USE OF AN ACOUSTIC EMISSIONS DETECTOR AND INTRAGALLERY INJECTION OF SPINOSAD BY PEST CONTROL OPERATORS FOR REMEDIAL CONTROL OF DRYWOOD TERMITES (ISOPTERA: KALOTERMITIDAE)

ELLEN M. THOMS
Dow AgroSciences LLC, 3225 S. MacDill Ave. #129-258, Tampa, Florida 33629

ABSTRACT

During 1997, four pest control companies in Florida (FL) participated in experimental use permit field trials to evaluate spinosad (NAF-85) for control of drywood termites (DWT). Forty-four DWT infestations of *Incisitermes snyderi* (Light) and *Cryptotermes brevis* (Walker) in 37 structures in FL were delineated using an acoustic emissions detector (AED). These infestations were injected with a 0.5% spinosad suspension concentrate formulation using a hand-held injector. The majority of these infestations were interior (68%) and were completely accessible (86%). The visible signs most frequently associated with DWT infestations were pellets (93% of infestations). A mean of 10 holes were drilled and 4.3 holes were injected with a total mean of 60.7 ml spinosad per infestation.

At a mean of 44 days post-treatment, the overall reduction in acoustic emission (AE) counts/30 sec was 94%. AE activity was reduced by ≥90% at 89% (n = 40) of the infestations and was completely eliminated at 61% (n = 27) of the infestations. The mean time to monitor a DWT infestation using the AED was 23.4 min for the 1st visit and 6.3 min for the 2nd visit. The mean time to drill, inject NAF-85, and plug drill holes was 13.7 min per infestation. The mean total time per trial site was 58.6 min for the 1st visit and 13.1 min for the 2nd visit. Results demonstrated the combination of the AED, spinosad and injector provided efficient and effective control of localized, accessible DWT infestations.

Key Words: *Incisitermes snyderi, Cryptotermes brevis, treatment time*

RESUMEN

Durante 1997, cuatro compañias de control de plagas de Florida participaron en ensayos experimentales para evaluar la efectividad de spinosad (NAF-85) en el control de termitas de madera seca (drywood termites). Cuarenta y cuatro infestaciones de *Incisitermes snyderi* (Light) y *Cryptotermes brevis* (Walker) fueron identificadas mediante un detector de emisiones acústicas (DEA). En los sitios infestados se inyectó una suspensión concentrada de spinosad al 0.5% usando un inyector manual. El 68% de las infestaciones estaba localizadas en interiores y eran completamente accesibles (86%). El signo más comunmente asociado con la infestación de termitas fue la presencia de pellets (93% de los casos). En promedio, en cada sitio sitio infestado se hicieron 10 perforaciones, de las cuales 4.3 se usaron para inyectar un promedio de 60.7 ml de spinosad por infestación. En promedio, a los 44 días post-tratamiento se detectó una reducción de 94% en el conteo de emisiones acústicas/30 segundos. En el 89% de los sitios infestados (n = 40), las emisiones acústicas se redujeron en ≥90%, mientras que no se detectó emisión acústica en 61% de los sitios infestados (n = 27). El tiempo promedio usado para monitorear una infestación de termitas con el DEA fué 23.4 minutos para la primera visita y 6.3 minutos para la segunda visita. En promedio, el tiempo empleado en hacer las perforaciones, inyectar el spinosad, y sellar las perforaciones fué de 13.7 minutos por sitio infestado. El tiempo total promedio por sitio experimental fué de 58.6 minutos para la primera visita y 13.1 minutos para la segunda visita. Los resultados demostraron que la combinación de DEA, spinosad e inyector lograron un buen control de infestaciones accesibles y localizadas de termitas.

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). Florida (FL) is one of the geographic areas within the United States in which drywood termites are considered important structural pests. Two species of drywood termites, *Cryptotermes brevis* (Walker) and *Incisitermes snyderi* (Light), are the most widely distributed and commonly occurring structure-infesting drywood termites in FL (Scheffrahn et al. 1988).

