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Project Title:

Quantification of the Effect of Turf on Pesticide Fate in Soils.

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Project Description: This project will quantify the effects of a turf on the fate of a pesticide applied to that turf. Large amounts of data and modeling have been conducted on pesticides used in row crop agriculture, i.e. pesticides applied directly to soil. However, turf has always presented a problem because the turf intercepts the applied pesticide,with a tremendous impact on the pesticide fate process. This study will correlate pesticide fate in turf in relation to the quantity of organic carbon present in the turf. Data developed with this approach would be useful for quantifying the impact of a turf, regardless of species composition, thatch thickness, etc., on the pesticide fate process.

How Ours is Different: All other studies of pesticide fate in turf have not examined the turf and associated thatch as a system but as a "black box" that impacts pesticide fate. Our hypothesis treats thatch and turf as merely organic carbon and organic carbon has been shown to have a large impact on pesticide fate. The high level of microbial activity associated with thatch is not some unique feature of thatch but merely a reflection of the large amount of organic carbon present in thatch. We propose to relate pesticide dissipation and leaching to the quantity of organic carbon present within the turf.

Deliverables: Data on the dissipation rate and leaching of triadimefon in turfs of widely varying organic carbon content. Data on the dissipation rate and deep leaching of three commonly used pesticides applied to a turf or a bare soil. Correlation of OC content with dissipation rate.

Budget Summary:	Amount of $
Year 1	33408
Year 2	46722
Year 3	47027
Total Amount $	127157

Potentail Benefits: This study will provide valuable information on the fate of pesticides applied to turf, and beyond simply generating data on dissipation rates and leaching potential, will examine the impact of the turf on pesticide fate in a quantitative manner. This work would provide regulators, modelers, and others with a means of determining how effectively a particular turf species at a given level of management would retain and help degrade an applied pesticide.

INTRODUCTION

The use of pesticides on the golf course is a necessity if the current standards of golf course conditions are to be maintained. From an environmental standpoint, pesticide use represents the thorniest issue because these products do not already exist in the environment. For nutrients such as phosphorus and nitrogen, some movement into groundwater can be tolerated since these elements are present in all drinking water to some degree. However, pesticides are a more difficult situation; they are intentionally applied toxic products and it is very difficult to decide what level, if any, can be tolerated in drinking water. Tolerance levels will not be set by any research undertaken by turfgrass scientists, but instead by legion of toxicologists, regulators, and bureaucrats. Therefore, turfgrass managers and researchers must work towards "zero" levels of pesticides in groundwater. While "zero" is a moving target, the best defense against regulators and environmentalists is to produce management systems which yield little or better yet "zero" pesticides in ground water.

Previous research has shown that pesticide leaching in turf is minimal, but a better understanding of the factors which control pesticide leaching in turf must be developed. This project seeks to develop a more comprehensive understanding of the effect of turf on pesticide fate, in general, and leaching in particular.

FACTORS AFFECTING PESTICIDE FATE

Pesticide fate is a complex process because each pesticide is a distinct organic chemical that will interact in different ways with the environment than other pesticides. While pesticides within the same chemical family will have some similarities, there will still be large differences in the fate of pesticides within the same family. The dinitroaniline herbicides represent a classic case of these differences (Weber, J.B., 1990). Pesticides such as balan, treflan, and pendimethalin are widely used for annual grass control in turf. However, they differ substantially in their degree of sorption to soil organic matter, and their photolysis and volatility rates. Each pesticide must be dealt with on an individual basis. In addition, each site of application will vary based upon soil type, climate, application rate, etc. Therefore, pesticide fate is a complex process dependent upon the physico-chemical characteristics of each individual pesticide and the environment and site of application. In field crops research, much effort has been expended to develop screening models and comprehensive models of pesticide fate in soils (Wagenet and Rao, 1990; Jury et al., 1983; Jury et al. 1984a,b,c). These models have good predictive value for soils although the models still have some shortcomings.

