A NOVEL, LOCALIZED TREATMENT USING SPINOSAD TO CONTROL STRUCTURAL INFESTATIONS OF DRYWOOD TERMITES (ISOPTERA: KALOTERMITIDAE)

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Abstract - Intragallery application of 0.23% or 0.5% spinosad (suspension concentrate, SC) resulted in 98-100% drywood termite mortality in a laboratory simulated gallery bioassay and significantly reduced drywood termite activity, as measured using an acoustic emissions detector (AED), in a comparative field trial through one year post-treatment. In the same trials, currently available localized treatments (Tim-bor and PT-270) provided inconsistent or incomplete reduction in drywood termite mortality. Tim-bor, (10% disodium octaborate tetrahydrate, DOT) applied as an intragallery treatment or surface treatment, did not result in mortality significantly different from untreated controls in the laboratory bioassay and did not have significantly lower termite activity by 5 months after surface treatment in the field trial. Intragallery application of Tim-bor dust (98% DOT) performed better in laboratory bioassays, but not in the field trial, compared to Tim-bor liquid treatments. Intragallery application of PT-270 (0.5% chlorpyrifos aerosol) resulted in variable termite mortality in the laboratory trial and did not result in significant reduction in termite activity by 2 months after treatment in the field trial. In the field trial, drywood termite activity recovered in all treatments except spinosad SC by one year after application. Pest control operators demonstrated they could effectively use spinosad SC and the acoustic emissions detector to significantly reduce termite activity by a mean of 94%, with at least 90% or greater reduction in 89% of the treated infestations.
Key words - *Cryptotermes brevis, Incisitermes snyderi,* acoustics, borate, chlorpyrifos

INTRODUCTION

Drywood termites account for about 20% of the $1.5 billion estimated for annual termite control expenditures in the United States (Su and Scheffrahn, 1990). Drywood termites, if left uncontrolled, will continuously recolonize a structure until the wood members and contents are severely damaged by numerous colonies. Although fumigation is an effective way to eliminate drywood termites from throughout a structure (Su and Scheffrahn, 1986), it is not always the preferred treatment option. A variety of insecticides are registered for localized remedial control of drywood termites; however, the efficacy of many of these treatments had not been adequately tested before 1994 (Scheffrahn and Su, 1994). Lack of testing was due, in part, to the absence of quantitative, biologically meaningful laboratory and field testing methods.

Beginning in 1992, the University of Florida and Dow AgroSciences (formerly DowElanco) began a long-term cooperative research program to evaluate and develop spinosad for localized remedial control of the drywood termites, *Cryptotermes brevis* (Walker) and *Incisitermes snyderi* (Light). Spinosad is derived from the fermentation product of a naturally-occurring soil bacterium, *Saccharopolyspora spinosa*, and is a proprietary material of Dow AgroSciences. Spinosad has a favorable human and environmental toxicity profile and negligible odor (Anonymous, 1996). This report reviews the innovative laboratory and field methods developed to evaluate spinosad and other localized treatments for remedial control of the drywood termites and the results of these trials conducted in Florida.

MATERIALS AND METHODS

Laboratory Bioassays. In these trials, termites were directly treated with the test material, or the test material was applied to a substrate, such as filter paper, on which a group of termites were placed

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(Randall and Doody, 1934; Ebeling and Wagner, 1959; Minnick *et al.*, 1972). These bioassays did not evaluate the termites' behavioral avoidance to test materials by providing termites with the choice of contacting treated and untreated substrates.

Scheffrahn *et al.* (1997) developed a choice bioassay using 1-m-long sapwood pine boards divided longitudinally with a 4.5-mm diameter rounded groove routed along the center of one board (Fig. 1). Test materials were applied to only 9.6 cm (10%) of the gallery chamber, simulating partial treatment of a termite gallery. Eighty termite pseudergates were acclimated for three days in an untreated portion of the chamber before being allowed access to the treated portion of the gallery. Results demonstrated that exposure of drywood termites to most test materials applied in this 3-dimensional arena yielded similar performance to that observed in field trials (Scheffrahn *et al.*, 1997) and provided different results from traditional forced exposure laboratory trials in 2-dimensional arenas (Scheffrahn, unpublished).

