Subterranean Termite, *Reticulitermes* spp. (Isoptera: Rhinotermitidae), Colony Response to Baiting with Hexaflumuron Using a Prototype Commercial Termite Baiting System[1]

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ABSTRACT Six subterranean termite colonies, representing two species, *Reticulitermes flavipes* and *R. virginicus* were characterized and baited during the spring and summer of 1993 at three locations in the Piedmont Soil Zone in west-central Georgia. Characterizations included population and foraging territory estimates, indices of activity, wood consumption rates, and number of termites collected per site per visit. The four characterized colonies that were baited averaged 43,000 termites per colony and occupied foraging territories averaging 16 m^2. An additional 12 colonies were baited in 1994 simulating a commercial bait application where only indices of termite activity were recorded. Each termite colony was baited using a prototype baiting system which included the active ingredient hexaflumuron. Activity of each colony was monitored before, during, and after baiting. Three of the characterized colonies were baited during June and July 1993, and activity was undetectable within 3 months. One colony, baited in September, continued to show activity for 8 months. Six of the colonies baited in 1994 showed no activity at least 5 months after bait acceptance, two colonies removed bait starting in September and were still showing activity in May, two colonies did not revisit monitors following bait stake attack, and one colony did not accept bait and remained active in the nearby monitor. Colony characterizations, baiting procedures, measures of termite activity, and the difficulties of determining termite baiting efficacy from field trials are discussed.

KEY WORDS Isoptera, Rhinotermitidae, control, bait, hexaflumuron

Suppressing populations of economically important subterranean termites using baiting techniques is not a new concept (Randall and Doody 1934). However, measuring efficacy of a baiting strategy against subterranean termites is hindered by their cryptic lifestyle (Su 1991). Field research conducted over the past 20 years has followed different protocols with mixed interpretation of treatment efficacy (Esenther and Beal 1974, 1978, Jones 1989, Su 1994, Su et al. 1982, 1991).

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Measuring termite activity for evaluation of baiting strategies requires a non-destructive sampling technique to insure any observed reduction is indicative of a treatment effect. Nondestructive sampling of termite field populations provides, at best, only several observation windows (termite monitoring stations) into the termite colony and, therefore, cannot provide a holistic view of the colony habitat. Variables that could affect subterranean termite visitation to monitoring stations include age and size of colonies, number of alternate food resources available to each colony, effects of predation on or competition between nearby colonies, and seasonal or weather-related activity patterns. Each of these parameters are difficult to measure with a high degree of certainty. Therefore, basic questions concerning the composition of termite colonies, determining population sizes, and delineating foraging territories in the field are difficult to definitively quantify.

Monitoring efficacy of a termite bait strategy depends on the anticipated result of the baiting procedure. Termites may be repelled by the use of particular bait materials due to overt repellency or accumulation of dead termites at the baiting site. If the goal of the baiting strategy is removal of termites from a structure, then baits with repellent action may be useful and monitoring termite activity at or near the baiting site would be appropriate. However, if the baiting strategy if intended to reduce or eliminate a termite population, then monitoring activity away from the bait site is essential. Subterranean termites exhibit site fidelity in laboratory studies (Delaplane 1990); therefore, one can assume field populations will continue to visit established field monitors, at least intermittently if not consistently, over the course of a year. Positioning toxic baits separate from monitoring stations should indicate if long-term reduction in activity at termite monitors is the result of treatment. The best strategy possible, therefore, would involve establishment of several active termite monitoring stations within a known termite colony territory and providing toxic baits at separate locations.

In 1994, DowElanco received registration for the chitin synthesis inhibitor hexaflumuron as an active ingredient for a termite bait control strategy. This paper details our field research on 15 termite colonies with a prototype baiting system using hexaflumuron in a termite bait matrix.

Materials and Methods

Field Site Establishment and Termite Colony Characterizations. Areas of termite activity were located using wooden, *Pinus* spp., survey stakes (1.5 × 3.5 × 30 cm) purchased at a local lumber yard (Thompson 1985). Stakes were placed approximately 27 cm into soil in inconspicuous locations (i.e., along fence rows, hedges, base of trees) in residential areas. Once a month, stakes were visually examined for signs of termite activity. When termites were found feeding on a stake, it was replaced with a termite monitor.

