Field Evaluation of the Bait Toxicant Chlorfluazuron in Eliminating *Coptotermes acinaciformis* (Froggatt) (Isoptera: Rhinotermitidae)

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ABSTRACT Two aspects of the Exterra Termite Interception and Baiting System (Ensystex, Fayetteville, NC) were evaluated in a field experiment using 13 termite mounds near Townsville, Australia. First, a cellulose-acetate powder containing either 0.05% wt:wt or 0.25% wt:wt chlorfluazuron (Requiem, Ensystex, Fayetteville, NC) was tested for its efficacy in eliminating colonies of the xylophagous mound-building subterranean termite *Coptotermes acinaciformis* (Froggatt). The moist bait matrix was replenished during the first inspection of 10 mounds (five mounds by two treatments) used in the experiment. Second, a single application of the moist bait matrix was used on three additional mounds to test termite responses and the effectiveness of 0.25% wt:wt chlorfluazuron. Although there was no evidence of repellence, there was little removal of replenished bait. Five colonies were eliminated by 0.05% wt:wt chlorfluazuron and five colonies by 0.25% wt:wt chlorfluazuron: another colony was moribund, and elimination appeared imminent. Colony decline was first suspected some 12 wk after bait application, and colony elimination was confirmed, by destructive sampling, about 5 wk later. Colony elimination may have occurred within 12 wk. One colony was an anomaly and did not succumb to the effects of the toxicant. Another colony was not eliminated because of invasion of the baiting system by ants. Ants, principally *Iridomyrmex purpureus* (F. Smith) group and *Papyrius nitidus* (Mayr) group, occurred commonly in the stations during the experiment. *Microcerotermes* sp. was found in five of the *C. acinaciformis* mounds, after colony elimination. Inspections of small sections of mounds and wooden dowels inserted into mounds were reliable methods for monitoring colony health.

KEY WORDS subterranean termites, bait technology, chitin synthesis inhibitor, chlorfluazuron, Australia

FOLLOWING THE WITHDRAWAL OF the cyclodiene termiticides as soil barrier treatments in Australia, there has been considerable interest in the use of bait technology to suppress and eliminate colonies of subterranean termites (Lenz 2002, Lenz and Evans 2002). Consequently, the Sentricon Termite Colony Elimination System (Dow AgroSciences LLC, Indianapolis, IN) and Intrigue termite dust (Bayer AG, Leverkusen, Germany) are both registered for termite control in Australia. These products use chitin synthesis inhibitors (CSIs) to interfere with the molting process and thus prevent immature termites from producing a complete exoskeleton. CSIs include hexaflumuron, used in the Sentricon system in an edible bait (Su et al. 2000), and triflumuron, used in Intrigue termite dust (Madden 1999, 2001; Madden et al. 2000). The advantage of CSIs is that they are slow acting and can be transferred between individuals in the termite colony through trophallaxis (Sheets et al. 2000). Eventually, colony numbers decline to an unsustainable level, due in part to the death of the egg-laying queen, and the colony ceases to exist as an organized social structure and dies (Lenz et al. 1996).

Coptotermes acinaciformis (Froggatt) builds mounds in northern Australia and is responsible for greater economic losses to timber-in-service, in the aggregate, than all the other Australian termite species (Gay and Calaby 1970). These mounds provide an opportunity to test the effectiveness of bait toxicants, under field conditions. Peters and Fitzgerald (1999), for example, demonstrated that the Sentricon Termite Colony Elimination System was successful in eliminating field colonies of *C. acinaciformis.* Baitube devices containing 0.1% wt:wt and 1% wt:wt hexaflumuron bait toxicant in a dry wood flour (Recruit) were readily accepted by *C. acinaciformis*, with no apparent repellence. There was considerable variation in caste susceptibility to hexaflumuron. The queen and brood appear particularly vulnerable to the effect of hexaflumuron compared with the workers and soldiers. The

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use of mounds avoids the need to use multiple mark-release schemes (see Su et al. 1991) to verify the effects of the bait toxicant on the termite colonies. Problems with multiple mark-release schemes are discussed by Evans et al. (1998, 1999) and by Evans (2001).

