EVALUATION of COMMERCIAL TERMITE BAITING SYSTEMS for PEST MANAGEMENT of the FORMOSAN SUBTERRANEAN TERMITE (ISOPTERA: RHINOTERMITIDAE)

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Abstract Commercially available termite-baiting systems were evaluated for efficacy in a management program for Formosan subterranean termites, *Coptotermes formosanus* Shiraki. Termite-baiting systems evaluated include Sentricon® (Dow AgroSciences), with hexaflumuron, FirstLine® (FMC Corp.), and Terminate® (United Industries Corp.), both containing sulfluramid (N-ethylperfluoro-octane-1-sulfonamide). The evaluations were conducted in two areas of Texas with high-density populations of Formosan termites (Galveston/La Porte area and Beaumont area), utilizing five structures for each of the termite baiting systems in each area, for a total of thirty structures. All structures qualified for the study with active infestations of Formosan subterranean termites. Results of the evaluation reveal mean numbers of days for first feeding on monitors, in monitored systems, or active-ingredient bait tubes in non-monitored systems, with an extremely wide range. Two of the three baiting systems also had study sites without any termite activity in the bait stations for an extended period of time. There was no discernible pattern of control with either of the sulfluramid-baiting systems; termite management relied on spot treatments with liquid termiticides. Efficacy results utilizing hexaflumuron were significantly different between the two test sites. In the La Porte area, 100% control was achieved with the baiting system, without a termiticide spot treatment, and has continued to exhibit control for an extended period of time. An aggressively active management program involving the utilization of multiple supplementary in-ground bait stations, above-ground bait stations, and biweekly monitoring contrasts sharply with the management program and reduced efficacy results in the Beaumont area.

Key Words *Coptotermes formosanus* termite baits hexaflumuron sulfluramid

INTRODUCTION

Current subterranean termite management strategies have turned toward baiting-system technologies (Traniello and Thorne, 1994) utilizing chitin synthesis inhibitors (hexaflumuron and diflubenzuron) or slow-acting stomach poisons (sulfluramid) as active ingredients (Getty et al., 2000; Pawson and Gold, 1996; Sheets et al., 2000; Su, 1991, 1994). The objective of a termite-baiting system is the management of termite populations, and is accomplished through distribution of a toxicant or inhibitor into a colony within a palatable food (cellulose) substrate (Grace et al., 1996; Thorne and Forschler, 1998). The strategy relies on the foraging activity of the pseudergates (workers) to gather and introduce this material into the social fabric of a colony in its subterranean milieu, where it will be shared through trophallaxis and will subsequently kill or inhibit the normal development and metamorphosis of colony members (Potter, 1997; Su and Scheffrahn, 1996a); the ultimate goal of this subterfuge tactic is the collapse and death of the colony.

The previously cited active ingredients of baiting systems have been investigated through laboratory and field bioassays to determine their efficacy against subterranean termite populations (Forschler and Chiao, 1998; Rojas and Morales-Ramos, 2001; Su et al., 1995). Several termite-baiting systems utilizing these ingredients are being marketed to pest-control companies or directly to the public as a means to achieve management of subterranean termites (Ballard and Lewis, 2000). Comparisons of effectiveness of these different termite-baiting systems under ac-

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Susan C. Jones, Jing Zhai, and Wm H. Robinson editors. (2002)

tual use situations, and in significant numbers, are generally lacking, however. This is particularly true for the active ingredient, sulfluramid, which is currently marketed as the active ingredient in two different termite-baiting systems. The objective of this evaluation was the investigation of effectiveness of available termite-baiting systems and their bait-toxicant active ingredients as a pest management strategy in structures infested with Formosan subterranean termites, *Coptotermes formosanus* Shiraki.

