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FIELD EVALUATION OF THIAMETHOXAM 2SC FOR MANAGEMENT OF THE WESTERN DRYWOOD TERMITE (ISOPTERA: KALOTERMITIDAE)

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Abstract Aqueous solutions containing thiamethoxam were applied via foam and liquid to boards containing active infestations of the Western drywood termite (*Incisitermes minor* (Hagen)). Two sites each in northern and southern California were included in the study. Structures included in field evaluations consisted of wood-frame construction and had a long history of problems with drywood termites. All infestations were verified active and extent delimited using termite detection equipment. For the Bodega Bay and Davenport sites in northern California, a termite-feeding detector (acoustic emissions (AE)) was used while for sites in Marina Del Rey, a termite-feeding detector and portable X-ray device were used. After verifying infestations active, boards containing termites were drilled and injected with liquid or foam formulations containing thiamethoxam (0.1%, 1000 ppm). The use of detection equipment aided the identification of locations within boards containing galleries active with termites. Termite-feeding activity (measured as AE) was monitored 30 and 90 days post-treatment. After 30 days, the reduction in AE termite-feeding activity for Bodega Bay, Davenport, and Marina del Rey was 99%, 91%, and 96%, respectively. After 90 days, the reduction in AE feeding activity had increased slightly to 99%, 94%, and 98% for the same sites. Results thus far suggest subsurface injections containing thiamethoxam significantly reduces or eliminate localized infestations of drywood termites. Advantages of using advanced detection technology in conjunction with thiamethoxam are discussed.
Key Words Acoustic emissions detection, X-ray detection, *Incisitermes*

INTRODUCTION

Localized treatments with chemicals have dominated the marketplace for drywood termites control for decades. Some estimates claim as much as 70% of the control marketplace for drywood termites uses localized treatments with chemicals (Potter, 1997; Lewis et al., 2000). Over the decades, at least 52 different chemical active ingredients have been tested for the localized control of drywood termites (Lewis, 2003). However, due to regulatory restrictions, the list of chemical active ingredients has dwindled to six: bifenthrin, cyfluthrin, disodium octaborate tetrahydrate, fipronil, imidacloprid, and permethrin (Lewis, 2002). Liquid nitrogen and some natural products (e.g. *d*-limonene, Lewis 2003) are additional chemicals that are registered for use; however they are infrequently used. Additional chemical active ingredients that are efficacious for controlling drywood termites are still needed.

An additional need for drywood termite control includes improved methods of detection and monitoring. Visual searches still dominate the inspection process for drywood termites (Lewis, 2003). However, visual searches leading to finding infestations, especially in concealed locations, can be very challenging and highly subjective (Scheffrahn et al., 1993; Lemaster et al., 1997). Attempts at improving drywood termite inspections and monitoring have lead to the development of optical borescopes, termite-sniffing dogs, electronic odor detectors, acoustic emissions devices, infrared, and microwaves (Lewis, 2003). More recently, portable X-ray devices for viewing inside walls are now commercially available (Lewis, personal communication). However, published studies to date for all detection techniques and devices are primarily laboratory, in depth field investigations are still lacking.

The study outlined in this proceedings paper evaluates the combination of X-ray and acoustic emission devices in locating and delimiting infestations, followed by subsurface injections of thiamethoxam in controlling drywood termite infestations under actual field conditions.

MATERIALS AND METHODS

Sites. The first field test site was in Bodega Bay, California. This small city is located along coastal California, roughly 112 km north of the San Francisco Bay Area. The specific building is in downtown Bodega Bay and houses telecommunications equipment. There were at least two-dozen interior and exterior locations (sills and exterior façade) at the wood-framed building showing visual evidence of drywood termite activity, including blister wood, exposed termite galleries, and voided fecal pellets. For the current study, we selected 4 boards for treatment. Davenport was the second field site selected from Northern California. This coastal city is 125 km south of the San Francisco Bay Area. The specific test site consisted of a single two-story private residence with a long-standing drywood termite problem. The third site used during the field study consisted of 2 building complexes (Marina Harbor and Mariners Village) in Marina del Rey, California. Both complexes are next door to each other. Marina del Rey is a coastal city in southern California approximately 590 km south of the San Francisco Bay Area. Both sites are composed of multi-story and multi-unit rental apartments. Visual evidence of drywood termite activity was readily found around windowsills and exterior facade wood.

