Evans et al. 2007). However, the field applicability of this novel finding has yet to be determined.

Taken together, the laboratory studies at UC Riverside and field investigations at UC Berkeley, suggest local treatments are limited in what can be expected in their field performance; best with exposed accessible boards and less when infestations are concealed or inaccessible. Additionally, when offered to consumers, care must be taken to inform them of treatment limitations and that they are not equivalent to whole-structure treatments. We realize for some situations fumigation is not an option and local treatments are the last resort, however these offerings are better served to consumers when packaged as a control service agreement.

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TABLE 1. Average number of holes drilled, average amount pesticide injected, Pre-treatment AE counts, Post-treatment AE counts, mean % reduction in AE and Lower and Upper 95% confidence limits in mean AE counts for field infestations of the western drywood termite randomly treated with one of six commercial products or untreated checks[1].

Treatment (Product & AI%)	N[2]	Number of drilled holes (Mean ± SD)[3]	Fluid oz. injected (Mean ± SD)[3]	Pre-treat AE counts/min (Mean ± SD)[3]	Post-treat AE counts/min (Mean ± SD)[3]	Mean % reduction[3]	Lower 95% confidence limit	Upper 95% confidence limit
Bora-Care® (1:1 with water 23% final DOT)	6	85 ± 42ab	10 ± 6a	53 ± 48a	5 ± 8a	-91.3a	-100	-81
Optigard™ ZT (thiamethoxam 21.6% injected 15:1 foam)	6	91 ± 17a	11 ± 8a	71 ± 111a	2 ± 2a	-77.3a	-100	-47
Premise Foam® (imidacloprid 0.05% ready to use foam)	4	58 ± 40ab	6 ± 6a	43 ± 17a	2 ± 1a	-95.1a	-100	-89

Termidor® SC (fipronil 0.12 %)	7	90 ± 44ab	12 ± 7a	43 ± 40a	2 ± 2a	-95.7a	-98.7	-93
Tim-bor® (diluted with water final DOT 15%)	4	34 ± 17b	12 ± 11a	131 ± 71a	30 ± 32a	-51.2a	-100	14
XT-2000 (*d*-limenone 92% ready to use liquid)	5	91 ± 54ab	11 ± 5a	104 ± 119a	7 ± 8a	-88.3a	-99	-77
Water only	4	44 ± 19ab	23 ± 20a	77 ± 29a	6 ± 7a	-92.1a	-100	-82
Untreated	7	n/a	n/a	47 ± 35a	34 ± 50a	3.9a	-100	128

[1]A total of 43 field replicates from 14 cities, including Northern and Southern California, and the Central valley were used in this study.

[2]Means in columns with the same letter are not significantly different level (P > 0.05) using Tukey's test (SAS Institute 2008).

[3]Untreated checks included water injection and untreated.

Figure 1. Example of UCB and Clark Pest Control research team examining a potential candidate home for the study; location Santa Ana, CA. Included in the image from left to right are V. Lewis and S. Moore, UC Berkeley and M. Red, cooperating PMP.

Figure 2. AE monitoring of board for drywood termite activity in Glendoa, CA. Include in image is R. Tabuchi, UC Berkeley.

Figure 3. Example of drilling a board infested with drywood termites before Treatment; location Torrance, CA. Included in image is M. Red, Clark Pest Control.

Figure 4. Example of injecting Optigard into infested board; location Petaluma, CA. Included in image is M. Red, Clark Pest Control.

Figure 5. A high-degree of difficulty local-treatment; inspection and treatment conducted in Lake Forest, CA. Included in image is V. Lewis, UC Berkeley.

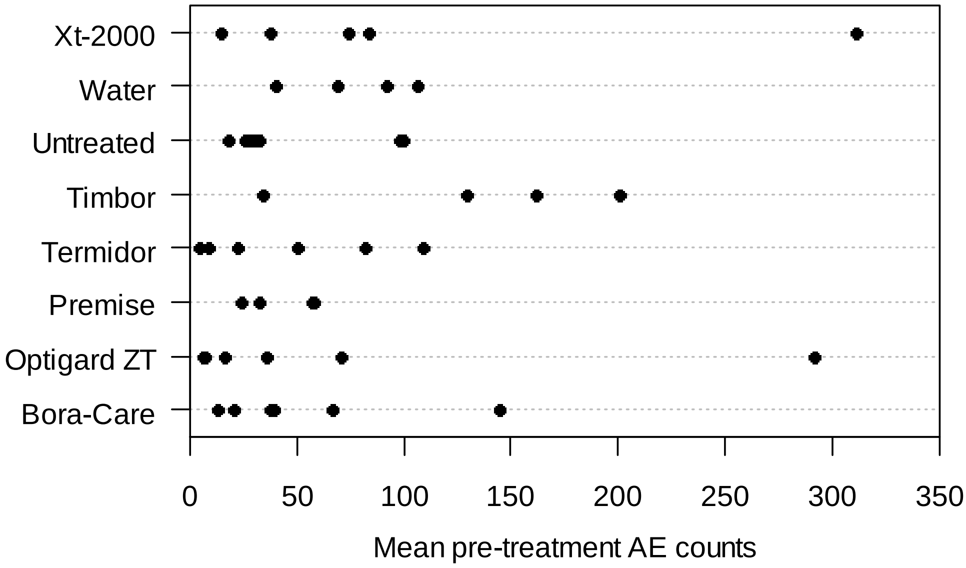

Figure 6. Point scatter plot of pre-treatment AE counts prior to treatments. Each point represents the mean of an individual field infestation.

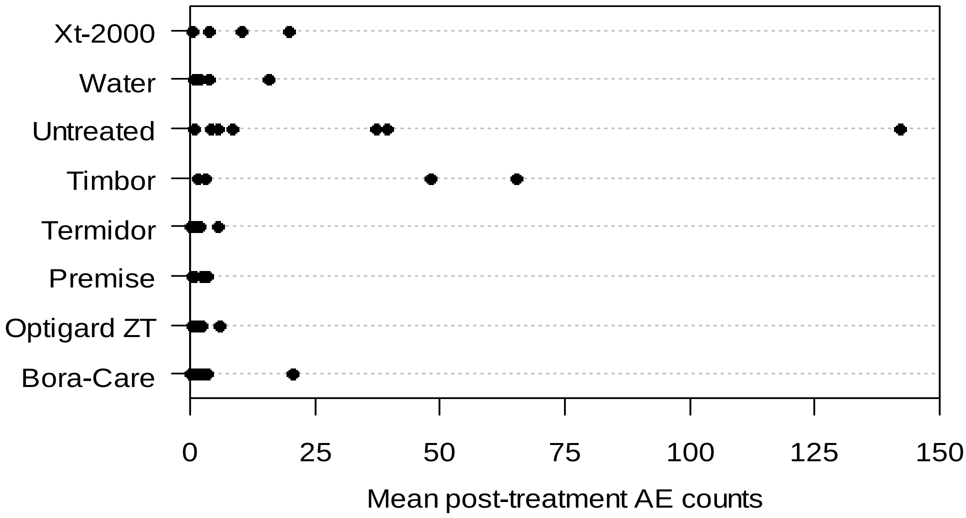

Figure 7. Point scatter plot of post-treatment AE counts prior to treatments. Each point represents the mean of an individual field infestation.