USE OF AN ACOUSTIC EMISSION DETECTOR FOR LOCATING FORMOSAN SUBTERRANEAN TERMITE (ISOPTERA: RHINOTERMITIDAE) FEEDING ACTIVITY WHEN INSTALLING AND INSPECTING ABOVEGROUND TERMITE BAIT STATIONS CONTAINING HEXAFLUMURON

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ABSTRACT

Soft- and hard-style aboveground bait stations containing 0.5% hexaflumuron in a cellulose matrix (Recruit[R] AG), were installed indoors in two condominium buildings and in one home. Bait stations were affixed to wood where Formosan subterranean termites [FST (*Coptotermes formosanus* Shiraki)] were observed in foraging tubes and subsurface galleries and adjacent to these locations where termite feeding was detected using an acoustic emission detector (AED). Bait stations were inspected monthly for the presence of termites, bait matrix consumption, and acoustic emission (AE) counts on adjacent wood. Bait stations were added as needed. Six to fourteen aboveground bait stations were installed in each structure at 3 or 6 placement sites. Termites fed in a mean of 73.3% of the stations installed to consume a total of 42-149

g of bait matrix. FST at the home had ground contact and consumed 2- 3.5 times more bait matrix than aerial infestations of FST at the condominiums. Acoustic emission counts generally declined from pretreatment levels at all monitoring locations following installation of the bait stations, with the exception of one condominium where AE counts peaked 6 weeks following installation. At all sites, bait matrix consumption in stations peaked during the first two months following installation of the aboveground bait stations. Baiting eliminated detectable FST activity in all structures, as indicated by lack of visual signs of termites and AED activity for at least two months. Elimination of detectable activity followed two or more months of bait matrix consumption by termites. Mean time to elimination of detectable activity for FST populations was 3.3 months (range 2-4 months).

Key Words: Acoustic Emission Detector, Formosan Subterranean Termite, Recruit AG, Aboveground Termite Bait Station, hexaflumuron, *Coptotermes formosanus*

RESUMEN

Se instalaron dentro de una casa y dos condominios estaciones de cebo de dos estilos, suaves y duras, que contenían un 0.5% de hexaflumuron en una matriz de celulosa (Recruit^{R} AG). Las estaciones de cebo se fijaron sobre madera en la que se habían observado termitas subterráneas formosas ("FST", *Coptotermes formosanus* Shiraki) en túneles de alimentación y en galerías bajo la superficie, y también se colocaron adyacentes a estos sitios donde alimentación por termitas fué detectada utilizando un detector de emisión acústica ("AED"). Las estaciones de cebo fueron inspeccionadas mensualmente en busca de la presencia de termitas, consumo de la matriz del cebo, y del número de emisiones acústicas en madera adyacente. Se añadieron estaciones de cebo cuando fue necesario. Se instalaron entre seis y catorce estaciones de cebo en cada estructura en tres a seis lugares. Las termitas se alimentaron en un promedio del 73.3% de las estaciones de cebo instaladas, consumiendo un total de 42 a 149 g de la matriz del cebo. La FST en la casa tuvo contacto con el suelo y consumió de 2 a 3.5 más de la matriz del cebo que la FST en las infestaciones aéreas en los condominios. El número de las emisiones acústicas generalmente declinó de los niveles anteriores al tratamiento en todas las localidadaes después de instalar las estaciones de cebo, con la excepción de un condominio en que el número de las emisiones acústicas alcanzó su máximo seis semanas después de la instalación de las estaciones. En todos los sitios, el consumo de la matriz del cebo alcanzó su máximo en los dos primeros meses después de la instalación de las estaciones de cebo arriba del piso. El uso del cebo eliminó la actividad detectable de la FST en todas las estructuras, que fué indicado por la ausencia de signos visuales de las termitas y de la actividad AED de por lo menos dos meses. Se eliminó la actividad detectable después de dos meses más de consumo de la matriz del cebo por las termitas. El tiempo promedio para la eliminación de toda actividad detectable de las poblaciones de FST fue de 3.3 meses (rango de 2 a 4 meses).

