Pesticide fate in turfgrass

By Dr. David Gardner

Although there are many advantages to maintaining a stand of turfgrass, serious questions have been posed in recent years concerning the use of certain synthetic fertilizers and pesticides that have been implicated as potentially harmful to the environment. Although turfgrass management accounts for a very small percentage of total pesticide usage, it is a very intensely managed system.

Turfgrass is unique in that, except at establishment, pesticides are applied directly to the plant material. Pesticide not intercepted by the plants is instead deposited in the thatch or mat (Branham, 1994). Thatch contains high amounts of organic matter and is defined as a layer of intermingled plant material that is living or in various stages of decomposition and it lies between the green vegetation and the soil surface (Beard, 1973).

After a pesticide has been applied to a turfgrass system, it is subject to numerous biological, chemical and physical processes that will determine its fate. Many of these processes interact, complicating our ability to predict or understand pesticide fate. The study of pesticide fate is also complicated by the wide array of chemicals used on turfgrass because each pesticide is unique. Differences in soil type and climate will also affect pesticide fate.

Several processes affect the environmental fate of pesticides including volatilization, uptake of the material by turfgrass or target weeds, photolysis (degradation by sunlight) and chemical degradation. However, sorption of the pesticide to soil particles or organic matter, leaching of the material through the soil profile or runoff and degradation of the compound by soil-borne microbes are the processes most important when considering pesticide fate in a turfgrass system.

How sorption works

"Sorption" is a term used to refer to both absorption and adsorption. Absorption is the transfer of material between phases, such as a plant root and the soil solution (Kenna, 1995). Adsorption refers to the concentration of a solution component at an interface. The extent to which a pesticide is sorbed greatly influences other fate processes by determining the amount of time the pesticide is available in the soil water system and thus subject to those processes (Branham, 1994). Sorption of pesticides is controlled by pesticide properties, as well as soil properties.

Pesticide properties that influence sorption include the water solubility of the compound, its polarity, and potential to become ionized in solution. Pesticides in the soil solution can occur as cations, anions or neutral molecules. Soil particles occur predominately as negatively charged species. Thus, soils attract positively charged species and repel negatively charged species including pesticides that occur as anions, e.g. 2, 4-D. As a result, 2, 4-D is considered among the most mobile of turfgrass pesticides in the soil (Gold et al., 1988).

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Measuring potential to leach

A 1988 EPA report stated that Koc values (a constant used to describe the tendency of a pesticide to sorb to organic carbon) lower than 300 to 500 or water solubilities higher than 30 ppm indicate a particular pesticide has the potential to leach (Kenna, 1995). It is important to note that there is a wide range of reported Koc values and water solubilities for pesticides used in turfgrass (Table 1).

However, in addition to water solubility and Koc, it is necessary to consider all of the properties of a particular pesticide and how they will influence pesticide fate. As previously mentioned, 2, 4-D exists in soil as a highly water-soluble anion. It is not adsorbed to soil organic matter to any great extent in the pH range found in turfgrass soils.

But, 2, 4-D and other phenoxy herbicides are quickly broken down by photolysis and are easily metabolized by soil microorganisms. In fact, few studies indicate that 2, 4-D has been detected to a significant extent in groundwater (Branham, 1994). Glyphosate is highly water soluble, indicating a high potential to leach. However, it has a high Koc, and is tightly sorbed to soil after application.

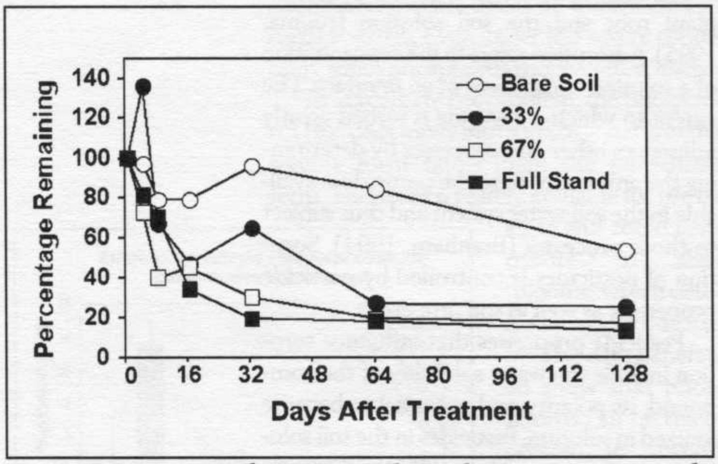

Figure 1. Percentage of cyproconazole residues remaining in each soil treatment as a function of sampling time in 1997.

