Dr. Al Smith, University of Georgia, is evaluating the fate of pesticides applied to bermudagrass and bentgrass putting greens. The lysimeter facility contains a series of buckets (not shown) buried underneath the surface of the green that collect water moving through the soil. Water samples analyzed in the laboratory indicate that the amount of properly applied pesticides passing through putting greens is negligible.

Beyond Appearance and Playability: GOLF AND THE ENVIRONMENT

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IT WAS just a short time ago at the 1990 U.S. Open at Medinah Country Club that then USGA President Grant Spaeth announced the funding of a three-year research program that would focus on the impact of golf course activities on the environment.

In the spring of 1991, 21 research projects were selected to focus on the following objectives: 1) the fate of pesticides and fertilizers applied to golf courses, 2) development of alternative methods of pest control, and 3) the benefits of turfgrass and golf courses to humans, wildlife, and the environment.

The research effort has already yielded several important publications. *Golf Course Management and Construction: Environmental Issues* by Drs. James Balogh and William Walker provides a comprehensive summary of the effects of construction and management of turfgrass systems. The *Landscape Restoration Handbook* by Donald Harker offers information to property owners and managers about naturalizing the managed landscape. Dr. James Beard has published a scientific article on turfgrass benefits entitled "The Role of Turfgrasses in Environmental Protection and Their Benefits to Humans" in the May/June 1994 *Journal of Environmental Quality.*

The alternative pest management projects funded as part of the program have made progress sorting out what may or may not work on the golf course for non-pesticide control of turfgrass diseases and insects. At Rutgers University, a new nematode was developed and released, holding promise as a control for white grubs equal to some insecticides. Researchers at the University of Kentucky have documented several beneficial predators of white grubs and cutworms that can help reduce pest egg populations if properly managed. However, it will require more time to evaluate these and some of the other alternative pest management strategies before their ultimate effectiveness in reducing pesticide use on golf courses can be determined.

This past April, the research project leaders involved with pesticide and fertilizer studies discussed their results with the USGA's Turfgrass Research Committee at Golf House. The November 1994 issue of the *Green Section Record* will feature summaries of the pesticide and nutrient fate projects prepared by the researchers. Overall, the preliminary reports indicate that there is a lot of good news, but there also are some areas where we can do an even better job protecting the environment.

Among the positive results is that when a fertilizer is properly applied, the amount of nitrogen that reaches groundwater is negligible. Researchers at Iowa State University (ISU) and Michigan State University (MSU) reported preliminary results that indicate that less than one percent of the nitrogen applied to a Kentucky bluegrass turf traveled to a depth of two and four feet, respectively. The MSU study also demonstrated that there were no differences between late fall and early spring nitrogen fertilizer applications (*Figure 1*). The ISU study indicated that four quarter-inch water applications were better than a single one-inch irrigation after nitrogen fertilization.

Often overlooked by scientists who study the fate of pesticides and fertilizers is the positive effect of thatch in retaining and breaking down organic chemicals. The preliminary results from most all of the projects indicate that pesticides break down faster in the turfgrass environment than what is typical when these materials are applied to agricultural crops.

