

# NITROGEN LEACHING LOSSES FROM CONVENTIONAL- AND NO-TILLAGE CORN

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## ABSTRACT

Equilibrium-tension lysimeters were used to quantify year-round drainage, inorganic nitrogen (N) concentrations, and inorganic N leaching losses from undisturbed Plano silt loam soil (fine-silty, mixed, mesic Typic Argiudoll) of N-fertilized no-tillage and conventionally-tilled chisel plow corn (*Zea mays* L.) agroecosystems for 1996, 1997, and 1998. The chisel plowed corn agroecosystem consistently had greater drainage losses of water from its soil profile than a no-tillage corn agroecosystem over the 3 year period. Both fertilized tillage treatments maintained nitrate-N concentrations above the 10 mg L<sup>-1</sup> safe drinking water standard for the majority of the three growing seasons monitored between 1996 and 1998. Inorganic N leaching losses were nearly the same for both fertilized corn tillage treatments for the first 2 years of this 3 year study. During the third year, inorganic N leaching losses from the fertilized no-tillage corn agroecosystem were greater than inorganic N leaching losses from the fertilized chisel plow corn agroecosystem.

## INTRODUCTION

Accurate quantification of solute leaching losses under field conditions is inherently difficult. Technological advancements in past decades and in recent years have allowed some of the obstacles to measuring water and solute movement through soil, even frozen soil, to be overcome with lysimetry (Prunty and Montgomery, 1991; Cameron et al., 1992; Brye et al., 1999). Bergstrom (1990) acknowledges that lysimetry offers a reasonable method to carry out investigations under field conditions that are subject to actual environmental influences. The use of both tension and tension-less lysimeters has provided a means to quantify solute leaching losses, particularly nitrate-N losses, from mainly fertilized agroecosystems (Tyler and Thomas, 1977; Bergstrom, 1987; Prunty and Montgomery, 1991; Shipitalo and Edwards, 1993; Baker and Timmons, 1994, Martin et al., 1994). However, a need still exists to establish year-round inorganic N leaching losses from common agroecosystems, concentrating on the time between harvest of one crop and planting of the next crop.

The potential magnitude of N leaching loss has been an unknown component of the nitrogen cycle. Martin et al. (1994) recognized the need for nitrate leaching data over annual cycles, not just for growing season lengths of time. Reducing the time period for examining the effects of various management practices to several months associated with a growing season

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seriously limits the inferences that can be drawn about the effects that various management practices may have on solute leaching. In many regions of the United States, especially in the Midwest, crop establishment occurs after one of the wettest periods of the year. Spring thaws of winter snow accumulation have great potential to move solutes deeper into the soil profile, out of reach of any root system that would be produced by the next crop. Depending on the residual soil storage of N, for example, and post-harvest tillage and fertilization practices, a significant quantity of nitrate-N could leach from the system over the winter and during the spring seasons while no crop exists to capture the highly mobile nutrients (Watts and Martin, 1981; Martin et al., 1994).

Determining solute leaching losses requires knowing two quantities: 1) the drainage flux and 2) the solute concentration in the drainage solution. Therefore, the objectives of this study were to measure year-round i) drainage, ii) inorganic nitrogen concentrations, and iii) inorganic nitrogen leaching losses from undisturbed soil of conventional- and no-tillage corn (*Zea mays* L.) agroecosystems using equilibrium-tension lysimeters.

## **MATERIALS AND METHODS**

### **Experimental Site**

Agroecosystem tillage treatments (i.e. conventionally-tilled chisel plow and no-tillage) were established during fall 1994 at the University of Wisconsin-Madison's Arlington Agricultural Research Station (Arlington, WI) on Plano silt loam soil (fine-silty, mixed, mesic Typic Argiudoll) in a randomized complete block experimental design (Brye et al., 1999; Brye et al., 2000). A 105-day relative maturity hybrid corn variety was planted for both tillage treatments and fertilized at 189 kg ha<sup>-1</sup> of N (10 kg N ha<sup>-1</sup> in starter fertilizer and 179 kg N ha<sup>-1</sup> broadcast as pelletized ammonium nitrate (NH<sub>4</sub>NO<sub>3</sub>) to represent optimal N requirements for corn (Kelling et al., 1991)). During spring 1995, the soil organic matter content was 3.2 and 3.4 % for the no-tillage and chisel plow agroecosystems, respectively.