Field evaluations have documented the elimination of subterranean termite activity by application of Recruit^{R} (DowElanco, Indianapolis, IN), a bait matrix containing the chitin synthesis inhibitor hexaflumuron applied in-ground (Su et al. 1995, DeMark et al. 1995, Grace et al. 1996) and aboveground (Su et al. 1997). In these field trials, mark-recapture methods were used to delineate termite foraging territories and to estimate foraging population sizes before and after bait application. Untreated wooden blocks in monitoring stations were used to measure wood consumption rates by termite populations and to determine foraging activity (DeMark et al. 1995, Su et al. 1995, Su et al. 1997).

Delineating termite foraging territories and determining foraging activity of aboveground termite populations can be very difficult. Mark-recapture methods are disruptive and labor intensive. Subterranean termites foraging above-ground, compared to those in soil, are more likely to abandon foraging areas after disturbance (N.-Y. Su, Ft. Lauderdale Research and Education Center, University of Florida, personal communication). Su et al. (1997) also documented that aboveground monitoring and baiting stations, compared to in-ground stations, had a lower acceptance rate for bait feeding by subterranean termites.

Acoustic emission (AE) detection has been successfully used to delineate aboveground foraging territories and foraging activity for drywood termites (Scheffrahn et al. 1997). Scheffrahn et al. (1993) verified that the acoustic emission detector (AED) quantitatively records high frequency sound as wood is fed upon by termites. Scheffrahn et al. (1997) then utilized acoustic emissions as a simple, non-disruptive method to quantify drywood termite activity in structural wood before and after application of localized chemical treatments.

The AED has not been previously used to determine subterranean termite activity in structural wood as a measure of treatment efficacy. Therefore, the purpose of this study was to evaluate the AED for delineating and measuring subterranean termite feeding activity in structural wood as criteria to position installation of aboveground bait stations containing hexaflumuron. In addition, the AED was evaluated as a tool to measure subterranean termite foraging activity before and after consumption of bait containing hexaflumuron.

MATERIALS AND METHODS

Termite Bait Stations.

Two types of aboveground bait stations, hard- and soft-style, containing 0.5% hexaflumuron in a cellulose matrix (Recruit^{R} AG) were evaluated. The hard-style station consisted of a rigid, plastic container (10 cm by 10 cm by 4 cm), with a snap-on cover containing 25 g of matrix (Fig. 1). The soft-style station consisted of a flexible laminated foil pouch (15 cm by 15 cm) and contained 15 g of matrix (Fig. 2). On the front of the soft-style station a cover flap sealed a removable inspection flap (7.5 cm dia.) which covered the matrix. The back of the soft-style station had a removable access flap (7 cm by 7 cm) and flexible adhesive used to affix the station to the target site.

Study Sites.

The aboveground bait stations were evaluated within three structures in Broward County, Florida; two multi-story condominiums (Condo1 and Condo2) and one single-story, single family residence (Home). All structures were infested with Formosan subterranean termites (FST), *Coptotermes formosanus* Shiraki. Formosan subterranean termite infestations in both condominium buildings were aerial; with no detectable ground contact as indicated by the presence of FST on the uppermost story of each building (16th and 6th stories for Condo1 and Condo2, respectively) with no activity on lower stories. The ability of FST to establish aerial infestations on flat rooftops of high rise (4-14 storied) buildings similar to Condo1 and Condo2 in Hallandale, FL was documented by Su et al. (1989). Formosan subterranean termites infesting the home were in contact with the ground.

