

Pesticides in Urban Environments

Fate and Significance

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Chapter 16

Leaching of Agrichemicals from Suburban Areas

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Groundwater leaching losses from home lawns of the herbicides 2,4-D and dicamba and the nutrient nitrate (NO_3^-) were found to be quite low in a multiple year study using application rates recommended for residential lawn care. Annual geometric mean concentrations of both 2,4-D and dicamba were less than $1 \mu\text{g L}^{-1}$. The annual flow-weighted mean concentration of NO_3^- -N never exceeded 5 mg L^{-1} and was typically less than 2 mg L^{-1} during 5 years of monitoring. When compared to silage corn plots monitored at the same location over the identical time period, home lawns generated approximately 15% of the NO_3^- lost to groundwater when comparable fertilization and irrigation practices were used. Levels of microbial biomass were found to be significantly higher in home lawns than in silage corn plots and were associated with higher rates of herbicide dissipation and potentially with higher rates of N immobilization. Higher rates of these microbial processes and the perennial nature of lawns may contribute to lower leaching losses of N and other agrichemicals from suburban lawns than those reported from many agricultural crops.

Leaching of agrichemicals applied to croplands is the result of the interaction of a number of processes including: 1) plant and microbial activity, which influence dissipation and residence time in the soil; 2) hydrology, particularly the timing and quantity of precipitation, evapotranspiration and the export of percolation water from the root zone; and 3) management of the crop, specifically the coupling of the timing and application rate of agrichemicals with planting and harvest activities. Integrated analysis of these diverse factors requires an ecosystem approach. Ecosystem analysis characterizes the structure, function and interactions between physical, chemical and biological components of a system. Structure refers to the characteristics of the organisms within the ecosystem, while function refers to system inputs, internal transformations and outputs.

Ecosystem analysis is particularly useful for comparing different land uses such as home lawns and silage corn when a number of ecosystem factors that affect agrichemical dynamics are strikingly different (Table I). On home lawns of the northeast United States, turfgrass has a dense, perennial growth form that actively photosynthesizes and transpires throughout much of the year. Whereas cool season turfgrass is biologically active from late March through early November in Rhode Island, row crops, such as silage corn, are planted in June and harvested in September. Even relative to deciduous forests of New England, turfgrass has a longer period of biological activity, often an additional 4-6 weeks in the spring and fall. Soil disturbance is a routine event for row crop agriculture usually occurring at least annually, while home lawns generally have minimal physical disturbance. With row crop agriculture the soil can be bare for the majority of the year which increases infiltration and percolation, while diminishing plant related activity within the soil.

In addition to the differences between turf and row crop ecosystems listed above, the frequency and application rate of agrichemicals can be quite different between turfgrass on home lawns and row crops such as silage corn. While annual applications of a given chemical may be comparable, row crops typically receive one large application, often within a 2-4 week period around planting, while on home lawns chemical inputs are often split into 3-5 small applications. Multiple applications to actively growing turfgrass lowers the intensity of input and can match application rates to changing requirements that occur throughout the long growing season. In most row crops the time surrounding planting and chemical application of fertilizer is the period with the highest potential to generate offsite losses of agrichemicals due to low plant uptake and high soil moisture at these times.

While the importance of plants as modulators of agrichemical dynamics are relatively well studied, the importance of microbial processes has received less attention. Microbial populations can take up or "immobilize" significant quantities of fertilizer nutrients, and are responsible for the degradation of many pesticides. There have been very few comparative studies of microbial processes in different rural and suburban land use types.

Conceptually, ecosystem analysis suggests that the fate and transport of agrichemicals in turfgrass managed as home lawns should differ from row crops. The purpose of this paper is to compare leaching losses of nitrate-nitrogen (NO_3^- -N), 2,4-D and dicamba from home lawns and silage corn and to relate those losses to ecosystem properties.

This chapter incorporates the results of several field studies conducted on the same set of research plots at the University of Rhode Island, including studies on leaching of NO_3^- -N, 2,4-D and dicamba (1, 2), and a study on microbial processes and dissipation of 2,4-D and dicamba (3).