Not only is the chemistry of the pesticide important, the dominant factor controlling pesticide fate is the degree of sorption of the pesticide in the soil. The sorption process is an equilibrium process which means that sorption is a dynamic, continual phenomena. Thus, just because a pesticide is strongly sorbed does not mean it is unavailable for leaching or volatilization, but does mean that the time in which a molecule is in solution and free to leach or volatilize will be relatively short. Sorption is the dominant mechanism controlling pesticide fate because when a pesticide molecule is sorbed it is not available for leaching or volatilization. Sorption in soil is controlled by the organic matter content of the soil (Weed and Weber, 1974). The higher the amount of organic matter, the greater will be the sorptive capacity of a particular soil. A standard method for expressing the tendency for a particular pesticide to be sorbed or in solution is to use the equilibrium coefficient, K, as a measure of the relative tendency to be sorbed.

$$K = \frac{[ads]}{[sol'n]}$$

Thus, K is measured for a particular soil and only has meaning for that particular soil. However, since it has been determined that soil organic matter content is the controlling factor in pesticide sorption, K values can be normalized so that the K value is relatively independent of the soil type from which it was derived. By dividing the experimentally determined K value by the percent organic carbon content of the soil, an equilibrium coefficient, termed K_{OC}, is determined which can be used as a way of comparing pesticide sorption across a wide range of soil types and of comparing the sorption potential of a range of pesticides to the same soil.

The two factors having the largest role in determining pesticide fate are the strength of sorption of a particular pesticide, as measured by an experimentally determined K_{OC}, and the organic matter content of the soil or turf.

Values for Koc for all pesticides have been experimentally determined or derived empirically from data on pesticides with similar chemistry. Therefore, the most important factor in understanding pesticide fate in turf is the **amount** of organic matter associated with the turf.

Turf can be pictured as a layer of organic matter resting atop the soil. The turf itself has a tremendous ability to attenuate the pesticide flux through the turf and into the soil. In attempting to model pesticide fate in turf, the system could be viewed as a two component system - turf and soil. The models for assessing movement in soil are well-developed. A simple approach to adjusting for the presence of turf is to develop data that correlates movement through turf in relation to the organic matter (i.e. organic carbon) content of the turf.

This relatively simple approach to pesticide fate in turf, and in particular pesticide leaching, would help develop attenuation factors for the ability of a particular turf, based upon its organic carbon content, to reduce the amount of the applied pesticide that actually reaches the soil. Once an estimate of the quantity of pesticide that is transmitted through the turf to the soil is known, conventional models such as GLEAMS can be applied to determine the likely movement to groundwater. This approach would also develop the theoretical knowledge of turf as a system. Researchers have previously discussed the importance of thatch as a zone of microbial activity that is important in reducing pesticide leaching by sorption and microbial degradation. However, the approach outlined here treats thatch merely as organic matter. The high level of microbial activity associated with thatch is not some unique feature of thatch but merely a reflection of the large amount of organic carbon, i.e. food, that is present in thatch.

PROPOSED RESEARCH

There will be two projects within the proposed research. The first project will focus on quantifying the ability of the turf organic matter to bind, degrade, and slow the movement of a pesticide through the soil. The second study will examine the dissipation rates of three pesticides in turf and bare soil.

Study #1

In order to determine the effects of turf on pesticide sorption and movement, the following treatments will be used at two locations. Reduction in stand density will be done the day prior to the pesticide treatments. Clearly, the turfs will recover some of the density during the course of the study; however, the initial application and early portion of the experiment will be under reduced organic carbon levels.

Michigan State University

1) Bare ground control.
2) Creeping bentgrass on 80/20 sand/peat mix.
3) Creeping bentgrass on a sandy loam soil.
4) Creeping bentgrass on a sandy loam soil with 50% of the plants and thatch removed by vertical mowing.
5) Creeping bentgrass on a sandy loam soil with 80-90% of the plants and thatch removed by vertical mowing.

