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Best Management Practices to Reduce Pesticide Runoff from Turf

A common-sense approach can greatly reduce the risk of water contamination.

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Golf turf management has made huge strides over the past 40 years that have allowed golf course superintendents to achieve excellent turf quality. However, achieving these very high levels of turf quality requires numerous inputs, including fertilizers, irrigation, topdressing, cultivation, wetting agents, biostimulants, and pesticides. While practices such as topdressing, cultivation, and wetting agents are considered environmentally benign, fertilizers and pesticides have received much scrutiny since some of these products can move off the turf and into ground and surface water.

Pesticide leaching from turf has been studied intensively,[1,5,6,9] and while pesticide leaching is a major problem in row crops, leaching of pesticides from turf presents much less risk than previously suspected. Pesticide leaching in turf is a much smaller problem than in row crops for two primary reasons.

First, the acreage treated with pesticides on all the golf courses in the United States is a drop in the proverbial bucket compared to row crop agriculture. The National Golf Foundation reported that at the end of 2002, there was the equivalent of 14,725 18-hole golf facilities in the United States. If we assume that each golf course contains, on average, 3 acres of putting greens, 5 acres of tees, and 30 acres of fairways, then the total number of golf course acres in the United States receiving pesticide applications (roughs typically receive little in the way of pesticide applications, although weed control may be practiced) would total 559,550 acres. This is less total acreage than the amount of corn and soybeans planted in a typical county in central Illinois. Nationally, in 2001, approximately 75.752 million acres of land were planted to corn, while 74.105 million acres were planted to soybeans. Most of these receive some kind of pesticide application. All the intensively managed golf course acres in the United States represent less than 0.4% of the total acreage planted to the two largest crops grown in the U.S.

A second reason why turf presents less of a risk for pesticide leaching is the turf itself. A previous USGA-funded research project examined the effect of turf on pesticide movement and degradation.[2,3,4] We found that when pesticides are applied to turf, leaching is reduced and degradation rates are increased when compared to the same pesticides applied to bare soil (a common practice in row crops).

These two differences have led many to conclude that the risk of groundwater contamination from turfgrass pesticides is low, but not non-existent. Proper management is still key, and on certain sites, particularly those with sandy soils, shallow groundwater, and proximity to water bodies, turf managers need to pick the pesticides they do use with care.

Pesticide runoff, however, is a completely different issue. What is runoff? Runoff is a natural event that occurs when a rain or irrigation event produces more water than the soil/turf can accept. This is a fairly common occurrence, and depending upon soil types, slopes, etc., it may occur often or rarely on a particular site. Runoff per se is not a bad thing, but when the runoff carries pesticides, nutrients, or other pollutants, problems may arise.

Whereas pesticide leaching is mostly a threat to groundwater (although the use of tile drains also can threaten surface waters with pesticide leachate), pesticide runoff is a threat to surface water. Most golf courses have some water features associated with them, and often streams, rivers, or storm drains are used to accept runoff from golf courses. Some initial research has shown that pesticide runoff can be significant, with some researchers reporting as much as 10% of the applied pesticide transported in runoff.[7]

INVESTIGATING RUNOFF

With this background in mind, we examined some management practices that might reduce the concentration of pesticides when runoff does occur from a golf course. We first constructed a site

Runoff plots with a 5% slope were constructed at the University of Illinois to study the effects of post-application irrigation and clipping management on runoff of pesticides of varying solubilities.

to conduct runoff research. This site was sloped, but it did require some modification to suit our needs. That modification was provided by Munie Outdoor Services, a St. Louis-based company that donated time and equipment to produce a plot area with a uniform 5% slope that was approximately 150 ft. × 35 ft.

They also installed a mist irrigation system that could provide two intensities of simulated rain events. Rain drops have much different energy than the output from a mist head, which is very important on bare soil, but we believe the energy difference is less important when a turf cover is in place. After the plots were constructed in the fall, they were allowed to settle over the winter and were sodded the next spring with creeping bentgrass. The rest of the summer was spent installing the runoff collection equipment and testing the system, and by the end of the summer we conducted a test run.

