Mortality of Eastern Subterranean Termites (Isoptera: Rhinotermitidae) Exposed to Four Soils Treated with Termicid Scs

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ABSTRACT Termite survivorship was affected by soil type and termicide tested in constant-exposure bioassay. Four soil types were tested at the same percentage soil moisture (35% w/w). Soil pH values were between 5.4 and 5.5 with organic matter contents ranging from 2.07% to 3.77%. Soils tested included a sand, sandy loam, sandy clay loam, and sandy clay. Six termicide formulations were tested including chlorpyrifos (Dursban TC, Intovaleate (Tribute), cypermethrin (Preval PT, Demon 2 EC), and permethrin (Dragnet PT, Torpedo). Estimated lethal concentrations for all termiticides were at least 7 times lower in sand compared with sandy loam or sandy clay loam soils. However, soil type alone could not be used to predict termite mortality with the termicides tested.

KEY WORDS Reticulitermes flavipes, survivorship, termicide, soil, bioavailability

CONVENTIONAL TERMITICIDE TREATMENTS require application of termicide solutions to the soil surrounding and beneath a structure. Studies with other soil insect systems have indicated that soil type, soil pH, insecticide type, moisture, temperature, microbial communities, and the target insect affect soil insecticide efficacy (Harris 1972, Tashiro and Kuhr 1973, Chapin et al. 1982, Macalady and Wolfe 1983, Febo 1989). The conditions that may affect soil insecticide efficacy are numerous and insecticide interactions with the aforementioned factors are often complex. Each active ingredient formulation combination must be tested individually, because efficacy in different soil types cannot be extrapolated from chemical structure alone (Harris 1972). Insecticides currently registered for use as termiticides have soil absorption coefficients (Kw values) which place them in the immobile classification, implying they do not readily leach through the soil profile (Helling and Turner 1968, McCull et al. 1980). This indicates the potential for interactions between these compounds and components of the soil matrix that could affect the biological activity of these insecticides. We report here results from tests concerning the bioavailability of selected termicides in several soil types at the same percentage soil moisture using termites in a continuous-exposure bioassay system.

Materials and Methods

Termites. Eastern subterranean termites, Reticulitermes flavipes (Kollar), were collected from infested logs found at the University of Georgia Westbrooke Farm near Griffin, GA. Termites were extracted from logs brought into the laboratory using the technique described by La Fage et al. (1983). Alates associated with each colony were used to identify species (Weeber 1965). Termites removed from logs were maintained in clear plastic boxes (26 cm long, 19 cm wide, 9 cm high) containing moistened No. 1 Whatman filter paper and several 1-cm blocks of white pine wood (Pinus sp.). Termites were maintained in an environmental chamber in total darkness at 24°C for no longer than 1 mo before inclusion in a bioassay. Only undifferentiated R. flavipes workers from 4 different colonies were used in the tests.

Termicides. The 6 formulations tested were chlorpyrifos (Dursban TC [termicide concentrate], DowElanco, Indianapolis, IN), fenvalerate (Tribute, Roussel Uclaf, Morrisville, NJ), cypermethrin (Preval PT [for termite], PMC, Princeton, NJ), Demon 2 EC (emulsifiable concentrate), Zenea, Wilmington, DE), and permethrin (Dragnet PT [for termite], PMC, Torpedo, Zenea). Commercial formulations of each product were serially diluted to provide a range of concentrations. Each termicide was tested at 7 of the following 11 rates: 0.001, 0.01, 0.05, 0.1, 0.5, 1, 5, 10, 50, 100, and 500 ppm (determined by weight of active ingredient per weight of oven-dried soil).

Soils. The soils tested included sand (play sand, Bosal, Charlotte, NC), a Cecil series sandy loam typical of A horizon soils (top soil) from the Piedmont region in Georgia, and 2 common Piedmont

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region B horizon soil types (subsoil)—a Ceric series sandy clay and a Worsaae series sandy clay loam. Soils were analyzed by the Soil Testing and Plant Analysis Laboratory at the University of Georgia, Athens. Soils were analyzed for structural composition (percentage sand, silt, clay), pH (w.), cation exchange capacity, and percentage organic matter.

