Research Article

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Bifenthrin longevity at the termiticidal application rate

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Abstract

BACKGROUND: The longevity, mobility and insecticidal activity of bifenthrin at the termiticidal application rate for perimeter treatment were investigated in packed-soil columns in the laboratory and greenhouse.

RESULTS: Bifenthrin was not detected in the eluates of packed-soil cones over a period of 6 months. In larger pipe plots incorporating bifenthrin into the top 15 cm of the soil, the compound degraded in a biphasic fashion. Within the treated soil, the effect of vegetation on the amount of bifenthrin remaining in the soil depended on soil depth and time, and soil half-lives were longer in non-vegetated soil. Bifenthrin residues were higher in the top 7.5 cm of soil and declined over time. Movement of bifenthrin into the top untreated soil depth was observed, but much less was observed in lower depths. The soil remained toxic to termites in 3 day and 7 day forced exposure bioassays for the 30 month duration of the study.

CONCLUSIONS: Concentrations of bifenthrin will remain in the soil at levels sufficient to kill termites for more than 30 months. Published 2011 by John Wiley & Sons, Ltd.

Keywords: bifenthrin; soil mobility; longevity; termiticide

1 INTRODUCTION

Bifenthrin is the active ingredient in Talstar Professional, manufactured by FMC Corporation (Princeton, NJ), and is used for termite control and prevention in the United States. When used in a perimeter treatment for the prevention of termite infestations, a trench is dug around a building foundation to the top of the footing, about one-half of the mixed formulation is added, the soil is replaced and the remainder of the insecticide solution is applied to the top of the replaced soil. In this way, a continuous barrier of treated soil is provided around the structure.

Insecticides used in this way are exposed to rain, sunshine and vegetation, all of which are known to lower the effective life of a product. Vegetation decreased the half-life of imidacloprid by about 90 days[1] or 142 days.[2] Microbial action associated with plant roots was suggested to reduce longevity,[3] although fipronil longevity did not differ significantly between vegetated and non-vegetated soils at termiticidal rates.[4]

Bifenthrin is much less water soluble (0.1 mg L^{-1}) than other currently or recently used termiticide active ingredients, such as imidacloprid (510 mg L^{-1}), fipronil (2 mg L^{-1}), chlorpyrifos (2 mg L^{-1}) and permethrin (<1 mg L^{-1}). Based on its lower water solubility, bifenthrin, compared with the other compounds, should distribute differently in soil and have a different response to the application of water. Water solubility is very closely related to soil mobility, but a soil's organic matter and clay content also determine the degree of soil binding.[5]

In the present study, soil was treated at the labeled rate for perimeter treatment and was placed in PVC pipes over untreated soil. The longevity, mobility and insecticidal activity of bifenthrin when formulated as Talstar were evaluated over the course of 30 months, with weekly applications of water to simulate 2.5 cm of rainfall per week.

2 MATERIALS AND METHODS

2.1 Chemicals and soil

Talstar (7.9% bifenthrin) was purchased from a commercial retailer (Pest Control Depot, Palm Bay, FL). Certified or Optima grade solvents were purchased from Fisher Scientific (Hampton, NH), and deionized water was obtained from a Barnstead Nanopure ultrapure water system (Dubuque, IA).

The soil used was a sandy loam (14.75% silt, 75.25% sand, 10.00% clay, pH 7.4, 1.49% organic matter and a field capacity of 20.0% moisture by weight). Bioassays and residue analysis showed it to be free of interfering pesticides.