In the summer of 2003, we had the personnel and equipment in place to conduct the experiments. We evaluated three possible strategies to reduce pesticide runoff. First, can irrigation applied a short time after pesticide application significantly reduce pesticide runoff? By washing the pesticide off the leaf surface and deeper into thatch and soil, can the concentration and total quantity of pesticide in runoff be reduced?

The second experiment examined the length of time between pesticide application and runoff event. Some turf managers and many homeowners use natural rainfall in place of irrigation. If rain is forecast, an application of pesticide or fertilizer may be applied and the rain is used to water-in the product. Of course if the rain produces runoff, pesticide loss could be quite high. Can runoff potential be reduced by applying a small amount of irrigation prior to the runoff event and thus reduce pesticide runoff?

The third experiment centered on clipping management. Turf is a unique crop in that each pesticide application is made directly onto the foliage. Even when a pesticide is primarily root-absorbed, a significant quantity of the pesticide will adhere to leaf tissue. I don't believe that we have considered clippings to be a source of pesticide contamination, but the first mowing following a pesticide application effectively frees up a significant portion of the pesticide application. If a rain event moves these clippings, a significant amount of pesticide will be transported with the clippings.

An even thornier issue results when clippings are collected. If the clippings are composted, rapid degradation of the pesticide residues will result, but care must be taken to prevent rainfall from leaching pesticides from the clippings. If the clippings are simply scattered in the rough, turf managers may be unintentionally producing areas with high concentrations of pesticides that may be susceptible to leaching or runoff.

EXPERIMENTAL PROCEDURES

In each experiment, pesticides were applied as a three-way tank mix. We selected pesticides based upon their water solubility and ease of analysis by high-performance liquid chromatography (HPLC). Each tank mix contained a pesticide we classified as having high, medium, or low water solubility. Water solubility plays a dominant role in the availability of the pesticide for runoff. Pesticides with higher water solubilities are more readily moved with flowing water. Pesticides with very low water solubilities will move in lower concen-

Following pesticide application, irrigation was applied until all plots produced at least 40 liters of runoff.

trations in water. Best management practices may need to be modified based upon water solubility. In other words, what works best to reduce runoff of a highly water-soluble pesticide may not be as effective with a water-insoluble pesticide.

Following pesticide application, the mist irrigation system was turned on at the appropriate time for each experiment to produce runoff. Irrigation was applied until all plots produced at least 40 liters of runoff. In each experiment, approximately 2 hours of irrigation was applied. From each 40-liter runoff sample, a 4-liter subsample was collected into amber glass jugs. The samples were analyzed by HPLC to determine the amount of each pesticide present in the water samples.

The first experiment examined the effectiveness of post-application irrigation in reducing pesticide runoff. Three pesticides — chlorothalonil (Daconil Ultrex™), paclobutrazol (Trimmit™), and mefanoxam (Subdue Maxx™) — were applied and 0.2 inch of post-application irrigation was hand applied at 0.25, 1, 4, 8, or 24 hours after pesticide application. The simulated runoff-producing rain event was initiated at 25 hours after pesticide application (i.e., simulated rainfall began 1 hour after the last pesticide washoff treatment was applied).

RESULTS

The results of the first experiment were disappointing. No matter how we examined the data, there were few meaningful differences. The largest point from the trial was that post-application irrigation was not effective in reducing the amount of pesticide available for runoff. Closer inspection of the data yielded one significant finding. Chlorothalonil runoff was reduced by post-application irrigation at 15 minutes after pesticide application. This may make sense from a pesticide chemistry viewpoint. Chlorothalonil is very water insoluble, with a commonly accepted water solubility of 0.6 PPM.[8] Products with water solubilities this low are usually applied as an emulsion in water in order to get the product into a sprayable form. Once the spray dries on the leaf surface, the emulsifying characteristics are lost and the pesticide behaves according to its natural water solubility.

A pesticide, or any organic chemical, with water solubility below 1 PPM will be very strongly sorbed to the wax and other non-polar compounds of the leaf surface. Once these pesticides dry on the leaf surface, they're literally stuck there. By applying irrigation soon after application, some of this drying will be prevented and a larger mass of the pesticide can be moved deeper into the turf profile. Once a water-insoluble pesticide has dried on the leaf surface, post-application irrigation will not be effective in moving the pesticide off the leaf.