These drywood termites (DWT), if left uncontrolled, will recolonize a structure until the wood members and contents are severely damaged by numerous colonies. Structural fumigation with fumigants such as sulfuryl fluoride has been documented to be more effective than currently available localized remedial chemical treatments for eliminating DWT infestations throughout a structure (Scheffrahn et al. 1997). Nonetheless, structural fumigation is not always a treatment option for economic or logistical reasons; infested structures cannot always be sealed to confine the fumigant or vacated of people, animals, or sensitive materials. In addition, fumigation may not be necessary if the DWT infestation is limited and confined to wood members accessible for an effective localized treatment. A variety of insecticides are currently registered for application directly to infested wood; however, the efficacy of many of these treatments for remedial control of DWT is inadequate or inconsistent (Scheffrahn et al. 1997, 1998).

One compound which has demonstrated consistent efficacy in research trials for local remedial control of DWT is spinosad, a proprietary material of Dow AgroSciences LLC (Indianapolis, IN). Spinosad is derived from the fermentation product of a naturally-occurring soil bacterium (*Saccharopolyspora spinosa*) (Anonymous 1996). Spinosad has a favorable human and environmental toxicity profile, is nearly odorless, and has long residual activity in wood galleries (Scheffrahn and Thoms 1999). In laboratory and research field trials in FL, spinosad injected into DWT galleries has demonstrated consistent and excellent control of DWT infestations (Scheffrahn et al. 1997, 1998, Scheffrahn and Thoms 1999). These field trials also validated the use of a hand-held acoustic emissions detector (AED) for nondestructively delineating DWT infestations and measuring DWT activity before and after treatment. The AED confirms the presence of DWT in wood by detecting sound emitted as termites chew on wood fibers (Scheffrahn et al. 1993).

In 1997, a Federal Experimental Use Permit (EUP) was granted to Dow AgroSciences for pest control operators (PCOs) to evaluate spinosad (NAF-85) for DWT control. The objectives of the EUP field trial in FL were to determine 1) if PCOs could obtain control of localized DWT infestations similar to that reported by Scheffrahn et al. (1997) and Scheffrahn and Thoms (1999), and 2) if the time required for PCOs to monitor and treat DWT infestations using the AED and spinosad, respectively, would be comparable to currently available local treatments. The results of the EUP trial are described below.

Materials and Methods

PCO Cooperators

Four PCO companies (Hobelmann Inc., Terminix International, Truly Nolen of America Inc., and Young Pest Control Inc.) located in Hillsborough and Pinellas Counties, FL, participated in the trials. All participating companies were licensed to fumigate in FL and had extensive experience in controlling DWT by fumigation with Vikane® gas fumigant (Dow AgroSciences LLC, Indianapolis, IN). Some companies also had experience with non-traditional localized treatment methods for DWT, such as heat (CleanHeat® by Terminix International) and borates (TruGuard® by Truly Nolen).

The PCO participants included technicians, managers, and technical personnel. They were responsible for inspecting the trial site, using the AED to delineate active DWT infestations, applying spinosad in these areas, and documenting the infestation as required by state law and pest control company policy. Two contractors experienced in the pest control industry were hired to observe and document the activities and conditions at each trial site. The contractors completed their activities in a manner that did not interfere with the PCO monitoring and treating the DWT infestations. All materials and equipment, with the exception of ladders, used in these trials were provided by Dow AgroSciences and were maintained by the contractors during the trial period.

All PCO participants and contractors were trained by the author and provided with a reference manual on how to use the AED, and information and application instruction on spinosad. Initial inspection, treatment, and reinspections were conducted from 4 September through 15 December, 1997. Three infestations were retreated and had a second reinspection on 25 February, 1998.

Study Sites

Trial sites selected by PCOs included residential and commercial structures. Sites had to contain at least 1 active DWT infestation accessible for monitoring with the AED and treatment with spinosad. The sensors for the AED must directly contact the insect-infested wood to detect the acoustic emissions (AE). Infested wood completely covered by drywall, plaster, stucco, or other structural elements could not be monitored using the AED and was not included in the trial. Each DWT infestation evaluated in the study was required to have AE readings exceeding 5 counts for 30 sec at one or more monitoring locations.

