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Pesticide Runoff Model for Turfgrass: Development, Testing and Application
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2000 Executive Summary

Goals

- *Adapt a previously developed pesticide runoff model to turfgrass conditions and test the accuracy of model predictions by comparisons with data from field experiments.*
- *Use the model to estimate pesticide runoff probabilities (return periods) for a range of chemicals and locations in the eastern U.S.*

Progress

TurfPQ model is a pesticide runoff model developed exclusively for turf. It has a runoff component based on the U.S. Soil Conservation Service Curve Number Equation, as described by Haith and Andre (2000). The chemical model is a mass balance of the pesticide in the turf foliage and thatch. The model was tested using published plot runoff data for 52 runoff events in four states, three soil hydrologic groups, and four different turfgrasses (Bermudagrass, bentgrass, tall fescue and ryegrass).

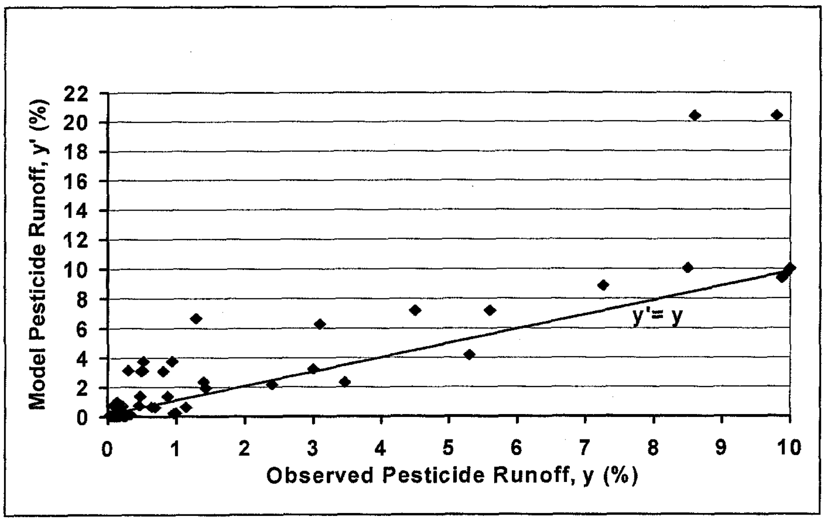

Figure 1. Comparison of Model Pesticide Runoff Estimates with Observed Values.

Estimated and observed pesticide runoff (y′ and y, respectively) for each event are compared in Figure 1. Although events generally lie above the line y′ = y, most are relatively close to the line. Mean predicted pesticide runoff is 3.2% of application, compared with an observed mean of 2.1%. TurfPQ captured the dynamics of the pesticide runoff events well with $R^2 = 0.76$. To the best of our knowledge, TurfPQ is the first pesticide runoff model developed exclusively for turf. Other models such as EPIC, GLEAMS and OPUS which have been applied to turf were originally developed for agricultural crops, and are much more data intensive. Although comparisons of accuracy are difficult because TurfPQ is the only model to have been tested with independent data sets for multiple chemicals and sites, it appears that the accuracy of TurfPQ meets or exceeds that of the more complex models.

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GOALS

- *Adapt a previously developed pesticide runoff model to turfgrass conditions and test the accuracy of model predictions by comparisons with data from field experiments.*
- *Use the model to estimate pesticide runoff probabilities (return periods) for a range of chemicals and locations in the eastern U.S.*

2000 PROGRESS

The dense vegetation of turfgrass and thatch minimizes possibilities for pesticide runoff. High water retention and infiltration constrain runoff opportunities and extensive pesticide adsorption by surface organic matter reduce chemical mobility. However, conditions such as thin stands, repeated irrigation applications and/or extreme hydrologic events can produce significant pesticide losses. Mathematical models can be used to simulate these conditions, and provided the simulations include sufficiently long weather records, return periods of pesticide runoff may be obtained. The approach is plausible only if a model can be shown to be a reasonable description of the pesticide runoff process, as confirmed by testing with field data. In this fashion, the model becomes a means of efficiently extrapolating the results of field experiments.

Research during the past year has finalized the development and testing of TurfPQ, a model for estimating pesticide runoff from turf. Previous attempts to estimate pesticide runoff from turf were based on models which were originally developed for agricultural applications (Rosenthal & Hipp, 1993; Wauchope *et al.* , 1990; Ma *et al.* ,1999; Durborow *et al.*, 2000). These models are basically soil chemistry models, and fail to capture the dominant influence of vegetation (foliage plus thatch) on pesticide runoff from turf.