### **Equilibrium-Tension Lysimeters**

Two stainless steel equilibrium-tension lysimeters (ETLs) (0.19 m<sup>2</sup>) were installed at 1.4 m below the soil surface in replicate plots of the fertilized no-tillage treatment and two additional ETLs were installed in replicate plots of the fertilized chisel plow treatment during the summer and fall 1995 (Brye et al., 1999). A portable, regulated vacuum system provided continuous suction to the 0.2 µm stainless steel porous plate of the ETLs (Brye et al., 1999). Heat dissipation sensors were placed immediately above the porous plate of each ETL and in the surrounding bulk soil to continuously monitor the matric potential at the two locations (Reece, 1996; Brye et al., 1999). The regulated vacuum system was adjusted manually several times a week to provide suction that was slightly more negative than the matric potential recorded in the surrounding bulk soil with the heat dissipation sensors (Brye et al., 1999). The purpose was to avoid ponding above and by-pass flow around the porous plate of the lysimeters to recreate as natural a drainage pattern as possible (Brye et al., 1999).

The lysimeters were sampled under vacuum every two weeks between March and

December and once every four weeks during the rest of the year (Brye et al., 1999). The sampling schedule was occasionally modified to accommodate extreme precipitation or melting events (Brye et al., 1999). Leachate was collected from the lysimeter's collection reservoir, which can contain ~ 23 L or ~ 110 mm of water, through a sampling tube that extends from a drain port on the lysimeter to the soil surface (Brye et al., 1999). The first 1 L of leachate was collected into a 1 L high-density polyethylene bottle and was transported back to the laboratory where the leachate volume was measured. Any remaining leachate from the lysimeters, > 1 L, was collected into 4 L high-density polyethylene bottles, leachate volumes were recorded, and the leachate was discarded in the field. Subsample aliquots of the initial 1 L of leachate were filtered through glass fiber filter paper (Whatman G6) and stored at 4° C until chemical analysis could be performed.

### **Chemical Analyses**

Stored subsamples of ETL leachate were analyzed for inorganic N ( $\text{NO}_3^-$ -N and  $\text{NH}_4^+$ -N), by colorimetric determination using a Lachat continuous-flow ion analyzer (Lachat 1993a; Lachat 1993b).

## **RESULTS AND DISCUSSION**

Drainage, inorganic N concentrations, and inorganic N leaching losses have been quantified on a continual basis since the ETLs began functioning during fall 1995. The following results and discussion focus on data collected for three complete annual periods, 1996 through 1998.

### **Drainage**

Annual drainage patterns for 1996, 1997, and 1998 are similar for the chisel plow and no-tillage agroecosystems (Fig. 1). Generally, drainage occurred between January and the end of June for all 3 years as winter snow melts and spring rains supply excess water to the soil (Brye et al., 2000). Drainage from the chisel plowed agroecosystem was consistently larger than drainage from the no-tillage agroecosystem. Deviations in drainage between tillage treatments began during the winter through frozen soil for all 3 years. In June 1996, an intense rainfall event delivered over 100 mm of water in 2 days to the agroecosystems causing the single largest drainage flux measured for either tillage treatment during the 3 years (Fig. 1; day of year 169 to 171) (Brye et al., 2000). This event suggests that preferential or macropore water flow can occur during the growing season in a fine-textured soil as a result of sporadic, intense rainfall events. Table 1 summarizes annual precipitation and drainage for 1996, 1997, and 1998 for the no-tillage and chisel plow agroecosystems.

**Table 1.** Summary of annual precipitation, drainage, and inorganic nitrogen (N) leaching losses for 1996, 1997, and 1998 for fertilized no-tillage and chisel plow corn agroecosystems.

Year/Ecosystem	Precipitation	Drainage	Inorganic N Leached	Nitrate Fraction of Inorganic N Leached
<b>1996</b>	———— mm ————		– kg ha <sup>-1</sup> –	
No-Tillage	744	262 (51) <sup>†</sup>	63.7 (15)	0.99
Chisel Plow	744	351 (32)	63.1 (15)	0.98
<b>1997</b>				
No-Tillage	616	271 (45)	32.1 (5.5)	0.95
Chisel Plow	616	411 (83)	35.0 (8.7)	0.96
<b>1998</b>				
No-Tillage	981	424 (3.2)	103 (52)	0.99
Chisel Plow	981	593 (86)	76.3 (19)	0.99

<sup>†</sup> Standard errors are provided in parentheses.