In Condo1, FST had infested wooden baseboards and door trim in the hallway (HALL) and the master bedrooms (BR) of two condominium units adjacent to the el-

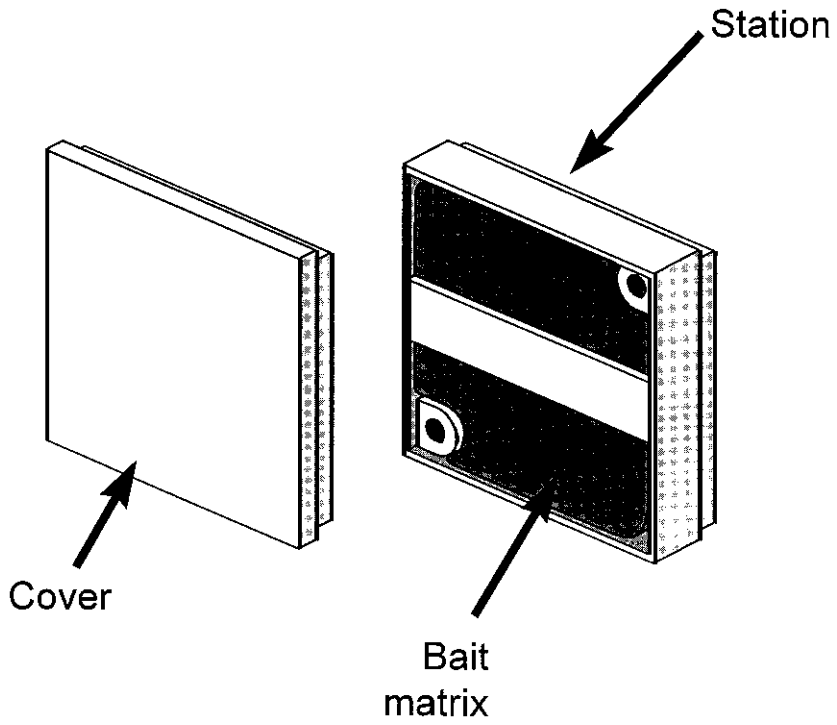

Fig. 1. Hard-style aboveground bait station containing hexaflumuron, showing snap-on cover.

evator (EL) on the top (16th) floor (Fig. 3). Formosan subterranean termites were no longer active in the master bedroom of one condominium when this study was initiated, so aboveground bait stations were installed in the hallway and master bedroom of the other condominium as indicated by Fig. 3. Infested baseboards and door trim had been replaced 6 months prior to testing in the condominium unit of Condo1. These baseboards and trim were subsequently reinfested and were used as sites for installation of aboveground bait stations. In Condo2, FST infested 2x4 wood framing in an elevator machinery (EL)/storage room (SR) on the roof-top of this 6-story building (Fig. 4). No localized insecticide treatments had been applied to control these aerial FST infestations.

In the Home, FST had infested doorframes in the recreation room (REC; Fig. 5). The Home was on low-lying, continuously water-saturated soil adjacent to a canal. The foundation was grade-beam construction comprised of an interior grid of load-bearing footings poured beneath the slab. Two professional pest control companies were treating the Home for subterranean termites. One company repeatedly applied soil termiticides around the perimeter foundation and sub-slab. The water-saturated soil and grade-beam construction may have prevented the establishment of a continuous termiticide soil barrier beneath the structure, because FST continued to reinfest the Home after termiticide applications. Drilling through the slab revealed that FST had constructed extensive carton in the honey-combed chambers beneath the slab.