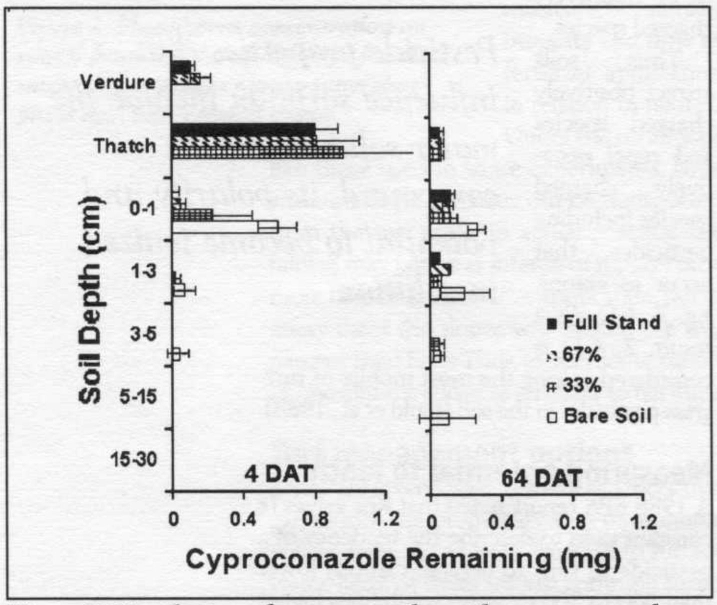

Figure 2. Distribution of cyproconazole residues among verdure, thatch and different soil depths 4 and 64 days after application (DAT). Horizontal bars represent standard error of the means.

There is an increasing amount of literature that demonstrates the ability of thatch to retain or retard the movement of most pesticides (Branham, 1994). Research conducted by Niemczyk et al. (1988) demonstrated that turfgrass thatch strongly sorbed three commonly used insecticides.

Similar results were found in studies conducted with turfgrass fungicides (Dell et al., 1994). Stahnke et al. (1991) found that most applied pendimethalin remained in the plant tissue and thatch, and none was detected below 30 cm in the soil. Traces of pendimethalin found in leachate after heavy rainfall were attributed to gravitational displacement of soil colloids that contained adsorbed herbicide (Stahnke et al., 1991).

Leaching and runoff

Leaching and runoff of pesticides might be considered the opposite of sorption to thatch or soil. The potential for runoff and leaching of pesticides from turfgrass areas is of environmental concern (Balogh and Anderson, 1992). Leaching of pesticides through a turfgrass system is a complex process that is highly variable due to differences in soil organic matter and turfgrass cover between sites.

However, it has been suggested that pesticides are less mobile in turfgrass than in agronomic soils and this decrease in pesticide mobility is due to retention by the thatch layer. Also, the grass plants can influence pesticide fate by directly absorbing applied pesticides or they can affect the potential leachability of a pesticide by altering the flow of water in the root zone (Kenna, 1995).

Turfgrasses have extensive, fibrous root systems dominating the upper 200 to 300 mm of the soil profile, and when combined with very dense above-ground plant growth reduces runoff and allows time for infiltration of water into soil (Beard and Green, 1994).

It would be logical to assume that irrigation practices and rainfall events would have a major impact on leaching of pesticides. However, in turfgrass the effect of post application irrigation on mobility and dissipation of pesticides has received some attention and the results of these studies are conflicting.

Niemczyk and Krueger (1987) studied movement of isazofos as affected by various irrigation regimes consisting of 10.2 L m-2 applied immediately or 8, 24 and 36 hours after treatment. Regardless of timing, 96 percent to 99 percent of detectable residues were recovered in the thatch. The authors concluded that post treatment irrigation had little effect on insecticide movement to the soil.