Delineating and Documenting Active DWT Infestations

First, the PCO inspected properties for visible signs of DWT infestation such as pellets, ejection holes, wood damage, buckled surfaces, live termites, or alate wings. When suspected DWT infestations were located in exposed wood, the PCO used the AED to confirm the presence of live termites as indicated by AE counts, locate the area of greatest AE counts, and delineate the extent of the active infestation (Fig. 1).

After delineating the infestation, the PCO selected monitoring locations using a 30-sec monitoring period. Peripheral monitoring locations marked the outer boundary of the DWT infestation in each wood member and were selected where AE counts diminished to about ≥5 AE counts/30 sec. The PCO also marked where AE counts were highest per 30 sec reading for each infestation.

Each monitoring location was marked, using ink pen or removable labels, and sequentially numbered for identification. AE readings were taken at the identical location during a follow-up inspection at all infestations. The number of monitoring locations varied depending on the extent of the infestation. In the example in Fig. 2, 5 monitoring locations, with AE counts of ≥5/30 sec, would be marked for future monitoring. At every test site, background AE counts were taken for 30 sec with AED sensors not attached to surfaces to measure background AE.

Fig. 1. Pest control operator using the acoustic emissions detector on wood trim in a boat to detect drywood termites.

Application of Spinosad

Per the EUP label, PCOs drilled treatment holes (2 mm diameter) with a battery-powered drill adjacent to monitoring locations and through DWT ejection holes and wood damage within the infested area delineated by AED readings (Fig. 2). Holes were drilled to intersect DWT galleries up to ¾ through the depth of the infested wood member. Holes accidentally drilled completely through the wood were not treated and were sealed using 2.4 mm diameter wood dowels or wax sticks (Touch Up Stiks®, Darworth Co., Simsbury, CT). Laboratory trials have verified that wax sticks were not repellent or toxic to DWT (R. H. Scheffrahn, Univ. of Florida, unpublished data). Drill holes were often clustered in areas with insect activity; spacing between clusters of drill holes generally did not exceed 60 cm.

Spinosad was provided in 1 ml volumes of suspension concentrate formulation (NAF-85, 44.2% a.i.) in dual chamber bottles containing 99 ml of water resulting in a 0.5% dilution of spinosad when mixed. After mixing, the dual chamber bottle was connected to the hand-held, low pressure automatic dosing syringe (Felton Medical Inc., Lenexa, KS) for application.

For vertical or diagonal wood members, the PCO injected at the highest elevation first, moving down towards ground level. Up to 50 ml of spinosad was injected into each drill hole. If the solution began to seep from other drill holes or the wood, injection was stopped, and the injection hole and all other drill holes with seepage were plugged as previously described.

If a gallery was not intersected while drilling, as indicated by less than 0.5 ml of dilution being accepted into the drill hole, or the wood member was completely penetrated, the PCO plugged the drill hole and drilled another hole if necessary. After treatment, all pellets, wings, or other signs of active infestation were removed if possible using a battery operated, hand-held vacuum cleaner (The Boss®, Eureka Co., Bloomington, IL).

