POTENTIAL MOVEMENT OF CERTAIN PESTICIDES FOLLOWING APPLICATION TO GOLF COURSES

A. E. Smith and D. C. Bridges

Executive Summary.
The objectives of our research program are to evaluate the potential movement of pesticides and fertilizer components following application to golf courses and to develop Best Management Practices to reduce the potential for pesticide transport to potable water systems. Results indicate that only very small quantities of the pesticides applied to simulated golf course greens are transported through the rooting medium (RM) and into surface water. The more water soluble pesticides (i.e. 2,4-D; dicamba; and mecoprop) were found to have short residence time under the sod due to rapid microbial degradation of the molecules. The pesticides with lower water solubilities (i.e. benefin, pendimethalin, dithiopyr, chlorothalonil, and chlorpyrifos) had higher soil sorption capacities increasing their residence time in the RM allowing for biotic and abiotic degradation even if the half-lives were fairly long.

In some areas of the United States as much as 70% of the rainfall/irrigation water can be lost, from fairways, as surface runoff. Results of our research indicate that fairly high quantities of the more water soluble pesticides (i.e. 2,4-D; mecoprop, and dicamba) are transported from the treated fairway. The less water soluble pesticides are more resistant to transport in surface water. A soil moisture content near field capacity at the time of pesticide application and rainfall results in as much as 5 times more pesticide to be transported from the fairway compared to a soil moisture content near the wilting point. Sequencing irrigation prior to and following pesticide application reduces the quantity of analyte to be transported in surface water runoff. More pesticide was transported from dormant sod than green sod. Pressure injection of pesticides reduced the pesticide transport in surface water by 6 fold and did not influence the quantity transported through greens RM. A buffer zone between the point of application and the exit point does not reduce the fraction of applied pesticide transported in surface-water solution. It only dilutes the concentration due to less area treated. The less water soluble pesticides have a longer residence time on the foliage resulting in as much as 20% of these pesticides to be removed with the leaf clippings.

Future research will be directed toward the development of practices for reducing the potential movement of chemicals applied to golf courses. Methods of application, types of analytes and formulations, sequencing of irrigation and chemical application, methods for increasing the infiltration/percolation rate of the soil, and use of pesticide adsorbents on the soil surface will be investigated. These strategies for pesticide application and site management will be tested in the simulated greens for transport through the RM. Models will be refined/developed to predict the potential for pesticide movement from golf courses. We anticipate developing a project for determining the urban contribution to the watershed load of contaminants. The Atlanta watershed to be used will include one 18-hole golf course. The watershed scale research is the next level following the development of the models from small plot research data. The conclusion of the project will be the development of a complete guide of Best Management Practices for applying chemicals to golf courses based on valid data.

Summary of percentage of time devoted to research program by the University personnel (budgeted*).

Name	Title	% of Time
*A. E. Smith	Professor	50%
*N. Mantripragada	Research Coordinator	75%
*H. Peeler	ARA III	50%
*M. Flynn	Word Processor Operator	20%
Various	Temporary Part-time§	90%

Summary of expenditures made during year (January - September 1996).

BUDGETED (Jan.-Sept.) $34,038

Expenditures

Labor§ $13,609

Operating Expense 10,736

(Supplies/materials, repairs/maintenance, freight/express/storage, tests/analysis, software, publishing, equipment)

Travel . . . . $ 2,614

Indirect Costs . . . . $ 4,641

TOTAL EXPENDITURES . . . . ($30,601)

INTRODUCTION

CURRENTLY, there are more than 14,300 golf courses in the United States and assuming an average size of 48.6 ha per course. There are nearly 695,000 ha of turfgrass in the golf course industry. Additionally, the National Golf Foundation estimates that by the year 2000 the number of golfers could easily exceed 30 million. To keep up with the demands of the rapidly increasing number of golfers, it is suggested that a new golf course must be opened every day over the next 10 years. Color, uniformity, and density of the turfgrass on these golf courses will be affected adversely by incursions of weeds, disease, and insects. Turfgrass of high quality and uniform playing surface has become the expected necessity on golf courses and this condition often requires the use of intensive management to control these pests.

Assuming that 2% of a golf course is managed as putting greens, there are 13,900 ha of greens in the U.S. which are constructed for maximum infiltration and percolation of water through the rooting media (RM). The RM composition, generally, includes at least 80% by volume (97% by weight) coarse sand allowing for rapid water percolation and having an extremely low cation exchange capacity. Additionally, soil sterilization is recommended during construction for weed and disease management. The sterilization ultimately influences soil microbial decomposition of applied pesticides. These characteristics of the RM could result in rapid movement of pesticides through the RM allowing for a potential source of contamination of the effluent water from the greens.

Fairways compose approximately 98% of the golf courses and are typically intensively managed. The fairways are developed on soils typical for the region and in the Piedmont these soils have a high clay content allowing for a low water infiltration rate especially when crusted. As much as 70% of the rainfall can occur as runoff water from the sloped areas. This surface water can eventually terminate in potable water containments.