6) Perennial ryegrass on a sandy loam soil.
7) Perennial ryegrass on a sandy loam soil with 50% of the plants removed by vertical mowing.

University of Illinois

1) Bare ground control
2) Creeping bentgrass on a silt loam soil
3) Creeping bentgrass on a silt loam soil with 50% of the plants and thatch removed by vertical mowing.
4) Creeping bentgrass on a silt loam soil with 80-90% of the plants and thatch removed by vertical mowing.

Procedure

A moderately mobile, non-ionic pesticide (e.g. triadimefon) will be applied to each turf/soil type. The experimental units (microplots) will be small, open-ended circular steel pipes 15 cm in diameter and 60 cm in length. For each sampling date and treatment, three replicate microplots will be excavated from the soil and stored at -5 C until analysis. Analysis of the cores will be accomplished by carefully removing the cores from the pipe and sectioning them into green tissue, thatch, and soil segments of 0-1, 1-3, 3-5, 5-15, 15-30, and 30-60 cm increments. By using the microplot approach a mass balance for each treatment will be generated. The microplots will serve two important functions. First, they will contain the applied pesticide so that no lateral movement can occur. This will allow a mass balance approach to pesticide fate with volatile losses accounted for by difference. Secondly, soil cores collected by hand often are contaminated from downward movement of the pesticide along the sides of the sampling device. Since these microplots will be installed prior to the application of the pesticides, no contamination will result from the sampling procedure.

Microplots will be sampled at day 0 (2 hours after treatment) and at 4, 8, 16, 32, 64, and 128 days after treatment. Each sample will be extracted and the amount of parent pesticide and detectable metabolites remaining will be determined. Extraction procedures will be based upon EPA methods for the pesticide choosen. Samples of each turf/soil type will be analyzed at day 0 for the mass of organic carbon per unit area in the leaf tissue, thatch, 0-1, 1-3, and 3-5 cm soil segments of the profile.

This study should produce enough data points to determine the effect of a turf on the fate of a particular pesticide and determine the importance of the organic matter content of a turf on pesticide dissipation.

Study #2

Because turf is a specialty crop without the large acreages of row crops, research on pesticide issues conducted specifically on turf is lacking. Decisions regarding the environmental consequences of pesticide use on the golf course are often made based upon assumptions on how pesticides would behave in turf or on data derived from pesticides applied to other crops. Neither situation is desireable because turf is a unique crop with a significant impact on the fate of a pesticide. The goal of this proposed research is two fold. First, a better understanding of the role of turf in pesticide dissipation studies will be achieved by comparing pesticide fate in turf versus a bare soil control for several pesticides used in turf. Second, the study will significantly increase the database of information on the dissipation rate constants for pesticides used in turf.

Procedure

This study will contrast the dissipation rates and leaching potential of four commonly used turfgrass pesticides on turf versus bare soil. Pesticides will be choosen in conjunction with USGA agronomists and based upon wide usage within the golf course industry. Possible choices include fenarimol, propiconazole, metalaxyl, chlorothalonil, ethoprop, ethofumesate, or clopyralid.

The study will use microplots to study movement and dissipation of these pesticides. As in study #1, steel microplots will be inserted into the turf and excavated periodically to measure pesticide dissipation rates.

Soil sampling will be conducted based upon the estimated half-life ($t_{1/2}$) of the pesticide. Half-life values compiled by Wauchope et al (1992) will be used. The sampling times will be day 0, $0.125*t_{1/2}$, $0.25*t_{1/2}$, $0.5*t_{1/2}$, $t_{1/2}$, and $2*t_{1/2}$. A total of 36 microplots will be installed per pesticide studied. This will permit 6 sampling dates, 3 replications, and 2 media types (i.e. turf and bare soil). The pesticide applications will be made concurrently with an application of KBr tracer. The bromide tracer will help determine transport time within the microplots.