2.2 Cone plot assay

The mobility of bifenthrin in treated soil was evaluated in cone plots for a period of 6 months. Each cone consisted of a Ray Leach UV-stabilized Conetainer (21.5 cm tall × 4 cm ID) purchased from Hummert International (Earth City, MO). The bottom of each cone was fitted with glass wool to prevent loss of soil. The soil was treated by placing 420 g of soil into resealable plastic bags and adding 35 mL (7.8 mL of concentrate into 1 L of water = 642 µg g^{-1} soil) of Talstar solution in three portions, with mixing between additions (about 8% final soil moisture). The soils were placed into the cones, two per replicate, to a depth of 15 cm (6 inches). One cone for each replicate received about 0.1 g of Bermuda grass (*Cynodon dactylon*) seed. Each cone immediately received 25 mL

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of distilled water. After sitting for more than 4 h, 30 mL of distilled water was added to each cone and the eluate was collected. At 1 week intervals for 6 months, 30 mL of water was added to each cone. Once per month, between 10 and 15 mL of the eluate was collected and analyzed for bifenthrin content. The total amount of water applied over 6 months was about 800 mL, or about 13 times the soil volume.

Solid-phase extraction (SPE) was used to concentrate the bifenthrin in the cone plot eluate. Each SPE cartridge (Thermo Scientific, Hypersep C-18, 500 mg) was conditioned by passing 7 mL of methanol followed by 7 mL of water under vacuum. This was followed by the application of 10 mL of the sample. The sample was dried by pulling air through for 15 min, and then the analyte was collected by washing the column with 2 mL of hexane. The collected sample was then analyzed by using an Agilent 6890 gas chromatograph with electron capture detection (GC-ECD). The GC analysis was conducted by the following method: 1 µL injection; injector temperature 250 °C; column Agilent 1909-1A-112, ultra 1 methylsiloxane, 25 m × 320 µm inside diameter and 0.52 µm film thickness; 1 mL min^{-1} helium flow rate; oven temperature 50 °C for 1 min, ramped by 30 °C min^{-1} to 200 °C and held for 10 min, ramped again by 30 °C min^{-1} to 230 °C and held for 8 min for a total run time of 25 min; detector temperature 300 °C; equilibration time between runs 3 min; two needle washes of hexane followed by two needle washes of acetone. This SPE method resulted in 88–95% recovery of bifenthrin at 10% the labeled rate, 82–100% recovery at 1% of the labeled rate and 80–89% recovery at 0.1% of the labeled rate of 624 µg g^{-1} soil (by weight in solution) (data not shown). The data were analyzed by using mixed analysis of variance with repeated measures and three replicates.

2.3 PVC pipe plot assay

This portion of the study was conducted as a completely randomized design with a split-plot arrangement with three replicates, with the combination of treatment, time and vegetated state as the whole-plot factor and depth as the subplot factor. PVC pipes of 10 cm inside diameter were cut to a length of 45 cm. The bottoms of the pipes were fitted with 10 cm square plastic plates with holes to allow drainage. Aluminum window screens were sandwiched between the plates and the pipes to prevent loss of soil through the drainage holes. The tubes were filled to a depth of 30 cm with sandy loam soil (14.8% silt, 75.2% sand, 10% clay, pH 7.8, 1.5% organic matter). Each pipe was flushed with water to settle the soil and to prevent later compaction. More soil was added to the 30 cm mark to compensate for settling. Talstar was mixed according to label directions and 3785 mL (1 gallon) was applied to 45 kg of soil in a cement mixer and tumbled for 15 min. Each of the three replications (and the water control) was mixed separately. Treated soil was packed to a depth of 15 cm on top of the untreated soil in the pipes. Bermuda grass seed (*Cynodon dactylon*) was worked into the top 1 cm of half the pipes to constitute the vegetated treatment. Water (200 mL) was added to each pipe, and the pipes were arranged in a greenhouse (uncontrolled temperature of 5–40 °C over the course of the year at natural day length). The pipes used for the initial residue analysis and toxicity determinations (the time = 0 pipes) were cut 24 h after treatment. Each pipe received 200 mL of water once per week to simulate one 2.5 cm (1 inch) rainfall event per week until the pipe was scheduled to be analyzed. Every 3 months for 2.5 years, selected pipes were cut with a miter saw into six 7.5 cm sections. The soil was removed from each section and then analyzed for soil moisture, insecticidal activity and bifenthrin content. Samples of the soil from each time point and soil depth were reserved at −20 °C for later confirmation of bifenthrin residue.