Pre-Treatment Acoustic Emissions (AE) And X-Ray Monitoring. Candidate infestations and boards for treatment were first visually identified; determined by the presence of blistered wood, open termite galleries, or voided fecal pellets in the surroundings. Since there is no currently agreed upon biological definition on what constitutes a drywood termite colony under field conditions, the designation we choose to use was infestation, defined spatially as a small number of boards on the same wall or in similar close proximity. These same infestations were acoustically monitored for termite feeding activity using an AE device (Tracker, Dunegan Engineering, San Juan Capistrano, California). Following other published studies on AE detection of drywood termites, three one-minute AE counts were taken for each board that revealed visual evidence of termite activity (Scheffrahn et al., 1993; Lewis et al., 2004). For Davenport, the pest control company collaborating on the project took only a single one-minute AE reading during pre-treatment evaluations; however all other pre- and post-treatment AE reading for other sites followed the original protocol of three 1-min recordings. The sensor used for this AE device has a pointed metal probe enabling subsurface collection of AE termite-feeding activity. Lewis et al. 2004 has shown subsurface sensors to have improved performance in detecting termites compared to surface attached probes. For longer boards, the sensor probe was moved in longitudinal increments of 60 to 91cm to optimize the collection of AE data for an entire board (Scheffrahn, 1993; Lewis et al., 2004). To aid the finding of active galleries within boards at Marina Harbor and Mariners Village, images were taken with a portable X-ray device (Predator, New Generation Pest Management, Santa Maria, California; and Golden Engineering, Inc., Centerville, Indiana).

Chemical applications. Boards that averaged 4 or more AE counts/min were selected for treatment. For Bodega Bay, 4 boards were drilled and chemically treated. One board was excluded from treatment due to severe damage, the recommendation being replacement. For Davenport, 8 infestations containing 9 boards were initially identified as being active for drywood termites and later drilled and chemically treated. There were 3 infestations treated at Marina del Rey. The 1^{st} infestation was at Marina Harbor. This infestation consisted of 10 boards, of which 3 were treated. The 2^{nd} and 3^{rd} infestations were at Mariners Village. The 2^{nd} infestation consisted of 5 boards, of which 2 were treated. The 3^{rd} and final infestation at Mariners Village consisted of a single board that was treated.

The active ingredient used for treating all infestations among sites was thiamethoxam (Syngenta Corporation, Greensboro, North Carolina). This chemical is classified as a non-repellent neonicotinoid and has a novel mode of action in insects affecting the nicotinic acetylcholine receptors (Anonymous, 2003). The concentrate used in this study was a suspension concentrate, containing 21.6% active ingredient (Anonymous 2004). Application of thiamethoxam followed industry standards and procedures outlined by Scheffrahn et al. (1997) and included drilling and injecting all visible drywood termite kick out holes. Kick out refers to small BB shot holes through which drywood termites push their fecal pellets out of the wood. Clark Pest Control (Santa Rosa, California) conducted the chemical applications at Bodega Bay using a hand-pressurized sprayer (B&G, Whitmire, St. Louis, Missouri). Amounts of injected solution varied among holes, but applications continued until the liquid, or foam, back-flowed out from the injection hole and/or from a distant hole, connected to the same gallery. For Marina Harbor and Mariners Village, New Generation Pest Management (Santa Maria, California) conducted treatments using foam application equipment (N12VFG Foam generator, NoHowe Product Development Ltd, Toronto, Canada). The foam carrier solution was ProFoam Platinum (NoHowe Product Development, Ltd., Toronto, Canada). Similar to Bodega Bay, small holes were drilled into drywood termite kick out holes, and visible galleries. Because X-ray images of infestations were taken at Marina Harbor and Mariners Village, additional holes were drilled into galleries systems after reviewing the image.

Post-treatment AE Monitoring. AE monitoring for all treated boards and field sites was conducted 30 and 90 days after treatment. For the Davenport site, after the 90-day monitoring check, Infestation #1 was retreated. For the Marina del Rey site, two infestations were retreated and included the single infestation at Marina Harbor and the 1st infestation at Mariners Village. Both were retreated at the 90-day monitoring check.

Data Preparation and Statistical Analysis. Board identification designation, pre-, and post-treatment AE data were organized into an Excel spread sheet prior to analysis (Microsoft Corporation, Redmond, Washington). Summary statistics for mean AE counts/min ± standard error were derived with the MEAN procedure (SAS Institute, Cary, North Carolina 1994). Reduction in mean AE counts/min for treated boards at 30 and 90 days were compared to pre-treatment levels (Day 0 in data table and figure) using a repeated measure analysis of variance model (PROC GLM with repeated measures, SAS Institute, Cary North, North Carolina 1994). Boards that did not have any measurable AE activity at the beginning of the study, indicating no active drywood termite infestation, did not require treatment and were excluded from the analysis. For the Davenport site, the single pre-treatment AE value was averaged for all boards revealing termite activity and used for further analysis and comparisons. We felt this pre-treatment transformation of data represented the high activity of drywood termites (>200 AE counts per min) present within infested boards.