<u>Model Description</u>

TurfPQ model is a pesticide runoff model developed exclusively for turf. It has a runoff component based on the U.S. Soil Conservation Service Curve Number Equation, as described by Haith and Andre (2000). The chemical model is a mass balance of the pesticide in the turf foliage and thatch. Once the pesticide is leached into the soil it is assumed to be unavailable for runoff. Sediment losses from turf are relatively small, and it is thus assumed that all pesticide runoff is in the dissolved form. The general mass balance is

$$P_{t+1} = (P_t + \Delta P_t - PQ_t - PL_t)\, e^{-\alpha} \qquad (1)$$

in which P_t = turf pesticide at the beginning of day t, ΔP_t = pesticide application on day t, PQ_t = pesticide in runoff on day t, and PL_t = pesticide leached into the soil by wash off and infiltration on day t (all in g/ha). The model presumes 1st order, or exponential decay of the pesticide with rate α (day^{-1}), given by $\alpha = - 0.693 / \ln(\tau_{1/2})$, where $\tau_{1/2}$ is the decay half life (d).

During a precipitation (rain or irrigation) event, the available pesticide $P_t^* = P_t + \Delta P_t$ is partitioned between dissolved and adsorbed forms. This partitioning is conceptualized as a two-stage process, corresponding to the division of precipitation first into infiltration ($R_t - Q_t$) and subsequently into runoff (Q_t). During the first, or infiltration stage of the event, we have

$$P_t^* = A_{1t} + D_{1t} \quad (2)$$

where A_{1t} = pesticide adsorbed to vegetation (foliage and thatch) and D_{1t} = pesticide dissolved in infiltration during stage one (g/ha).

Assuming a linear equilibrium partitioning,

$$a = K\, d \quad (3)$$

with a = adsorbed concentration (μg/g), d = dissolved concentration (μg/cm^3), and K = partition coefficient (cm^3/g), equations 2 and 3 can be combined as

$$P_t^* = 0.001\ a\, M + 10\ d\, (R_t - Q_t) = d\ \ [0.001\ K\, M + 10\ (R_t - Q_t)] \quad (4)$$

where M = vegetation dry mass (kg/ha). Solving equation 4 for d, we can obtain the pesticide leached from the turf by infiltration:

$$PL_t = D_{1t} = 10\ d\, (R_t - Q_t) = \frac{10\ (R_t - Q_t)\ P_t^*}{0.001\ K\, M + 10\ (R_t - Q_t)} \quad (5)$$

Partition coefficients are generally determined from K_{oc}, the organic carbon partition coefficient, and equation 5 is more conveniently written as

$$PL_t = D_{1t} = \frac{P_t^*}{[0.0001\ K_{oc}\ OC\ /\ (R_t - Q_t)] + 1} \quad (6)$$

in which OC = organic carbon in vegetation dry matter (kg/ha).

The remaining pesticide $P_t^* - D_{1t}$ is assumed to reach an equilibrium with runoff water,

$$P_t^* - D_{1t} = A_{2t} + D_{2t} \quad (7)$$

where A_{2t} = pesticide adsorbed to turf vegetation and D_{2t} = pesticide dissolved in runoff (g/ha). Through a process similar to equations 4-7, we obtain the pesticide in runoff,

$$PQ_t = D_{2t} = \frac{P_t^* - D_{1t}}{(0.0001\ K_{oc}\ OC\ /\ Q_t) + 1} \quad (8)$$

The TurfPQ model is a very simplified description of pesticide behavior in turf. The division of event water first into infiltration (R_t - Q_t) and subsequently runoff (Q_t) approximates a more complex process in which runoff is minimal early in the event and gradually becomes more significant in the later stages. The model neglects adsorption kinetics, volatilization, pesticide incorporated into plant tissue and dissolved pesticide in water remaining on vegetation following the precipitation event. As a result, TurfPQ should generally over-estimate pesticide runoff losses.

Model Testing

Any single set of plots provides a very limited basis for model testing. However, in the last several years pesticide runoff data from a number of different sites have been published, including Georgia (Smith & Bridges, 1996; Hong & Smith,1997), Kentucky (Evans *et al.*, 1998), Oklahoma (Cole *et al.*, 1997), and Pennsylvania (Watschke, *et al.* ,2000). These data provide a rich variety of information for model testing, including 52 runoff events in four states, three soil hydrologic groups, and four different turfgrasses (Bermudagrass, bentgrass, tall fescue and ryegrass).