The unintentional introduction and subsequent spread of this termite into large areas of the United States and other areas of the world (Bennett et al., 1997; Howell et al., 2001; Su and Scheffrahn, 1988) (Figures 1, 2) has created concern to many with vulnerable structures and vegetation (Figures 1, 2). The large population size of the colonies, aggressive nature, and the ability to form aerial infestations of "carton" material with no connection to the ground has led to the well-deserved destructive reputation of the species, particularly in southern coastal regions, where they cause serious damage in a relatively short period of time (Cornelius and Osbrink, 2001; Jones and Howell, 2000). This target pest was chosen as the most severe test of efficacy of termite-baiting systems.

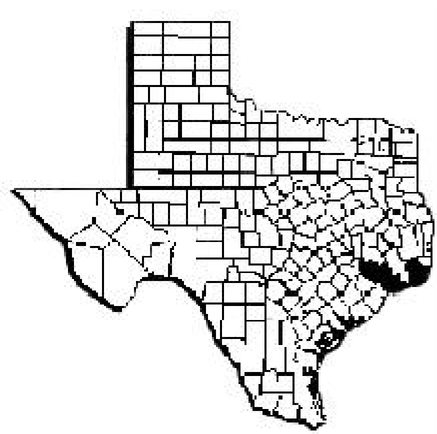

Figure 1. Confirmed identification of Coptotermes formosanus *in Texas in 1980 (3 Counties: Galveston, Harris, Jefferson).*

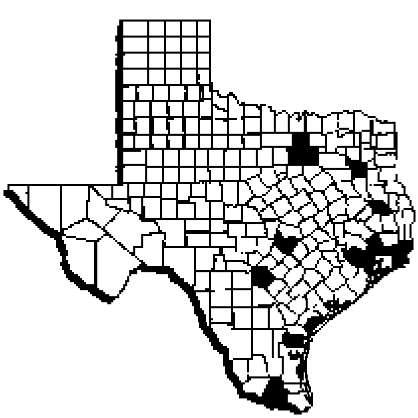

Figure 2. Confirmed identification of Coptotermes formosanus *in Texas in 2002 (15 Counties: Angelina, Aransas, Bexar, Dallas, Denton, Galveston, Harris, Hidalgo, Jefferson, Liberty, Nueces, Orange, Smith, Tarrant, and Travis).*

Proceedings of the 4th International Conference on Urban Pests.
Susan C. Jones, Jing Zhai, and Wm H. Robinson editors. (2002)

MATERIALS and METHODS

Candidate structures with active infestations of Formosan subterranean termites were selected for treatment. Cooperating pest-control companies were hired to install and monitor the termite-baiting systems, under the supervision of Department of Entomology staff. Each had the required licenses, certifications, authorization, and necessary training to participate in the evaluation and utilize the commercial baiting systems evaluated. Termite-baiting systems were provided through commercial vendors or manufacturers, and all installations and inspections followed the manufacturer's label directions and instructions.

Three commercial baiting systems were available at the onset of the evaluation. The Sentricon® system, manufactured by Dow AgroSciences, utilizes the bait-toxicant, hexaflumuron (0.5%), a chitin synthesis inhibitor (Getty et al., 2000; Su and Scheffrahn, 1996b). The FirstLine® system, manufactured by FMC Corporation, and the Terminate® system, manufactured by United Industries, Inc., both contain N-ethylperfluoro-octane-1-sulfonamide [sulfluramid (0.01%)], a slow-acting stomach poison (Ballard and Lewis, 2000). Label instructions for both of these sulfluramid-containing bait systems require a spot-treatment with termiticides for any active termite infestation. Termite-baiting systems were installed around the perimeter of each of the infested structures, according to label instructions. Appropriate spot treatments (permethrin termiticide) were made as required at structures chosen to utilize baiting systems with the active ingredient, sulfluramid. The Sentricon® system and the FirstLine® system utilize wooden monitors that were examined on a monthly basis until termite-feeding activity was revealed, at which time an active ingredient tube was inserted in order to make the bait-toxicant available to the termite colony. The Terminate® system did not utilize a monitoring step prior to placement of bait toxicant; active ingredient is present in a cardboard matrix in all bait tubes placed around a structure.