With the fungicide chlorothalonil, post-application irrigation immediately after application would not be a good practice since the product needs to be on the leaf surface to exert its fungicidal activity. However, if the intended site of action is the soil or thatch surface, as, for example, preemergence herbicides, these products should receive post-application irrigation as soon as the application is completed. This not only reduces the amount of pesticide available for runoff; it also increases the amount of pesticide reaching the soil or thatch surface.

The second experiment examined the impact of the interval between pesticide application and runoff event. While no one can control when it rains, it is still instructive to understand the importance of the interval between pesticide application and runoff. In this experiment, pesticides were applied at 12, 24, 48, or 72 hours prior to the runoff event. The pesticides applied were pendimethalin (PreM™), propiconazole (Banner Maxx™), and mefanoxam (Subdue Maxx™).

In this experiment, the results were dramatic. Regardless of water solubility, the longer the time between pesticide application and runoff, the less pesticide was detected in runoff. And while this would be expected, what was interest-

Table 1

Pesticides used in runoff studies at the University of Illinois

Common Name	Trade Name	Water Solubility (mg/L)
mefanoxam	Subdue Maxx	26,000
propiconazole	Banner Maxx	110
paclobutrazol	Trimmit	35
chlorothalonil	Daconil	0.6
pendimethalin	Pendulum	0.3

ing was that, in general, the differences in runoff were significant between runoff at 12 hours following application versus 24, 48, or 72 hours after application. In other words, if runoff occurs 1, 2, or 3 days following application, there is not a great difference in the amount of pesticide that runs off. But if the runoff event occurs at 12 hours or less after application, there will be a substantial increase in the amount of pesticide runoff that occurs. For example, on a mass basis, we recovered 8.9 mg of pendimethalin in runoff water when runoff occurred at 12 hours after application, but only 1.5, 1.6, or 1.2 mg if runoff occurred at 72, 48, or 24 hours following application, respectively. Similar results were obtained for the other two pesticides in this study.

One surprising result of this trial was that, on a mass basis, there was more propiconazole in the runoff than mefanoxam. This result was counter to our hypothesis that the more water soluble a pesticide, the more susceptible it is to runoff. In general, the initial concentration of mefanoxam in the runoff was higher than propiconazole, but as more runoff came off, the concentration of mefanoxam decreased while that of propiconazole did not decrease appreciably. Perhaps since mefanoxam is much more water soluble (see Table 1), some of it may move into the soil and thatch more readily with the onset of precipitation, whereas propiconazole, which is less water soluble, may remain in the upper canopy where it can continue to partition into water flowing across the turf surface.

Our third experiment evaluated the effects of removing clippings on pesticide runoff. On golf course greens, tees, and fairways, pesticides are applied as often as once every two weeks during the summer. A significant portion of the pesticide application is deposited on the leaf tissue, and much of the application will remain sorbed (a term that describes substances that can be both adsorbed and absorbed) to the leaf tissue. This study was simplified so that we compared only two treatments, clippings removed versus clippings returned. In this experiment, pesticides were applied at 9 a.m. on July 15, 2003. The plots were mowed the following day at 9 a.m. and the runoff event was initiated one hour later at 10 a.m. by simulating runoff via irrigation.

As might be expected, removing clippings reduced pesticide runoff (Table 2). When examining the data on a mass basis, i.e., the total quantity of pesticide removed, the data must be considered in view of several important factors. First, an important factor in reducing pesticide runoff (as well as other forms of off-site transport) is to use pesticides that require smaller amounts of active ingredient. On a mass basis, more chlorothalonil was lost than either of the other two pesticides. However, on a percent-of-applied basis, chlorothalonil lost much less than the other two pesticides (Table 2). Chlorothalonil is an older product that requires higher use rates than many newer pesticides, thus chlorothalonil was applied at a rate of 11.2 lbs. ai/A, while newer chemistries are usually applied at rates of 1 lb. ai/A or less. Even though chlorothalonil is very water insoluble and less likely to run off (as shown by the percentage data), more chlorothalonil was recovered in runoff because it was applied at rates of 16 to 44 times higher than the other two pesticides. Second, pesticide mass is the product of pesticide concentration in runoff and the total volume of runoff collected. The plots we used in this trial were developed to be as uniform as possible, and yet there were still large differences in runoff volumes between plots. This directly affects the runoff mass and can make the data difficult to interpret.