Termite monitors consisted of a 16-cm length of 10-cm diam PVC pipe receptacle placed on top of a white pine board (10L × 4W × 2H cm) buried below the PVC pipe to serve as an undisturbed feeding site. Two termite feeding and aggregation substrates (sandwiches) were placed inside the PVC pipe receptacle on top of the undisturbed feeding site. Termite monitors were capped using a

10-cm diam plastic knock-out plug. A thin layer (1 to 3 cm) of soil was then placed over the monitor.

Termite sandwiches were comprised of 10 pieces of weathered white pine wood (4 cm H × 12 cm L × 2 mm W) separated by 2-mm diam wooden dowel sticks and held together by 18-cm length plastic cable ties (GB Electric, Inc., Milwaukee, WI). Termite sandwiches were oven-dried at 70°C for 48 h before and after exposure to termites in the field for determination of wood dry weight. These dry weights were used to calculate termite wood consumption rates based on grams of wood consumed per colony per day. The number of termites collected was determined after separating termites by caste (soldiers, workers, and nymphs) and weighing from 5 groups of 10 termite workers to obtain a mean weight per termite. This mean weight was divided by the total weight of all workers collected to provide an estimate of the number of termites collected. The number of soldiers and nymphs were counted individually.

When several active monitors were established at a site, termites from one monitor were removed, marked with spray paint (Aervoe-Pacific Co. Inc., Gardnerville, NV), and immediately released (Forschler 1994). One week later, all active monitors in the area were inspected for marked termites. Foraging territories for each group of termites were defined as the area encompassed by those active termite monitors from which the same color paint-marked termites were recovered. Following assessment of colony foraging areas, foraging/feeding populations were estimated using the fat soluble dye Nile Blue A and a triple mark-release-recapture technique (Su et al. 1994).

Six subterranean termite colonies were characterized at three sites between 1992-93 in the Piedmont soil zone of west-central Georgia. The first site was in Gwinnett Co. in a northern suburb of Atlanta, GA. The second and third sites were in Spalding Co. on the Georgia Experiment Station campus. The fourth and fifth sites were in Lamar Co. in Aldora. The first site contained one colony (Colony 1) of *Reticulitermes virginicus* (Banks) in a small woodlot behind a home in a subdivision. The second site had three colonies including two *R. flavipes* (Kollar) colonies (Colonies 2 and 3) near the Weed Science building and a *R. virginicus* colony (Colony 4) near the Entomology/Horticulture building on the Georgia Experiment Station campus in Griffin. The third site had two *R. flavipes* colonies (Colonies 5 and 6) located in the same backyard (Fig. 1).

Baiting Characterized Termite Colonies. Prototype termite detection/baiting stations were positioned in the soil within 0.5 m of each active termite monitor. Prototype termite detection/baiting stations consisted of a 4-cm (ID) cylindrical plastic tube, 23.5 cm long, with a solid plastic cone-shaped bottom (2 cm length) and forty openings (1.2 × 3 cm) around the circumference. Termite detection stakes were placed inside each termite detection/baiting station. Termite detection stakes consisted of two sections of wood (*Pinus* sp.) measuring 20.8 × 2.8 × 1.9 cm (L:W:H) held together with metal staples (1 × 1.2 cm). One 5-mm hole (ID) was drilled through the two wooden detection stakes. A plastic bread twist-tie (14-cm length) was drawn through the hole to assist in removing the detection stake from the prototype detection/baiting station.

When termites were found in a detection/baiting station, detection stakes were removed and termites collected by gently tapping the separated stakes together over an aluminum baking pan (39 × 25 × 2.5 cm). The collected