A total of 30 structures infested with *C. formosanus* were selected, with 15 structures in each of the two major areas of infestation in Texas: Galveston-Texas City-La Porte area, and Beaumont-Port Arthur-Orange area. Five structures were treated with each of the three baiting systems in each area. The evaluation had a two-year time line, and an annual inspection of each structure was also performed by pest-control company personnel, accompanied by Department of Entomology staff. Supplemental monitoring stations were also used to confirm the presence or absence of foraging termites through time. These stations consisted of 4cm x 4cm x 15.5 cm pine stakes with a 20 mm hole drilled through the length of the long axis of the stake. Regularly spaced 4mm holes were also drilled into each of the four sides of the stake to connect with the larger hole, which allowed subterranean termites access to the center cavity. The top hole was closed with a #3 rubber stopper, which was removed to monitor termite activity in the station.

Results from termite-baiting system activity, monitoring, bait-toxicant consumption, and structural inspections were utilized to determine efficacy or control of termites. The number of days between the installation of the baiting systems and the first termite activity on monitors underground (tamu) was recorded for each structure. Presence or absence of termites in baiting systems, in supplemental monitoring stations, or in structures, and reproductive swarming were considered in the determination of efficacy against the termites for each test site. Observations were also made of any differences in the methods of application or monitoring utilized by pest control company personnel.

Data Analysis

Comparisons of days to first termite activity for each of the termite bait systems at all sites were performed using a nonparametric Kruskal-Wallis analysis of variance (ANOVA on Ranks). An All Pairwise Multiple Comparison Procedure (Dunn's Method) differentiated the significantly different treatment. All data were analyzed using SigmaStat (SPSS, 1997).

RESULTS

Observations were made and recorded by the cooperating pest-control company personnel as they monitored termite bait stations placed around the infested structures. These observations of termite activity are illustrated as timelines for each of the termite-baiting systems evaluated (Figures 3, 4, and 5). The period of time for monitoring of bait stations prior to any termite activity at the bait stations, and the number of days of active feeding on the active ingredient, were recorded to ascertain the interaction of termites and the bait systems surrounding the infested structures. Results of the evaluation revealed numbers of days for first feeding on monitors, in monitored systems, or active ingredient bait tubes in non-monitored systems, with an extremely wide range. All three baiting systems had termite activity in at least one bait station in at least one study site within 61 days. There were also examples for each of the three baiting systems where there was no termite activity in the bait stations for an extended period of time. The Terminate® system had at least one site without any termite activity for more than 100 days, and the Sentricon® system and the FirstLine® system had one or more study sites that exhibited more than 350 and 700 days, respectively, without any termite activity in the bait stations.

There was termite activity on the bait stations on eight of the 10 structures treated with the FirstLine® system, on all 10 structures treated with the Sentricon® system, and on nine of the 10 structures treated with the Terminate® system over the two-year time frame of the evaluation (Tables 1, 2, and 3, respectively). The number of days to first termite activity, on any one of the bait stations installed around the perimeter of the structures, for all bait systems, ranged from a low of 26 days to a high of 379 days. There was no significant difference between groups when comparing (t-test) days to first termite activity data from the two sites for each baiting system (P = 0.307, 0.325, and 0.555, respectively for FirstLine®, Sentricon®, and Terminate®). When