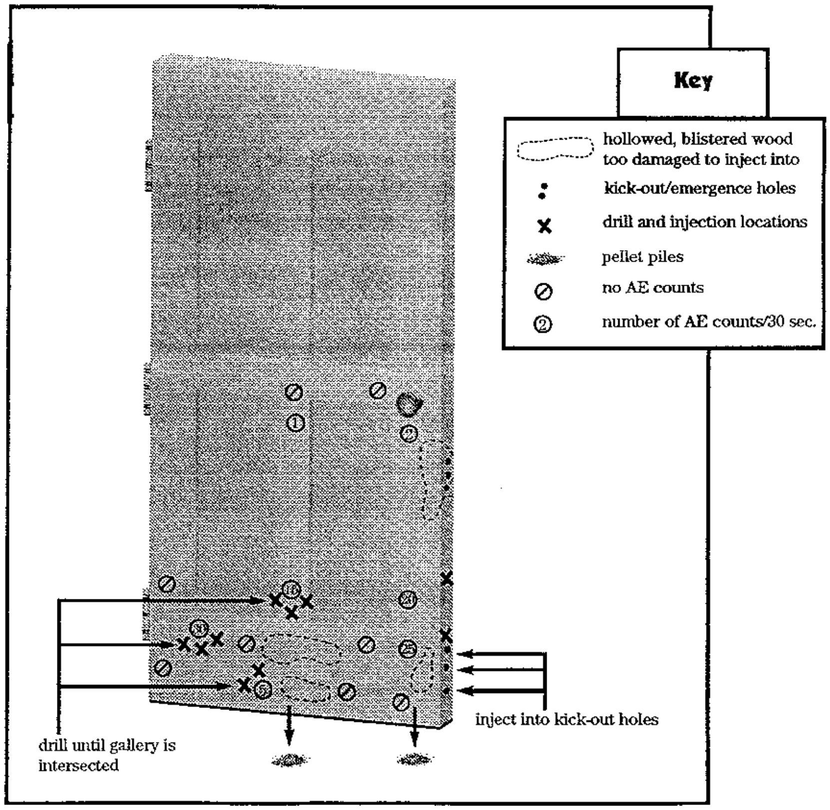

Fig. 2. Example of termite damage, pellets, AE monitoring locations, and drill and injection locations for spinosad in typical drywood termite infestation in a door. Five monitoring locations, containing AE counts of ≥5/30 sec, would be marked for future monitoring.

All active, accessible DWT infestations were treated with spinosad. Property owners were unwilling to have active infestations remain untreated as controls for these commercial trials. In addition, 84% of the structures only had 1 infestation to treat (See Results and Discussion below).

Post-treatment Inspection

One to 2 months after spinosad application, study sites were reinspected by the PCO and contractor. This reinspection interval was selected based on time observed to obtain significant reduction in DWT activity following application of spinosad in previous field trials (Scheffrahn et al. 1997, Scheffrahn and Thoms 1999). AE readings were taken by the PCO for 30 sec at all monitoring locations. Background AE counts were taken as previously described. At this time, additional application of spinosad was at the discretion of the PCO based on AE readings or other signs of DWT activity. Retreated sites were reinspected 3 months following retreatment.

Data Recording

All contiguous monitoring locations with AE activity were designated as 1 infestation site. Data recorded included; infestation location and accessibility, time at site, background AE counts, AE counts for monitoring locations, time for monitoring and treating the infestation, number of drill holes, ml spinosad injected, and presence of damage, pellets, or wings, removal of pellets or wings, and dimensions of wood member(s) treated. Treated infestations were photographed, with each monitoring location marked by fluorescent 1.5 cm diameter circular sticker, and graphed.

Statistical Analyses

AE counts before and after treatment and time measurements were log transformed and compared by *t*-test (Minitab 1998).

RESULTS AND DISCUSSION

Study Sites

A total of 37 structures were treated. Treated structures included residential properties (19 single family homes, 3 garages, 1 apartment, 1 fence), commercial properties (4 offices, 1 motel, 1 marina, 1 store, 1 manufacturing facility, 1 church), the wood frame of a 1929 Buick automobile, and 3 boats.

Delineation of DWT Infestations

A total of 44 DWT infestations were delineated using the AED. The majority (84%) of structures had only 1 DWT infestation treated, 13% (n = 6) had 2 infestations, and 3% (n = 1) had 3 infestations.

Over half (57%) of the wood members infested and treated were doors (n = 9), door frames (8), and window frames (8). Other wood members treated included trim (n = 3), rafters and beams (3), floors (3), studs (3), baseboards (2), cabinets (2), a fence, a boat hatch, plywood sheathing, a pillar base, and wall paneling.

One or more visual signs of DWT activity; damage (including DWT ejection holes), pellets, or alate wings, occurred at every DWT infestation. The AED can detect DWT feeding up to about 60 cm along the grain of the wood and 6 cm across the grain of the wood from where the sensor is placed (Scheffrahn et al. 1993). Because the AED cannot be used efficiently to test every accessible wood member in a structure, signs of DWT infestation were necessary to determine where to take AE readings. The most common indicator of DWT activity was pellets, found at 93% of the infestations treated. Damage was found at 64% of the infestations treated. Wings were found at only 16% of the infestations treated, probably because trials were initiated in September after DWT termite peak swarming in May-July (Scheffrahn et al. 1988).

