Northern New York
Agricultural Development Program

FACT SHEET

Nitrate Leaching as Affected by Manure Application Timing and Soil Type

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Why Study the Factors Affecting Nitrate Leaching?

Crop production is affected by factors that cannot be controlled, e.g., soil type, and by factors that can be managed, such as cropping practices.

A three-year research project on nitrate leaching conducted at the Cornell Baker Research Farm in Willsboro in Essex County, NY, offers farmers insight into production practices that promote a well-balanced production-stewardship operation.

Introduction

Crop production is affected by some factors that cannot be controlled, e.g., soil type, and by factors that can be managed, such as cropping practices. A team of researchers working at Cornell Baker Research Farm in Willsboro in Essex County in Northern New York undertook a three-year (1997-2000) study to assess how two different soil types and the timing of liquid manure application affects the leaching losses of nitrate (NO_3-N) from farm fields.

Elevated levels of nitrates and nitrites in surface and ground-water can cause degradation of aquatic ecosystems and affect public water systems. These elevated levels of nitrates are often associated with nearby farming operations. Any insight on how farmers can maintain crop quality while reducing field fertilization is welcomed by farmers looking to balance production with good stewardship.

The objective of a three-year study on how nitrate leaching is affected by manure application timing and soil type was to quantify the transport to groundwater of manure-derived and fertilizer N from fields under corn and orchardgrass on clay loam and loamy sand soils as affected by the environmental conditions associated with the timing of manure application.

Past Research:

The researchers working on this study began their work with the following earlier research conclusions in mind:

- highest nitrate-N levels occur with corn crops
- less fertilized crops such as soybeans and wheat show intermediate levels of nitrate leaching
- lowest nitrate-N levels occur with perennial crops, such as alfalfa and grasses

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- the timing of crop water uptake and rooting depths affect leaching levels
- drainage from row crop systems is greater than that from perennial crops by anywhere from 1.1 times greater to 5.3 times greater, primarily as a result of different timing of crop water uptake and rooting depths (Randall et al., 1997)
- Crop type affects leaching levels and the use of perennial crops is preferred when nitrate leaching is a concern
- the timing and method of manure application impacts nitrate leaching in that the urea in manure that is surface applied and not incorporated into the soil will quickly turn to ammonium and ammonia as the manure dries and may then be lost by volatilization (Lauer et al., 1976)
- the urea in manure that is incorporated into the soil converts to ammonium and nitrate that can taken up by a crop or lost to leaching and denitrification.
- the relatively stable organic nitrogen (N) fraction in solid manure mineralizes and as it decays becomes available for plant uptake
- soil, weather, manure composition and crop management practices all affect the rate of N mineralization
- the timing of manure application affects leaching levels
- soil temperatures and precipitation at the time of application, along with crop uptake potential and water percolation have also been shown in past research to be influencing factors on nitrate losses.

Methods:

Sixteen research plots were established on both a Muskellunge clay loam soil and a Stafford loamy fine sand soil at the Cornell Baker Research Farm at Willsboro in 1997. The plots were surrounded by a 0.8-mm/0.03 inch-thick impermeable PVC geomembrane.

Measurement of soil N prior to manure application showed higher residual N levels in the corn plots as compared to the grass plots. Previous studies showed that the clay loam soil had longer periods of soil saturation than the loamy sand soil and have higher N losses to denitrification (Sogbedji et al., 2002a,b), while the loamy sand soil showed higher NO_3-N leaching losses (Sogbedji et al., 2000).

Manure Application on Corn
Manure was applied to the corn plots in early fall (target date: October 1), late fall (target date: November 1), early spring (target date: April 15) and as a split application of half in early spring and half sidedressed in late spring (target date: June 15).

Liquid manure was surface-applied with a Nuhn Industries manure applicator. Manure was applied at a total annual rate of 10,000 gallons/acre for early fall, late fall and early spring applications. The split application was applied as two equal halves of the same rate.

The manure was disc-incorporated twice within three hours of application with the exception of the spring sidedressing that used a four-unit drop hose system with S-tine cultivators between crop rows for immediate incorporation.

The corn was planted in mid-May at a rate of 29,000 seeds per acre. Starter fertilizer was band-applied at a rate of 240 lbs/ac of 20-10-10 in 1998 and 15-15-15 in 1999 and 2000. Supplemental sidedress was applied as a urea ammonium nitrate solution based on soil sample Pre-Sidedress Nitrate Tests each year. No supplemental N fertilizer was applied to plots that received early spring application and late spring sidedress.