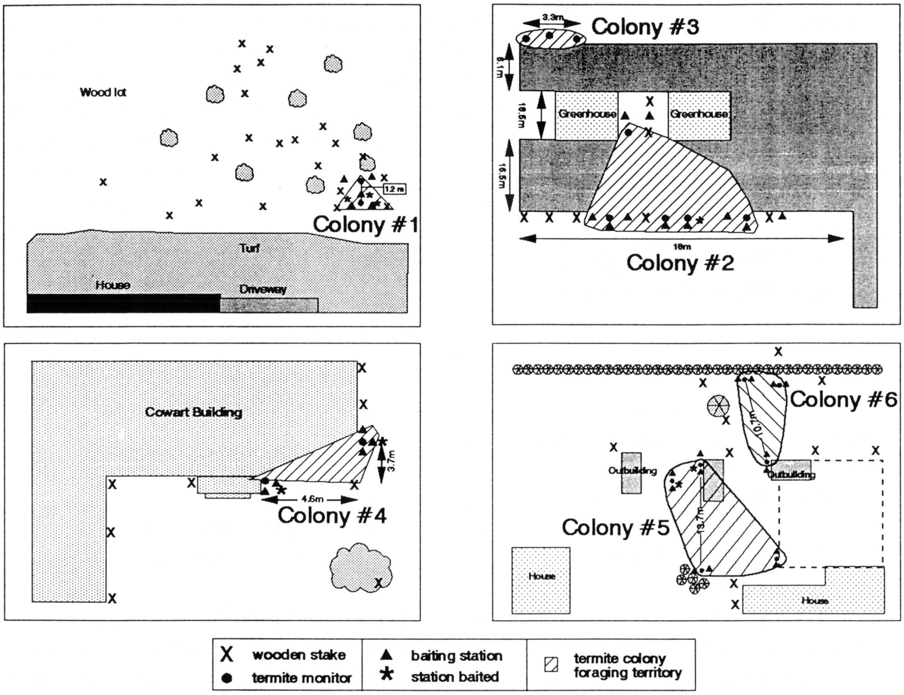

Fig. 1. Maps of the six *Reticulitermes* colonies characterized for the hexaflumuron baiting study showing estimated foraging territories and relative positions of important landscape characteristics and buildings.

termites were then placed into a bait tube. A bait tube consisted of a 22 × 3.8 cm plastic cylinder with 72, 2 mm holes drilled in 9 rows of 8 holes each around the circumference. The first row of holes was positioned 2 cm below the top of the tube. Each tube was filled to 1 cm of the top with bait matrix leaving a void designed to hold termites removed from the detection stakes. Placement of termites in bait tubes was designed to allow termites to tunnel through the bait to reestablish contact with the colony (Su 1994). Colonies 1, 3, and 5 were provided with the bait matrix containing hexaflumuron as described by Su (1994). Colonies 2 and 4 were baited with a hexaflumuron treated dry sawdust matrix.

Detection/baiting stations containing bait tubes were checked on a monthly basis with the exception of Colony 1, which was not checked between 1/93-5/93. When half or more of a bait was removed, the bait tube was replaced with a new bait tube. Amount of active ingredient removed was extrapolated based on percent active ingredient in the bait and amount of bait removed from each bait tube estimated by visual examination. When bait removal was not recorded for 2 consecutive months after initial indication of bait removal, it was replaced with termite detection stakes at that detection/bait station. In areas where two separate termite colonies were identified, one colony was baited and the other left unbaited as unreplicated controls. Termite activity was recorded for 2 years after baiting at both termite monitors and prototype detection/baiting stations.

Baiting Uncharacterized Termite Colonies. In 1994, 12 termite colonies were identified in the Adamsville section of southeast Atlanta, GA. Termite activity was detected using wooden stakes, and termite monitors were established as described above. These termite colonies were not characterized to establish population or foraging/feeding territories, although activity at termite monitors (e.g., wood consumption rates and number of termites collected) was recorded. Prototype termite detection/baiting stations were established, and baiting of these colonies was conducted as previously described.

Results and Discussion

The goal of this termite baiting strategy using hexaflumuron was colony elimination. Therefore, prototype detection/baiting stations were placed separately from active termite monitors. Baiting could then be conducted away from areas of known termite activity where indices of colony activity (wood consumption rates, numbers of termites collected) were being conducted. This placement scheme allowed us to use reduced activity at termite monitors as an indication of treatment efficacy.