Similarly, Cisar and Snyder (1996) found less than 0.1 percent of applied organophosphate insecticides in percolate water under a United States Golf Association (USGA) putting green, despite substantial variations in rainfall and total percolation. However, Niemczyk and Krause (1994) found that the mobility of pre-emergence herbicides such as pendimethalin was correlated to major rainfall events that occurred prior to sampling.

Microbial degradation

Microbial degradation is the primary process by which most pesticides are removed from soil (Wagenet and Rao, 1985). The amount of time that it takes for dissipative processes to reduce pesticide concentrations by 50 percent is called a half-life, expressed in days.

Several processes influence the rate of pesticide degradation including soil moisture, temperature, soil pH and soil mineral composition. As a result, the half-life of a given pesticide can vary considerably under different environmental conditions. Pesticides with longer half-lives are a greater threat to leach or runoff than those with short half-lives.

Generally, if the half-life of a pesticide exceeds 21 days, it is more likely that this compound will persist for a long enough time to pose a contamination risk (Kenna, 1995).

There is evidence that pesticides persist for shorter periods of time in thatch compared to soil. Mancino et al. (1993) found 40 to 1600 times as many bacteria, 500 to 600 times as many fungi, and up to 1000 times as many actinomycetes in thatch compared to soil. These organisms provide a very active system for the degradation of trapped organic chemicals and pesticides.

Horst et al. (1996) found that the half-lives of metalaxyl, pendimethalin, chlorpyrifos and isazofos applied to turfgrass were 16, 12, 10 and 7 days, respectively. This compares to published soil half-life data of 70, 34, 30 and 90 days, respectively.

Pesticide fate studies at Illinois

Regulators are using pesticide fate models when they assess pesticide exposure risk. These computer models can predict pesticide mobility and dissipation rates but they were intended for use in bare soil agronomic environments that include tillage.

A major weakness of using such models in a turfgrass environment is that they do not account for the high levels of organic carbon found in the turfgrass thatch layer. As a result, agronomic models may overestimate the amount of pesticide that is leached when applied to a turfgrass environment. Also, soil half-life data may not agree with half-lives observed in turfgrass. Therefore, the use of half-life data from soil studies may result in overestimating the leaching potential of pesticides applied to turfgrass.

Before 1985, little research had been conducted on the fate of pesticides applied to turfgrass. Recent research suggests that the mobility of pesticides applied to turfgrass is lower than in agronomic soils and that dissipation rates are faster when pesticides are applied to turfgrass than when applied to soil. While studies investigated the fate of pesticides applied to turfgrass, few attempts were made to directly compare the amount of organic carbon associated with thatch to pesticide mobility and dissipation rates.

The purpose of this research was to directly compare the fate of pesticides applied to turfgrass or bare soil. Cyproconazole was the active ingredient in Sentinel fungicide and has properties indicating the potential for some leaching through the turfgrass-soil profile. It is highly persistent, with a half-life of about 90 days in agricultural soils (Anonymous, 1991). It was introduced for use on turfgrass in 1994 but voluntarily removed by the manufacturer in 1999 due to concerns raised by the Food Quality Protection Act.

Plots were prepared that had either creeping bentgrass mowed at one-half inch or bare soil. The bare soil plots were prepared by stripping away the bentgrass with a sod cutter. Other plots with amounts of creeping bentgrass intermediate of the full stand and bare soil were prepared with a vertical mower. A hydraulic press mounted on a tractor was used to push sampling cylinders into

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the bentgrass and bare soil plots. The sampling cylinders were sections of PVC pipe.

The plots were sprayed with Sentinel at its maximum label rate. After two hours, a sampling cylinder was removed from each of the plots. The cylinder was cut open to reveal the intact soil core. The core was divided into sections (green leaf tissue, thatch and the 0 to 1; 1 to 3-; 3 to 5-; 5 to 15-; and 15 to 30- cm soil depths). Any pesticide present in the core sections was extracted and quantified. This allowed for the determination of how far the pesticide had leached and how much of the original amount applied was left. Other soil cores were removed and tested for pesticide residues at 4, 8, 16, 32, 64 and 128 days.