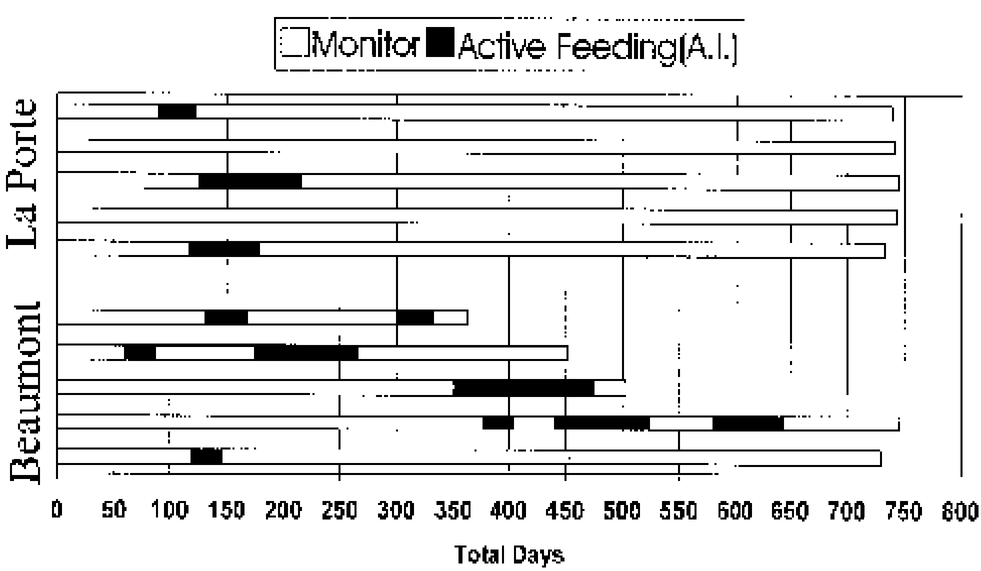

Figure 3. Termite activity observations of C. formosanus *while utilizing the FirstLine® termite-baiting system, with "tamu" (termite activity on monitors underground) and subsequent time periods of feeding on active ingredient in bait tubes at two different coastal Texas research sites/cooperating pest management companies.*

Proceedings of the 4th International Conference on Urban Pests.
Susan C. Jones, Jing Zhai, and Wm H. Robinson editors. (2002)

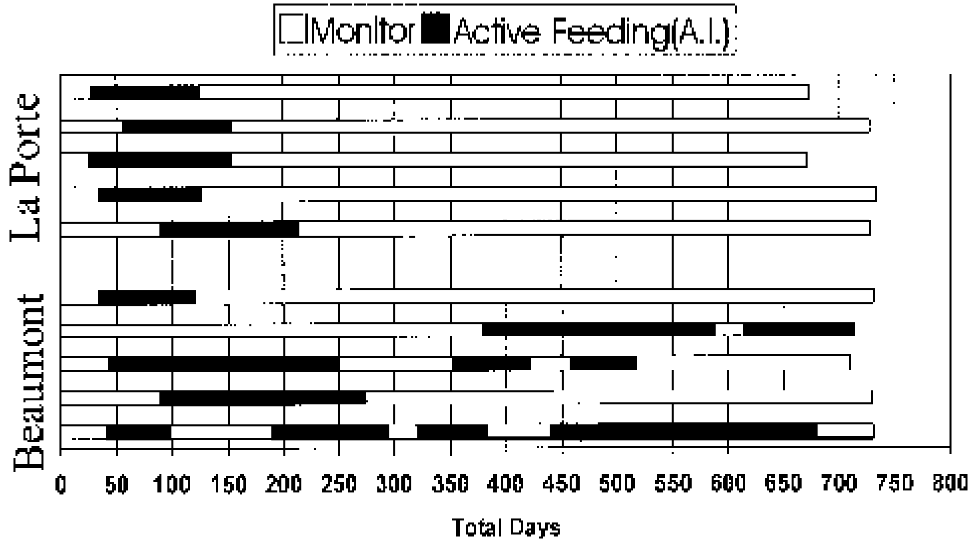

Figure 4. Termite activity observations of C. formosanus *while utilizing the Sentricon*Ò *termite-baiting system, with "tamu" (termite activity on monitors underground) and subsequent time periods of feeding on active ingredient in bait tubes at two different coastal Texas research sites/cooperating pest management companies.*