Bioassay and Data Analysis. Termiteicide solutions were prepared to obtain the required concentration in a volume of distilled water necessary to bring 200 g of autoclaved and oven-dried soil to 15% (w:w) soil moisture. The appropriate volume of termiteicide solution was slowly poured into soils in clear plastic boxes (20 cm long, 15 cm wide, 9 cm high). Solutions were mixed using a stainless steel teaspoon obtained by visual inspection, an even distribution of soil moisture. One replicate consisted of a container of soil mixed as previously described and divided into 4 petri dishes (100 by 15 mm) for each termiteicide-soil type tested. Untreated control soils received distilled water only. Twenty-five termites were immediately added to each petri dish of moist soil for a total of 100 termites from one source colony for each replicate. Termiticide mortality was recorded at 48 h. Probit analysis was used to calculate LC50 of 4 replicates for each soil type-termiteicide combination (SAS Institute 1988).

Results and Discussion

Soil pH ranged from 5.4 to 5.5 for each of the soils tested (Table 1). Differences in structural components of soils included higher percentage sand in the sandy loam (71%) top soil compared with the sandy clay loam (55%) and sandy clay (52%) subsols (Table 1). There were similar percentages of silt between the sandy loam (21%) and the sandy clay loam (24%) (Table 1). Percentage clay was closer between the sandy clay (39%) and sandy clay loam (31%) subsols compared with the sandy loam (8%) or sand (0%) (Table 1). Organic matter was higher with the sandy loam (3.7%) and lowest with sand (<0.07%), although barely detectable levels were found in sandy clay (0.07%) (Table 1). The sandy clay loam had a percentage organic matter (1.3%) intermediate between the aforementioned soils. Cation exchange capacity was highest in the sandy loam topsoil and lowest in the sand, whereas the two subsols were similar (Table 1).

Data from constant-exposure bioassays show general trends concerning toxic effects of termiteicides; however, they do not measure soil termiteicide efficiency (Su et al., 1992). All termiteicides tested, with the exception of chlorpyrifos, are effective as repellents (Su and Scheffrahn 1990, Forschler 1994). Therefore, we cannot extrapolate these data directly relative to field efficacy of the termiteicides tested. However, mortality data from these tests, expressed as LC50, indicate there were interactions between the termiteicides and soils tested (Tables 2 and 3). At the same percentage soil moisture, the toxic effects of the formulations were reduced in certain soils (Table 2).

Bioassays indicated a higher level of termiteicide activity versus the other soils tested. All of the termiteicides regardless of soil type, with the exception of permethrin (Fusar and Torpedo) and the cypemethrin (Fusar in sandy clay), showed a statistically significant reduction in toxicity compared with sand as judged by the lack of 95% CI overlap (Tables 2 and 3). There was a difference in termiteicide toxicity between sand and sandy clay or sandy clay loam within each termiteicide tested (Tables 2 and 3).

There were no general trends in termite mortality attributable to soil type alone. For example, with the exception of sand, fenvanlate (Fusar)
Table 3. Slope ± SE for LC50 values by termiteicide and soil type from constant-exposure bioassays