The most interesting results were the differences in pesticide persistence on creeping bentgrass. Figure 1 shows the percentage of cyproconazole remaining in each treatment. In the plots containing 33 percent, 67 percent or a full stand of bentgrass, half of the cyproconazole dissipated in 8 to 15 days. On day 128, the cyproconazole detected in the bentgrass plots was less than 20 percent of what was originally detected two hours after application (Gardner et al., 2000). But the half-life of the same product applied to bare soil was about 128 days. Why the difference?

When a pesticide is applied to turfgrass it may, depending on its characteristics, become bound to the thatch. The thatch contains a rich flora of microorganisms that break down the pesticide. These microorganisms also exist in soil, but thatch tends to contain much higher populations. Remember, degradation of pesticides by microorganisms is one of the most important avenues of pesticide fate.

The other important aspect of this research was to study the extent of leaching of the pesticide. Figure 2 shows the soil distributions of cyproconazole in the different plots 4 and 64 days after application. The horizontal bars denote the standard error. If two standard error bars overlap, then statistically, these plots are considered to have similar levels of pesticide residues. For example, the 33 percent, 67 percent and full stand plots had similar levels of cyproconazole on days 4 and 64. But on day 4, the amount detected in bare soil in the 0 to 1-cm section was different than that detected in the 33 percent, 67 percent and full stand plots.

Note the amount of cyproconazole in the soil under a full stand of creeping bentgrass was only about 1 percent of that observed in bare soil 4 days after application (Figure 2). This increased to just 11 percent by 32 days after application (Gardner et al., 2000). Remember, the pesticide had a half-life in bentgrass of 8 to15 days. Samples collected on day 32 showed only 4 half-lives of 8 days to 2

TABLE 1:

COMMON PESTICIDES USED IN TURFGRASS ALONG WITH REPORTED WATER SOLUBILITIES AND SOIL KOC VALUES

Common Name	Type	Water Solubility (PPM)	Soil Adsorption K_{oc}
Mancozeb	Fungicide	0.5†	2,000
Chlorpyrifos	Insecticide	0.4-4.8	2,500-14,800
Bensulide	Herbicide	5.6-25	740-10,000
Propiconazole	Fungicide	100-110	390-1,100
Dicamba	Herbicide	4,500-8,000	0.4-4.4
Glyphosate	Herbicide	12,000	24,000
Trichlorfon	Insecticide	12,000-154,000	2-6
Fosetyl Al	Fungicide	120,000	20
2, 4-D amine	Herbicide	2,000,000-3,000,000	0.1-136

† PESTICIDE PROPERTIES SUMMARIZED FROM INFORMATION PRESENTED IN BALOGH AND ANDERSON (1992).

half-lives of 15 days of the pesticide originally applied remained on the plots.

By day 64, cyproconazole applied to bare soil was detected in the 1 to 3-, 3 to 5- and 5 to 15-cm soil sections. Cyproconazole still was not detected below the 1 to 3-cm soil section in a full stand of creeping bentgrass. In other words, not much of the pesticide leached past the thatch layer and into the soil when it was applied to creeping bentgrass.

Summary

It is important to avoid drawing conclusions from the results of a single study. There are limitations to these studies that preclude making recommendations based solely on the data. First, our studies and others were conducted on one site during one year. Different locations with different soil types or conditions could affect leaching and dissipation rates. Second, the studies investigated the fate of the primary compound only. We do not know what happened to the breakdown products or if they pose more or less of a threat to the environment.

Pesticide properties influence the effect thatch has on their leaching and dissipation rates. Some behave the same in turfgrass as they do in bare soil, but many pesticides behave differently when applied to turfgrass. For the most part, pesticides applied to turfgrass do not persist or leach as much as they do when applied to bare soil.

Research continues today using computers and knowledge of pesticide behavior and soil physics to predict pesticide fate. Based on what we learned so far, the use of certain pesticides may not pose as much of a threat to the environment as was once feared. However, responsible management practices and proper usage always will continue to be important.

2

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