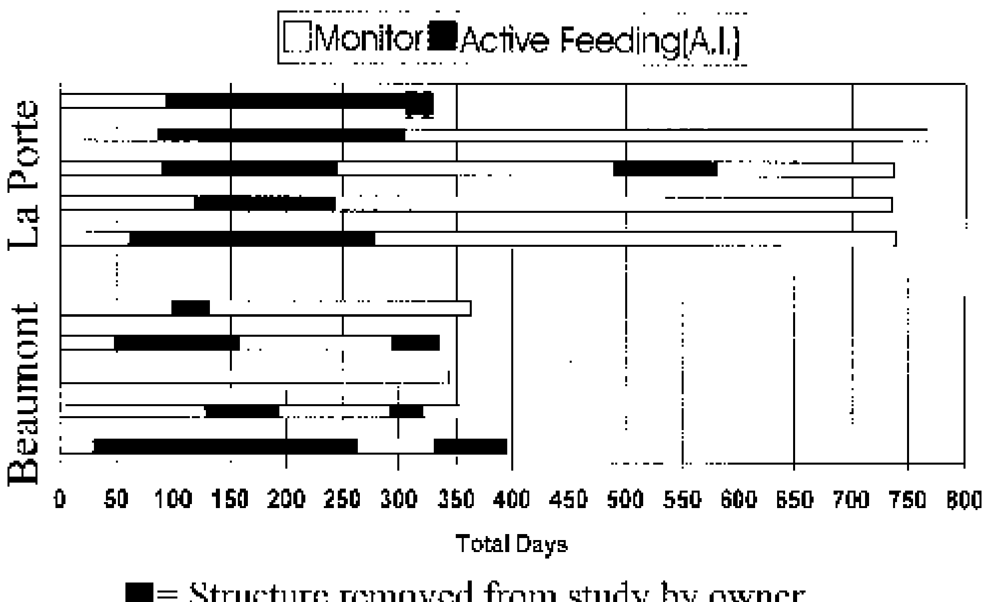

Figure 5. Termite activity observations of C. formosanus *while utilizing the Terminate*Ò *termite-baiting system, with "tamu" (termite activity on monitors underground) and subsequent time periods of feeding on active ingredient in bait tubes at two different coastal Texas research sites/cooperating pest management companies.*

Table 1. Days to first "tamu" (termite activity on monitors underground) of *C. formosanus* while utilizing the FirstLine® termite-baiting system at two research sites

Sites	Days to First "tamu"	# of sites with "tamu"	Mean (±) SEM
Beaumont	61;118;131;350;376	5/5	207.2 ± 64.8
La Porte	90;116;125	3/5	110.3 ± 10.5
	Cumulative	8/10	170.9 ± 42.7

(Based on sites that have "tamu" & A.I. (active ingredient) bait tube placement; does not include sites that have no activity)

Table 2. Days to first "tamu" (termite activity on monitors underground) of *C. formosanus* while utilizing the Sentricon® termite baiting system at two research sites

Sites	Days to First "tamu"	# of sites with "tamu"	Mean (±) SEM
Beaumont	34;41;43;90;379	5/5	117.4 ± 66.1
La Porte	26;27;34;56;91	5/5	46.8 ± 12.3
	Cumulative	10/10	82.1 ± 33.8

(Based on sites that have "tamu" & A.I. (active ingredient) bait tube placement; does not include sites that have no activity)

Table 3. Days to first "tamu" (termite activity on monitors underground) of *C. formosanus* while utilizing the Terminate® termite baiting system at two research sites

Sites	Days to First "tamu"	# of sites with "tamu"	Mean (±) SEM
Beaumont	34;41;43;90;379	5/5	117.4 ± 66.1
Beaumont	30;49;100;129	4/5	77.0 ± 22.8
La Porte	61;88;92;95;119	5/5	91.0 ± 9.2
	Cumulative	9/10	84.8 ± 10.8

