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TOXICITY AND LETHAL TIME OF N-ETHYL PERFLUOROOCTANE SULFONAMIDE AGAINST TWO SUBTERRANEAN TERMITE SPECIES (ISOPTERA: RHINOTERMITIDAE)

NAN-YAO SU AND RUDOLF H. SCHEFFRAHN
Ft. Lauderdale Research and Education Center
University of Florida, IFAS
3205 College Ave.
Ft. Lauderdale, FL 33314

ABSTRACT

The topical LD_{50} of N-ethyl perfluorooctane sulfonamide (GX071) was estimated at 9.94 μg/g against the Formosan subterranean termite, *Coptotermes formosanus*, and 68.61 μg/g against the eastern subterranean termite, *Reticulitermes flavipes*. Under force-fed conditions, *C. formosanus* was ca. three fold more susceptible to GX071 (LC_{50} = 4.22 ppm) than *R. flavipes* (LC_{50} = 13.6 ppm). When applied topically, 5-15 days elapsed before 90% of the *R. flavipes* died (corresponding dose range:100-250 μg/g), while a similar mortality rate was recorded for *C. formosanus* after 2-7 days exposure at a lower dose range: 14.0-37.5 μg/g. Ninety percent of both termite species were killed 3-12 days after being force-fed with GX071, but at a lower concentration range for *C. formosanus*.

RESUMEN

El LD_{50} típico de N-ethyl perfluorooctane sulfonamidae [G X 071) se estimó ser 9.94 μg/g contra la termita subterránea de Formosa, *Coptotermes formosanus*, 68.61 μg/g

contra la termita subterránea del este, *Reticulitermes flavipes*. Cuando se les forzó a comer, *C. formosanus* fue aproximadamente tres veces más susceptible a G X 071 (LC_{50} = 4.22 ppm) que *R. flavipes* (LC_{50} = 13.6 ppm). Cuando se aplicaron tópicamente, pasaron de 5 a 15 días antes de que muriera el 90% de *R. flavipes* (fluctuación de la correspondiente dósis:100-250μg/g), mientras que un grado similar de mortalidad se registró en *C. formosanus* después de 2 a 7 días expuestos a una dósis menor de fluctuación: 14.0-37.5μg/g. El 90% de las dos especies de termitas murieron de 3 a 12 días de haber sido forzadas a comer G X 071, pero a una fluctuación de concentración más baja para *C. formosanus*.

Subterranean termites (Rhinotermitidae) are major structural pests in the United States. Monetary loss in 1983 due to the eastern subterranean termite, *Reticulitermes flavipes* (Kollar), and the dark southern subterranean termite, *R. virginicus* (Banks), amounted to ca. $470 million for nine southeastern states (Hamer 1985). In the western United States, *R. hesperus* Banks causes damage and loss of similar magnitude. In addition to these native rhinotermitids, the Formosan subterranean termite, *Coptotermes formosanus* Shiraki, is found in Hawaii and at least six southeastern states. The control cost in 1985 for *C. formosanus* in Hawaii alone was estimated at $60 million (Tamashiro et al. 1987).

Current control measures for subterranean termites depend heavily on soil termiticides such as chlorinated hydrocarbons, organophosphates, and more recently, pyrethroids. Reliance on these persistent compounds in the urban environment has aroused public concern (La Fage 1986). Moreover, soil treatments are not designed to eliminate termite colonies but only provide barriers to separate structures from soil-born infestations of subterranean termites. Sources of infestations, especially with expansive colonies such as those of *C. formosanus*, therefore remain viable near the structures even after treatment.

Esenther and Beal (1974, 1978) used baits containing the slow-acting compound, dechlorane (mirex), to suppress activities of *Reticulitermes* colonies under field conditions. Gao et al. (1985) reported successful field control of termite infestations with mirex baits. The use of slow-acting and nonrepellent insecticides offers a possible strategy for subterranean termite control. This probably remains the only feasible method for destruction of established *C. formosanus* colonies that may contain massive populations (Su et al. 1982b). If introduced into the colony's foraging gallery system, such a compound could be transferred to unexposed nestmates via social grooming or trophallaxis. The characteristics of slow-acting baits required for effective control of *C. formosanus* are similar to those for baits used against the red imported fire ant, *Solenopsis invicta* Burn (Williams et al. 1980).

Laboratory studies have shown that hydramethylnon, avermectin B_1, and some insect growth regulators exhibit delayed toxicity against *C. formosanus* or *R. flavipes* (Jones 1984, Su et al. 1985, 1987). A field trial using hydramethylnon baits, however, did not successfully control *C. formosanus* colonies (Su et al. 1982a).

