Turfgrass and Environmental Research Online

...Using Science to Benefit Golf

Researchers at Cornell University have developed a runoff model, called TurfPQ, based on the unique characteristics of turf that can predict chemical runoff from turf areas more accurately than soil-based models developed primarily for field crops. (*Photo courtesty of Dr. Kevin Armbrust*)

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 215 projects at a cost of $21 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Modeling Pesticide Runoff from Turf

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SUMMARY

Previous pesticide runoff models were developed for agricultural crops and are difficult to apply directly to turfgrass. To address this, researchers at Cornell University developed a runoff model, TurfPQ, specifically designed for turfgrass.

- The model was tested using published plot runoff data for 52 runoff events in fours states, three soil hydrologic groups, four different turfgrasses (bermudagrass, creeping bentgrass, tall fescue, and perennial ryegrass) and six different pesticides (2,4-D, chlorpyrifos, diazinon, dicamba, dithiopyr, and mecoprop).
- Mean predicted pesticide runoff was 2.9% of that applied compared with an observed mean of 2.1%. It appears that the accuracy of TurfPQ meets or exceeds that of more complex models (e.g., EPIC, GLEAMS, OPUS), and predicted the dynamics of the pesticide events well (R^2=0.65).
- The model was used to simulate runoff of two common turf fungicides, chlorothalonil (Daconil) and iprodione (Chipco 26019) from creeping bentgrass fairways in Boston, Philadelphia, and Rochester. These simulations allowed researchers to estimate quantities of these pesticides that could reach nearby surface waters thus enabling them to environmental risk to two species, rainbow trout and *Daphnia magna* (water flea).

Turf professionals recognize that many chemicals used to control turfgrass pests are harmful to the plants and animals that live in and around the ponds, streams and lakes surrounding golf courses and other grassed areas. Indeed, care is taken to prevent contamination of these waterways from spills, rinse water or inadvertent applications. However, it may be difficult to control pollution from another route: the runoff of pesticides caused by rainstorms and melting snow. When waters from these natural events flow off the turf, they may carry the pesticides with them to surface waters.

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Understanding runoff

The considerable water-holding capacities of the components of turf systems (i.e., verdure, thatch and soil) will limit water runoff from all but the most severe weather events, unless the system is already saturated. Also, the extensive adsorption by turf organic matter tends to bind pesticides on the turf even when water runoff does occur. Nevertheless, the threat of pollution cannot be discounted. Sampling of waters near golf courses has detected many turf pesticides, and it is likely that at least some, if not most, of those chemicals were transported in runoff.

Whether the pollution is large or small, the ultimate concern must be prevention, or at least management to control it. But such management requires information. Which chemicals are most likely to run off? What practices reduce or eliminate runoff? If chemicals do move from turf to waterways, what will their impacts be?

Pollution of surface waters from pesticide runoff can be a result of significant rainfall occurring soon (e.g., less than 24 hours) after the chemical application. Successful turf managers are always cognizant of current and forecasted weather conditions, so in well-managed turf, this may rarely occur. This limits our ability to draw con-

Modeling pesticide runoff can be useful in evaluating the potential for chemicals to migrate to surrounding surface waters from sites of application such as golf course fairways.

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Pesticide	Number of Events	Model	Observed
		Mean Pesticide Runoff (%)	
2,4-D	7	8.3	4.3
Chlorpyrifos	3	2.9	0.5
Diazinon	6	0.3	0.7
Dicamba	7	3.2	3.6
Dithiopyr	18	1.2	0.3
Mecoprop	11	3.7	3.7
Overall Mean		2.9	2.1

Table 1. Comparison of observed and modeled pesticide runoff for six pesticides.

clusions regarding the extent of runoff from field experiments. Although it is possible to experimentally create the extreme precipitation conditions that produce significant pesticide runoff, the effort required cannot account for all turf chemicals or the broad range of weather and site conditions encountered in the field.