(Based on sites that have "tamu" & A.I. (active ingredient) feeding at bait station placements; does not include sites that have no activity)

comparing the number of days to first termite activity in the three baiting systems at all sites, however, there was a significant difference (Kruskal-Wallis test: H = 8.638, df = 2, P = 0.013) between the FirstLine® and the Sentricon® system by All Pairwise Multiple Comparison Procedure (Dunn's Method). The mean number of days to first termite activity for the FirstLine® system was 170.9 ± 42.7, while it was only 82.1 ± 33.8 and 84.8 ± 10.8 for the Sentricon® and Terminate® systems, respectively, at all treatment sites.

The performance of the two sulfluramid-containing bait systems on *C. formosanus* was low, based in part on the limited amount of the active ingredient that was consumed. Successes noted relied on spot treatments with liquid termiticides, which repelled the termites away from one area, only to have them reappear in other locations of the structure at a later date. Several structures required multiple spot treatments during the two-year evaluation period. These results were similar to that of a previous evaluation of these baiting systems on the Eastern subterranean termite, *Reticulitermes flavipes*. In addition, the Terminate® system was deemed not suitable for treatment of *C. formosanus*, as the small bait stations were emptied in a short period of time by

Proceedings of the 4th International Conference on Urban Pests.
Susan C. Jones, Jing Zhai, and Wm H. Robinson editors. (2002)

foraging termites. The pest management company personnel also found it very difficult to find the bait stations of this system in any turf areas due to the small footprint of the stations.

The most significant observation made during this evaluation was the difference in treatment regime, and corresponding results, between the two different pest-control companies utilizing the Sentricon® system. While both were authorized and trained to use this technology, the regime followed by personnel in the La Porte area differed markedly from that used by personnel in the Beaumont area. La Porte area personnel utilized what would have to be termed an aggressive regime, utilizing many supplementary in-ground bait stations at areas of conditions conducive to subterranean termites (existing cellulose and moisture sources), as well as areas of termite activity on existing monitors. They also relied heavily on the placement of above-ground bait stations available in this system. They placed multiple units on active shelter tubes, whether on vertical surfaces of walls, slab foundations, or piers or inside wall voids, after determining the presence of infestation by means of a non-destructive moisture meter and gaining access by means of keyhole saw or removal of wood trim. The treatment regime also involved frequent visits to the bait stations to insure active ingredient availability in the bait stations with termite activity. The visits were never less than every two weeks, rather than the monthly visits suggested in the system protocol. The treatment regime by the Beaumont personnel, on the other hand, involved a protocol by the book with few supplementary in-ground or above-ground bait stations utilized. Inspections to monitor bait stations and add active ingredient tubes to stations with termite activity were limited to monthly visits.

The results of this difference are quite apparent in Figure 4. After early, consistent termite activity on monitors and extensive feeding of active ingredient at all sites, *C. formosanus* were not detected again in either the structures or the bait stations for an extended period of time. No liquid termiticide treatments were performed, or required, in any of the 5 sites treated with this regime in the La Porte area. Table 4 shows this aggressive regime with a very abbreviated (46.8 ± 12.3 days) period of time to first termite activity by foraging termites, followed by 107.8 ± 7.3 days of active feeding of the active ingredient in the system, and only 154.6 ± 16.3 days between installation of the baiting system to feeding cessation. The mean number of days that elapsed after feeding cessation without any new termite activity on bait stations, indicative of subsequent termite activity in or around the test site structures, was 455.6 ± 35.5 days for the five structures (Table 5). In contrast, frequent, alternating periods of termite activity by *C. formosanus*, followed by periods of inactivity and no consumption of active ingredient in the bait stations were exhibited at 3 of the 5 Sentricon® system sites in the Beaumont area. Bait stations would frequently be depleted of active ingredient during the monthly inspection regime, and the foragers would aban-