RESULTS AND DISCUSSION

Pre-treatment AE Activity. Pre-treatment AE activity for drywood termite infestations was similar among sites (Table 1). Mean AE levels ranged from 124 to 225 counts per min, and although variable were not significantly different ($F = 2.94$; $df = 2, 90$; $P < 0.06$). Scheffrahn et al. (1993) reported similar AE values from field collected and untreated logs containing *Incisitermes synderi* (Light) in Florida and suggests infestations used during our study were healthy and robust prior to treatment.

Table 1. Pre-treatment, 30 d, and 90 d post-treatment mean acoustic emissions (AE) counts ± SE for field infestations containing drywood termites treated with thiamethoxam.

Site Location[1]	No. Infestations/ No. boards treated[2]	Pre-treatment AE mean ± SE*	30-d post-treatment AE mean ± SE*	90-d post-treatment AE mean ± SE*
Bodega Bay	4/4	124.1 ± 29.2a	1.8 ± 0.4b	0.8 ± 0.2b
Davenport	8/8	225.1 ± 13.1a	21.9 ± 5.7a	13.9 ± 3.7a
Marina del Rey	3/7	153.5 ± 40.9a	7.6 ± 1.7b	3.8 ± 1.8b

*Means followed by the same letter in columns are not significantly different (p > 0.05; Ryan-Einot-Gabriel-Welsch multiple range test [RROC GLM SAS Institute 1994]).
[1]Bodega Bay and Davenport sites in Northern California, Marina del Rey is in Southern California.
[2]All infestations revealed visual signs of drywood termites (e.g., damaged and/or blistered wood, voided fecal pellets, alates, and/or workers termites).

Results on Applications. Number of drilled holes and amount of pesticide injected was minimal among treated boards. For Bodega Bay, approximately two-dozen holes were drilled and 1,500 ml of thiamethoxam were injected among the 4 boards treated, roughly 6 holes and 375 ml of pesticide per board. For initial chemical applications conducted at Davenport, few holes were drilled, instead existing kickout holes and pushing through blistered wood was the preferred application technique. The total amount of foam used was 1,500 ml, roughly 187 ml per board (8 total boards). For the 3 infestations treated at Marina del Rey, because X-ray technology was used to better target galleries, fewer holes were drilled and a lesser quantity of pesticide was applied, 13 holes and a total of 472 ml of thiamethoxam among 7 boards treated; 2 holes and 67 ml per board, respectively. The range in number of drilled holes and amounts of pesticide used for the field study was similar to laboratory values reported for 15 boards similarly treated with thiamethoxam (25 to 75 drilled holes and 40 to 250 ml of pesticide) (Lewis and Power, 2004).

Efficacy results. Treated boards for all test sites displayed a dramatic decline in drywood termite feeding activity (Table 1 and Figure 2). The reduction in AE activity for all sites was significant compared to pre-treatment levels ($F = 85.27$; $df = 2{,}180$; $P < 0.0001$). Pre-treatment AE count averages were at least an order of magnitude or greater compared to 30-day and 90-day post-treatment averages (Table 1 and Figure 2). Similar declines in drywood termite feeding behavior 30-days after treatment have been reported from laboratory studies using thiamethoxam (Lewis and Power 2004) and well as laboratory and field studies using other active ingredients (Scheffrahn et al., 1997; Ferster et al. 2001).