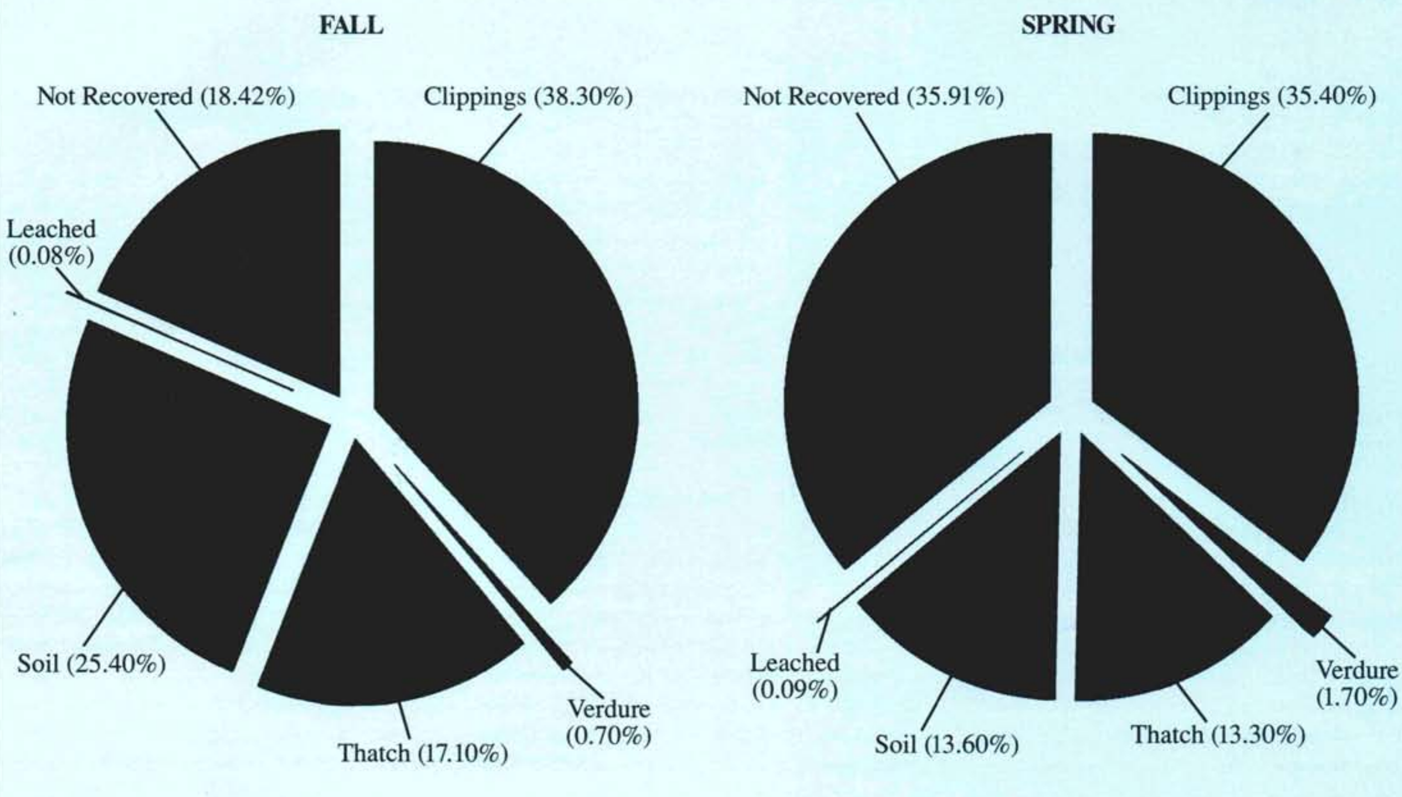
The turfgrass leaves, shoots, and thatch intercept most of the pesticide during application (*Figure 2*). Over time, the amount of pesticide recovered in the leaves decreases due to irrigation, rainfall, and clipping removal. The thatch layer, which retains pesticide residues and is somewhat unique to turfgrass systems, generally contained the greatest amount of pesticide residue.

