Penetration of Sized-Particle Barriers by Field Populations of Subterranean Termites (Isoptera: Rhinotermitidae)

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ABSTRACT Barriers of seven single-sized and two mixed-sized particles were exposed to field populations of the Formosan subterranean termite, *Coptotermes formosanus* Shiraki, and the eastern subterranean termite, *Reticulitermes flavipes* (Kollar) for 1–3 mo. Compared with previous laboratory results, field populations of subterranean termites were generally more successful in penetration of sand barriers composed of sized particles. Barriers of particles in sizes 2.00–2.36 and 2.36–2.80 mm were least penetrated by soil-borne colonies of *C. formosanus*. Three single-sized barriers (1.70–2.00, 2.00–2.36, and 2.36–2.80 mm) and two mixed-sized barriers (1.18–2.80 and 1.70–2.36 mm) were most effective against field populations of *R. flavipes*. In areas where both *C. formosanus* and *Reticulitermes* spp. occur, the two single-sized particle barriers (2.00–2.36 and 2.36–2.80 mm) appeared to be the most effective exclusion devices against field populations of these subterranean termites.

KEY WORDS physical barriers, subterranean termites, exclusion devices

FOR THE PAST FOUR DECADES, soil termiticides have been used for preventive control of subterranean termites. Currently, termiticides with long residual activity (e.g., organophosphates or pyrethroids) are applied on the soil bedding to form a continuous chemical barrier on which the structure foundation is built. The goal of termiticide application is to exclude soil-borne termites from structures.

In a laboratory study, Ebeling & Pence (1957) discovered that layers of sand particles ranging in size from 10–16 mesh (1.2–1.7 mm diameter) were not penetrated by the western subterranean termite, *Reticulitermes hesperus* Banks. Because of the availability of inexpensive and effective soil termiticides, their discovery had been overlooked until recently, when Tamashiro et al. (1987) confirmed that the finding of Ebeling & Pence (1957) could be applied to the Formosan subterranean termite, *Coptotermes formosanus* Shiraki. Smith & Rust (1990), who extended the study of Ebeling & Pence (1957), reported that *R. hesperus* did not penetrate particles of 8–20 mesh (0.85–2.36 mm diameter).

Our laboratory results agreed with findings of Tamashiro et al. (1987); their results indicated that soil barriers composed of particles 1.7–2.4 mm in diameter were not penetrated by *C. formosanus*, and that a wider size range of particles (1.00–2.36 mm) excluded penetration by the eastern subterranean termite, *Reticulitermes flavipes* (Kollar) (Su et al. 1991a). Although *C. formosanus* coexists with *Reticulitermes* spp. in some areas of Florida (Scheffrahn et al. 1988), our laboratory study showed that barriers composed of mixed particle sizes (1.18–2.80 mm) effectively prevented penetration by both *C. formosanus* and *R. flavipes*.

Tamashiro et al. (1987) reported that a structure built over a layer of basaltic barrier was not invaded by *C. formosanus*. In our study, we exposed sized particle barriers to field populations of *C. formosanus* and *R. flavipes* to test the validity of our previous laboratory results (Su et al. 1991a).

Materials and Methods

Field bioassays were done in centrifuge tubes (21 mm inside diameter, 100 mm high) in which a 5-cm-long particle-sized sand was sandwiched by a 2-cm segment of wet sawdust (*Pinus* sp.) on the closed end and a 2-cm segment of 5% agar on the open end (Fig. 1). The remaining 1-cm segment at the opening was filled with more wet sawdust. The sand, consisting of crashed quartz rocks and fossilized coral, was sifted through a series of eight sieves (Tyler screen scale 5, 6, 7, 8, 9, 10, 12, 14, and 16; Fisher Scientific, Pittsburgh, PA) to obtain groups of seven uniform sizes: 1.00–1.18, 1.18–1.40, 1.70–2.00, 2.00–2.36, 2.36–2.80, 2.80–3.35, and 3.35–4.00 mm diameter. Two groups of mixed sizes of particles (1.18–2.80 and 1.70–2.36 mm diameter) were also tested. Nine tubes, each containing one of the sizes, were placed vertically in a clear plastic

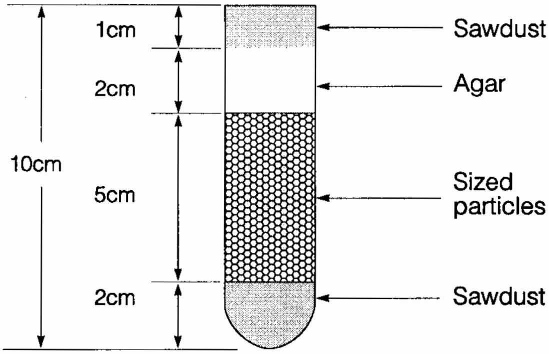

Fig. 1. Centrifuge tube containing a 5-cm segment of a sized particle barrier to be exposed to field populations of subterranean termites.