The number of monitoring locations per DWT infestation was 4.2 ± 3.0 (mean ± SD) and ranged from 1 to 15. The more extensive the DWT infestation, the greater the number of monitoring locations. The majority of the infestations treated were interior (68%) and were completely accessible (86%), probably because these infestations were more readily observed by building occupants and by PCOs during inspection. In addition, DWT pellets would be more easily observed indoors than outdoors, where they are dispersed by wind and rainfall.

Application of spinosad

A mean ± SD of 10 ± 5 holes (range 2-19) were drilled per DWT infestation and 4.3 ± 3.1 holes (range 1-17) were injected with spinosad, resulting in 43% of the drill holes injected with spinosad. A mean ± SD of 60.7 ± 35.2 ml of spinosad (range 10-160 ml) was injected per DWT infestation. The mean amount of spinosad injected per DWT infestation in the 1997 FL EUP trial was similar to the amount (56 ml) applied in the 1994 FL field trial (Scheffrahn et al. 1997). Qualitatively, PCOs observed no staining of structural surfaces or detectable odor when applying spinosad.

The EUP label for spinosad indicated best results would be achieved when spacing between injection holes does not exceed 60 cm. This spacing recommendation was based on previous field research (Scheffrahn et al. 1997, Scheffrahn and Thoms 1999). The spacing between drill holes was 60 cm or less at all infestations, with the exception of two infestations in which the maximum spacing was 118 cm and 175 cm. These sites had 81% and 100% reduction in AE counts, respectively, following application of spinosad, indicating that satisfactory results can be obtained in certain circumstances with wider hole spacing.

AE Monitoring and Post-treatment Inspection

Post-treatment inspections occurred a mean ± SD of 44 ± 15 days (range 21-74) after initial treatment. The post-treatment AE counts (1.5 ± 5.6, range 0-40) were significantly lower (paired *t*-test on log transformed data; $P < 0.0001$) than the pretreatment AE counts (23.9 ± 27.5; range 1-240).

Application of spinosad resulted in mean 94% reduction in termite activity as indicated by AE counts. Ninety percent or greater reduction in DWT activity was obtained at 89% (n = 40) of the infestations. In fact, DWT activity as determined by AE counts was eliminated at 61% (n = 27) of the treated infestations.

Five untreated drywood termite infestations were monitored in southeast Florida (Scheffrahn and Thoms 1999) during the Fall of 1997, concurrent with this trial. These infestations had a slight reduction (9% decrease) in AE counts during the evaluation period. These results indicate any significant reduction in DWT activity following application of spinosad could reasonably be attributed to spinosad.

The overall 94% reduction in AE counts obtained by PCOs applying spinosad was equivalent or better than that obtained by researchers applying spinosad in previous field trials. Researchers demonstrated reduction in DWT activity after application of spinosad by 88% 2 months post-treatment (Scheffrahn et al. 1997) and by 92% (Scheffrahn and Thoms 1999).

Retreatment was attempted by one PCO at 3 DWT infestations. Two of these 3 infestations had the lowest reduction in trial post-treatment AE counts, 57% and 43%, and 60 ml and 40 ml, respectively, of spinosad was injected into 2 drill holes in each infestation. Retreatment further reduced AE activity by an additional 32-34% at these 2 infestations. The third infestation had a 91% reduction in AE counts; retreatment was attempted due to the large number of new pellets observed on the post-treatment inspection but no spinosad could be injected. No new pellets were observed at this infestation on subsequent reinspection. A lower percentage, 24%, of the drill holes were injected during retreatment than the 43% injected during initial treatment. These results indicate that intersecting the active galleries in some DWT infestations can be difficult.

In 30 of 41 DWT infestations with pellets, pellets were removed by vacuuming during the first inspection. Eight (23%) of these infestations had pellet piles present again during the post-treatment inspection. These infestations had a mean reduction of 97% (range 91-100%) in AE counts/30 sec during the post-treatment inspection. These results suggest that time for termites to contact a lethal dose of spinosad varies, resulting in pellets being ejected from some infestations after initial application of spinosad.