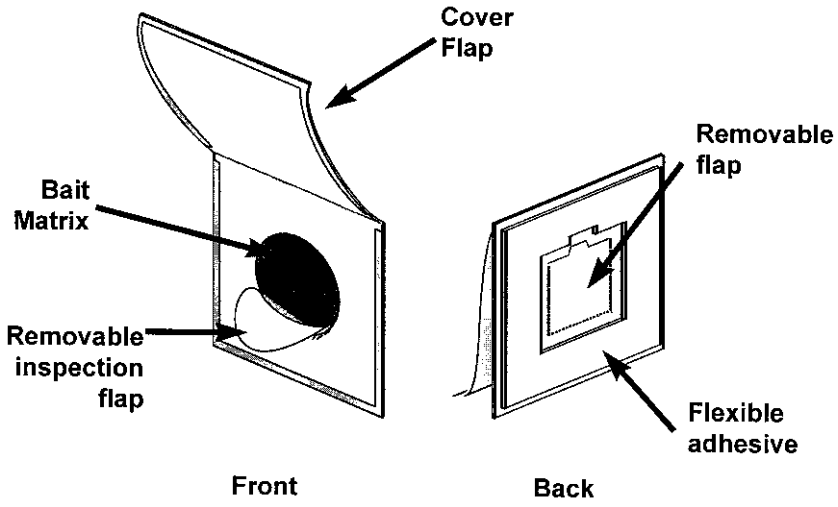

Fig. 2. Soft-style aboveground bait station containing hexaflumuron, showing cover flap and removable inspection flap on station front and removable flap and flexible adhesive on station back.

The other pest control company installed 20 in-ground Sentricon[R] System (DowElanco, Indianapolis, IN) stations on June 6, 1995. These stations, containing monitoring devices, were inspected monthly (x = 37.5 days) and 23 additional in-ground stations were added during subsequent inspections. The installation and inspection procedures followed label and manufacturer guidelines. Nonetheless, termites were never detected in the in-ground monitoring stations. Water-saturated soil and extensive termiticide perimeter treatments appeared to deter FST from foraging outside of the foundation to sites where in-ground monitoring stations were installed.

AED Monitoring.

Infested wood members were located initially by the observations of building occupants. Wood members were visually surveyed for signs of FST infestation and were monitored using the AED (Locator[R]) currently under development by DowElanco (Indianapolis, IN). The AED is a hand-held, battery-powered instrument designed to detect low frequency ultrasonic sound emitted as wood fibers are damaged by insect chewing. It consists of a main processor unit connected by two coaxial cables to two identical sensors. The sensors are attached with putty to the wood members to be monitored for termite activity.

One AED monitoring location was established adjacent to each bait placement site, even if no termite feeding activity was detected using the AED. These locations were monitored once for 60 seconds during each visit, and marked for monitoring on subsequent visits. In areas where there was no visible termite activity (e.g. subsurface galleries, feeding damage or emergence holes) but termite feeding activity was detected using the AED, 2.3 mm diameter holes were drilled through the wood surface to intersect termite galleries. These holes were located within a 50 cm^2 area to fit within the access area on the back of aboveground stations.

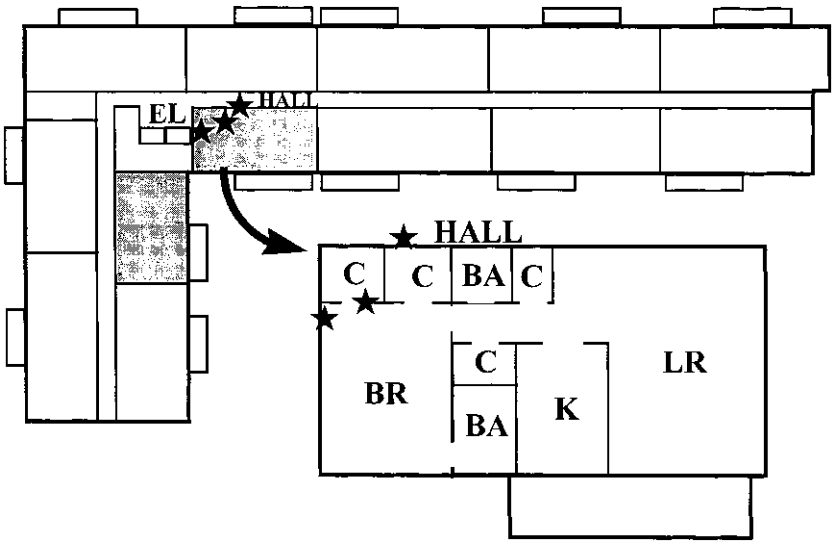

Fig. 3. Floor plan of top (16th) floor of Condo1. Shaded areas are condominiums infested by Formosan subterranean termites prior to application of aboveground bait stations. Stars show placement sites for bait stations on baseboards in hallway (HALL) and master bedroom (BR) and on door trim of closet (C) of master bedroom; K = Kitchen, LR = Living room, BA = bathroom.