The major concern for the impact of pesticides on the environment is their potential entrance into drinking water sources which is facilitated by movement in surface water and groundwater from the treated site. Although the predominance of the drinking water for rural areas comes from groundwater, much of the drinking water in urban areas is derived from surface water containments such as reservoirs. It is estimated that as much as 95% of the drinking water for some major metropolitan areas comes from reservoirs.

We developed a research program in 1991 to determine the potential movement of pesticides following application to golf courses. Funds for this research program were furnished by the United States Golf Association and the University of Georgia Agricultural Experiment Stations. The methods used in this research and the results have been reported in five previous annual reports and six semiannual reports submitted to the Greens Committee. Since the research has been a continuum, the same research facilities, with minor changes, have been used throughout the project for the various treatments. Analytical methods have been changed as new analytes are used in treatments to the existing facilities. Realizing that there are new members on the Greens Committee, we have included a brief description of the facilities and methods and more detailed descriptions can be found in previous semiannual and annual reports. Dr. Song Hong recently completed the requirements for the Ph.D. degree and the subject of his dissertation research was "Fate of the Herbicide dithiopyr Following Application to Golf Courses". The chapters of the dissertation were submitted for publication and have been included in the Appendix of this report. Only a summary of that data is included in the body of this report. Other manuscripts that have been submitted for publication during 1996 and have not been published are also included in the Appendix of this report. The purpose of this document is to report data obtained over the last year, since the last annual report, and to place that data in a summary report on the potential movement of certain pesticides following application to golf courses with special reference to the development of pesticide management practices that will reduce the potential for movement of pesticides following application to turfgrass.

MATERIALS AND METHODS

Measurement of Pesticide Movement Through Simulated Greens

Greenhouse Lysimeters: Thirty-six lysimeters were constructed during 1991 by placing turfgrass growth boxes (40 X 40 X 15 cm deep) on top of the bases. The bottom of the wooden growth boxes was perforated steel and at the inside-center of the growth boxes a 13-cm length of polyvinyl chloride (PVC) tubing (15 cm diam.) was fastened to the bottom with acrylic caulk. The base of the lysimeter consisted of a 52.5 cm length of PVC tubing (15 cm diam.) with a cap over the bottom of the tube. The cap had a drain tube placed in the bottom for the collection of aqueous effluent in 1-L black glass bottles. The PVC bases contained 3 equally spaced (1.5-cm thick) rings of acrylic caulk on the interior to restrict edge flow. The growth boxes were designed for removal from the bases to allow for pesticide application to the turfgrass sod using a spray chamber at a location separate from the greenhouse in order to minimize contamination to the greenhouse.

Prescribed rooting medium (RM) (sand and sphagnum peat moss) was based on the percolation rate as determined for the sand used in the mixture. The distribution of the sand-particle size used in the RM was: (>2) 0, (1-2) 5, (0.5-1) 29, (0.25-0.5) 45, (0.1-0.25) 19, (0.05-0.1 mm) 1, and (silt) 1%. The RM component proportions were selected to give percolation rates of 39 and 33 cm hr^{-1} as recommended for Penncross bentgrass and Tifdwarf bermudagrass, respectively. The RM mixture of sand and sphagnum peat moss at v:v ratios of 85:15 and 80:20 (87.7:2.3 and 86.8:3.2 by mass, respectively) resulted in the respective percolation rates as tested (Tifton Physical Soil Test Laboratory, Tifton, GA). The RM was steam sterilized prior to use. The lysimeter bases were filled with sized gravel (10 cm), coarse sand (7.5 cm), and RM (35 cm) in ascending sequence from the bottom simulating USGA specifications for greens construction. The layers were carefully packed into the tubes using a vibrating table. Prior to placement into the lysimeters, the 85:15 medium had a field capacity of 0.13 cm^3 cm^{-3}, a wilting point of 0.03 cm^3 cm^{-3}, and an effective saturated conductivity of 39.6

cm hr^{-1}. The 80:20 medium had a field capacity of 0.15 cm^3 cm^{-3} and an effective saturated conductivity of 33.5 cm hr^{-1}.

The base of the lysimeter was located against the bottom of the growth box aligned with the PVC tube on the inside of the box for direction of the aqueous percolation from the center of the growth box into the base of the lysimeter. Although the total growth box was seeded with Penncross bentgrass or sodded Tifdwarf bermudagrass and treated to minimize edge effects, the only area of concern for effluent movement was the central area directly above the lysimeter base (176.6 cm^2). The grass cultivars were sodded or seeded in all lysimeters allowing for the determination of the influence of the two organic matter contents in the rooting media on pesticide movement. The bases of the lysimeters were enclosed and cooled by an air conditioner in order to maintain the soil temperature between 18-21°C. The lysimeters were housed in a greenhouse covered with Lexan[R] thermoclear sheet glazing. The glazing had approximately 90% of the light transmission of monolithic glass and a transmission of 80% for the wavelengths between 400 and 1200 ηm. The ambient temperature was monitored and controlled with a steam heating system and water cooled pads.