Vander Meer et al. (1985) reported on a new class of delayed-action insecticides, the fluoroaliphatic sulfones, for control of *S. invicta*. We tested one of the promising compounds in this class, N-ethyl perfluorooctane sulfonamide (GX071), for its topical and oral toxicity, and lethal time against *C. formosanus* and *R. flavipes*.

Materials and Methods

Both *C. formosanus* and *R. flavipes* were collected from field colonies by the method of Su & Scheffrahn (1986). Termites (undifferentiated larvae, i.e. "workers") of at least

the third instar were tested. Technical grade (> 99%) GX071 (Griffin Corp., Valdosta, GA) was used in this study.

1. Topical toxicity and lethal time.

Thirty workers were anesthetized with CO_2 gas for 20 sec and inoculated with a 0.5 μl droplet of GX071 in acetone solution at delivered dosages of 0, 0.075, 0.1, 0.2, 0.3, 0.4, and 0.5 μg/termite for *C. formosanus* and 0, 0.2, 0.25, 0.3, 0.4, and 0.5 μg/termite for *R. flavipes*. A microapplicator (Model M, Instrumentation Specialities Co., Inc.) was used to administer the droplet onto insects' abdomens. The mean worker biomass of the source colonies, 5.3 mg for *C. formosanus* and 2.0 mg for *R. flavipes*, was used to convert the μg/termite dose to μg/g termite biomass. Treated termites were transferred to petri dishes (5.0 cm diam by 1.5 cm high) provisioned with two filter paper discs (Whatman No. 1) moistened with deionized water. Three *C. formosanus* soldiers or one *R. flavipes* soldier were added to each unit for each species to approximate colony soldier proportions. The experimental units were stored in an environmental chamber at 29 ± 1 °C. Dead or moribund workers were recorded and removed from each unit daily for 14 days. Mortalities at 14 days were corrected by Abbott's (1925) formula and topical LD_{50} values were computed by probit analysis (SAS Institute 1985). The *effective lethal time* (ELT_{90}), defined as the time required for a fixed dosage of GX071 to kill 90% of the test insects (Su et al. 1987), was derived to quantify lethal time using the daily mortality data.

2. Oral toxicity and lethal time.

One hundred workers (plus five soldiers for *C. formosanus* and one soldier for *R. flavipes*) were placed in petri dishes (5.0 cm diam by 1.5 cm high) provisioned with absorbant cellulose pads (4.7 cm diam, Gelman Instrument Co.), impregnated with GX071, and moistened with deionized water. Concentrations tested for *C. formosanus* were 0-10 ppm (wt./wt.) in one ppm increments, and 0, 2, 4, 6, 8, 10, 20, 30, 40, 50, and 60 ppm for *R. flavipes*. All treatments were replicated three times. Termites were forced-fed on the treated paper for 24 h at 29 ± 1 °C and transferred to similar petri dishes containing untreated filter paper. The post-exposure observation period was 14 days. Oral LD_{50}s and ELT_{90}s were computed by procedures described above.

Results and Discussion

Mortality of untreated termites after 14 days was <9% for *C. formosanus* and <3% for *R. flavipes* in both tests. The topical LD_{50} (at 14 day) of GX071 was estimated at 9.94 μg/g for *C. formosanus* and 68.61 μg/g for *R. flavipes*, equaling a seven-fold greater susceptibility for the Formosan subterranean termite than the eastern subterranean termite (Table 1). A significant ($\alpha = 0.05$) difference in the susceptibility between these two species was also found for the oral LC_{50}. Again, GX071 exhibited a ca. three fold greater toxicity against *C. formosanus* ($LC_{50} = 4.22$ ppm) than *R. flavipes* ($LC_{50} = 13.60$ ppm).

Beal & Smith (1971) who studied the relative susceptibilities of three subterranean termites to aldrin, chlordane, dieldrin, and heptachlor, concluded that *R. flavipes* and *R. virginicus* were more vulnerable to these compounds than *C. formosanus*. Based on their findings, the current chlordane label recommends twice the concentration for *C. formosanus* soil treatments over the *Reticulitermes* rate. Laboratory studies with insect growth regulators and other slow-acting insecticides also support the norm that *C. formosanus* is more tolerant to chemical treatments than *R. flavipes*.