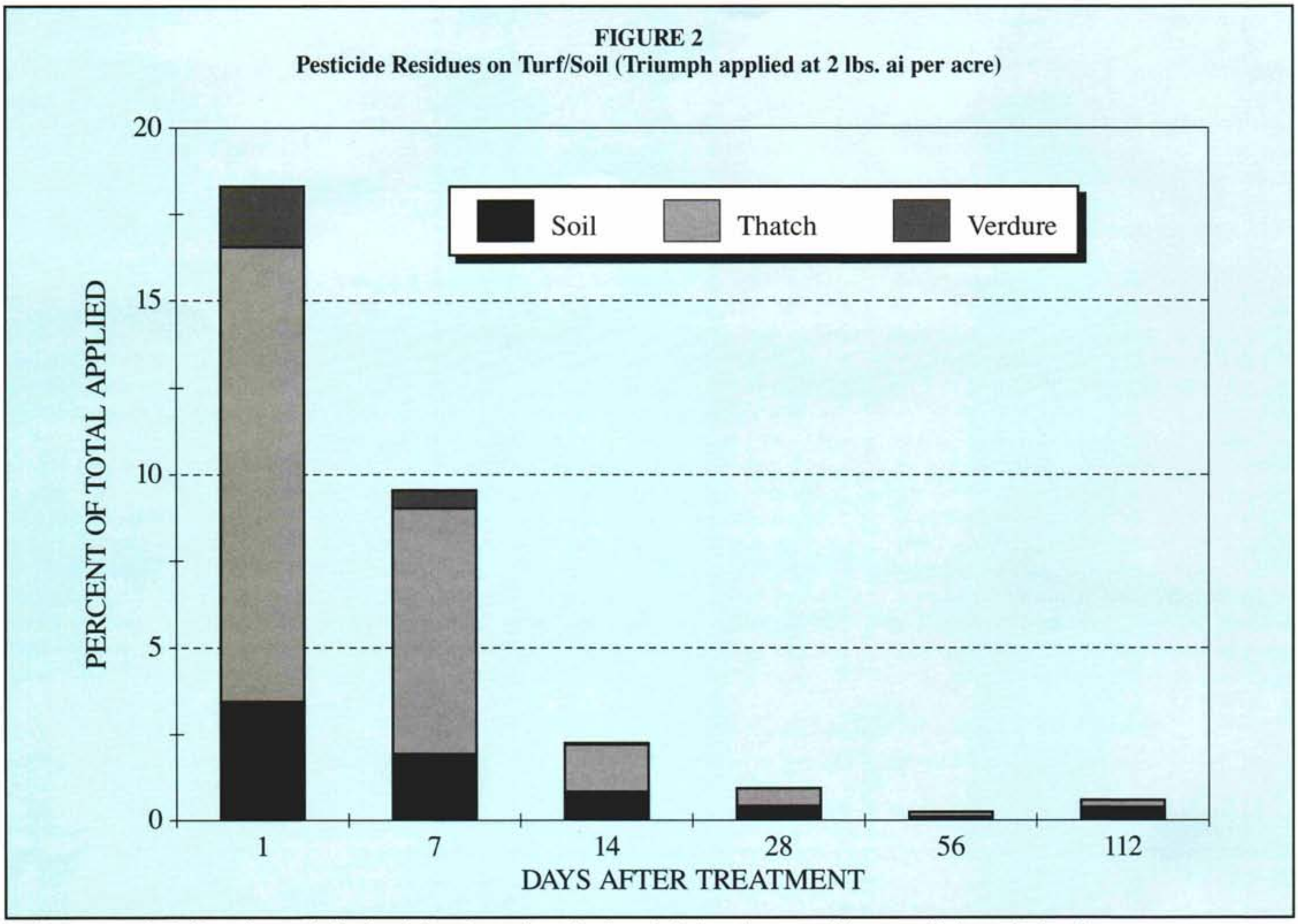
Research projects at the University of Massachusetts and the University of California at Riverside indicate that pesticides applied to turf volatilize in various amounts. Volatilization is the process by which a solid or liquid changes to a gas.

The amount of applied pesticide lost as volatile residues was generally less than 13 percent for the products tested. After two weeks, volatile residues were either non-detectable or less than 0.03 percent of the total applied to turf. The vapor pressure and surface temperature of the turfgrass site were directly related to the volatilization process. Irrigation after pesticide application delayed

The two diagrams show the fate of a fall and spring application of fertilizer two full years after the initial treatment. Less than 1 percent of the nitrogen fertilizer reached a depth of four feet during the two-year study. The 18.4 and 35.9 percent of nitrate nitrogen not recovered for the fall and spring applications, respectively, is thought to have volatilized or undergone denitrification. Critics of turfgrass fertilization programs have incorrectly assumed that nitrate nitrogen not found in the verdure, thatch, soil, and clippings leaches into groundwater.

FIGURE 1
Percent of Total Nitrogen Applied Recovered Two Years After Application





Preliminary results indicate that pesticides break down faster than what is typical when these materials are applied to agricultural crops. The turfgrass verdure (leaves, shoots, stolons, etc.) and thatch intercept most of the pesticide after application.

volatilization, but did not prevent the production of volatile residues.

Dislodgeable pesticide residues were only significant immediately after a pesticide was applied to turf. Research at the University of Florida and the University of Massachusetts indicated that once the leaf surface dried, dislodgeable residues were greatly reduced. Irrigation reduced dislodgeable residues on the first day after application, but apparently due to an upward wicking type of movement, dislodgeable residues were present two and three days after the pesticide was applied.

Preliminary estimates of the health effects for the amount of dislodgeable and volatile residues indicate that the levels found are safe, according to EPA standards. However, caution should be taken immediately after a pesticide has been applied to the golf course. Golfers, owners, and municipalities need to recognize that golfers should not be following spray equipment around the golf course.