The research was designed to simulate golf course greens following seeding of bentgrass and sodding bermudagrass onto RM. Treatments were made to established stands of Penncross bentgrass or Tifdwarf bermudagrass on predetermined periods. All treatments were replicated three times and all experiments were repeated at least once over time.

An automatic track-irrigation system was developed for controlling the rates and times for irrigation. The watering nozzles traversed a horizontal track located above the growth boxes at a speed of 2.9 m min^{-1}. The flow rate of the water was adjusted to 1.82 mL sec^{-1} at 138 kPa. The daily irrigation of 0.625 cm of water and a weekly rain event of 2.5 cm were controlled with an automatic timer. These conditions were chosen to simulate management practices and average rainfall events for golf course greens in central Georgia. During watering the coefficients of variation were less than 0.08 across the boxes laterally and on the length of the track. The turf was mowed and clippings removed thrice weekly with a greens (reel-type) mower leaving 0.4 cm of verdure. Broadcast pesticide applications were made in 204 L ha^{-1} water diluents at 160 kPa under compressed air. After the spray on the foliage had dried, the growth boxes were returned to the top of the tubes. The leachate in the sample bottles, at the base of the lysimeters, was collected on alternate days. The samples were stored in a refrigerator maintained at 4°C. The collections were combined for weekly intervals and quantified for pesticides in the leachate.

Field Lysimeters: The Field-lysimeter facility consisted of small greens subtended with lysimeters for directing the flow of water and pesticides into a collection area. The small greens were developed with similar RM as used in the greenhouse experiments. The RM of 85:15 and 80:20 (v:v) sand:sphagnum peat moss subtended Penncross bentgrass and Tifdwarf bermudagrass, respectively, according to specifications developed by USGA. The design of the lysimeters allowed for replacement of the RM at the end of the experiment if necessary. Stainless steel inserts placed into fiberglass jackets resulted in easy removal of each lysimeter. The interior diameter of each lysimeter was 55 cm and the depth was 52.5 cm allowing for layers of gravel, sand, and rooting media as developed in the bases of the greenhouse lysimeters. The tops of the lysimeters were located 5 cm below the surface for seeding the bentgrass and at the base of the sod for the bermudagrass and were plumbed in the bottom for the collection of the aqueous effluent from the rooting profile in closed stainless steel containers housed in a covered walkway located between the two greens. Controlled applications of irrigation water and fertilizer were according to cultural practices for maximum maintenance. Penncross bentgrass was seeded on 15 October 1991 and Tifdwarf bermudagrass was sodded during March, 1992. All broadcast pesticide treatments were applied with a CO_2 backpack sprayer in 252 L ha^{-1} water diluent at 260 kPa. A horizontal moving irrigation system, similar to the one developed in the greenhouse, was used to simulate irrigation and rainfall events and an automatic moving rain shelter was constructed for movement over the greens area during natural rain events. The event intensities and frequencies were similar to the ones described for the greenhouse. A complete fertilizer (N:20 P:20 K:20) was applied biweekly in water to an N rate of 2.44 g m^{-2}. The sod was mowed and the clippings removed using a greens (reel-type) mower leaving 0.4 cm of verdure. The treatments were applied in three replications randomized over the lysimeters for each cultivar.

2,4-D Degradation in Golf Course Greens RM

The major consideration, when determining the half-life for a pesticide is to utilize a model system that closely resembles the real system. We obtained the RM from the greenhouse lysimeters that had previously been used as checks in the pesticide transport studies. These lysimeters had an excellent stand of 'Tifdwarf' bermudagrass maintained as simulated greens for 2 years. No pesticides had been used on the lysimeters for 6 months prior to recovering the RM for the incubation study. The RM (85:15) contained microorganisms, enzymes and exudated carbon/energy sources necessary for maximum microbial degradation of 2,4-D.

The RM from 4 growth boxes and lysimeter tubes was removed and thoroughly mixed together in order to get a uniform mixture for the study. Field capacity moisture content of the rooting mixture was determined. Quantities of soil [280 g (d.w.)] were placed into glass soil incubation tubes (15 cm X 5 cm diam.). The soil was brought to field capacity with tap water and the dimethylamine salt formulation of 2,4-D treatment was applied using a spray booth. The tubes were placed into the spray booth and the herbicide applied as a broadcast spray over the RM surface. The application rate was equivalent to 1.12 kg ha^{-1} applied as a surface application. Seventy tubes were placed in each of 5 incubators controlled to a temperature of 11, 17, 23, 29, or 35°C. At 0, 7, 14, 21, 28, 42, and 56 days 10 tubes were removed from each incubator and the 2,4-D remaining in the RM, each tube, was extracted and quantified. The RM in the tubes were brought to field capacity by adding water to the original weight of the rooting media on alternate days throughout the experiment.