Ensystex (Fayetteville, NC) has developed the Exterra Termite Interception and Baiting System, which also uses a CSI incorporated into an edible bait matrix. The CSI is diflubenzuron, and the bait matrix is a cellulose-acetate compound. Exterra is registered in the USA for use in subterranean termite management. Both the system and bait toxicant required testing under Australian conditions against an economically important species of termite to facilitate registration in Australia by the National Registration Authority for Agricultural and Veterinary Chemicals (NRA) (Australian Standard 2000). Chlorfluazuron is an effective CSI against termites in the laboratory (Rojas and Morales-Ramos 2001) and was the target bait toxicant for testing.

The aim of this research was to evaluate the termiticidal activity of chlorfluazuron when presented in a bait matrix, for the management of the subterranean termite *C. acinaciformis* in the field. Specifically, we investigated whether termites would forage on the bait matrix (with or without chlorfluazuron) and whether chlorfluazuron could eliminate termite colonies after a single or multiple applications of the bait matrix.

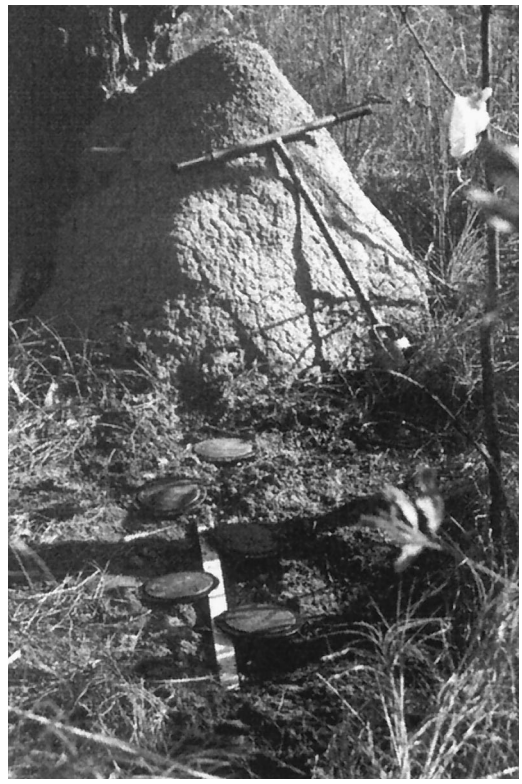

Fig. 1. Arrangement of bait stations and pine stud next to *C. acinaciformis* mound.

Materials and Methods

Termites. The work was conducted in Clemant State Forest (19° 02′ S, 146° 24′ E), ≈45 km northwest of Townsville, North Queensland, where *C. acinaciformis* occurs commonly in mounds. Thirteen *C. acinaciformis* mounds (mounds 1–13) were selected, based on their physical proximity to one another, ease of access, and other subjective attributes. All mounds housed active colonies at the time of bait matrix application.

Field Technique. Peters and Fitzgerald (1999) used a supply of susceptible timber below the soil surface to provide a food source and an environment conducive to sustained foraging by *C. acinaciformis* (Lenz and Creffield 1993). This principle was used to induce the same species into Exterra in-ground stations (latest version Quarterra stations) situated near the mounds. The Quarterra Extended Inspection Interval Station is a round plastic bait station consisting of two interlocking halves with horizontal slots, to allow the entry of termites, and a lockable plastic lid. On the inside wall of the station are a series of vertical slots that house the wooden interceptors (pieces of untreated wood) used to facilitate contact between the termites and the moist bait matrix. Each station holds ≈500 g of bait matrix.