Clipping management can have a big impact on pesticide runoff. Pesticide runoff was reduced by 34% to 57% by removing clippings. We doubt that the higher mass of pesticide runoff where clippings were returned can be attributed to clippings in the runoff. While we did observe some clippings in the runoff water, we removed the clippings by filtration prior to analysis. The mass of pesticide found on the sediment (clippings and other particles) was a small fraction of the amounts recovered from the runoff water. Thus, the reduc-

Table 2

Mass of pesticide loss during runoff — effect of clipping removal

Pesticide	Application Rate (lbs. ai/A)	Clipping Treatment	Total Mass Lost (mg)	Percent of Applied
mefanoxam	0.7	Removed	21.3	0.98
		Returned	37.2	1.70
paclobutrazol	0.25	Removed	8.3	1.06
		Returned	12.7	1.62
chlorothalonil	11.2	Removed	65.4	0.19
		Returned	153.7	0.44

tion in pesticide runoff where clippings were removed is most likely a direct result of the decrease in the amount of pesticide available when the runoff occurs. However, while the reduction in pesticide in the runoff was substantial, it begs the question of what happens to the clippings. If the clippings are simply deposited elsewhere on the golf course, then the runoff problem hasn't necessarily been reduced; it's just redistributed.

LESSONS LEARNED

The purpose of this research was to develop best management practices to reduce pesticide runoff. The most effective practice was to remove clippings, but the clippings themselves contain a significant amount of pesticide, and these must be dealt with responsibly. The turf in the field represents what is termed a non-point source pollution problem; that is, the potential pollutants are distributed across a large area at low concentrations. Collecting clippings and putting them in a pile would essentially create a point source pollution problem. However, creating a compost pile of clippings should permit relatively rapid degradation of the pesticides in the pile, and if drainage is controlled, this would be a particularly good option.

Regardless of whether or not you remove clippings as part of a best management program to reduce pesticide runoff, this research illustrates that clippings can be an important source of pesticides. Whether you return clippings or collect them, be aware that clippings harvested immediately following a pesticide application will contain a significant quantity of pesticide. Returning those clippings to the turf would be valuable particularly in the case of soil-active pesticides such as preemergence annual grass control herbicides and root-absorbed products such as the plant growth regulators paclobutrazol or flurprimidol.

Pesticide application within 12 hours of an expected rain event should be avoided. Runoff events occurring at 24-72 hours after pesticide application will contain reduced pesticide concentrations versus runoff that occurs within 12 hours of a pesticide application.

Choosing pesticides that require low active ingredient application rates dramatically reduces the amount of pesticide runoff. Many newer pesticide chemistries have application rates of 30-120 grams ai/A (~0.1-0.3 lbs. ai/A). The best way to reduce pesticide runoff or leaching is to not use a pesticide. The second best way is to choose a pesticide with good environmental properties, and one of the best is a low application rate.

Lastly, the use of buffer strips is a best management practice. A buffer strip is a vegetated strip that is not treated with pesticide. In our runoff experiments, the pesticides were applied within 2 feet of the runoff collection apparatus. Any increase in the length of untreated turf or other landscape plantings between the treated turf and the point where runoff water would enter a stream, drain, or other direct access to water will dramatically reduce pesticide runoff. This occurs for two reasons. First, turf will remove some of the pesticide that is flowing across it; that is, some pesticide will absorb to the turfgrass plants. Second, as runoff containing pesticide enters the buffer strip where no pesticide is present, simple dilution reduces the pesticide concentration that ultimately enters the water body.

Pesticide runoff is an important issue that golf course superintendents must be aware of and recognize where potential problems exist. Bodies of water flowing through the golf course need to be protected. Even if your golf course does not have a surface water feature, care must still be exercised. Many golf course superintendents use surface drains to remove excess water from low-lying or poorly drained areas. Often these drains ultimately lead to a surface water body. As a result, pesticides applied to a fairway may be readily moved off the golf course if surface drains are used to remove excess water.

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