METHODS

Site Description. All studies were conducted on field plots located on well drained soils characterized by a silt loam or sandy loam mantle overlying a 2C horizon of highly permeable sands and gravels. The NO_3^- -N leaching studies reported here were conducted from January 1987 to December 1988 on: home lawns, silage corn, mature forest lands and a septic system leaching field. Table II describes each of the treatments. The herbicide leaching study was conducted in 1985 and 1986 and was restricted to the home lawn plots. The herbicides 2,4-D and dicamba were applied in a manufactured mixture of TRIMEC (marketed by PPI Gordon, Kansas City, MO) in the amine salt form. The

herbicide was applied three times per year (April, June, September) at a rate of 1.1 kg ha⁻¹ and 0.11 kg ha⁻¹ per application of 2,4-D and dicamba, respectively. Annual precipitation ranged from 109 cm in 1986 to 127 cm in 1988.

As described in Gold et al. (1), soil water percolate from the home lawns, silage corn and forest treatments was collected with ceramic lysimeter plates 27.4 cm in diameter connected to subsurface PVC vacuum reservoirs. All plates were located below the root zone at the point where an abrupt texture change between sandy/silt loam and gravelly coarse sand occurred. The plates were placed at a depth of 0.2 m in the home lawns and 0.5 m in the silage corn and forest treatments. A suction of 0.01 MPa was imposed on each lysimeter to simulate field capacity. For a given precipitation event, samples were removed from the reservoirs at intervals of 24 to 48 hours until drainage ceased, then composited and stored at 4°C pending analysis.

Septic system leachate was monitored with ceramic suction cup lysimeters (5 cm diameter) located 1 m below the bottom of the constructed leaching trench. Septic system leachate was monitored monthly. A minimum of 3 lysimeters were monitored for all leaching studies.

The dissipation study of 2,4-D and dicamba was conducted in August, 1989 on the silage corn and home lawn treatments. At the inception of the study the herbicides in a TRIMEC mixture were applied at a rate of 1.1 and 0.11 kg ha⁻¹ of 2,4-D and dicamba, respectively, to 3 replicate 1 m² plots within each treatment. Soil samples were collected at 5, 10, 20, 40 and 80 days following herbicide application. Soils were sampled at three depths: 0-5 cm, 5-25 cm, and 25-50 cm. Herbicide residues were extracted from the soil samples and concentrations determined using a high performance liquid chromatograph following the methods of Arjmand et al. (4) and Hardy (personal communication).

Soil microbial biomass nitrogen of the upper 50 cm of soil was determined on the silage corn and home lawn treatments on April, 1988, December 1988, and 5 separate dates during August 1989 by the chloroform fumigation-incubation method (5, 6). For the leaching study, NO₃⁻ was analyzed by ion chromatography. For the microbial study, mineral nitrogen was analyzed on an Alpkem RFA 300 Rapid Flow Analyzer using a cadmium reduction method. For the herbicide leaching study lysimeter samples were extracted with diethyl ether (7), esterified with diazomethane followed by solvent exchange with hexane (8), and then analyzed with a Shimadzu gas chromatograph equipped with a ⁶³Ni electron capture detector.

RESULTS

Nitrate Leaching Study. The concentrations of NO₃⁻-N in leachate during the two year study are displayed in Figure 1. Septic system leachate consistently had the highest concentrations of NO₃⁻-N with a two-year mean of 59 mg L⁻¹ while the forest treatment generated leachate concentrations near the detection limit of 0.2 mg L⁻¹. Although the annual rate of N fertilization was comparable for the home lawn and silage corn treatments, concentrations of NO₃⁻-N in leachate from home lawns were markedly lower than from silage corn. In over 60 leaching events during the two year study, leachate from the turfgrass had ranged from 5.0 mg L⁻¹ NO₃⁻-N to less than 0.2 mg L⁻¹. During extended periods each year, leachate concentrations from the fertilized home lawns were

comparable to those from the forest. In contrast, the silage corn plots had NO_3^- -N leachate concentrations from 3-50 mg L^{-1} . Leachate concentrations from the silage corn treatments followed a seasonal pattern, rising dramatically each fall following harvest and lowering by the early spring.