Installation of Aboveground Bait Stations.

Bait stations were affixed to wood where termites were visually observed in foraging tubes and subsurface galleries and/or the AED detected termite feeding. Directions on the Recruit AG label (DowElanco 1996) were followed. For soft-style stations, the adhesive backing and back access flap were removed and the exposed matrix was aligned with termite gallery openings, exit holes, drill holes, or mud foraging tubes. Soft-style stations were affixed to baseboards and door trim in Condo1 (13 June, 1996) and the Home (28 October, 1996) using a staple gun or hot glue, in addition to the adhesive on the station back. Hard-style stations were affixed to 2 × 4's in Condo2 (13 June, 1996) using screws and hot glue. All stations were located indoors. Thirty to forty ml of water was added to the matrix of each station after installation, and stations were resealed with covers.

Inspection of Aboveground Bait Stations.

Bait stations were initially inspected every 2-6 weeks. After carefully removing bait station covers, the presence or absence of termites in stations was noted, and the percent of bait matrix consumed was estimated. In addition, AED readings were taken during each inspection and if additional termite activity, indicated by damage, mud tubes, and/or AE counts, was observed at new locations in wood, additional stations were installed at these sites. If less than 50% of the bait matrix was consumed at the time of inspection, it was re-moistened with water and the station cover was put back in place. If termites had consumed 50% or more of the matrix, a second station

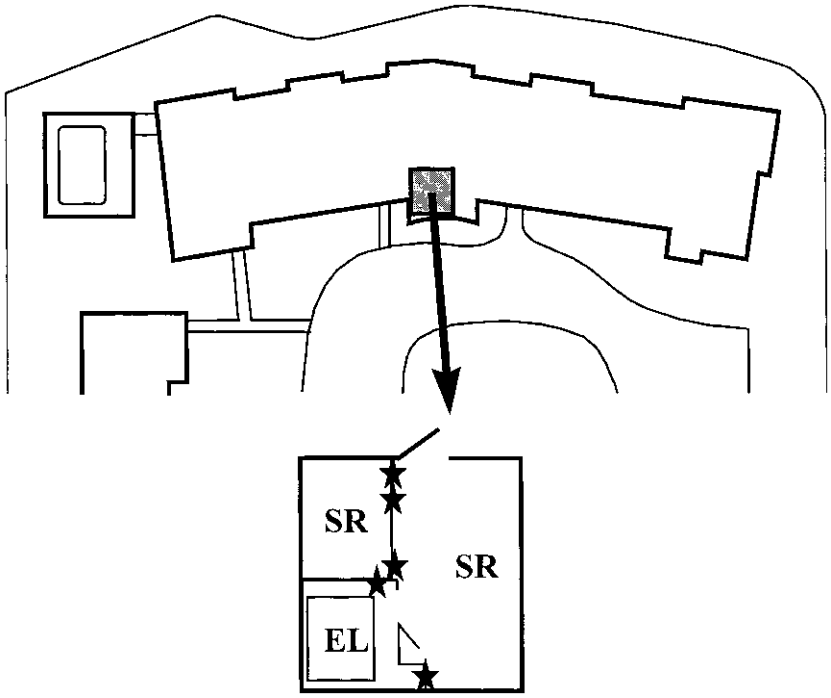

Fig. 4. Floor plan of roof top of six-story Condo2. Shaded area is elevator machinery (EL)/storage room (SR) infested with Formosan subterranean termites prior to application of aboveground bait stations. Stars show placement sites of bait stations on 2 × 4 wood framing in machinery/storage room.