Soil moisture was determined by placing 35 g of recovered soil into foil weigh boats. Soils were dried in an oven overnight at 90 °C, and the percentage moisture (by weight) was found by subtraction.

The bifenthrin content of the top four soil portions (0–7.5, 7.5–15, 15–22.5 and 22.5–30 cm) was determined by using a Dionex (Salt Lake City, UT) accelerated solvent extractor of the frozen soil samples. Dried soil (25 g) was mixed with hydromatrix to a total volume of 40 mL and placed into the extraction cells. A 70 + 30 by volume mixture of acetonitrile and acetone was passed through the sample at 120 °C and 10 342 kPa (1500 psi). The collected extract was reduced to 10 mL under a stream of nitrogen prior to analysis by gas chromatography as described in Section 2.2.

2.4 Insecticidal activity

The insecticidal activity of soil recovered from the pipes was tested by placing approximately 20 g of soil into 60 mm diameter petri dishes. Soils were remoistened (if necessary) so that all assays were conducted at about 17–23% soil moisture (by weight). Cardboard squares (1 cm^2) were soaked in methanol and then oven dried at 90 °C to prevent the growth of mold. One square was placed in each dish, and ten worker termites (*Reticulitermes flavipes*) were added. The number of surviving termites was counted at 3 and 7 days of forced exposure. Survival data were converted to mortality, corrected using Abbott's equation[6] and arcsin transformed prior to statistical analysis.

3 RESULTS AND DISCUSSION

3.1 Cone plots

Bifenthrin was not detected in the cone plot eluates at levels above the limit of quantitation during the course of the study. By comparing the amounts of imidacloprid and fipronil present in cone plot eluates in previous studies,[1,4] it is likely that this is a function of bifenthrin's much lower water solubility. Because soil binding was not directly measured in this study, it is unknown whether the lack of detection was due entirely to its low water solubility or to soil binding, although the two properties are not mutually exclusive. In a study of soil bedding media (90% pine bark and 10% sand), bifenthrin was detected in the ng g^{-1} soil range initially and then declined steadily to nearly 0 ng g^{-1} soil by 120 days.[7] The differences between the present study and that of Harris[7] is probably due to a much higher porosity in the bedding media, although some pesticides are known to sorb to clay particles,[5] which were not a significant component of the bedding media.

3.2 PVC pipe plots

Bifenthrin dissipated in a typical first-order fashion, with an initial rapid decline followed by a slower trailing phase (Fig. 1). Within the treated soil there was a significant three-way interaction between soil depth, time and the presence of vegetation ($F = 2.61$; df = 10, 44; $P = 0.014$). Dissipation was less rapid in non-vegetated soil from 15 to 24 months, but the final concentration at 30 months was not different between the two treatments, with final soil concentrations of 20–40 µg g^{-1} soil regardless of vegetation or soil depth. In spite of this apparent lack of a long-term effect of vegetation, fitting the data to an exponential model and