container (11.2 cm diameter, 13.7 cm high). A wire mesh disk (11 cm diameter; openings 12 by 12 mm) was placed on the open end of the plastic container and fastened by an open plastic ring lid (Fig. 2). Approximately 10–15 wooden sticks (*Pinus* sp., ≈3 mm by 6 mm by 14.5 cm) were inserted through the wire mesh among the tubes. A layer of wet sawdust ≈5 cm thick was poured

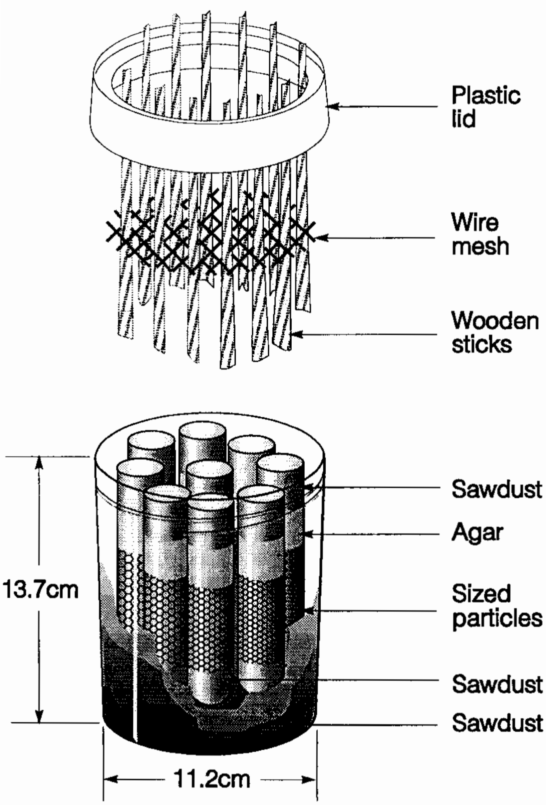

Fig. 2. Bioassay unit comprising plastic enclosure, nine tubes containing sized particles, wet sawdust, and wooden sticks.

into the plastic container to fill the spaces between tubes and wooden sticks.

Plastic containers filled with the nine bioassay tubes were exposed to termite activity in bait stations described by Su & Scheffrahn (1986). The bait station was composed of a wooden block (12 by 7 by 10 cm) placed in an underground cavity surrounded by a polyvinylchloride collar (15.3 cm inside diameter, 15 cm high, 0.8 mm thick). Termites were routinely collected from the wooden blocks for laboratory studies. The number of termites collected from wooden blocks was used as an indicator of termite activity (Su et al. 1991b). Bait stations with high termite activity (>5,000 termites collected from a wooden block) were chosen for testing. Bioassay containers were placed in bait stations with opening ends facing down. Foraging termites in the soil entered the containers through the extruding wooden sticks.

The bioassay units were exposed to termite activity in the field for 1–3 mo until the 5-cm-thick layer of sawdust at the closed end of the container housing the bioassay tubes was totally consumed. The units were then brought back to the laboratory to measure the vertical distances of tunnels in sand barriers excavated by termites. Each field bioassay was repeated three times using three different bait stations of a colony. Three colonies each of *C. formosanus* (I, II, and III) and *R. flavipes* (A, B, and C) were tested. Particle size was the factor for evaluation. Tunneling distances were subjected to analyses of variance. Differences of distance among particle sizes were analyzed for each colony with a completely randomized design; those for each species were analyzed using a completely randomized block design with colony origin as the blocking factor. Significant differences among particle sizes for each colony or termite species were separated by Fisher's least significant difference (LSD) test at $\alpha = 0.05$ (SAS Institute 1987).

Results and Discussion

The ability of termites to penetrate barriers of various particle sizes differed from colony to colony even within a species (Table 1). Barriers with particle sizes that were too small (1.00–1.40 mm) or too large (2.80–4.00 mm) were penetrated 80% (or 4 cm) by at least one of the field populations of both termite species.

C. formosanus from colonies II and III penetrated significantly deeper into barriers with particle sizes of 1.18–2.00 mm than foragers of colony I. Termites from the former two colonies also reached the midsection of the 5-cm barrier composed of mixed-size particles (1.18–2.80 mm). Our laboratory study (Su et al. 1991a) showed that particles of three single sizes (1.70–2.00, 2.00–2.36, and 2.36–2.80 mm) and two mixed sizes (1.18–2.80 and 1.70–2.36 mm) were least

Table 1. Distance penetrated by field populations of *C. formosanus* and *R. flavipes* through 5-cm barriers consisting of single-sized or mixed-sized particles