was stacked on top the original, per Recruit AG label directions (DowElanco 1996). The cover of the original station was removed prior to stacking and the matrix in the station was moistened, if necessary. Subsequent hard-style stations were affixed using screws. Subsequent soft-style stations were affixed using a staple gun or hot glue, in addition to the sealant on the back of the station. Two hard-style stations or three soft-style stations were the maximum number of stations that could be stacked. Thirty to forty ml of water was added to the matrix of each new station after installation. The percent of matrix consumed in stacked stations was based on visual inspection of the outer most layer at each bait placement site on subsequent inspections. Additional consumption of matrix in underlying stations could not be determined until all stations were removed at the end of the trial to calculate the total amount of matrix consumed for each site. Trials were completed and stations were removed when no termite activity, as determined by visual inspection, AE monitoring, and destructive sampling of previously infested wood, and sound structural wood, was observed for two or more months following at least two months of bait consumption. Condo1 and Condo2 were inspected approximately 7 and 19 months after completion of baiting for signs of FST activity. Inspection consisted of visual survey, destructive sampling, and monitoring using the AED. Home could not be inspected after bait removal because of a change in ownership.

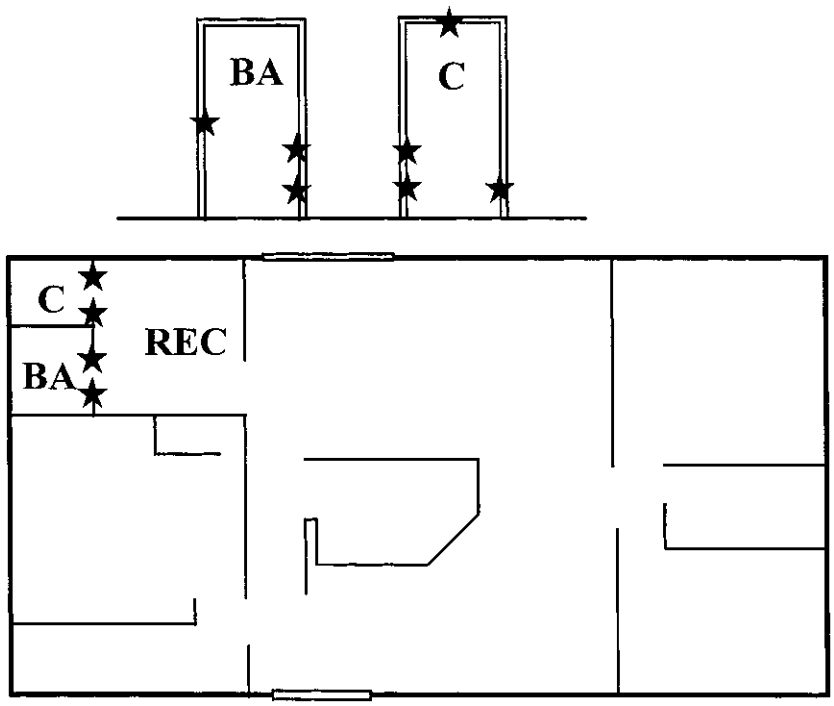

Fig. 5. Floor plan of single-story Home. Stars show placement sites of bait stations on door trim of the bathroom (BA) and closet (C)in the recreation room (REC).

Results and Discussion

Six to fourteen aboveground bait stations were installed in each structure at 3 or 6 placement sites (Table 1). In all structures, bait stations were stacked, and at Condo2 and the Home, new bait station placement sites were added after the initial installation. Termites fed at 14 of 15 (93.3%) of the bait station placement sites, consuming an estimated total of 42-149 g matrix at each structure and feeding on a mean of 73.3% of the bait stations installed in a structure. With the exception of one bait station placement site at Condo2, bait stations that were not fed upon had been installed late in the baiting program, when termite populations and subsequent feeding had already begun to decline. Su et al. (1997) reported that FST only fed in a mean of 17.6% of the aboveground bait stations applied. To compensate for lack of termite activity in stations, Su et al. (1997) installed more bait stations per structure compared to the number installed in this study (X = 18 vs. 10, respectively).