Computer modeling

Environmental engineers rely on mathematical models, or equations, to predict water pollution. The models are usually referred to as "fate

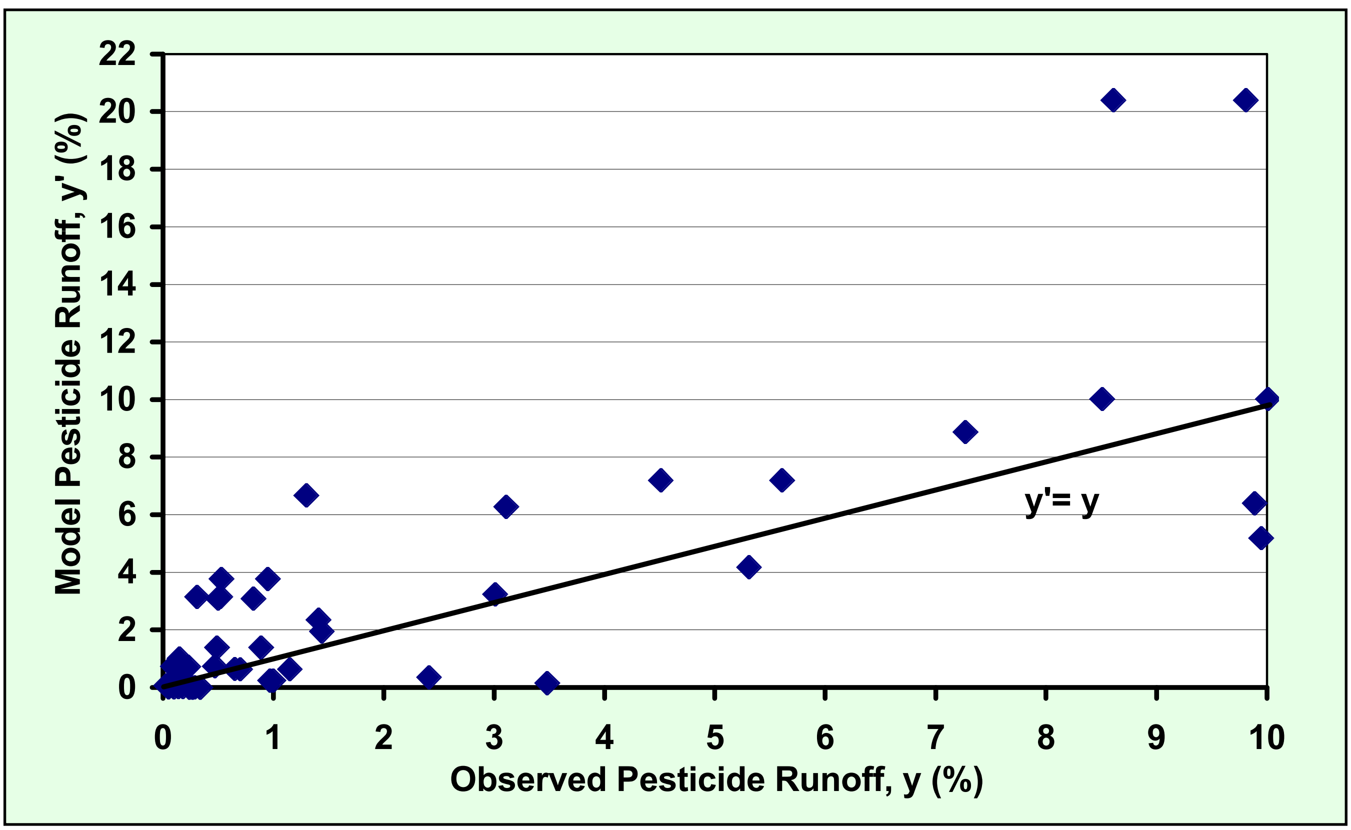

Figure 1. Comparison of model pesticide runoff estimates with observed values.

and transport" models because they predict the movement and ultimate deposition of water contaminants.

Until recently, no fate and transport models were available specifically for turf. Rather, researchers and consultants resorted to models that were developed for agricultural crops. It was reasoned that the interaction of chemicals, plants, and soils are similar for turf and field crops. However, when pesticide runoff values were calculated from these models for turf areas and compared with actual measurements taken in the field, large discrepancies became apparent. These discrepancies arose because of fundamental differences in the ways that plants and soil influence pesticide behavior in crops and turf.

Agricultural models typically view chemical runoff losses as originating in the surface layer of soils. Chemicals are washed off crop foliage and added to the soil surface where they subsequently contribute to runoff. However, given the dense vegetation of turfgrass foliage and thatch, most surface losses from turf occur directly from vegetation. Runoff losses from turf soils play a relatively minor role. From the point of view of pesticide behavior, field crops are soil systems and turf is a plant system.