Particle size, mm	Tyler screen scale, mesh	Distance in cm ± SE			
		Colony[a]			Species mean
		I, A	II, B	III, C	
		C. formosanus			
1.00–1.18	14–16	2.7 ± 0.3ab	5.0 ± 0.0a	3.5 ± 1.5ab	3.7 ± 0.6a
1.18–1.40	12–14	1.7 ± 1.1b	4.0 ± 0.5a	5.0 ± 0.0a	3.6 ± 0.5a
1.70–2.00	9–10	0.1 ± 0.0b	3.0 ± 0.9ab	2.9 ± 1.1abc	2.0 ± 0.6bc
2.00–2.36	8– 9	0.4 ± 0.2b	0.8 ± 0.2bc	0.5 ± 0.1c	0.6 ± 0.1d
2.36–2.80	7– 8	0.2 ± 0.0b	0.4 ± 0.1c	1.1 ± 0.2bc	0.5 ± 0.1d
2.80–3.35	6– 7	1.8 ± 0.2b	1.0 ± 0.0bc	1.7 ± 0.2bc	1.5 ± 0.1bc
3.35–4.00	5– 6	4.2 ± 0.8a	4.3 ± 0.3a	3.8 ± 1.2ab	4.1 ± 0.4a
1.18–2.80[b]	7–14[b]	1.3 ± 1.2b	2.6 ± 0.6abc	2.5 ± 0.8abc	2.2 ± 0.5b
1.70–2.36[b]	8–10[b]	0.3 ± 0.1b	1.7 ± 0.5bc	0.5 ± 0.2c	1.0 ± 0.3cd
		R. flavipes			
1.00–1.18	14–16	4.3 ± 0.7a	3.3 ± 0.2a	4.2 ± 0.8a	3.9 ± 0.6a
1.18–1.40	12–14	2.1 ± 1.5a	2.8 ± 1.3a	4.2 ± 0.4a	3.0 ± 0.7a
1.70–2.00	9–10	0.3 ± 0.2b	0.3 ± 0.1b	0.3 ± 0.1b	0.3 ± 0.1b
2.00–2.36	8– 9	0.3 ± 0.2b	0.4 ± 0.1b	0.2 ± 0.0b	0.3 ± 0.1b
2.36–2.80	7– 8	0.7 ± 0.3b	0.3 ± 0.1b	0.2 ± 0.1b	0.4 ± 0.1b
2.80–3.35	6– 7	5.0 ± 0.0a	0.4 ± 0.1b	5.0 ± 0.0a	3.5 ± 0.8a
3.35–4.00	5– 6	5.0 ± 0.0a	4.4 ± 0.1a	3.8 ± 1.2a	4.4 ± 0.8a
1.18–2.80[b]	7–14[b]	0.6 ± 0.2b	0.3 ± 0.1b	0.4 ± 0.1b	0.4 ± 0.1b
1.70–2.36[b]	8–10[b]	0.4 ± 0.2b	0.4 ± 0.1b	0.3 ± 0.1b	0.4 ± 0.1b

Values are means of three replicates for each colony and nine replicates for each species (three replicates each of three colonies). Means followed by the same letter within a column are not significantly different ($\alpha = 0.05$; Fisher's LSD test [SAS Institute 1987]).

[a] Colonies I, II, III: *C. formosanus;* colonies A, B, C: *R. flavipes.*

[b] Mixed-sized particle barrier.

penetrated by *C. formosanus.* Field populations of *C. formosanus,* however, infiltrated deeper into barriers with particles 1.70–2.00 mm and one of the mixed sizes (1.18–2.80 mm) than the laboratory groups (Su et al. 1991a). Only barriers of two single sizes (2.00–2.36 and 2.36–2.80 mm) and the narrower range of the barrier with mixed-size particles (1.70–2.36 mm) prevented penetration by field populations of *C. formosanus* at <1.0 cm.

An inconsistency between laboratory and field results also occurred with *R. flavipes.* Our laboratory results demonstrated that barriers of four single particle sizes (1.00–1.18, 1.18–1.40, 1.70–2.00, and 2.00–2.36 mm) were poorly penetrated by *R. flavipes.* Foragers of colonies A and C entered the entire 5-cm barriers of some of the replicates of particle sizes 1.00–1.18 mm, but barriers of particles in size 1.18–1.40 mm were partially invaded by *R. flavipes* of three tested colonies (Table 1). Although field populations were generally more aggressive in invading the sized particle barrier, field foragers of *R. flavipes* penetrated less into barriers of size 2.36–2.80 mm (0.4 ± 1 cm [mean ± SEM]) than laboratory groups (1.3 ± 0.1 cm) (Su et al. 1991a). Barriers of both mixed sizes were equally effective in preventing penetrations by field and laboratory populations of *R. flavipes.* Results of this field study demonstrated that field populations of subterranean termites are generally more successful in penetration of soil barriers of sized particles than laboratory groups. This may be because of the larger numbers and wider ranges of foragers' body sizes in field colonies.

Our results suggest that barriers of particles in sizes 2.00–2.36 and 2.36–2.80 mm are best to use in areas with active infestations of *C. formosanus.* The barrier with mixed-size particles of 1.70–2.36 mm also allows only a slight penetration by this aggressive termite species. In a longer exposure to a wider variety of field populations of *C. formosanus,* the outcome of any partially penetrated barriers may be unpredictable. Three single-sized barriers (1.70–2.00, 2.00–2.36, and 2.36–2.80 mm) and both mixed-sized barriers (1.18–2.80 and 1.70–2.36 mm) may prove effective if used for field colonies of *R. flavipes.* In areas where both *C. formosanus* and *Reticulitermes* spp. occur, the two sized particle barriers (2.00–2.36 and 2.36–2.80 mm) appear to be the only effective means of exclusion. The feasibility of commercial production of gravel particles in such narrow range sizes merits further investigation.

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