Naturally-infested wood trials. A reliable way to evaluate efficacy of remedial treatments was to determine direct mortality by destructive sampling of naturally-infested wood in the absence of control treatments (Randall and Doody, 1934; Lewis and Haverty, 1996). This technique was modified by Scheffrahn *et al.* (1998) by trimming termite-infested boards, limbs, and trunks from both ends until live termites were encountered, then cutting the wood member in half and sealing exposed gallery openings. One half was treated with the test material, the other half was treated with water as a control. Both halves were later destructively sampled to compare mortality of termites in the treated and control halves of the same infestation.

Scheffrahn *et al.* (1997) developed the methods to use an acoustic emissions detector (AED), developed by Dow AgroSciences, to nondestructively evaluate the efficacy of treatments against drywood termites in-situ. Scheffrahn *et al.* (1993) previously determined that the AED quantitatively records the feeding activity of termites. The AED sensors attach directly to infested wood to detect high-frequency sound emitted as termites scrap wood fibers while chewing. For in-situ infestations, Scheffrahn *et al.* (1997) used the AED to quantify drywood termite infestations for minimum levels of activity and delineate separate infestations prior to treatment, and to monitor marked locations within each infestation for a predetermined time interval before and at intervals after treatment. The AED enabled determination of the long-term fate of infestations, up to one year after treatment in Florida field trials (Scheffrahn *et al.*, 1997).

Pest control operators (PCOs) used the AED in a similar manner to delineate and monitor drywood termite infestations pretreatment and 1-2 months after treatment with 0.5% spinosad (Thoms, 1999). The AED enabled PCOs to evaluate the efficacy of spinosad treatments to 44 drywood termite infestations in a wide variety of construction elements in residential, institutional, and commercial buildings, boats, and a 1929 Buick automobile, which could not have been evaluated post-treatment by destructive sampling.

Treatments Evaluated. Spinosad was evaluated in all laboratory and field trials as a diluted suspension concentrate (0.23% and 0.5%). Early trials indicated that an experimental "A" formulation (0.1% and 0.23%) and a pine wood dust formulation (1%) of spinosad generally resulted in significantly less termite mortality compared to the SC formulation (Scheffrahn *et al.*, 1997), so further testing was conducted using only the SC formulation of spinosad diluted to 0.5% (Scheffrahn *et al.*, 1998; Thoms, 1999).

PT-270 (0.5% chlorpyrifos aerosol, Whitmire Micro-Gen, St. Louis, MO) and Tim-Bor[R] (10% aqueous and 98% dust, disodium octaborate tetrahydrate, US Borax, Valencia, CA) were evaluated as current industry standards. All materials were evaluated by intragallery injection in narrow diameter drill holes that intersected the termite galleries. Scheffrahn *et al.* (1997) injected materials at 50-cm spacing, which exceeded the maximum recommended spacing of 25.4 cm for PT-270 and Tim-bor (Anonymous, 1994, 1995). The purpose for increasing the hole spacing was to minimize defacing of wood members and determine if any treatment provided adequate termite control with partial coverage of the galleries.

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The recommended maximum spacing interval was increased to 60 cm for the PCO evaluation of spinosad (Thoms, 1999).

In preliminary field trials, injections of diluted test materials were made using narrow gauge metal wood injector attached to 1.9 L hand-held compressed air sprayer (Scheffrahn, unpublished). For later trials, spinosad and Tim-bor were injected using a blunt-end needle attached to a 10-ml syringe (Scheffrahn *et al.*, 1997, 1998) or a hand-held, low pressure automatic dosing syringe (Felton Medical, Lenexa, KS; Thoms, 1999).