Ground-based FST at the Home, compared to aerial FST infestations at Condo1 and Condo2, consumed 2 and 3.5 times more matrix, respectively (Table 1). Su et al. (1997) obtained similar results; LES, a ground-based FST colony, consumed 710.7 mg of hexaflumuron compared to 747 mg consumed in this study by the Home FST colony. Baiting eliminated all detectable signs of FST foraging activity at the three study structures, as indicated by the absence of live termites in structures and bait stations, no new termite damage or foraging tubes, and no AE counts. In addition, no dispersal

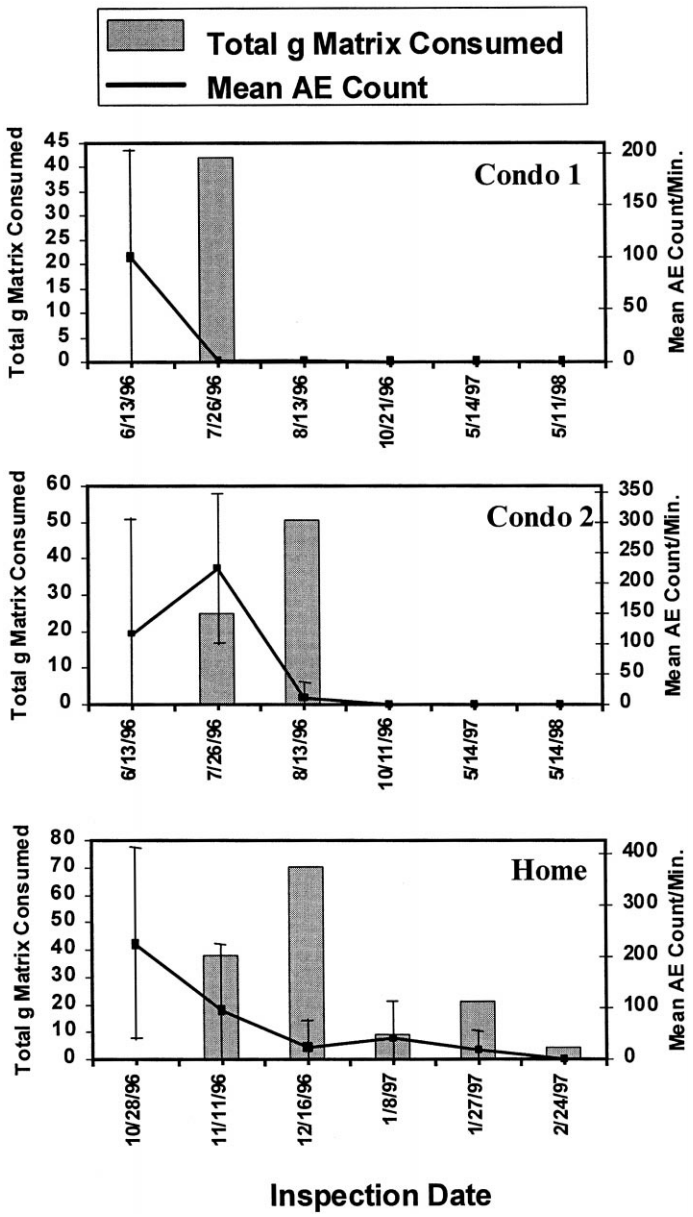

Fig. 6. Foraging activity (Total g Bait Matrix After Previous Inspection) and mean AE counts (± SD) per minute per monitoring location before, during, and after application of aboveground bait stations containing hexaflumuron; Condo1, Condo2, and Home, Broward County, Florida, 1996-1997.

flights were observed nineteen months after baiting was completed at the condominiums. Mean time to elimination of detectable activity was 3.3 months for FST populations in this study, compared to 5.8 months for FST populations by Su et al. (1997).