Development of a pesticide runoff model for turf

The United States Golf Association has sponsored research on runoff modeling for several years at Cornell University. Early on, we thought that agricultural models could be adapted for turfgrass systems, but this approach was eventually abandoned for the development of a new model based on the unique charac-teristics of turf. This model is called TurfPQ and is available (including the user's manual) by request (dah13@cornell.edu).

As the model was developed, it was important that it be practical and function as a

	Boston			Philadelphia			Rochester		
Period	Runoff (mm)	Pesticide (%)	Concentration (mg L^{-1})	Runoff (mm)	Pesticide (%)	Concentration (mg L^{-1})	Runoff (mm)	Pesticide (%)	Concentration (mg L^{-1})
Means									
January	11.5	0.018	0.217	5.5	0.009	0.236	3.8	0.006	0.221
February	14.3	0.015	0.145	6.3	0.007	0.145	6.6	0.007	0.150
March	13.3	0.009	0.094	6.4	0.004	0.087	10.6	0.007	0.096
April	2.7	0.001	0.059	2.6	0.001	0.056	1.9	0.001	0.065
May	1.1	0.002	0.226	1.5	0.002	0.164	0.1	<0.001	0.290
June	1.2	0.005	0.552	5.6	0.024	0.588	0.7	0.003	0.524
July	1.8	0.011	0.817	7.1	0.040	0.774	1.3	0.007	0.788
August	1.6	0.011	0.922	3.9	0.025	0.897	1.4	0.009	0.902
September	1.4	0.010	0.978	2.6	0.018	0.992	0.2	0.002	1.054
October	1.4	0.009	0.894	1.6	0.010	0.868	0.4	0.003	0.907
November	6.3	0.025	0.548	5.4	0.022	0.564	1.2	0.005	0.529
December	11.4	0.030	0.366	6.7	0.017	0.350	2.6	0.007	0.361
Year	67.9	0.145	0.296	55.1	0.179	0.450	30.9	0.057	0.256
Events									
1 in 10 yr	23.9	0.104	0.605	19.3	0.148	1.066	16.5	0.045	0.376
1 in 20 yr	29.1	0.186	0.884	33.1	0.203	0.850	10.7	0.074	0.958

LC_{50} (mg L^{-1}): Rainbow trout - 0.047; *Daphnia magna* - 0.07

Table 2. Estimated chlorothalonil runoff loads and concentrations in runoff from creeping bentgrass fairways in Boston, Philadelphia, and Rochester using TurfPQ model.

	Boston			Philadelphia			Rochester		
Period	Runoff (mm)	Pesticide (%)	Concentration (mg L^{-1})	Runoff (mm)	Pesticide (%)	Concentration (mg L^{-1})	Runoff (mm)	Pesticide (%)	Concentration (mg L^{-1})
Means									
January	11.5	0.049	0.078	5.5	0.027	0.090	3.8	0.021	0.100
February	14.3	0.037	0.047	6.3	0.017	0.050	6.6	0.022	0.062
March	13.3	0.020	0.028	6.4	0.009	0.026	10.6	0.022	0.037
April	2.7	0.002	0.015	2.6	0.002	0.015	1.9	0.002	0.024
May	1.1	0.001	0.009	1.5	0.001	0.010	<0.1	<0.001	0.012
June	1.2	0.029	0.462	5.6	0.159	0.520	0.7	0.016	0.414
July	1.8	0.091	0.913	7.1	0.328	0.842	1.3	0.065	0.908
August	1.6	0.094	1.070	3.6	0.217	1.029	1.4	0.081	1.041
September	1.4	0.058	0.740	2.6	0.100	0.717	0.2	0.010	0.740
October	1.4	0.034	0.431	1.6	0.035	0.395	0.4	0.010	0.443
November	6.3	0.081	0.234	5.4	0.070	0.237	1.2	0.017	0.253
December	11.4	0.090	0.145	6.7	0.050	0.135	2.6	0.024	0.165
Year	67.9	0.586	0.158	55.1	1.015	0.337	30.9	0.290	0.172
Events									
1 in 10 yr	60.9	0.629	0.189	21.3	1.090	0.936	6.9	0.345	0.909
1 in 20 yr	11.7	0.752	1.171	43.8	1.668	0.696	10.7	0.616	1.048

LC_{50} (mg L^{-1}): Rainbow trout - 4.1; *Daphnia magna* - 0.25

Table 3. Estimated iprodione runoff loads and concentrations in runoff from creeping bentgrass fairways in Boston, Philadelphia, and Rochester using TurfPQ model.

credible tool for turf professionals and consultants. This meant that the input data required for the model is readily available, and software should be easy to run on desktop computers. It also meant that the model would be subjected to extensive field testing to determine if its predictions were accurate.