All drill holes were plugged using a wooden dowel (Doody, 1934; Scheffrahn *et al.*, 1997, 1998; Thoms, 1999) or wax pencil (Thoms, 1999).

In the 1-m bioassay (Scheffrahn *et al.* 1997) and treatment of naturally-infested wood (Scheffrahn *et al.*, 1997, 1998), Tim-bor was also evaluated as a surface treatment. Tim-bor (10%) was applied twice to run-off at one-hour intervals on all exposed external surfaces of wood members using a hand-held pump sprayer.

RESULTS AND DISCUSSION

In all laboratory and field trials, spinosad applied as a 0.23% or 0.5% aqueous suspension concentrate (SC) provided consistently significant reduction in *C. brevis* and *I. snyderi* populations throughout the trial period. In the 1-mgallery bioassay trial (Scheffrahn *et al.* 1997) and destructive sampling trial (Scheffrahn *et al.*, 1998), spinosad (SC) yielded the highest percent mortality of the treatments evaluated, reducing drywood termites at least 98% (Table 1) and 97% (Fig. 2), respectively, through 4 or 8 weeks post-treatment. In the field trial comparing different localized treatments (Scheffrahn *et al.*, 1997), spinosad (SC, 0.23%) was the only treatment that resulted in significantly lower AE counts than controls for all monitoring intervals through 12 months (Wilcoxon signed-ranks test at P = 0.05 using normal approximation; SAS, 1998). In this trial, termite activity rebounded in all treatments by 12 months

Table 1. Mean ± SD (n = 4) percent mortality of *I. snyderi* and *C. brevis* pseudergates in treated simulated gallery bioassay after 4 or 8 weeks (abstracted from Scheffrahn *et al.*, 1997).

	4 weeks	8 weeks		
Treatment	*I. snyderi*	*C. brevis*	*I. snyderi*	*C. brevis*
Spinosad (0.23%)	98.1 + 3.8 A	100.0 + 0.0A	-	-
Spinosad (0.5%)	-	99.4 + 1.3A	-	100.0 + 0.0A
PT-270	92.3 + 15.4A	72.7 + 35.7A	-	-
Tim-bor (dust)	16.5 + 7.6B	13.8 + 9.2B	81.2 + 18.2A	67.0 + 26.8B
Tim-bor (surface)	-	-	26.4 + 12.7B	-
Tim-bor (gallery)	14.2 + 9.3B	20.3 + 9.2B	33.9 + 7.5B	47.2 + 21.1BC
Untreated Control	16.9 + 12.3B	18.7 + 8.8B	26.3 + 20.4B	32.1 + 6.0C
Water Control	14.5 + 9.1B	16.0 + 7.2B	24.4 + 10.4B	37.8 + 9.9BC

Means followed by the same letter in columns are not significantly different (Student-Newman-Keuls test, P = 0.05; SAS, 1988).
- = treatment not conducted