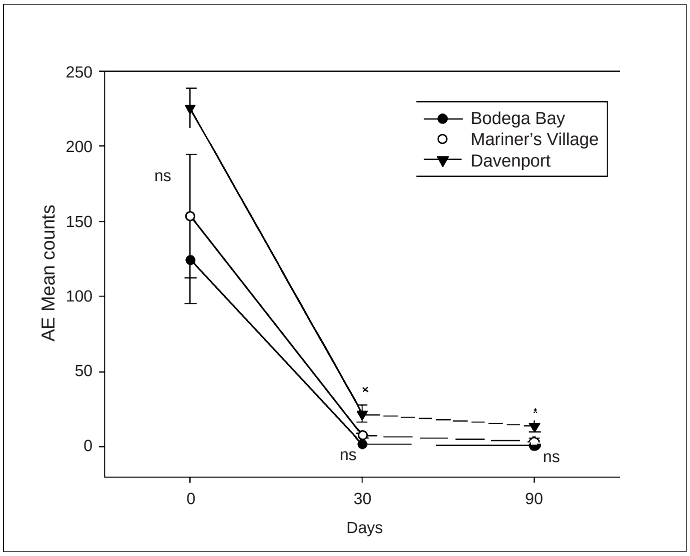

Figure 2. Pre-treatment, 30-d and 90 d post-treatment acoustic emission (AE) levels (Mean ± SE) for 3 field sites in California treated with thiamethoxam for drywood termites. Statistically significant designated as (*) and non-significance denoted as ns.

Re-treatments. At the 30-day monitoring check, Davenport revealed signs of continual drywood termite activity (Table 1). These post-treatment AE activity levels were significantly higher ($F = 5.29$; $df = 2, 90$; $P < 0.006$) compared to results from Bodega Bay and Marina del Rey; 21.9 ± 5.7, 1.8 ± 0.4, and 7.6 ± 1.7, respectively. Three boards at Davenport were retreated after the 30-day check. However, some residual AE activity still remained at Davenport at the 90-day check period (Table 1). A second re-treatment was conducted on two boards at Davenport after the 90-day check. Although the study is still ongoing, at the 1 year monitoring check, residual AE activity has been reduced compared to the 30-d and 90-d monitoring visits (V. Lewis, personal commun.). We suspected the failed performance of treatments at Davenport were due to difficulty in finding residual drywood termite populations in a large deck support beam; however after reviewing field formulation notes from the initial treatment, it was discovered that actual percentage of thiamethoxam used was 0.023% not the targeted rate of 0.1%. Subsequently, all four spots were retreated with the 0.1% formulation.

Care must be demonstrated when following labeled rates to ensure the required amount of toxicant is used when treating for drywood termite infestations. At 30 days post-treatment, 3 boards at Marina del Rey also displayed mean AE counts in excess of 4 per min. Previous studies suggest AE counts exceeding 4 counts/min represent at least 20 live drywood termites (Scheffrahn et al., 1993; Lewis et al., 2004). Upon finding the increased AE activity 30 days post-treatment, X-ray images were re-evaluated, searching for galleries to retreat. Evaluations of X-ray images found gallery connections for the two boards; so in fact, the boards represented a single infestation not two as were originally thought. The X-ray image of the third board revealed a large gallery deep within a larger structural support beam. A re-treatment was conducted using a longer drill bit, enabling the better piercing of the gallery for toxicant injection. An additional 236 ml of 0.1% of thiamethoxam was administered into 5 holes for the 3 re-treatments conducted at Marina del Rey. These 3 boards were subsequently re-inspected at 90 days post-treatment, and AE values had fallen below the 4 counts per min minimum threshold suggesting no activity and successful treatment (Table 1).

Increased AE activity noted at Davenport and Marina del Rey and post-treatment results are difficult to decipher and explain. Previous laboratory studies for other active ingredients suggest as little of 10% of the gallery treated can results in high level of mortality (> 90%) for drywood termites (Scheffrahn et al., 1997). We believe our initial field applications affected at least 10% of the gallery system. There can also be variance in the results collected using AE, as much as 20%, especially when conducting post-treatment evaluations (Scheffrahn et al., 1993; 1997; Lewis et al., 2003). How drywood termites forage within galleries is another source of variance, its magnitude largely unknown (Scheffrahn et al., 1997). For subterranean termites, the use of internal dyes (Su et al., 1983), cuticular hydrocarbons (Haverty and Nelson, 1997), agonistic behavior (Haverty et al., 1999), and molecular markers (Husseneder et al., 2003; Deheer and Vargo, 2003; Vargo 2003, a;b) have been used to biologically define colonies and follow their seasonal movements through soil. Similar investigations are needed for drywood termite colony foraging behavior inside single boards as well as groups of infested boards and could help to explain successful as well as unsuccessful local treatments.

Summary and concluding remarks. The performance of thiamethoxam during field tests is similar to laboratory findings using the same active ingredient, precipitous drop in AE activity > 90% and probably resulted in high levels of drywood termite mortality (> 99%, 5 of 2,207, Lewis and Power, 2004). Both lab and field results suggest thiamethoxam is non-repellent, has a quick mode of action, and can be spread throughout boards containing natural infestations of drywood termites. Incomplete control was infrequent and due to missed applications of galleries, and resolved during re-treatment. Although X-ray imagery helped in locating galleries, the search time, technology learning curve, and equipment cost pose significant hurtles to large-scale adoption by the pest control industry. Additional research is also needed on the number of drywood termite colonies and foraging dynamics in single and multi-board infestations.