Field testing is a critical aspect of model development. A fate and transport model is nothing more than a set of mathematical equations translated into computer code. The equations may or may not accurately reflect reality. Until a model is tested, it is just an elaborate hypothesis. To test the model, field experiments are designed to measure pesticide runoff from turf systems subject to controlled applications of water and chemicals. The fate and transport model is then run with appropriate input parameters corresponding to the experiments. The runoff values predicted by the model are compared with the observed, or measured pesticide runoff. If the measured values and the predicted values are relatively close, the model can be accepted as a reasonable tool for predicting pesticide runoff.

Testing the model

TurfPQ was tested using published plot runoff data for 52 runoff events in four states involving three soil groups, four different turfgrasses (bermudagrass, creeping bentgrass, tall fescue and perennial ryegrass) and six pesticides. The outcome of this testing is shown in Figure 1, which compares observations and model predictions. Each data point in the figure corresponds to the model prediction and observed pesticide runoff for a single runoff event. Points, or events, lying on the line y' = y represent perfect model performance; model values are exactly equal to observations. Points above the line indicate overprediction by the model; predicted pesticide runoff is higher than the measured value. Events lying under the line are under-predicted.

Most of the events are relatively close to the line, indicating that TurfPQ predictions are fairly close to the actual measured pesticide runoff. There are exceptions, however. For two of the events, the model predicts pesticide runoff of approximately 20% of that applied, but the actual values were closer to 10%. The comparisons are also summarized by pesticide in Table 1. On average, model results are about 50% larger than the measured values.

Use of TurfPQ for risk analysis of pesticides on fairways

The value of a model such as TurfPQ is that it can rapidly evaluate or simulate the effects of widely differing chemicals, weather, management and site conditions. When run with extensive multi-year weather records, simulations can provide long-term estimates of pesticide runoff.

As an example, we used TurfPQ to simulate runoff of two common turf fungicides, chlorothalonil (Daconil) and iprodione (Chipco 26019) from creeping bentgrass fairways in Boston, Philadelphia, and Rochester (Tables 2 and 3). One-hundred-year records of daily precipitation and temperature were produced for each of these locations. The simulations produced 100-year daily records of three variables: water runoff, pesticide runoff, and pesticide concentration in runoff.

These simulations allowed us to estimate quantities of pesticide that could reach nearby surface waters. Comparing those predicted runoff values with the LC_{50} for *Daphnia magna* (water flea) and rainbow trout, gives an indication of the environmental risk posed to surrounding surface waters. LC_{50} is the chemical concentration which kills 50% of the test species over a 48- or 96-hour period.

Even allowing for the fact that TurfPQ predictions tend to be 50% larger than actual values, it is hard to escape the conclusions that the current use of chlorothalonil and iprodione may pose significant water quality risks. However, it may be possible to mitigate these risks by modifying application schedules and amounts. One of the virtues of models such as TurfPQ is that such modifications can be easily evaluated.

A new era in environmental assessment of turf chemicals

Concerns for the environmental impacts of turf chemicals seem to have gone through three phases: problem awareness, understanding, and solution. During the first phase, which largely overlapped the 1980s, we became aware of the potential for water pollution from the extensive use of turf chemicals. Reactions from environmental groups and turf managers were sometimes extreme, and it is probably safe to say that many of the concerns were based more on emotion than fact.

During the 1990s, a great deal of scientific research on the issue was published, and the results of experiments and monitoring brought us to a much better understanding of problem. We are now in the third, or problem-solving phase. With mathematical models, such as TurfPQ to evaluate potential for pesticide runoff, we now have the tools to evaluate alternative chemicals and management strategies to help safeguard the environment.

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