### Inorganic Nitrogen Concentrations

Nitrate-N concentrations in leachate solutions were generally in excess of the 10 mg L<sup>-1</sup> safe drinking water standard during the 3 growing seasons for both agroecosystems (Fig. 2). Ammonium-N concentrations were generally very low, < 1 mg L<sup>-1</sup>. Peak nitrate-N concentrations below the rooting zone of the corn crops occurred prior to July for all 3 years, 43.6 and 31.3 mg L<sup>-1</sup> in 1996, 16.1 and 15.7 mg L<sup>-1</sup> in 1997, and 32.8 and 17.4 mg L<sup>-1</sup> in 1998 for the fertilized no-tillage and chisel plow corn agroecosystems, respectively. Nitrate-N concentrations in leachate solutions collected from equilibrium-tension lysimeters under the fertilized no-tillage corn agroecosystem were generally higher than nitrate-N concentrations under the fertilized chisel plow corn agroecosystem.

### Inorganic Nitrogen Leaching

The combination of knowing the drainage flux and solute concentrations in leachate solutions allows leaching losses to be quantified. Annual inorganic nitrogen, the sum of nitrate- and ammonium-N, leaching losses are plotted in figure 3 for the fertilized no-tillage and chisel plow corn agroecosystems for 1996, 1997, and 1998. With slightly higher nitrate-N concentrations and less drainage in the fertilized no-tillage agroecosystem compared to the fertilized chisel plow agroecosystem, annual inorganic N leaching losses are nearly the same for both tillage treatments during 1996 and 1997. The intense rainfall event that occurred during June 1996, which produced a large drainage flux, produced an equally large loss of inorganic nitrogen. This single event, which occurred approximately 6 weeks after fertilization, removed 51

kg ha<sup>-1</sup> of inorganic N due to leaching from each of the fertilized corn agroecosystems (Fig. 3).

The pattern of inorganic N leaching losses was different in 1998 compared to the two previous years. Fertilized no-tillage agroecosystem leaching losses began to deviate from fertilized chisel plow agroecosystems leaching losses before the growing season began, around the end of April. Even though drainage was smaller (Fig. 1) in 1998 for the no-tillage agroecosystem compared to the chisel plow agroecosystem, higher nitrate-N concentrations throughout most of the growing season (Fig. 2) produced greater leaching losses from the fertilized no-tillage agroecosystem compared to the fertilized chisel plow agroecosystem (Fig. 3). Additionally, nitrate-N leaching losses represented  $\geq 95\%$  of the total inorganic N leaching losses quantified with equilibrium-tension lysimeters for 1996, 1997, and 1998 (Table 1). Table 1 also summarizes annual leaching losses for 1996, 1997, and 1998 for both the fertilized no-tillage and chisel plow corn agroecosystems.

## CONCLUSIONS

Drainage between January and June is a significant component of the water balance of agroecosystems in Wisconsin. Tillage (i.e. no-tillage versus conventionally-tilled chisel plow) greatly influences infiltration and drainage through the soil profile. A conventionally-tilled chisel plow corn agroecosystem consistently had greater drainage losses of water from its soil profile than a no-tillage corn agroecosystem over a 3 year period, 1996 through 1998.

Commercial fertilization of field crops supplies additional nutrients for optimal crop production, but also elevates soil solution concentrations of fertilizer-added solutes such as nitrate-N. Nitrate-N concentrations in soil solution at 1.4 m below the soil surface were generally greater under a no-tillage corn agroecosystem compared to a conventionally-tilled chisel plow corn agroecosystem. Both fertilized tillage treatments maintained nitrate-N concentrations above the 10 mg L<sup>-1</sup> safe drinking water standard for the majority of three growing seasons monitored between 1996 and 1998.

Since solute leaching losses are confined to occur during periods when drainage is occurring (i.e. January through June), the months early in the growing season (i.e. April, May, and June) are time periods vulnerable to potential significant inorganic N leaching losses. Inorganic N leaching losses were nearly the same for both fertilized corn tillage treatments for the first 2 years of this 3 year study. During the third year, inorganic N leaching losses from the fertilized no-tillage corn agroecosystem were greater than inorganic N leaching losses from the fertilized chisel plow corn agroecosystem.

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