At each mound, a trench (≈5 × 10 × 100 cm long) was dug radially to the mound. One end of the trench was extended into the outer crust of the mound until live termites were encountered. A radiata pine (*Pinus radiata* D. Don) stud (3.5 × 7 × 100 cm long) was placed in each trench with one end inserted into the mound. Two or five stations (mounds 1–10 and 11–13, respectively) were then placed into the ground along each stud. Station 1 was proximal, and station 5 was distal, to the mound. Once the devices were in place, the trenches were backfilled with soil to the level of the station lid (Fig. 1).

Application of Bait Matrix. The bait matrix (cellulose-acetate powder with chlorfluazuron) and control matrix (cellulose-acetate powder only) were supplied in 2-kg containers. In the field, water was added to the powder (3:1 wt:wt) to achieve a "doughy" bait matrix, which set quickly to an agar consistency. Approximately 400 g of dry bait matrix was mixed with water and added to each station. The station lid was then locked in place using the small plastic key provided. Three treatments were applied. Bait matrix was applied to five stations on each of mounds 1–5 (0.05% wt:wt chlorfluazuron) and mounds 6–10 (0.25% wt:wt chlorfluazuron). Control matrix was applied to station 1, and bait matrix (0.25% wt:wt chlorfluazuron) was applied to station 2 on each of mounds 11–13. Repellence, if any, of the 0.25% wt:wt chlorfluazuron could be estimated by comparing the percentage of bait removed at station 1 with that removed at station 2. Mounds were inspected on four occasions (6, 9, 12, and 17 wk) after the initial treatment, and a visual estimate was made of the percentage of bait removed

at each station. Bait matrix was replenished for 35 of 50 (70%) of the stations at mounds 1–10 during the first inspection. Bait matrix was not replenished at mounds 11–13. Strict control mounds with stations containing cellulose-acetate powder only were not used because the powder is not termiticidal (Rojas and Morales-Ramos 2001).

Monitoring Colony Health. During the initial treatment, a hole was drilled into the side of each mound using a chainsaw-driven auger, and a 1.9-cm-diameter plastic conduit (≈30 cm in length) was inserted about two-thirds of its length into the hole. A 40-cm-long pine dowel was placed into the conduit. The presence of termites, faecal mottling, and feeding on the dowel was used as an indicator of an active colony. Fresh dowels were inserted at each inspection. The presence of termites in the stations, on the wooden interceptors, and monitoring dowels was recorded, including comments on the health of the colony, at the time of inspection. Commencing at the third inspection, a small (≈5-kg) section of the mound was separated from the main structure using a hammer and chisel, and the presence of live termites was noted. The section was replaced, and repairs were noted at the next inspection. Colonies showing decline were destructively sampled during the fourth inspection using a pick and shovel, and a search was made for live termites in the mound, including the nursery and royal chamber.

Results and Discussion

First Inspection (wk 6). Inspection of stations 1–5 of mounds 1–5 (0.05% wt:wt chlorfluazuron) revealed that termites had damaged the wooden interceptors in all stations, but no live termites were present. Bait matrix removal was greatest in station 1 and least in station 5, with some variation between mounds (Table 1). A similar situation existed at mounds 6–10 (0.25% wt:wt chlorfluazuron) and mounds 11–13, with bait matrix removed at all mounds (Table 1). Live termites were found in stations at mounds 7 and 9. Termites had reached all five stations at mound 8, but little bait matrix was removed and no live termites were found. Termites had "muddied" the inside of most stations. The mud packing had set hard and was removed before bait matrix was replenished at seven mounds. Ants, principally *Iridomyrmex purpureus* (F. Smith) group and *Papyrius nitidus* (Mayr) group, were present in seven stations, especially where bait matrix removal was least. The wooden monitoring dowels had at least termite faecal mottling on all dowels and termites feeding on most. All 13 colonies in the mounds appeared to be healthy.

Second Inspection (wk 9). Replenished bait matrix was removed only at mound 1 (station 1, 400 g; station 2, 100 g). A strong malodor was noticed emanating from mound 11, which may be an early indicator of colony death. All other colonies in mounds appeared to be healthy.