Preliminary results from studies concerned with the loss of pesticides and nutrients in runoff have been variable. Pennsylvania State University runoff plots irrigated with six inches of water per hour have yielded nitrogen and phosphorus amounts less than or equal to what was found in the irrigation water itself. Pesticide concentrations reported thus far are less than or equal to one part per millon. An interesting finding of this study was that bentgrass fairway plots had significantly lower amounts of water runoff than mature ryegrass plots. Compared to ryegrass, bentgrass has higher shoot density, stoloniferous growth habit, and more thatch, which ultimately reduced the amount of runoff.

The first year's results from runoff plots at the University of Georgia indicate that heavy-textured, kaolinite clay loam soils will not be as forgiving as the sandy loam soil found at the Penn State runoff plots. At least 40 percent of the water from a one-inch rainfall simulation moved off the sloped plots. Also, this water contained up to 10 percent of the herbicides that were applied 24 hours before the rain simulation. These data would indicate that precautions should be exercised when applying some pesticides to golf course fairways with heavy-textured soils and slopes greater than 5 percent.

The mathematical models used by environmental regulators and scientists to predict the fate of pesticides and fertilizers will need some major overhaul before they accurately represent what happens on golf course turf. The study at the University of Georgia demonstrated that the GLEAMS (Groundwater Loading Effects of Agriculture Management Systems) model significantly overestimated the amount of 2, 4-D that moved through a putting green root system (*Figure 3*).

The GLEAMS mathematical model is commonly used to help identify chemical and soil properties, as well as plant and meteorological factors, influencing the transport of pesticides through soils in agricultural lands. Only minute quantities of 2, 4-D were actually detected in the water that leached from the putting green root system lysimeters.

Even though the GLEAMS model greatly overestimated the amount of herbicide moving through the putting green, the maximum predicted was still below the maximum contamination level established by the U.S. EPA. The difference between the measured and predicted amounts of herbicide found in water moving through the lysimeter may be due to a lack of understanding of the role played by a dense surface of turfgrass leaves and thatch in pesticide fate. Also, surface evapotranspiration (ET) and water movement through the turfgrass/soil system are not adequately accounted for in current prediction models.

During the last three years, USGA-sponsored environmental research has demonstrated that nitrogen leaching is minimal, that the turf/soil ecosystem enhances pesticide degradation, and that the current agricultural models are inadequate at predicting the fate of pesticides and fertilizers applied to turfgrass maintained under golf course conditions. There are still some questions with regard to runoff, volatilization, and dislodgeable residues that need to be addressed.

The USGA is committed to continuing environmental research at land grant universities. The program will expand our focus to investigate best management practices, bioremediation, and human and wildlife exposure issues. Pesticide and nutrient fate projects will continue to evaluate products not examined during the first three years and will start the process of overhauling existing mathematical prediction models.

Best management practices projects will apply appropriate agronomic principles to demonstrate that golf course turf can be maintained while protecting the environment. The emphasis of these projects will be to identify cultural practices that minimize volatilization and surface runoff.

Bioremediation studies will demonstrate the potential of turfgrass to serve as a biological filter. The benefits that plants and microorganisms found on golf courses provide when dealing with storm water runoff from parking lots and rooftops needs to be addressed. The positive role golf courses can play in further cleansing effluent wastewater also needs to be documented.

Pesticide and nutrient fate research will continue because there remains a need to classify the chemical, physical, and microbial characteristics of the turf/soil ecosystem and their effects on nitrogen cycling, uptake and movement of phosphorus, and pesticide degradation and transport. With a better understanding of the positive role turf plays in breaking down, adsorbing, and absorbing pesticides and fertilizers, existing computer models used to predict their fate will be overhauled to accurately estimate the impact golf courses have on the environment.

At the USGA 1994 annual meeting held in Scottsdale, Arizona, outgoing President Stuart Bloch said, "The player, club, and ball have always been essential elements to the integrity of the golf equation. Our challenge today is to tackle the fourth element of that equation: the environment. Properly mastering the environmental element may be the USGA's most important contribution to preserving the future of golf."

The mathematical models used by environmental regulators and scientists to predict the fate of pesticides and fertilizers will need a major overhaul before they accurately represent what happens on golf course turf. Values predicted by the GLEAMS model and measured 2,4-D transport in water percolated from greenhouse lysimeters containing soil mixtures of 85:15 and 80:20 (sand:peat) did not agree.

FIGURE 3
Measured and Predicted Levels of Pesticide Transport in Water Percolated from Greenhouse Lysimeters