<table>
<thead>
<tr>
<th>Termiteicide</th>
<th>Soil type</th>
<th>Sand</th>
<th>Sandy clay</th>
<th>Sandy loam</th>
<th>Sandy clay loam</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2.03 ± 0.27</td>
<td>3.13 ± 0.02</td>
<td>2.52 ± 0.16</td>
<td>1.90 ± 0.02</td>
</tr>
<tr>
<td>Previa</td>
<td></td>
<td>2.51 ± 0.09</td>
<td>1.85 ± 0.06</td>
<td>2.22 ± 0.09</td>
<td>1.54 ± 0.09</td>
</tr>
<tr>
<td>Demon</td>
<td></td>
<td>4.29 ± 0.85</td>
<td>2.56 ± 0.66</td>
<td>3.30 ± 1.11</td>
<td>1.96 ± 0.07</td>
</tr>
<tr>
<td>Draget</td>
<td></td>
<td>5.23 ± 0.09</td>
<td>2.16 ± 0.09</td>
<td>1.53 ± 0.25</td>
<td>1.37 ± 0.16</td>
</tr>
<tr>
<td>Torpedo</td>
<td></td>
<td>3.31 ± 0.02</td>
<td>2.13 ± 0.03</td>
<td>2.14 ± 0.09</td>
<td>0.97 ± 0.03</td>
</tr>
<tr>
<td>Tribune</td>
<td></td>
<td>3.09 ± 0.15</td>
<td>0.68 ± 0.44</td>
<td>0.94 ± 0.00</td>
<td>1.49 ± 1.19</td>
</tr>
<tr>
<td>Dursban</td>
<td></td>
<td>4.69 ± 0.65</td>
<td>1.85 ± 0.06</td>
<td>2.22 ± 0.09</td>
<td>1.54 ± 0.09</td>
</tr>
</tbody>
</table>

*Cypermethrin.
*Permethrin.
*Fenvalerate.
*Chlorpyrifos.

probably had a greater affinity for components of the soil matrix than the other termiteicides tested. This is indicated by the 22 times higher LC50 estimates when comparing fenvalerate is sand with the other soils. The effect of soil type on termite mortality varied between different termiteicides. LC50 for both cypermethrin products (Previa and Demon) and the permethrin Draget showed at least a 4.5 times difference in activity between the sandy clay and the sandy loam soils. However, only Draget provided statistically different LC50 in this soil comparison. Comparing the same soils, differences were 2.9 times for the permethrin Torpedo, 50 times for chlorpyrifos (Dursban), and no difference for fenvalerate (Table 2). In contrast, there was <2 times difference in the LC50 between any of the termiteicides when comparing the sandy loam and the sandy clay loam soils, none of which were statistically significant (Table 2).

Comparisons between soil types may indicate which individual soil components affect soil termiteicide toxicity in constant-exposure bioassays. The sand and sandy clay soils had low percentage organic matter but major differences in amounts of silt and clay. The soil structural components (silt and clay) affected the termiteicide Tribute (fenvalerate) most and Dursban (chlorpyrifos) and the permethrin Torpedo and Draget least (Table 2). Comparing the sandy loam soil, which had 50 times the organic matter but 4 times less clay than the sandy clay, only Draget provided significantly lower toxicity (Table 2). However, all other termiteicides, with the exception of Tribute (fenvalerate), provided LC50 values at least 3 times higher in the same soils, indicating a trend toward reduced toxicity. A comparison between the sandy clay and the sandy clay loam is also indicative of the effect of organic matter on termiteicide activity. These soils had similar percentage soil structural components (percentage sand:silt:clay) but the sandy clay loam had 19 times more percentage of organic matter (Table 1). With the exception of Tribute and Torpedo, all termiteicides were significantly less active in the sandy clay loam (Tables 2 and 3). Therefore, of the termiteicides tested, all but fenvalerate (Tribute) appear to interact more strongly with the organic matter content in soil than with the other soil structural components. Comparisons of percentage silt and clay are less clearly defined because of confounding influence that each of the other soil components may have on potential interactions. Carbon exchange capacity, however, was not related to termite mortality.

Results of these tests illustrate the importance of stating soil physical characteristics when reporting results from soil termiticide bioassays. Smith and Frost (1965) reported differences in toxicity and repellency of termiteicides tested in sand amended with cellulose or kaolinite clay. Although our bioassays in natural soils were not designed to define which specific components of the soil matrix affected termite mortality, they can help explain differences reported from past studies concerning termiteicide efficacy (Forschler 1994). Termite mortality between soil types within termiteicide indicates that physical or chemical affinity by the active ingredient for portions of the soil matrix affected the percentage of toxins available for biological interactions. This phenomenon (bioavailability) may affect the field performance of a termiteicide used in different soils. Therefore, termiteicide bioassay efficacy must be reported in relation to soil type.

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