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MOVEMENT AND RESIDUAL ACTIVITY OF DELTAMETHRIN IN A GOLF COURSE FAIRWAY UNDER TWO POST-TREATMENT IRRIGATION TIMINGS

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ABSTRACT

The impacts of two post-treatment irrigation timings on the field efficacy and residual activity of deltamethrin against nymphs of the southern mole cricket, *Scaptericus vicinus* Giglio-Tos, and the tawny mole cricket, *S. borellii* Scudder, as well as movement of deltamethrin in the turfgrass profile, were investigated in 1998. Deltamethrin followed by irrigation 24 h after treatment provided the best mole cricket control versus immediate irrigation in both field and greenhouse studies. Regardless of irrigation timing, grass clippings had the highest residual levels of deltamethrin followed by the thatch layer. Clipping residues were higher with post 24 h irrigation than immediate irrigation with few residues in the upper soil profile (top 5 cm).

Key Words: mole crickets, deltamethrin, irrigation, residue, *Scapteriscus borellii*, *Scapteriscus vicinus*

RESUMEN

El impacto de dos tiempos diferentes del riego después del tratamiento sobre la eficaz en el campo y la actividad residual del deltametrin contra las ninfas del grillotopo sureño, *Scaptericus vicinus* Giglio-Tos, y del grillotopo aleonados, *S. borellii* Scudder, y el movimiento del deltametrin en el perfil del césped, fueron investigados en 1998. El Deltametrin seguido por el riego 24 horas después del tratamiento suplió el mejor control del grillotopo versus el riego inmediato en ambos estudios en el campo y en el invernadero. Prescindiendo del tiempo de riego, los recortes de grama tenian el nivel más alto de residuo de deltametrin seguidos por la capa de paja seca enrollada en la base de la grama viva. Los residuos en los recortes fueron más altos con el riego hecho 24 horas después que en el riego inmediato con pocos residuos en el perfil superior del suelo (los primeros 5 cm).

Deltamethrin [(*S*)-*a*-cyano-3-phenoxybenzyl (1*R*,3*R*)-*cis*-2,2-dimethyl-3-(2,2-dibromo-vinyl)cyclopropanecarboxylate] is a pyrethroid insecticide used for the management of a variety of insect pests. Typically irrigation is recommended immediately after treatment with pyrethroid insecticides when used to control of mole crickets or other soil-inhabiting turfgrass insect pests. This recommendation is partly based on the assumption that immediate irrigation aids in moving the insecticide downward into the soil where the target pests are located. However, current research suggests that the effect of irrigation timings on insecticide efficacy is not consistent (Xia & Brandenburg, unpublished). For example, in preliminary work, immediate post-treatment irrigation did not provide better control of mole crickets versus delayed irrigation. It is also unclear how irrigation timings affect the residual toxicity and the movement (i.e., residue distribution in the grass, thatch, and the upper soil) of insecticides. Mole crickets are the most serious pest of golf course turfgrasss in the southeastern U.S. and an understanding of how to improve pesticide efficacy is critical (Brandenburg 1997). Therefore, the objectives of this study were to: (1) compare field efficacy and greenhouse residual activity of deltamethrin under immediate and delayed irrigation timings against mole cricket nymphs and (2) determine deltamethrin residue levels in turfgrass clippings, thatch, and upper soil under two irrigation timings.

MATERIALS AND METHODS

Field Efficacy Experiment

This test was conducted on a bermudagrass, *Cynodon dactylon* (L.) Pers., fairway at Fox Squirrel Golf Course in Brunswick County, NC, on 1 Sep 1998. Plots were established in an area with consistent mole cricket damage throughout and arranged in a completely randomized design with four replicates per treatment. Plot sizes were 7.5 × 7.5 m. Soapy water samplings (Short & Koehler 1979) prior to the experiment indicated that the

population was approximately 70% southern mole cricket, *Scapteriscus vicinus* Giglio-Tos, and 30% tawny mole cricket, *S. borellii* Scudder. The thatch layer was 1.3 cm thick and dry. Both soil (at 10 cm) and air temperatures at the time of application were 30°C. Soil at the test site was classified as a mineral soil with a pH of 6.2 and 0.46% humic matter.

Deltamethrin (DeltaGard® 5 SC, AgrEvo USA Co., Wilmington, DE) was applied with a boom sprayer (R & D Sprayers Inc., Opelousas, LA) mounted on a Turf-Gator (Deere & Co., Moline, IL) calibrated to deliver 209 L/ha with ten 8003 nozzles. Plots in treatment one were treated with deltamethrin at a rate of 140 g a.i./ha followed immediately with irrigation. The second deltamethrin application (treatment two) was applied and irrigated 24 h later. The golf course irrigation system was used to apply approximately 0.6 cm water each time. The normal golf course irrigation schedule was followed thereafter. Approximately 0.3 cm of rainfall occurred 3.5 h after treatments.