Time line of Proposed Research

Study two will be initiated in the spring of 1996 and the length of time of the study will be determined by the $t_{1/2}$ of the pesticides chosen for the study. Study one will be initiated in the spring of 1997. The field sampling portion of this study will be completed in 1997. This will leave 1998 to conclude all the soil and plant tissue analyses from the two studies.

Expected Results and Rationale

Previous research on the sorption of fungicides and an insecticide on thatch has demonstrated that thatch was similar to soil organic matter in its ability to bind pesticides (Dell et al. 1994, Lickfeldt and Branham,1995). Both of these articles indicated that K_{oc} values derived for thatch were slightly lower than K_{oc} values derived from soil. These data indicate that thatch has a similar, although slightly reduced, sorption capacity as compared to soil organic matter. The slightly lowered K_{oc} probably results because thatch is less decomposed than soil organic matter and may not be as active a sorbent as soil organic matter. However, the important point is that thatch from two different sources was very similar in its ability to sorb pesticides. This research will determine whether thatch from different species has the same capacity to sorb and degrade pesticides.

This research will demonstrate that the ability of turf to bind, retard the movement, and breakdown the pesticide is a function of the level of organic carbon in the system. Regardless of whether the turf is a bentgrass, bermudagrass, or ryegrass; the effectiveness of the turf should be related to the amount or mass of organic carbon above the soil. This research will be very valuable in developing a rational approach to studying the movement of pesticides through turf soils.

The dissipation rate study will provide direct evidence of the power of turf to sorb and degrade applied pesticides and the bare soil plots will provide a meaningful benchmark to which to compare the turf data. Differences in the dissipation rates between turf and bare soil would provide a valuable database useful in the modeling of pesticide dissipation in turf. This information may allow the prediction of pesticide behavior in turf from dissipation rate constant data developed under row crop agriculture conditions.

FACILTIES

The principal investigator oversees the operation and maintenance of the University of Illinois Turfgrass Research Center, an eight acre site for turfgrass research. Experimental areas appropriate for this study were established in the fall of 1995 at the research center. Plots at Michigan State University have been established on modified sand-based soils as well as the native sandy loam soils available at that site.

All pesticide amalyses will be performed under the direction of hte principal investigator. Two Hewlett Packard 3890A gas chromatographs with automatic injectors are available for routine pesticide analysis. The PI also has access to two HPLC systems should they be required. Excellent lab and freezer space is available for sample analysis and storage. The University of Illinois has excellent facilities and support for research.

BUDGET

University of Illinois

Based upon the experimental plans described, approximately 1700 soil samples will need to be analyzed. Estimated sample cost for each soil sample is $40/ sample. This amounts to $68,000 for analysis costs.

1996

Graduate Research Assistantship @ $14550/yr	14550	
Sample analyses	14250	
SUBTOTAL		28800
16% overhead		4608
1996 TOTAL		33408

1997

Graduate Research Assistantship @ $ 15277/yr	15277	
Sample analyses	25000	
SUBTOTAL		40277
16% overhead		6445
1997 TOTAL		46722

1998

Graduate Research Assistantship @ $ 16040/yr	16040	
Sample analyses	24500	
SUBTOTAL		40540
16% overhead		6487
1998 TOTAL		47027

GRAND TOTAL 1996-1998 $127,146

BUDGET

Michigan State University

1995-7

Preparation of steel microplots	3500	
Installation and treatment of microplots	2000	
Travel to East Lansing, MI from Champaign, IL 4 trips	1000	
Shipment of samples from East Lansing, MI to Champaign, Il	1500	
Labor to maintain microplots	1500	
Subtotal		9500
Overhead @16%		1520
Total		11020

Matching funds

The Illinois Turfgrass Foundation has agreed to support this project at a level of $7,000 per year. This money will help cover the full cost of the analytical portion of this grant that could not be covered due to the scope of this project and the level of funding allowed per proposal. In addition, these funds will be used to pay for cost of attending professional meetings, paper publication fees, and any miscellaneous expenses.

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