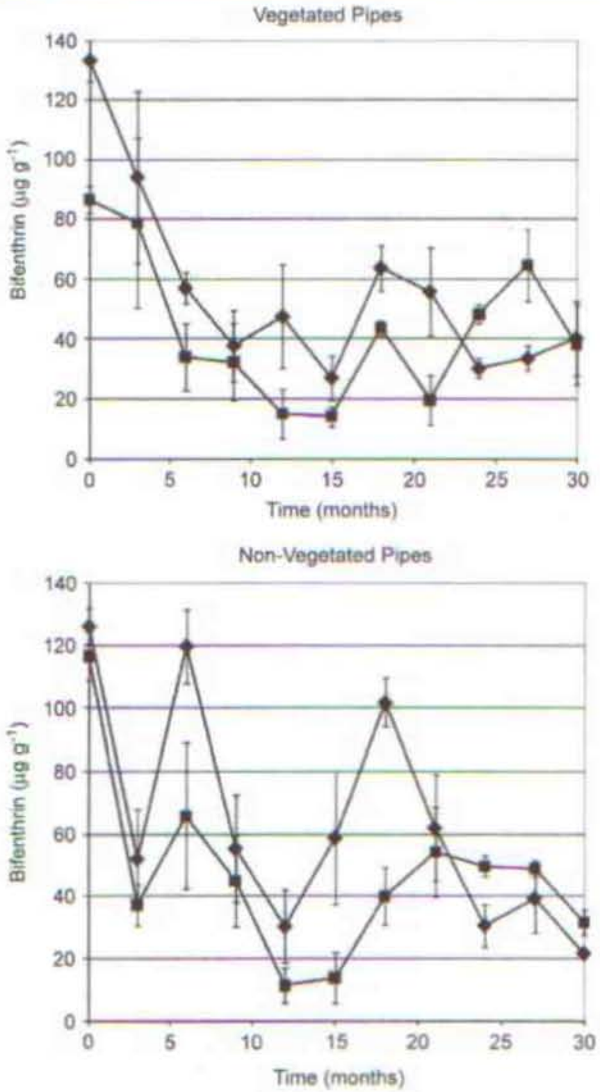

Figure 1. Dissipation of bifenthrin in the 0–7.5 cm (diamonds) and the 7.5–15 cm depths (squares).

determining the time to one-half the initial concentration gave soil half-lives of about 200 and 235 days in the vegetated soil for the 0–7.5 cm and 7.5–15 cm depths, respectively, but 345 and 390 days in non-vegetated soil for the same respective depths. Such a marked difference due to vegetation was not observed in similar studies from this laboratory for imidacloprid[1] or fipronil.[4]

Previous studies found aerobic soil half-lives of bifenthrin in the laboratory ranging from 97 to 250 days, depending on test conditions and soil type, and from 122 to 345 days in the field.[8] Bifenthrin dissipated by about half from potting media within the first 30 days after treatment, but no further dissipation was observed from 30 to 180 days.[7] The *cis* isomer of bifenthrin had a half-life of 277–630 days under aerobic conditions and 408–770 days under anaerobic conditions, depending on soil type.[9] In that study, differences between the *R-cis* and *S-cis* isomers were only observed under anaerobic conditions, and therefore differences in dissipation between isomers were attributed to enantioselective action of microbes associated with anaerobic conditions.[9] At the rates used for termite control, 31–35% dissipation of bifenthrin was observed in about 730 days when stored in the laboratory in plastic bags.[10] Bifenthrin was much less persistent in a similar test conducted by Saran and Kamble,[11] where it had a half-life of 214 and 434 days at 60 and 120 $\mu g\ g^{-1}$ soil, respectively. In exposed Arizona soil, bifenthrin degraded from 92 to 30 $\mu g\ g^{-1}$ soil in 2 years and to 28 $\mu g\ g^{-1}$ soil in three years, after which it degraded to 7 and 5 $\mu g\ g^{-1}$ soil at years 4 and 5, respectively.[12] This pattern of initial rapid dissipation followed by a relatively slower dissipation rate was observed in the present study as well, and the determined half-lives are consistent with those found by others.

Several studies have examined the longevity of bifenthrin beneath miniature concrete slabs at the rates used for termite control in the field. Bifenthrin dissipation was reduced from an initial level of 82 $\mu g\ g^{-1}$ soil to 67 $\mu g\ g^{-1}$ soil at 2 years, 52 $\mu g\ g^{-1}$ soil at 3 years, 52 $\mu g\ g^{-1}$ soil at 4 years and 17 $\mu g\ g^{-1}$ soil at 5 years in Arizona.[12] In Mississippi, which has generally more acidic soil of higher moisture, bifenthrin residues were reduced to about half their initial value by 270 days in the top 2.5 cm of soil, after which they did not decrease further.[13] This is shorter than the half-life of 400 days determined by Mulrooney *et al.*[14] in a similar study some years later. When applied at the termiticidal rate in a trench and exposed to the elements, similar to the procedure in the present study, about 30–40% of the applied bifenthrin dissipated within a year of application.[15] This was less dissipation than was seen in the present study, where bifenthrin residues at 12 months were about 30% of their initial values.