Comparisons of matrix consumption and AE counts for Condo1, Condo2 and the Home are shown in Fig. 6. Table 1 compared to Fig. 6 depicts six more g of matrix consumed (149 vs. 143 g, respectively) for the Home, because additional consumption of matrix in underlying stations could not be determined until all stations were removed and carefully inspected at the end of the trial.

After installation of aboveground bait stations at all sites, AE counts generally declined below pretreatment levels except at Condo2 where counts peaked 6 weeks following bait station installation. At all sites, matrix consumption and number of termites in stations peaked during the first two months following installation of bait stations. No termites were found in stations during the last two inspections at Condo1 and Condo2, and during the last inspection at the Home. The absence of termites coincided with the absence of AE counts at monitoring locations. In addition, when the doorframes of the Home were replaced in March, 1997, only dead FST were found in the damaged wood.

In this study, a higher percentage of aboveground bait stations containing hexaflumuron were fed upon by FST and fewer bait stations were required to eliminate detectable termite activity more rapidly than previously documented by Su et al. (1997). Recruit AG has a different cellulose matrix (nonparticulate) compared to the particulate matrix containing hexaflumuron evaluated by Su et al. (1997). Laboratory and field testing (E. King, pers. comm.) have documented that subterranean termites preferentially consume the matrix of Recruit AG compared to that evaluated by Su et al. (1997). Therefore, the improved matrix of Recruit AG could explain part of the improved performance observed in this study. Nonetheless, researchers installing Recruit AG without using an AED to determine where termites were feeding in wood had a lower percentage of aboveground stations fed upon compared to that in this study. A similar study was conducted at six structures in Texas using the same aboveground termite bait stations and protocol, with the exception that an AED was not available to determine bait placement sites (T. Atkinson, pers. comm.). In that study, subterranean termites fed upon only 38 out of 86 placement sites (44%) at the six structures. Subterranean termite activity was, however, eliminated at these six sites in Texas. These studies suggest that aboveground bait stations containing hexaflumuron can eliminate detectable subterranean termite activity in structures. These studies also indicate that the AED has the potential to be used to determine optimal bait placement in order to reduce the number of stations needed to achieve control.

Because of the potential for bait avoidance, absence of termites in baiting stations, by itself, is not considered to be a reliable method of measuring the efficacy of toxic baits on subterranean termites (Su & Scheffrahn 1996). Rather, foraging activity is considered to be a more reliable evaluation variable (Su & Scheffrahn 1996). The absence of termites in bait stations in this study coincided with the lack of AE counts in previously-infested wood. In addition, no termite activity could be detected with the AED in sound wood adjacent to previously infested wood indicating that termites had not moved away from baits to other locations. These observations suggest that the AED can be used to reliably evaluate the efficacy of control procedures for subterranean termites in aboveground wood by detecting foraging activity.

This study confirmed the findings of previous research (Su et al. 1997) that baits containing hexaflumuron applied in aboveground stations eliminate detectable activity of aerial and ground-based populations of subterranean termites within structures. Baits such as Recruit AG will be useful where conditions prevent structural

TABLE 1. SUMMARY OF BAITING USING ABOVEGROUND BAIT STATIONS CONTAINING HEXAFLUMURON FOR FORMOSAN SUBTERRANEAN TERMITES INFESTING THREE STRUCTURES IN BROWARD COUNTY, FLORIDA.

Study Site	Station Type	FST Colony	Total No. Station Placement Sites	Total No. Stations Used (Fed Upon)	g dry wt Matrix Consumed	mg AI Consumed	Months to No Termite Activity After Instal
Condo1	Soft-style	Aerial	3	6(3)	42	210	2
Condo2	Hard-style	Aerial	6	10(7)	75	375	4
Home	Soft-style	Ground	6	14(12)	149	747	4

infestations of subterranean termites from foraging to in-ground bait stations (e.g. aerial infestations, previous soil termiticide treatment, water-saturated soil), or at locations where soil access for installation of in-ground bait stations is limited by asphalt or concrete pavement.

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