Time Efficiency

The time per site visit was significantly greater (paired *t*-test on log transformed data; $P < 0.0001$) for the first visit (58.6 ± 24.3 min; range 20-125 min) than that of the second visit (13.1 ± 6.5 min; range 5-35 min). The increased time for the first visit was due to identifying, delineating, and treating infestations, which was not repeated during the second visit with the exception of 3 sites where retreatment was attempted.

The time for the first visit varied depending on the number of infestations per trial site (Fig. 3). The more DWT infestations, the longer the initial visit. For all infestation sizes, the post-treatment inspection took less time than the first visit, because the infestations were already delineated and treated as previously discussed.

The time to monitor an infestation using the AED was significantly greater (paired *t*-test; $P < 0.0001$) on the first visit (23.4 ± 11.9 min; range 9-60 min) than that on the second visit (6.3 ± 2.9 min; 2-14 min). For all infestations, the time to monitor during the post-treatment inspection was always less, generally by at least 50%, than that of the pretreatment inspection because the monitoring locations were previously marked.

The time to drill, inject spinosad, and plug treatment holes during the first visit was 13.7 ± 5.7 min (range 5-30 min) per infestation. The time to treat an infestation was dependent on its size, which was indicated by the number of monitoring locations (Table 1). Photographs and graphs of treated infestations document the minimum mean distance between monitoring locations was ca. 30 cm. The average size of an infestation, with a mean of 4 monitoring locations, was equivalent to treating a 90-cm length of a 10 cm × 4 cm wood member.

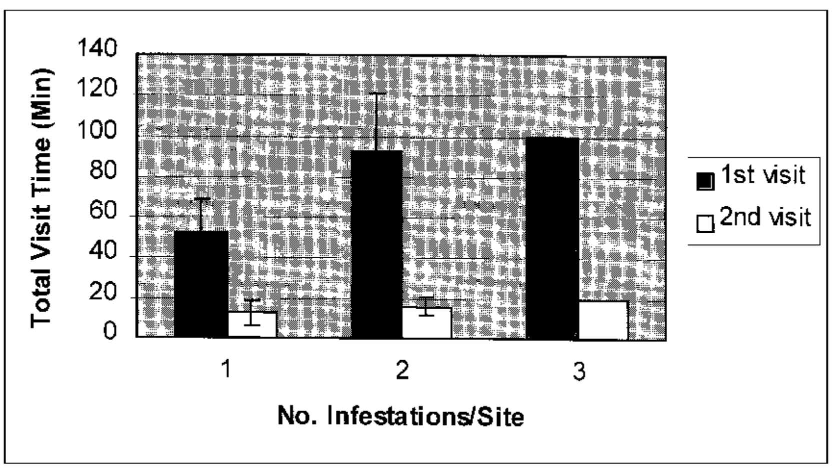

Fig. 3. Mean (± SD) total time (min) for first and second visit to trial sites in FL, 1997.

TABLE 1. ESTIMATED TIME (MIN) TO TREAT GIVEN LENGTHS OF WOOD SECTIONS (10 CM WIDE × 4 CM IN DEPTH) USING VARIOUS LOCAL DRYWOOD TERMITE TREATMENT METHODS

Treatment method	Estimated time in min to treat given lengths (cm) of wood sections 10 cm wide × 4 cm in depth[a] One section (30 cm)	Three sections (90 cm)	Fourteen sections (420 cm)
Spinosad Injected[b]	11	12	30
Microwave[c]	8	24	112
Electro-Gun[d]	15	45	210

[a]One, 3, and 14 sections equivalent to the smallest area (1-2 monitoring locations = 30 cm in length), mean area (4 monitoring locations = 90 cm in length), and largest area (15 monitoring locations = 420 cm in length) treated, respectively, for 1997 PCO trial.

[b]Does not include AED monitoring time.

[c]Time estimates derived from Lewis and Haverty (1996) did not include time for equipment set-up and removal.

[d]Time estimates derived from Creffield et al. (1997) did not include time for equipment set-up and wood preparation using the "drill-and-pin" method.