The concentration of bifenthrin in the untreated soil depths depended only on depth ($F = 31.67$; df $= 1, 44$; $P < 0.0001$), as bifenthrin was only observed at significant levels in the top untreated depth (15–22.5 cm) and not in any depth below this. There was little bifenthrin observed in the 2.6–7.6 cm depth beneath a concrete slab.[13] Because no bifenthrin was observed in the eluates of the cone plots, the detection of bifenthrin in the top untreated depth was likely due to settling of the soil into the section rather than movement of the chemical with soil water.

3.3 Insecticidal activity

The 3 day LC_{50} for Talstar as used in this test was 0.074 (0.056–0.092) $\mu g\ g^{-1}$ soil, and the 3 day LC_{95} was 0.724 (0.548–0.9) $\mu g\ g^{-1}$ soil. There was no significant increase in toxicity by extending the toxicity test to 7 day exposure. In similar tests on the same soil, imidacloprid, formulated as Premise 2, was not significantly toxic to termites within 3 days, and in 7 days 0.69 $\mu g\ g^{-1}$ soil was not toxic to the termites but 6.9 $\mu g\ g^{-1}$ soil caused 80% mortality.[1] Fipronil, formulated as Termidor SC, in this soil caused 100% mortality at 0.6 $\mu g\ g^{-1}$ soil in 3 day bioassays and at 0.06 $\mu g\ g^{-1}$ soil in 7 day bioassays,[4] which is similar to the 0.49 $\mu g\ g^{-1}$ soil 4 day LC_{50} value in sandy loam reported by Mulrooney and Gerard.[16]

Treated soil remained toxic to termites in 3 day and 7 day bioassays throughout the duration of the study. Mortality in the top untreated soil section was observed sporadically, but more so toward the end of the study (Fig. 2). A previous study determined that the LT_{50} (5–22 h) and LT_{95} (8–34 h) values in treated soil increased with increasing time following application, and this was due to decreasing levels of the compound remaining in the soil.[11] A threshold dose of 0.6 $\mu g\ g^{-1}$ soil was determined, and 100% mortality was observed initially, but this decreased to 63% at 5 months and 73.9% at 10 months.[17]

This study demonstrates that bifenthrin when formulated as Talstar remains in the soil at levels sufficient to kill termites for at

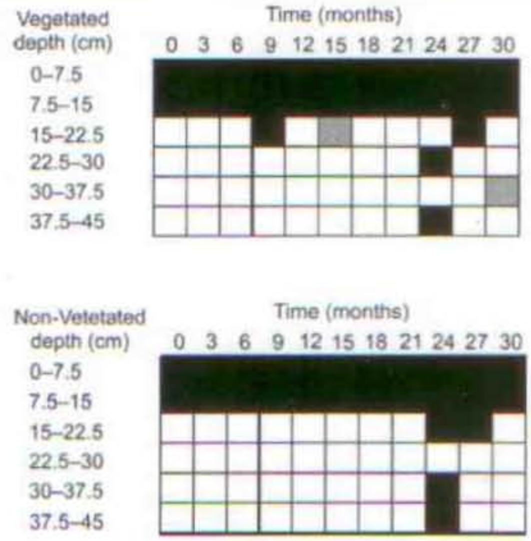

Figure 2. Termite mortality (average of three replications) in soil recovered from PVC pipes. Solid black cells represent soil portions in which 100% of the termites died, grey-shaded cells represent soil portions in which 70–99% of the termites died and white cells represent soil portions in which less than 69% of the termites died. The 0–7.5 and 7.5–15 cm soil depths are the treated soil depths.

least 30 months when applied at the perimeter labeled rate. The treatment will likely remain effective for much longer, as a relatively steady soil concentration of about 20–40 μg g^{-1} soil at 30 months was many times higher than the LC_{95} value of 0.72 μg g^{-1} soil. Unlike previous studies,[1,4] the presence of vegetation had an effect on the half-life of the treatment, although the 30 month concentrations between vegetated and non-vegetated plots were similar. Homeowners and landscape technicians should not place vegetation too near the treated perimeter to avoid mechanical disruption of the chemical barrier.

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