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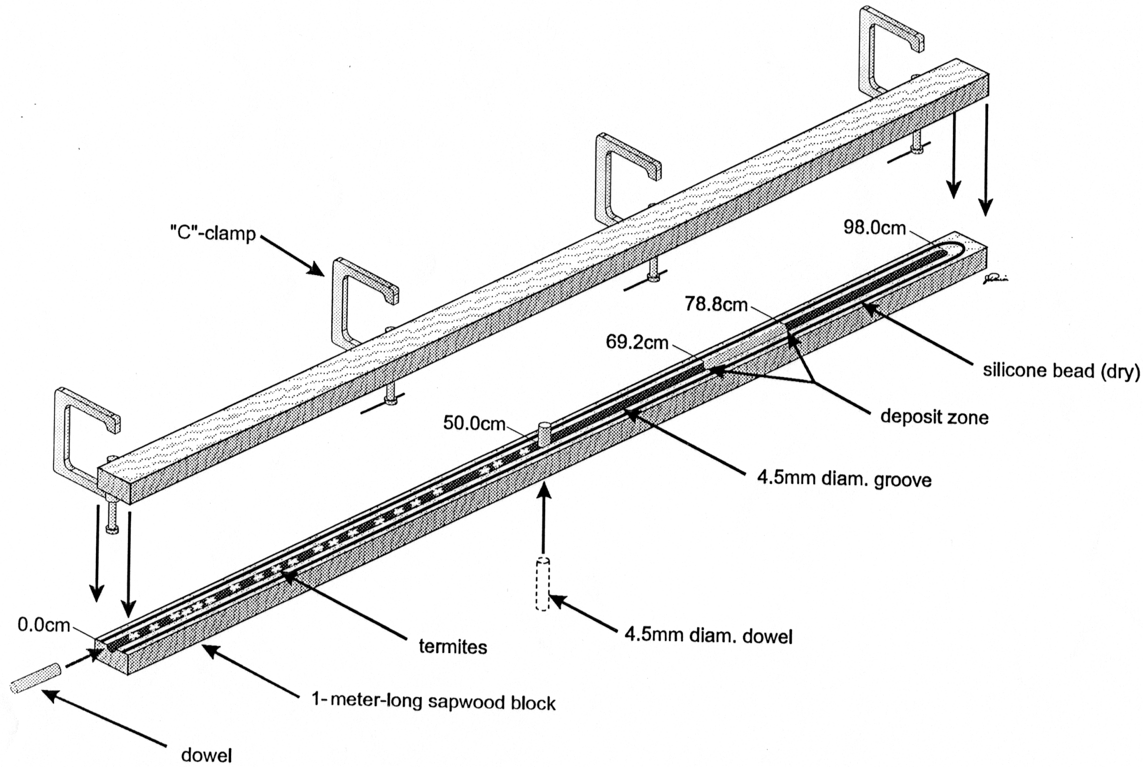


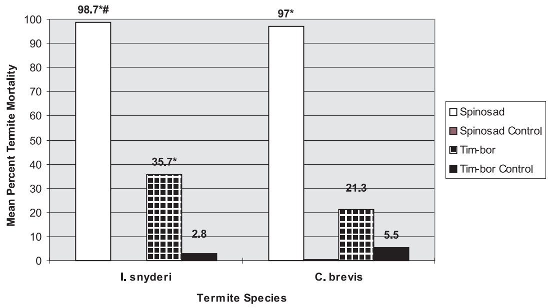
Figure 1. Simulated gallery bioassay (1-m-long) used to quantify the efficacy of various chemical treatments against drywood termites (from Scheffrahn et al., 1997).

except spinosad (SC, 0.23%), in which AE activity was reduced by 99% (Fig. 3). In the PCO trial, AE counts were significantly reduced (paired t-test on log transformed data; P = 0.000; Minitab, 1998) a mean of 94% by 1-2 months after treatment with 0.5% spinosad (Thoms, 1999). In the PCO trial, drywood termite activity was reduced by $\geq$ 90% in 89% of the treated infestations and was eliminated in 61% of the infestations.

In all laboratory and field trials, PT-270 and Tim-bor treatments generally provided inconsistent or incomplete control. In the 1-m-bioassay (Scheffrahn *et al.,* 1997), the relatively high standard deviations calculated for PT-270, compared to those of other treatments, reflect the greater range in mortalities among the PT-270 replicates (Table 1). In the comparative field trial (Scheffrahn *et al.,* 1997), AE counts in PT-270 treatments were not significantly different from the controls at 2 months after treatment, and had rebounded above pretreatment levels by 5 months after treatment (Fig. 3).