Herbicide Leaching Study. Concentrations of 2,4-D and dicamba in leachate from the root zone of the home lawn treatments were quite low. As shown in Table III, 98% of all leachate samples had concentrations of $< 5 \mu\text{g L}^{-1}$ for both 2,4-D and dicamba. Although 2,4-D was applied at 10 times the rate of dicamba, the geometric mean concentration of 2,4-D was roughly twice that for dicamba, suggesting more rapid dissipation of 2,4-D. Both these herbicides have been found to leach in sandy soils and in soils low in organic matter (9). The home lawn treatment plots had sandy loam soils (85% sand) with relatively low organic matter, yet generated little herbicide in leachate from the rootzone.

Dissipation Studies. The home lawn treatments showed more rapid dissipation of 2,4-D and dicamba than the silage corn plots (Figures 2 and 3). Differences in dissipation of 2,4-D were most pronounced; after 5 days 4 fold greater residues of 2,4-D remained in soil from the silage corn soil versus the home lawn treatment. In both treatments, no residues of either herbicide were detected 20 days following application. A large rainfall event ($> 5 \text{ cm}$) occurred on day 19.

Microbial Biomass N. Soil microbial biomass N was consistently higher in the home lawn treatments than in the silage corn treatments (Figure 4). In the silage corn treatment there was considerable temporal variability, with soil microbial biomass N at a low in December, roughly 10 weeks after harvest, and rising to a high in April, after more than 6 months without disturbance. During the August 1989 herbicide dissipation study, soil microbial biomass N was nearly twice as high in the home lawn treatments than the silage corn treatments.

DISCUSSION

The striking contrasts in NO_3^- -N leachate concentration and the dissipation rate of 2,4-D and dicamba between home lawns and silage corn are the product of the major differences in ecosystem properties between these land uses. The extended period of plant growth and the small, frequent applications of fertilizer to the turfgrass maximized the opportunity for grasses to absorb applied N. The silage corn treatment had a substantial rise in NO_3^- -N leaching and a decline in soil microbial biomass N in the fall, following harvest. At harvest, silage corn roots undergo rapid decomposition and mineralization. Without plant uptake, a rapid increase in leachable inorganic N occurs. Finally, the frequent disturbance by tillage, and the removal of plant residues by harvest reduces the level of soil microbial biomass in silage corn ecosystems relative to home lawns. High levels of soil microbial biomass facilitate storage of N in non-leachable organic forms and dissipation of organic compounds such as 2,4-D and dicamba.

Table I. Ecosystem Comparisons: Home Lawns versus Silage Corn

Home Lawn	Silage Corn
Perennial	Annual
Dense permanent cover with organic thatch layer	Extended periods of bare ground
Active growth at >5°C (in R.I. late March to early November)	Active growth June 1 - September 15
Soil undisturbed for years	Mechanical disturbance of soil at least annually
Agrichemicals applied incrementally throughout season	Most agrichemicals applied around planting

Table II. Description of Treatments in Leaching Studies

Treatment	Nitrogen Source	Application Rate kg N ha ⁻¹ y ⁻¹	Time of Application
Home lawns (established 1981, thatch not removed, irrigated only to avoid drought stress)	50% Urea plus 50% UREAFORM (liquid)	344	Split over 5 applications (J, J, A, S, N)
Silage corn (no cover crop; plowed each spring; continuous corn since 1982)	Urea	202	June (34 kg ha ⁻¹) July (168 kg ha ⁻¹)
Forest (mixed oak-pine 80-120 years old)	Natural deposition		
Septic system (3 person home; occupied 1985)	Household wastewater		Continuous

Table III. Frequency Distribution of 2,4-D and dicamba concentrations ($\mu\text{g L}^{-1}$) in soil water leachate from home lawns. Data from Gold et al. 1988 (1)

Herbicide	< 1.0	1.0 - 5.0	5.0 - 10.0	> 10.0
2,4-D (n=47)	72%	26%	2%	0%
Dicamba (n=44)	95%	3%	0%	2%