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REFERENCES CITED

Anonymous. 2003. Thiamethoxam termiticide/insecticide. Syngenta Professional Products, Greensboro, NC. BF0210

Anonymous. 2004. Thiamethoxam 2SC termiticide/insecticide. Consumer product safety bulletin. Syngenta Professional Products, Greensboro, NC

Deheer, C.J. and E.L. Vargo. 2004. Colony genetic organization and colony fusion in the termite Reticulitermes flavipes as revealed by foraging patterns over time and space. Molecular Ecol. 13: 431-441.

Ferster, B., R.H. Scheffrahn, E.M. Thoms and P.N. Scherer. 2001. Transfer of toxic from exposed nymphs of the drywood termite *Incisitermes snyderi* (Isoptera: Kalotermitidae) to unexposed nestmates. J. Econ. Entomol. 94(1): 215-222.

Haverty, M.I. and L. Nelson. 1997. Cuticular hydrocarbons of *Reticulitermes* (Isoptera: Rhinotermitidae) from northern California indicate undescribed species. Comp. Biochem. Physiol. 118B: 869-880.

Haverty, M.I., K.A. Copren, G.M. Getty and V.R. Lewis. 1999. Agonistic behavior and cuticular hydrocarbon phenotypes of colonies of Reticulitermes (Isoptera: Rhinotermitidae) from northern California. Ann. Entomol. Soc. Am. 92: 269-277.

Husseneder, C., J.K. Grace, M.T. Messenger, E.L. Vargo and N.-Y. Su. 2003. Describing the spatial and social organization of Formosan subterranean termite colonies in Armstrong Park, New Orleans. Sociobiology 41(1): 61-65.

Lemaster, R.L., F.C. Beall and V.R. Lewis. 1997. Detection of termites with acoustic emission. Forest Prod. J. 47: 75-79.

Lewis, V.R. 2002. Pest notes: drywood termites. Oakland Univ. Calif. Agric. Nat. Res. Publ. 440.

Lewis, V.R. 2003. IPM for drywood termites (Isoptera: Kalotermitidae). J. Entomol. Sci. 38(2): 181-199.

Lewis, V.R. and A.B. Power. 2004. Thiamethoxam trial against drywood termites. Pest Control Technology 42(9): 74, 76, 78, and 80-81.

Lewis, V.R., A.B. Power and M.I. Haverty. 2000. Laboratory evaluation of microwaves for control of the western drywood termite. Forest Prod. J. 50(5): 79-87.

Lewis, V.R., A.B. Power and M.I. Haverty. 2004. Surface and subsurface sensor performance in acoustically detecting the western drywood termite in naturally infested boards. Forest Prod. J. 54(6): 57-62.

Potter, M. F. 1997. Termites. In, D. Moreland (ed.), Mallis Handbook of Pest Control, 8th Ed., A. Mallis. Franzak & Foster Co., Cleveland.

SAS Institute. 1994. SAS/STAT guide for personal computers, version 6.10 ed. SAS Institute, Cary, NC.

Scheffrahn, R.H., W.P. Robbins, P. Busey, N.-Y. Su and R.K. Mueller. 1993. Evaluation of a novel, hand-held, acoustic emissions detector to monitor termites (Isoptera: Kalotermitidae, Rhinotermitidae) in wood. J. Econ. Entomol. 86: 1720-1729.

Scheffrahn, R.H., N.-Y. Su and P. Busey. 1997. Laboratory and field evaluations of selected chemical treatments for control of drywood termites (Isoptera: Kalotermitidae). J. Econ. Entomol. 90: 492-502.

Su, N.-Y., M. Tamashiro, J. Yates, P.-Y. Lai and M.I. Haverty. 1983. A dye, Sudan Red 7B, as a marking material for foraging studies with the Formosan subterranean termite. Sociobiology 8: 91-97.

Vargo, E.L. 2003a. Hierarchical analysis of colony and population genetic structureof the eastern subterranean termite, *Reticulitermes flavipes*, using two classes of molecular markers. Evolution 57(12): 2805-2818.

Vargo, E.L. 2003b. Genetic structure of *Reticulitermes flavipes* and *R. virginicus* (Isoptera: Rhinotermitidae) colonies in an urban habitat and tracking of colonies following treatment with hexaflumuron bait. Environ. Entomol. 32(5): 1271-1282.