Contrary to the above general perception, GX071 was selectively more toxic to *C. formosanus* than *R. flavipes*. Results of lethal time studies further confirm this observation. When applied topically, 5-15 days elapsed before 90% of the *R. flavipes* workers died (corresponding dose range: 100-250 μg/g), while a similar mortality rate was re-

TABLE 1. TOPICAL AND ORAL TOXICITY OF N-ETHYL PERFLUOROOCTANE SULFONAMIDE AGAINST TWO SUBTERRANEAN TERMITE SPECIES, *C. FORMOSANUS* AND *R. FLAVIPES*.

	Species	Wt. (mg ± SE)	LD_{50} (μg/g) or LC_{50} (ppm) (95% FL)	Slope ± SE
Topical LD_{50} (μg/g)	*C. formosanus*	5.3 ± 0.4	9.94 (8.91-11.7)	0.35 ± 0.0054
	R. flavipes	2.0 ± 0.2	68.61 (23.4-99.5)	0.03 ± 0.0085
Oral LC_{50} (ppm)	*C. formosanus*	5.4 ± 0.3	4.22 (3.13-5.24)	0.78 ± 0.1980
	R. flavipes	1.8 ± 0.1	13.60 (9.25-21.9)	0.14 ± 0.0369

corded for *C. formosanus* after 2-7 days post-exposure at a lower dose range: 14.0-37.5 μg/g (Fig. 1). All *C. formosanus* workers exposed to GX071 at >50 μg/g were killed within 24 h after the inoculation. Oral ELT_{90}s were similar for both species: 3-12 days (Fig. 1), but at a lower concentration range for *C. formosanus*.

Higher concentrations of GX071 used in preliminary tests (>10 ppm for *C. formosanus* and >250 ppm for *R. flavipes*) caused instantaneous death to both termite species. Shortly before death, the termites showed ataxia and subsequent involuntary jittering of appendages. Termites exposed to a lower concentration, as shown in this study, also exhibited ataxia and body size reduction before the onset of death. Vander Meer et al. (1985) who reported some fluoroaliphatic sulfones were effective against the house fly, American and German cockroaches, and a mosquito species, speculated that these compounds may be stomach poisons.

Results of this study indicate that GX071 concentrations >10 ppm for *C. formosanus*, and >250 ppm for *R. flavipes* may be effective as soil termiticides or wood preservatives due to the acute toxicity. The slower ELT_{90} doses (5-10 ppm and 100-250 ppm for *C. formosanus* and *R. flavipes*, respectively) should be considered for baits or tracking powder. More studies are needed to investigate the inter-relationship among concentration, feeding deterrency, and mortality before a candidate bait or tracking powder can be developed for field tests.

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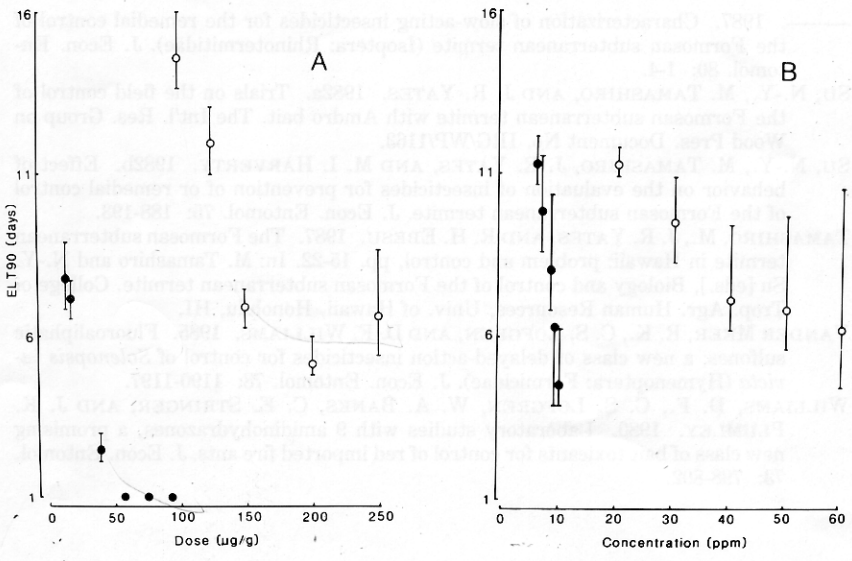

Fig. 1. Time (days) required to kill 90% (or $ELT_{90} \pm 95\%$ FL) of *C. formosanus* (solid circles) and *R. flavipes* (open circles) topically (A) inoculated with or force-fed (B) on papers treated with N-ethyl perfluorooctane sulfonamide.

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