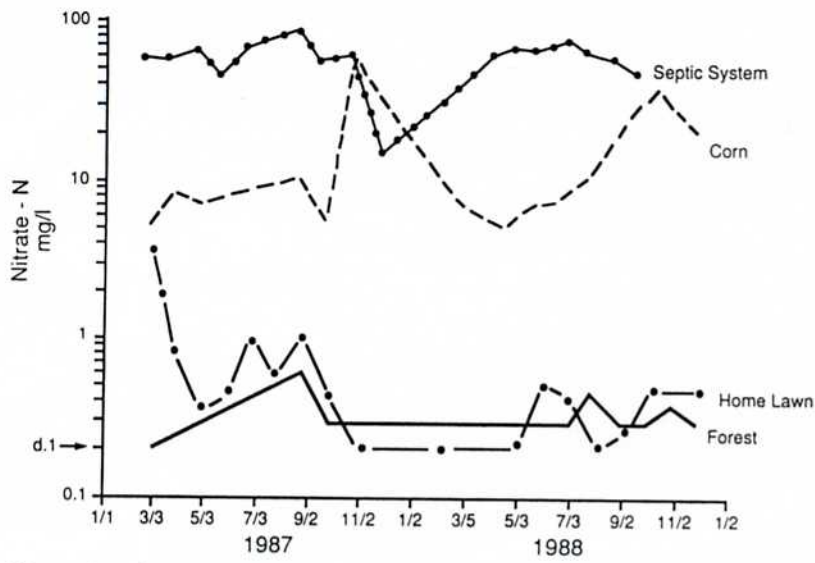


Figure 1: NO₃-N concentrations in groundwater leachate from different landuses in Rhode Island. Data from Gold et al. (2).

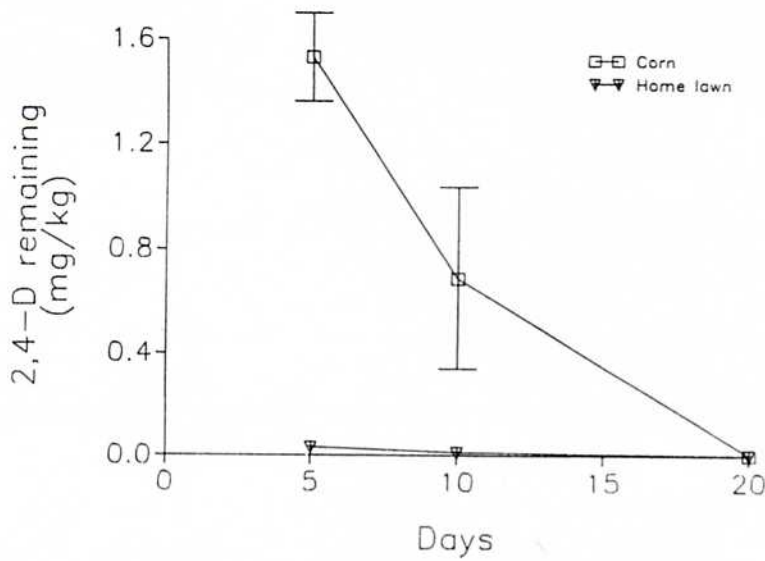


Figure 2: 2,4-D remaining in soil in field dissipation study. Data from Groffman and Voos (3). Values are mean ± standard error.

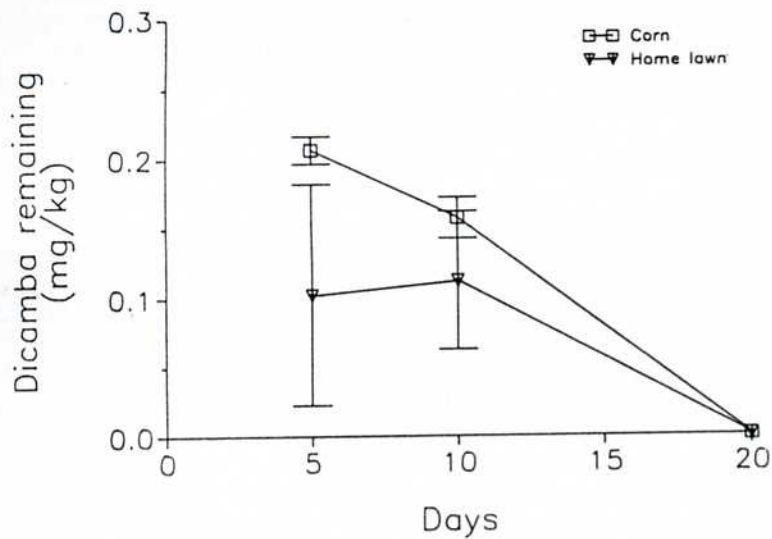


Figure 3: Dicamba remaining in soil in field dissipation study. Data from Groffman and Voos (3). Values are mean \pm standard error.