Third Inspection (wk 12). There was no additional bait matrix removal. Termites and evidence of feeding were absent from dowels inserted into mounds 1–7, 9, 11, and 12, suggesting these 10 colonies may be in decline. Termites were also absent when small sections of these mounds were removed. In some of the stations, the ant activity had increased, with ants removing bait matrix at mound 4 (stations 4 and 5).

Table 1. Visual estimate of bait matrix removed (g) at each Exterra bait station on 13 *Coptotermes acinaciformis* mounds at the first inspection, approximately 6 wk post-treatment

Mound Number	Station Number					Total
	1	2	3	4	5	
1	400[a]	400[a]	80[b]	80[a]	80[a]	1040
2	400	400	0	0	0	800
3	400[a]	400[a]	400[a]	400[a]	400[a]	2000
4	400[a]	400[a]	400[a]	400[a]	400[a]	2000
5	400	40	0	0	0[b]	440
6	400[a]	320[a]	320[a]	320[a]	320[a]	1680
7	400[a]	400[a]	400[ac]	400[ac]	400[ac]	2000
8	40	40	0	0[b]	0[b]	80
9	200[ac]	240[ac]	320[ac]	120[ac]	120[ac]	1000
10	400[a]	80[a]	400[a]	80[a]	80[a]	1040
11	400	400	—	—	—	—
12	400[b]	400[b]	—	—	—	—
13	80	0[b]	—	—	—	—

Bait matrix was treated with 0.05% w/w chlorfluazuron (Mounds 1–5, Stations 1–5) or 0.25% w/w chlorfluazuron (Mounds 6–10, Stations 1–5; Mounds 11–13, Station 2) or untreated (Mounds 11–13, Station 1).

[a] Bait matrix replenished.

[b] Ants present.

[c] Termites present.

Final Inspection (wk 17). Eleven colonies (mounds 1–9, 11, and 12) were identified as in decline, or possibly eliminated, based on lack of repair of the incision made in the mound at the previous inspection. These mounds were destructively sampled, but live *C. acinaciformis* were found only in mound 12, when a small section of the mound was removed; sampling in this mound then ceased. Mounds 2, 7–9, and 11 were occupied by *Microcerotermes* sp. Ants occupied the other five mounds. A white fungus was found near the center of some mounds. Mound 11 had a strong malodor emanating from the soft carton material, but this was not detectable in other mounds. Ten colonies were confirmed dead because of the effects of the bait toxicant, while the colony in mound 12 was moribund and elimination appeared imminent. Mounds 10 and 13 were inspected, but not destructively sampled because the termites had repaired the incisions made during the previous inspection and termites were active in the mound and on the monitoring dowel. Why the colony in mound 10 did not succumb to the effects of the toxicant is unclear. Peters and Fitzgerald (1999) reported a similar anomaly when working with hexaflumuron. Evans (2001) notes that removal of bait does not always equate to consumption, as shown by Duncan (1997) for *Hodotermes* in South Africa.

The presence of many ants at mound 13, station 2, may have precluded termites from entering the station and removing the bait matrix. Scharf et al. (2002) concluded that of all nontarget invertebrate taxa collected from underground termite monitoring stations,

ants were the most likely to interfere with the use of stations by termites.

The results of the 4-mo experiment indicate that both 0.05% wt:wt and 0.25% wt:wt chlorfluazuron (at the quantities supplied) were sufficient to cause colony elimination of the mound-building termite *C. acinaciformis.* In fact, based on visual estimates, ≈440 g of 0.05% wt:wt chlorfluazuron and 80 g of 0.25% wt:wt chlorfluazuron were sufficient to cause colony elimination. The bait matrix was readily removed, with no evidence of repellence, supporting work by Rojas and Morales-Ramos (2001). Replenished bait matrix was seldom removed and was unnecessary for colony elimination. Indicators used to monitor colony health were reliable.

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