Colony 1 had an estimated foraging territory of 0.6 m^2 with an estimated foraging/feeding population of 20,000 termites. It was initially baited in mid-July. Bait was provided until mid-November 1993. During this time termites removed an estimated 31.5 mg of active ingredient from three bait tubes. Colonies 2 and 3 had foraging territories of 40 and 12 m^2 and population estimates of 81,000 and 35,000 termites/colony, respectively. Colony 2 was baited in early July, 1993, and bait was provided until October, 1993. The colony removed an estimated 10.5 mg of active ingredient from one bait tube during the first 2 months. The foraging/feeding population of Colony 4 was estimated at 38,000 termites with a foraging territory of 8.3 m^2. Colony 4 was baited in late September 1993 and bait remained available until April 1994. This colony removed an estimated 70 mg of active ingredient from two bait tubes. The last two colonies (5 and 6) had foraging/feeding population estimates of 28,000 and 128,000 termites/colony and foraging territories of 42 and 15.6 m^2, respectively (Table 1, Fig. 1). Colony 5 was baited in June 1993; 16 mg of active ingredient were removed from one of two bait tubes by the end of August. Colonies 3 and 6 were not baited but were monitored as unreplicated controls until May, 1995 (Table 1).

Fig. 2 shows the wood consumption rates and numbers of termites collected per colony, including the dates when baits were initially provided for each of the aforementioned characterized termite colonies. These data demonstrate that the baiting procedure affected the activity of those termite colonies that were provided and had removed hexaflumuron bait. The two unbaited colonies (Colony 3 and 6) exhibited no reduced activity comparable to those baited.

Results from the 12 colonies identified in Adamsville are less definitive. Three sites included termites that did not return to termite monitors after attacking survey stakes at those locations and, therefore, were not included in

Table 1. Population estimates and activity at termite monitors from termite colonies baited with hexaflumuron in Georgia, 1993-94.

Colony Number	Spp*	Pop** Esti.	No.† Monitor	Mon.‡ Baited	Mon.$ Termites	Time§	Esti.¶ Bait
			Characterized Colonies				
1	Rv	20,000	2	7/93	9/93	2	31
2	Rf	81,000	5	7/93	10/93	3	10
3	Rf	35,000	3	N/A	N/A	N/A	N/A
4	Rv	38,000	2	9/93	4/94	7	70
5	Rf	28,000	4	6/93	8/93	2	16
6	Rf	128,000	3	N/A	N/A	N/A	N/A
			Characterized Colonies				
7	Rv	N/A	1	5/94	8/94	3	10
8	Rf	N/A	2	6/94	9/94	3	98
9	Rf	N/A	2	7/94	8/94	1	120
10	Rv	N/A	2	6/94	11/94	5	38
11	Rf	N/A	2	6/94	9/94	3	21
12	Rf	N/A	1	6/94	8/94	2	10
13	Rf	N/A	2	9/94	5/95	8+	40
14	Rv	N/A	1	9/94	5/95	8+	16
15	Rv	N/A	1	9/94	5/95	N/A	N/A

* Species of termite; Rf = *Reticulitermes flavipes*, Rv = *R. virginicus*.
** Population estimates based on triple mark-release-recapture procedure.
† Number of termite monitors established.
‡ Month when baiting was initiated.
$ Last month when termites were recorded at termite monitors.
§ Time from bait acceptance to last record of termite activity.
¶ Estimated amount of hexaflumuron removed in mg.