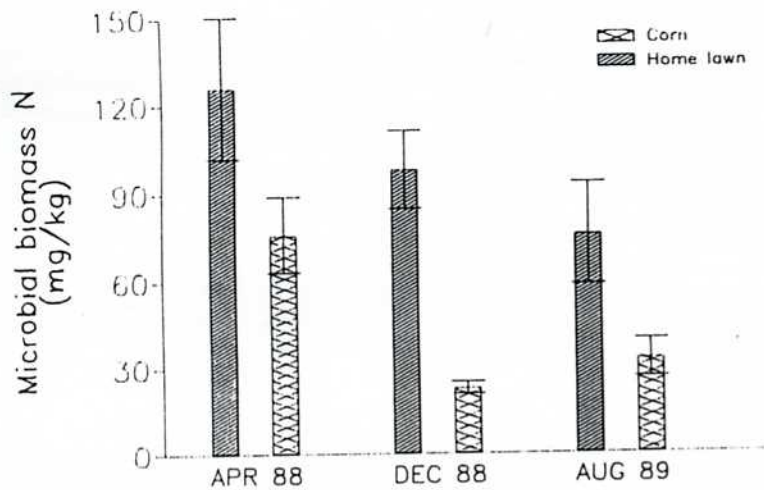


Figure 4: Soil microbial biomass N in corn and home lawn soils. Values are mean \pm standard error.

Septic system leachfields are major contributors of nitrogen to groundwater. Within a septic system leachfield, nitrogen-rich wastewater is introduced to the soil below the rootzone at extremely high rates per unit area ($\sim 0.2 \text{ kg m}^{-2} \text{ yr}^{-1}$). The large influx of N exceeds the capacity of the microbial pool to efficiently cycle the nitrogen, resulting in substantial percolation losses. Denitrification is not a large sink for N in septic system leachate, due to an absence of available carbon and anaerobic conditions following initial filtration and nitrification within the first 100 cm of the soil.

In suburban developments lacking sewers the extent of NO_3^- -N contamination to groundwater will largely depend on housing density rather than the area of home lawns. At low densities, NO_3^- -N contributions from septic systems will be diluted by percolating water from other permeable land covers such as home lawns or forests. The NO_3^- -N concentrations in leachate from the home lawn treatments are comparable to other studies where urea and urea formaldehyde have been used as the source of N fertilizer; however, much higher concentrations of NO_3^- -N have been found when inorganic forms of N such as NH_4NO_3 are used as fertilizer. Most commercial lawn care companies use a formulation and rate of application similar to that reported in this study, so our estimates may be widely applicable. For the studies reported here, the home lawn plots were carefully managed and had no notable problems with disease, excessive traffic or establishment. In residential situations, agrichemicals may be applied to dead or dormant patches of turf which may have less potential for dissipation and immobilization. In addition, mechanical disturbance of home lawns may result in significant leaching losses of N accumulated in thatch and soil organic fractions.

There is concern that after many years of fertilization, N losses from home lawns may increase. Whether such an increase occurs will depend on where fertilizer N inputs are being stored in the ecosystem. If soil organic N levels are building up, or if high gaseous losses are occurring, then hydrologic losses may not increase for many years. Research on the fate of fertilizer N added to home lawns is continuing.

The results of the leaching and dissipation studies suggest that significant differences exist in the fate of agrichemicals applied to turfgrass managed as home lawns versus silage corn. Many simulation models of the fate of agrichemicals do not account for differences in structure and function between these ecosystems and without calibration of field data, these models may not accurately depict leaching of chemicals from home lawns.

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