The mole cricket damage rating system of Cobb and Mack (1989) was used to evaluate control. Damage was rated on a 0-9 scale based on the occurrence of fresh surface damage on nine subgrids of a frame (1 × 1 m) where 0 indicates no damage and 9 (damage observed at all 9 subgrids) indicates severe damage. Damage was rated at 7, 14, 21, and 28 days after treatment (DAT) by making five random frame ratings per replicate each time.

Greenhouse Residual Activity Experiment

Soil cores were taken from the field plots at 0, 1, 4, 7, 14, 21, and 28 DAT by using PVC pipe chambers (15.5 cm long and 10.5 cm in diam). Three cores were sampled per plot on each sample day. The PVC chamber was hammered into the soil until the top of the chamber was level with the turfgrass surface. Chambers containing the soil cores were taken to a greenhouse at North Carolina State University in Raleigh, N.C. Three 3rd to 5th instar mole crickets (>80% tawny mole crickets) were placed on the surface of each chamber to crawl through the soil core on the same day. Mole cricket nymphs used in this study were collected from golf course fairways by the soapy water flushing method (Xia & Brandenburg, unpublished) and kept in a laboratory with house cricket diet and small earthworms for 14 days before initiating the study. Both ends of the chamber were covered with plastic petri dishes tied together by rubber bands. Mortality was checked 72 h later.

All data were transformed (square root of X + 0.5 arcsine for percentage data) prior to statistical analysis. Analysis of variance (ANOVA, MEANS, SAS Institute 1990) was used to conduct analysis of variance among treatments and to compute means and standard errors of dependent variables. Waller-Duncan K-ratio T-test was used to compare mole cricket damage ratings and mortality means between the treatments.

Laboratory Residue Analysis

Samples of grass clippings, thatch, and soil in upper 5 cm depths were taken from the untreated and deltamethrin treated plots at 0, 4, and 14 DAT. Grass clippings and thatch were taken with a hand trowel. Soil samples were taken with a standard soil sampler (2.0 cm in diam) (Lesco, Inc., Rocky River, OH). All samples were placed in Ziploc® plastic bags and immediately placed in a freezer.

Gas chromatography analysis of deltamethrin residue on grass clippings, thatch, and soil was conducted at EN-CAS Analytical Laboratories (Winston-Salem, NC). The procedures for deltamethrin analysis in grass, thatch, and soil followed EN-CAS Analytical Laboratories Method No. ENC-7/89, entitled "Analytical method for the simultaneous determination of alpha-R-deltamethrin, cis-deltamethrin, trans-deltamethrin, and/or tralomethrin in soil samples by gas chromatography" (EN-CAS Analytical Laboratory, internal publication, issued May 22, 1990). Residue levels of deltamethrin were the sum of *alpha-R*, *cis*, and *trans* isomers.

Results

Field Efficacy Experiment

Twenty four hour deltamethrin post-treatment irrigation had numerically the lowest mole cricket damage ratings consistently during the experimental period (Table 1), and was the only treatment with significantly lower damage ratings compared to the untreated control at 7 and 14 DAT (Table 1). There were no significant differences in damage ratings between the untreated control, or deltamethrin with immediate post-treatment irrigation at 7, 14, 21, and 28 DAT.

Greenhouse Residual Activity Experiment

Results of the greenhouse test showed a similar trend as the field efficacy test. Mole cricket mortality from deltamethrin with delayed irrigation was significantly higher than all other treatments at 0 and 1 DAT (Table 2). Mole cricket mortality from deltamethrin with irrigation 24 h later was significantly higher than the untreated control at 0, 1, 4, 7, and 14 DAT. Deltamethrin followed by immediate irrigation provided higher mortality than the untreated on 0, 1, and 7 DAT.

Laboratory Residue Analysis

Results of the residue analysis indicated that bermudagrass clippings had the highest delta-

TABLE 1. FIELD EFFICACY OF DELTAMETHRIN AND BIFENTHRIN AGAINST NYMPHS OF SOUTHERN AND TAWNY MOLE CRICKETS, 1998.