Estimated and observed pesticide runoff (y′ and y, respectively) for each event are compared in Figure 1. Although events generally lie above the line y′ = y, most are relatively close to the line. The significant exceptions are two of the largest events, which are over-estimated by more that 10% of pesticide application. Mean predicted pesticide runoff is 3.2% of application, compared with an observed mean of 2.1%. TurfPQ captured the dynamics of the pesticide runoff events well with $R^2 = 0.76$.

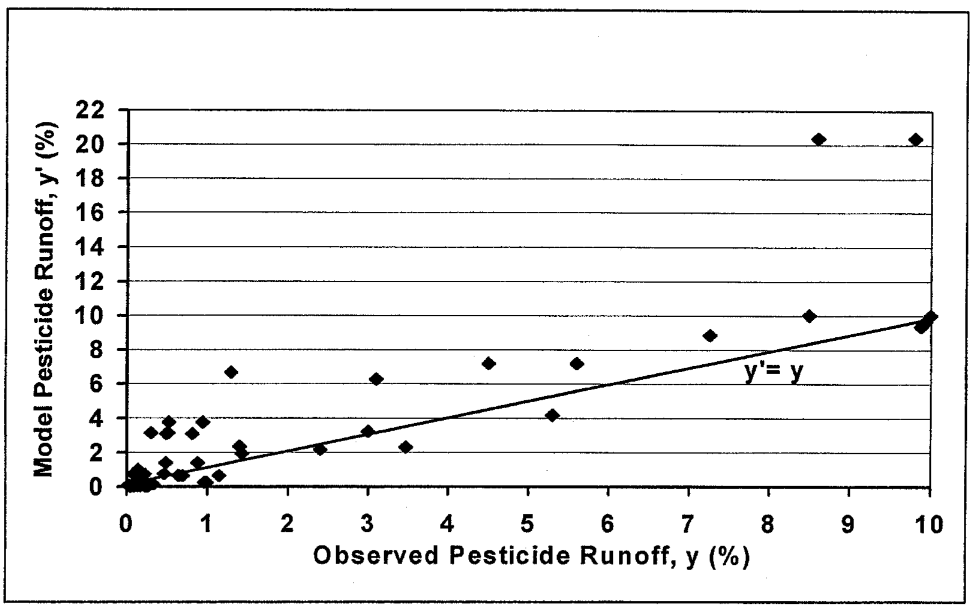

Figure 1. Comparison of Model Pesticide Runoff Estimates with Observed Values.

Table 1 summarizes the testing results by pesticide. With the exception of diazinon, model values are higher than observations for all pesticides. Model results are most accurate for dicamba and mecoprop, which are the least strongly adsorbed chemicals. Conversely, for chlorpyrifos and dithiopyr, the most strongly adsorbed pesticides, model results exceed observations by factors of more than five and three, respectively.

Pesticide	Number of Events	Mean Pesticide Runoff (%) Model	Observed
2,4-D	7	8.28	4.34
Chlorpyrifos	3	2.85	0.53
Diazinon	6	0.30	0.68
Dicamba	7	4.13	3.64
Dithiopyr	18	1.18	0.32
Mecoprop	11	4.17	3.72

Table 1. Comparison of Observed and Modeled Pesticide Runoff for Six Pesticides.

To the best of our knowledge, TurfPQ is the first pesticide runoff model developed exclusively for turf. Other models such as EPIC, GLEAMS and OPUS which have been applied to turf were originally developed for agricultural crops, and are much more data intensive. Although comparisons of accuracy are difficult because TurfPQ is the only model to have been tested with independent data sets for multiple chemicals and sites, it appears that the accuracy of TurfPQ meets or exceeds that of the more complex models.

REMAINING RESEARCH

With the availability of a tested model for pesticide runoff, the final component of the research can be completed. TurfPQ will be used to estimate pesticide runoff probabilities (return periods) for eight pesticides (bensulfide, chlorthalonil, iprodione, mancozeb, mecoprop, propiconazole, thiophanate, triademefon and trichlorfon) applied to greens and fairways at 5 locations in the eastern U.S. (Augusta, ME, Bridgeport, CN, Philadelphia, PA, Ithaca, NY and Worcester, MA.).

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