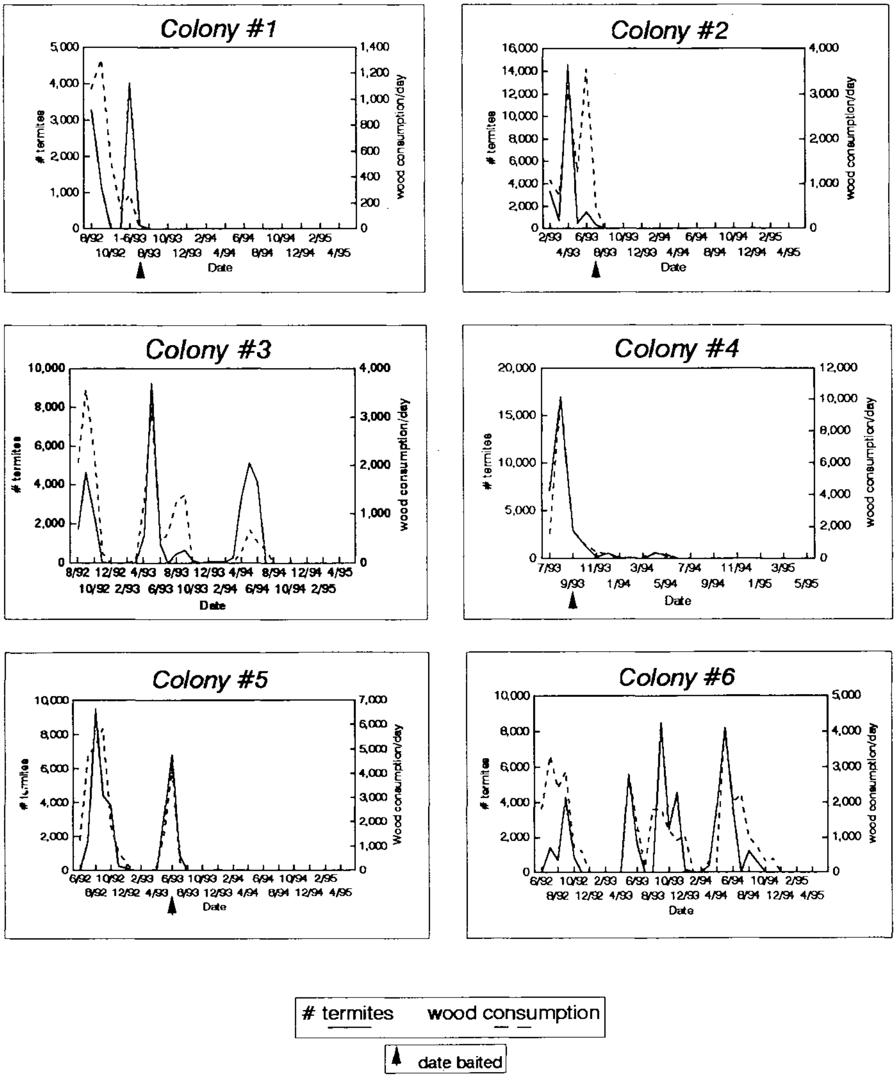

Fig. 2. Number of termites collected and wood consumption rates, in mg of wood consumed per day, by month for each of the six *Reticulitermes* colonies characterized for the hexaflumuron baiting study.

the baiting study. One site (Colony 15) provided continued activity in the termite monitor, but termites did not remove bait from the nearby detection/baiting station. Two additional groups (Colony 13 and 14) began removing bait in October, 1994, and were providing low levels of activity in termite monitors up to the last sample period on 11 May 1995. Termites collected during the last sample period included 188 termites from Colony 15 and 272 and 993 from colonies 13 and 14, respectively. Termites from Colony 15, which did not remove bait, remained active in the laboratory on 25 August 1995 (163 termites alive). In contrast, termites from colonies 13 and 14, which had accepted bait in the field, were all dead by 9 June 1995. Six colonies (colonies 7 to 12) removed bait from bait tubes during May to July, 1994; activity in the termite monitors were at undetectable levels in 5 months or less and remained that way through the last sample date (Table 1).

Data from colonies 4, 13, and 14 show that baiting native subterranean termites with hexaflumuron in Georgia after September will result in continued termite activity through the following spring. This seasonality in recording efficacy results with this active ingredient appears associated with reduced metabolic and feeding activity (Fig. 2) in termites during the winter months. Our field data from termites dyed with fat soluble dyes and released into the field during September to December show recovery of dyed termites up to 9 months after release compared to only 3 month recovery times for dyed termites released from April to July (Forschler, unpublished data). Although termite activity may be evident throughout the year at a field site, seasonal physiological activity may result in lack of indications of termite baiting efficacy until 8 to 9 months after initial bait acceptance.

In summary, these tests provided complete reduction in termite activity in 93% of the termite colonies where baiting was attempted. When termites removed bait from the prototype detection/bait stations, complete reduction in activity was recorded in 100% of the colonies examined. The problem of verification of baiting efficacy is highlighted by the number of inconclusive results from termite colonies where only one termite monitoring station was established for observation of termite activity. Of the seven termite colonies initially identified as visiting only one termite monitor, two never provided evidence of activity after monitor establishment and the third showed inconsistent visitation to the monitor. Therefore, results from these groups could not be verified. Our experience with over 60 subterranean termite colonies in four soil zones in Georgia has indicated that termite visitation to monitoring stations can be inconsistent. Therefore, interpretation of results from field trials with termite baits intended for population reduction or elimination requires monitoring of several termite monitoring sites over a timeframe of at least 1 year before population reductions can be reasonably verified.

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