Insecticide/irrigation timing	Rate g (a.i.)/ha	Mole Cricket Damage Rating[1,2]			
		7 DAT	14 DAT	21 DAT	28 DAT
Untreated		4.1 b	4.0 b	4.3 a	4.0 a
Deltamethrin/immediate	140	3.1 ab	3.5 ab	4.4 a	3.7 a
Deltamethrin/24 h later	140	2.3 a	2.2 a	2.6 a	2.8 a
Bifenthrin/immediate	120	2.7 ab	3.4 ab	3.5 a	3.2 a

[1]Mole cricket damage rating ranged from 0 to 9, 0 = no damage and 9 = severe damage.
[2]Means followed by the same letter in each column are not significantly different ($\alpha = 0.05$, Waller-Duncan K-ratio T-test).

methrin residue levels, followed by thatch, and the soil at 0, 4, and 14 DAT (Fig. 1). Deltamethrin residues in the upper 5 cm soil were very low, ranging from less than 0.02 to 0.04 ppm under either irrigation timing during the experimental period. The deltamethrin residues in thatch were similar between the two irrigation timings at 0, 4, and 14 DAT. Analysis of clippings indicated that deltamethrin residues were consistently higher with irrigation 24 h later versus immediate irrigation.

DISCUSSION

Results of this study indicate that post-treatment irrigation timing affects field efficacy and residual activity of deltamethrin against mole cricket nymphs. Irrigation timings also influenced the movement of deltamethrin into the turfgrass profile. Delayed irrigation resulted in greater deltamethrin residue on bermudagrass leaf clippings when compared to immediate irrigation. However, only traces of deltamethrin residue were found in soil under either irrigation timing. Results indicate that field efficacy, residual activity, and deltamethrin residue levels in leaf clippings are related.

Deltamethrin with delayed irrigation provided better mole cricket control than immediate irrigation. This trend was observed in the field study and reinforced in the greenhouse bioassay. However, mole crickets in the small and closed PVC chambers had an increased chance to contact grass leaves compared to the real situations in the field. This could have contributed to the high mole cricket mortality in the delatmethrin with delayed irrigation in the greenhouse bioassay because deltamethrin residues in leaf clippings under irrigation 24 h later were higher than with immediate irrigation.

This study underscores the challenges in managing soil insect pests in turfgrass: how to move insecticides into the soil where the target insects live. Neither immediate nor delayed irrigation improved movement of the insecticide into soil in this study. The physical properties of deltamethrin, turfgrass mowing height, and thatch layer thickness were the main factors that contributed to low deltamethrin residues in the soil profile. Deltamethrin is almost insoluble in water (<0.1 mg/L) and has a moderately high partition coefficient (4.6 at 25°C). This indicates that irrigation water cannot easily carry the chemical into the soil, and the compound tends to bind to organic matter (i.e., grass, thatch, and decayed organic matter in soil). This explains why deltamethrin was mainly retained by clippings and not the thatch. This result is different from other insecticides which are mainly retained by the thatch layer (Niemczyk 1987; Niemczyk & Krueger 1987; Schleicher et al. 1995). Fox Squir-

TABLE 2. GREENHOUSE BIOASSAY OF RESIDUAL ACTIVITY OF DELTAMETHRIN AND BIFENTHRIN AGAINST NYMPHS OF SOUTHERN AND TAWNY MOLE CRICKETS, 1998.

Insecticide/irrigation timing	Rate g (a.i.)/ha	% mole cricket mortality, 72 h after infestation[1,2]						
		0 DAT	1 DAT	4 DAT	7 DAT	14 DAT	21 DAT	28 DAT
Untreated		2.8 a	0 a	0 a	0 a	2.8 a	5.6 a	2.8 a
Deltamethrin/immediate	140	72.2 b	56.9 b	9.7 ab	30.5 c	36.1 ab	22.2 a	5.60 a
Deltamethrin/24 h later	140	94.5 c	90.3 c	25.0 b	30.5 c	61.1 b	25.0 a	13.9 a
Bifenthrin/immediate	120	41.8 b	41.7 b	18.1 ab	16.3 b	5.6 a	—[3]	—[3]

[1]Means followed by the same letter in each column are not significantly different ($\alpha = 0.05$, Waller-Duncan K-ratio T-test).
[2]Mole cricket nymphs were exposed to treated soil cores for 72 h.
[3]The bifenthrin treatment was dropped due to low residue activity.