Currently available localized treatments for DWT include microwaves and the Electro-Gun® (Etex Ltd, Las Vegas, NV). The Electro-Gun emits high frequency electricity (60,000 HZ), high voltage (100,000+ volts), and low current (below 0.5 amp) to exposed wood to kill termites (Creffield et al. 1997). The mean time to treat small infestations (wood members 30 cm long, Table 1) using spinosad was similar to that documented for microwaves (Lewis and Haverty 1996) and the Electro-Gun (Creffield et al. 1997). The efficiency of the spinosad treatment times increased, compared to other localized treatments, as the infestation size increased. The mean time to treat medium infestations (wood members 90 cm long) using spinosad was 50% and 73% faster than that documented for microwaves and the Electro-Gun (Table 1), respectively. The time to treat the largest infestation (wood member 420 cm long) using spinosad was even faster, 73% and 86%, than that of microwaves and the Electro-Gun, respectively.

The apparent increase in efficiency for spinosad treatments, compared to microwaves and the Electro-Gun, as the infestation size increased can be explained by actual size of the treatment zone. Spinosad is applied as point injections, while for the latter two methods, the entire wood member is exposed to microwave energy or electrical current, respectively. Termites do not need to be directly contacted by spinosad during application for them to acquire a lethal dose by later contact with treated substrates. Choice bioassays in which only 10% of the gallery was pretreated with spinosad yielded 98-100% termite mortality through 2 years of aging (Scheffrahn et al. 1997, Scheffrahn and Thoms 1999). Conversely, microwave and Electro-Gun treatments are non-residual; the entire infestation must be contacted by the microwave energy or electrical current, respectively, to insure killing significant numbers of termites.

Other non-fumigation treatments for control of DWT include freezing and heating infested wood members. Freezing requires injecting liquid nitrogen (N_2) into wall voids to reduce structural lumber temperatures within the void to -20°C, the lethal temperature required to kill DWT (Rust et al. 1997). Rust et al. (1997) documented the mean time to reach this temperature when injecting N_2 was 7 min, which varied from 1-28 min depending on the injection rate of N_2 and the relative location of the wood member and the N_2 injection point. Heating involves enclosing infested areas with thermal confinement barriers and applying heat using propane gas blowers to heat infested wood to 49°C for 30 min (Woodrow and Grace 1998). Woodrow and Grace (1998) documented the mean time to achieve this temperature accumulation was 128 min, which varied from 45-330 min depending on the location of the wood member. It is difficult, however, to compare the time efficiency of spinosad treatments to temperature modification techniques, which are used to treat compartmentalized areas and not individual wood members. In fact, exposed, isolated wood members may be difficult to treat with liquid N_2. Additionally, both methods require heavy, expensive equipment and offer no residual efficacy.

The time estimates in Table 1 for spinosad are the entire treatment time, including time to drill and plug holes. By comparison, the time estimates for microwaves, the Electro-Gun, heat and freeze treatments were conservative and do not account for the total time required to conduct the treatments. Only the time to apply the lethal dosage was documented for these treatments: previous reports did not include time for drilling and pinning holes for the Electro-Gun (Creffield et al. 1997), or time to prepare structures or install and remove microwave equipment (Lewis and Haverty 1996) or temperature modification equipment (Rust et al. 1997, Woodrow and Grace 1998). These additional procedures could significantly increase the time required to apply these treatments. PCOs select treatment protocols based on labor requirements as well as efficacy. Therefore, it is important for researchers to document total time required to conduct efficacious treatments.

CONCLUSIONS

The quantitative and qualitative results of the 1997 EUP trials in FL demonstrated that the combination of the AED, spinosad, and injector provide efficient control of localized, accessible DWT infestations. The AED provided a simple method to nondestructively delineate DWT infestations before treatment and monitor efficacy of treatments. The active ingredient, spinosad, had no detectable odor, did not stain, was simple and fast to apply, and did not require complete coverage of the drywood termite galleries to be effective.

The new technology does have limitations. The AED sensors must have direct contact with infested wood to detect DWT. The active galleries must be at least partially accessible and intersected by drilling to inject spinosad. In spite of these limitations, the EUP field trial indicated many localized infestations of DWT in FL can be effectively and efficiently treated using this new technology.

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