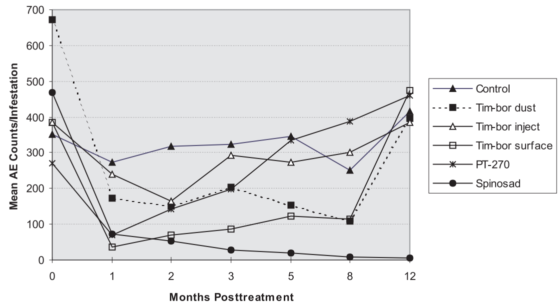
The efficacy of the Tim-Bor treatments varied depending on formulation (aqueous dilution vs. dust) and area treated (gallery vs. surface). Gallery treatment with aqueous dilutions of 10% Tim-bor always yielded mortality that was not significantly different from the controls (Scheffrahn *et al.,* 1997; Table 1, Fig. 3). Gallery treatment with Tim-bor dust (98%) yielded mortality which was significantly lower than that of the untreated control by 8 weeks post-treatment in the 1-m-bioassay (Table 1). The same results were not observed in the comparative field trial; AE counts for Tim-bor dust treatments were not significantly different from those of the controls for all sampling intervals through 12 months post-treatment (Fig. 3; Scheffrahn *et al.,* 1997). It was concluded that dust formulations of Tim-bor flow poorly and result in inadequate coverage in natural gallery systems, compared to that obtained in laboratory bioassays.

Figure 2. Percentage mortality of *I. snyderi* and *C. brevis* pseudergates in wood members that were bisected, one-half injected with 0.5% spinosad or surface treated with 10% Tim-bor, the other half treated with water, and dismantled one month after treatment with spinosad and 3 months after treatment with Tim-bor (abstracted from Scheffrahn *et al.* 1998).



*Percent mortality of insecticide-treated half significantly different from control (water-treated) half (Median test (PROC NPAR1WAY), $P < 0.05$; SAS, 1988).
One replicate omitted from percent mortality calculation for spinosad/*I. snyderi* due to unbalanced distribution of workers

Figure 3. Mean total AE counts for treated drywood termite, *Cryptotermes brevis*, infestations in two buildings in Monroe County, Florida (July 1994-July 1995). Means plotted for 5-12 months exclude colonies in fumigated building (abstracted from Scheffrahn *et al.*, 1997).



[1]Five infestations per treatment were monitored for months 0-3. Three control treatments (water, air, untreated) did not differ for months 0-12 ($P > 0.20$) and were pooled as a single treatment. After the fumigation, infestations were reduced to 3 for spinosad (0.23%), 2 for PT-270, and 2 for Tim-bor surface treatments for months 5-12.

Surface treatments with 10% Tim-bor solution yielded the most inconsistent results. These treatments resulted in mortality which was not significantly different than that of the controls in the 1-m bioassay (Table 1; Scheffrahn *et al.*, 1997) and destructive sampling for *C. brevis* (Fig. 2; Scheffrahn *et al.*, 1998). Nonetheless, Tim-bor surface treatments compared to the controls yielded significantly lower mortality in destructive sampling for *I. snyderi* (Fig. 2; Scheffrahn *et al.*, 1998) and significantly lower AE counts for the first month post-treatment in the comparative field trial (Fig. 3; Scheffrahn *et al.*, 1997). In the comparative field trial, the AE counts for Tim-bor surface treatments were not significantly different from the controls by 2 months post-treatment and had rebounded above pretreatment levels by 12 months. Overall, these tests confirm that Tim-bor, applied as a gallery or surface treatment, has low toxicity for remedial control of drywood termites compared to that of spinosad.

In the PCO trial (Thoms, 1999), a mean $\pm$ SD of 10 $\pm$ 5 holes were drilled per infestation, of which 43% could be injected with a mean of 63 ml of 0.5% spinosad. Two infestations were retreated, during which a lower percentage, 24%, of holes were injected. These results indicate that drilling to intersect galleries in some drywood termite infestations can be difficult.

The time to drill, inject spinosad, and plug treatment holes during the first visit was 13.7 $\pm$ 5.7 min (range 5-30 min) per infestation for the PCO trial (Thoms, 1999). This treatment time was less than that documented for other localized treatments for drywood termite control, including the Electro-Gun (Creffield *et al.*, 1997) and microwaves (Lewis and Haverty, 1996).

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