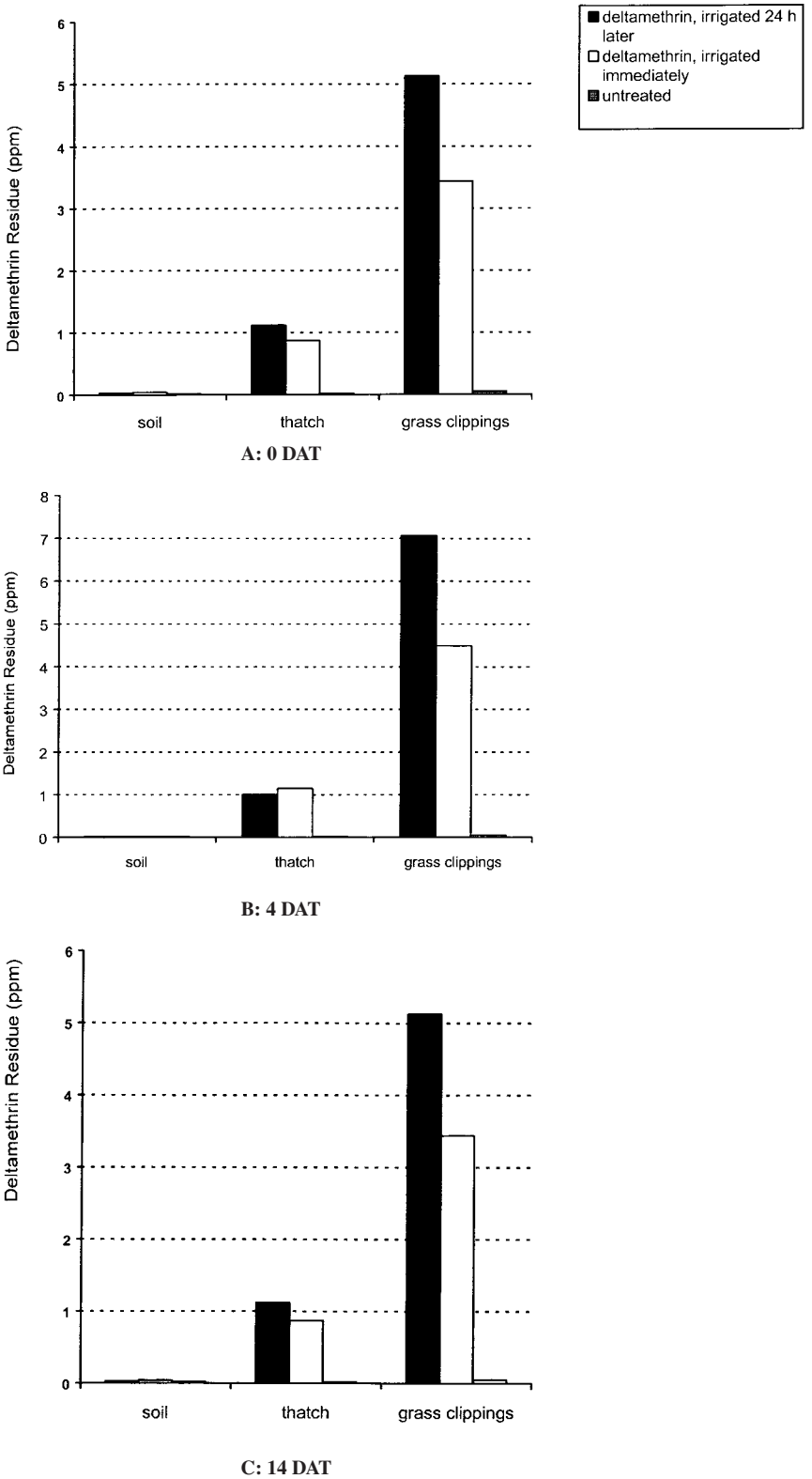

Fig 1. Deltamethrin residue (recovered ppm) in soil, thatch, and grass clippings at 0 (A), 4 (B), and 14 (C) DAT.

rel Golf Course fairways were seldom dethatched. Over time, this resulted in a thick thatch layer. Also, grass cut height in the fairway was higher than many other golf courses in North Carolina.

Deltamethrin provided 100% control of 3rd to 5th instar mole cricket nymphs a week after treatment in another greenhouse bioassay test using 19 L plastic buckets (Xia & Brandenburg, unpublished). Based on this study and the unpublished data, it appears that a major obstacle in achieving maximum deltamethrin efficacy in the field is the difficulty of moving the product past the grass and thatch into the soil. A granular formulation may provide better control versus sprayable formulations because limited quantities of insecticides in granular formulations will be retained on the grass. This has been demonstrated with the herbicide pendimethalin, which is noted for its tendency to be retained in the thatch layer (Gasper et al. 1994). Round, small, and heavy granular particles of an insecticide may help to improve mole cricket control since they have a better chance of avoiding grass leaves and the upper portion of the thatch layer. Another alternative is to dethatch the turf prior to insecticide application. Verticutting removes the thatch layer and may help insecticides penetrate into the soil. Subsurface application may be the best way to avoid the retention by grass and thatch. However, few golf courses have subsurface application equipment.

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