Table 4. Summary activity periods of termite baiting of *C. formosanus* observed while utilizing the Sentricon® termite baiting system (La Porte, Texas, site)

Site	Days to First "tamu"	Days Feeding on Bait System A.I.""	Installation to Feeding Cessation (Days)
1	91	124	215
2	34	92	126
6	26	127	153
4	56	98	154
5	27	98	125
Mean ± SEM	46.8 ± 12.3	107.8 ± 7.3	154.6 ± 16.3

*"tamu" (termite activity on monitors underground)
** active ingredient

Table 5. Time intervals (days) from installation of termite baiting system to feeding cessation and elapsed time since feeding cessation without new "tamu" of *C. formosanus* observed while utilizing the Sentricon® termite baiting system (La Porte, Texas, site)

Site	Installation to Feeding Cessation (Days)	Days Elapsed Since Feeding Cessation w/o New "tamu"
1	215	455
2	126	551
6	153	363
4	154	516
5	125	393
Mean ± SEM	154.6 ± 16.3	455.6 ± 35.5

"tamu" (termite activity on monitors underground)

don the station in their search for cellulose. Termites would then have to be re-recruited to a bait station, which took additional time in the baiting process. At the end of the two-year evaluation period, *C. formosanus* was still active in 2 of the 5 structures and in surrounding bait stations in the Beaumont area.

DISCUSSION

The best management of subterranean termites utilizing a baiting system would have to be characterized as an active management strategy. Rather than placing a passive barrier of liquid termiticide around and beneath a structure, which has been a standard treatment in the management of these cryptic organisms, the baiting systems require a labor-intensive regime. It is noteworthy that despite the placement and regular monitoring of these systems, there are examples of little activity on the bait stations for an extended period of time, despite the aggressive foraging and feeding reputation of *C. formosanus.* The activity timelines exhibited in Figures 3, 4, and 5, for each of the respective baiting systems evaluated, show agreement with the comment by Weesner (1965) that we have "only fragments of information" about termites. The monitoring stations at some structures remained inactive for an extended period of time, for years in some cases, despite the presence of active *C. formosanus* infestations.

The period of time between installation of the baiting systems and the first termite activity, revealing termite feeding/activity exhibited an extremely wide range for the systems. The time period observed was from a low of 26 days to a high of 376 days for the various systems that exhibited termite activity on the stations. Three of the 30 structures (10%) never exhibited termite activity in the bait stations during the two-year time frame of the evaluation; hence no active ingredient of bait-toxicant was consumed at those structures, and no possibility of management was afforded by the technology of a termite-baiting system.

The evaluation results observed in the two different baiting systems utilizing sulfluramid corroborate the present instructions on the label and training materials provided by the manufacturers that a liquid termiticide spot treatment is required at points of active infestation, and that baiting systems must subsequently be installed in a supplementary manner to the barrier treatments. Of the termite baiting systems evaluated, the Sentricon® system proved to be effective in the management of structural infestations of *C. formosanus*, particularly if used in an aggressive, labor-intensive manner. If used as an active pest management strategy, with the necessary labor

Proceedings of the 4th International Conference on Urban Pests.
Susan C. Jones, Jing Zhai, and Wm H. Robinson editors. (2002)

and materiel devoted to the process, with multiple supplementary in-ground and above-ground stations monitored in a frequent, two-week schedule, the system was successful in protecting the structures in a relatively short period of time. The period of time between installation of termite bait stations to feeding cessation for this system at the five La Porte sites had a mean value of 154.6 ± 16.3 days, and after the management was achieved, the days elapsed since feeding cessation without any new termite activity had reached 455.6 ± 35.5 days, to date (Tables 4 and 5). It is concluded that the human involvement of the pest management personnel is the determining factor in a successful termite baiting system regime, requiring that sufficient time, energy, and problem-solving be devoted to the process.

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