Manure Application on Orchardgrass
The orchardgrass plots received surface-applied liquid manure in two equal applications of 5,000 gallons/ac. One set of plots on each soil type received applications in early spring and after the first cut in late spring. A second set of plots received manure after the first cut in late spring and after the third cut in early fall. To meet the crop's large demand for N in the early growth period, these plots received supplemental N fertilizer topdressed as ammonium nitrate in early spring at a rate of 68 lbs/ac.

Four plots received no manure, but were topdressed three times each year - in the early spring (136 lbs/ac) and after the first and second cuts (68 lbs/ac). All grass plots also received 69 lbs/ac in April 1999. Cornell guidelines for pest control and nutrients were followed.

Precipitation
Precipitation levels for the plots included a high point of 426 mm/16.8 in during the winter season of 1997-98 and a low point of 123 mm/4.8 in of rainfall (one-third the normal rainfall) during the very dry 1999 growing season. The 2000 growing season received higher-than-normal precipitation of 396 mm/15.6 in.

The manure was disc-incorporated twice within three hours of application with the exception of the spring sidedressing that used a four-unit drop hose system with S-tine cultivators between crop rows for immediate incorporation.

Seasonal leaching losses were consistently higher for the loamy sand soil than for the clay loam.

Researchers attribute this to the higher hydraulic conductivity and lower retentivity of the loamy sand soil.

Water Sampling
Water samples were collected at least weekly during flow periods and more often following manure applications. The Cornell University Nutrient Analysis Laboratory determined NO_3-N content for each sample.

Corn Yield and Grass Quality Assessment
Researchers annually collected crop yield data for the corn plots in mid-September. Crop water content was tested and yields adjusted accordingly.

Orchardgrass was assessed for the forage quality of test cuts three times each growing season (in mid-May, mid-July and early September of 1998; in mid-June, mid-July and mid-September of 1999; and in mid-June and mid-July of 2000).

Results

Higher N contents were generally associated with the spring manure applications, implying that, given equal liquid manure application volumes, the spring applications had higher N concentrations.

The three-year total N applications on the corn plots were 779, 778, 785 and 667 lbs/ac for early fall, late fall, early spring, and early and late spring treatments, respectively.

The three-year averages for annual N application to the orchardgrass plots were 244 and 252 lbs/ac/yr for the early fall and late spring, and early and late spring treatments respectively.

A statistically-valid total number (1,062) of test samples was collected over the three-year study. Researchers caution, however, that interpretation of the leaching data should be considered with the fact that no continuous flow measurements were made and that water flow and quality measurements and derived flow-weighted means are based on the conditions at the time of sampling.

Soil Type
Seasonal leaching losses were consistently higher for the loamy sand soil than for the clay loam. Researchers attribute this to the higher hydraulic conductivity and lower retentivity of the loamy sand soil. They also suggest that the higher losses may be due in part to a higher manure mineralization potential on well-drained soils (Magdoff, 1978) and a lower denitrification potential (Sogbedji et al., 2001ab) that is supported by the patterns of leaching lossses on the research plots at the Cornell Baker Research Farm. The corn plots on loamy sand showed higher peak concentrations of nitrate-N losses following manure applications.

Losses from both soil types varied with precipitation levels. Losses from the loamy sand were 53 and 63 percent higher in winter 1997-98 and during the 2000 growing season when above-normal precipitation was recorded. In other seaons - growing season 1998, winter 1998-1999 and winter 1999-2000, losses from the loamy sand soil plots were respectively 91, 998 and 250 percent higher than losses from the clay loam soil plots.

Researchers suggest that the very high NO_3-N groundwater concentrations in fall and winter 1999-2000 were the result of high residual soil N levels as a result of limited crop uptake during the very dry 1999 growing season.

Corn yields were higher on loamy sand than on the clay loam. Yields were highest in the highest precipitation growing season of 2000. Farm level yield data, combined for both soil types, showed that corn silage yield was minimally affected by the timing of manure application.

Cropping System

On both soil types, manure application on corn resulted in significantly higher NO_3-N concentrations than on grass, particularly on the clay loam soil.

Researchers suggest that the lower leaching losses from the orchardgrass plots were due mostly to higher atmospheric manure-N losses through ammonia volatilization and lower manure mineralization because the manure was not incorporated into the soil. Longer periods of active crop growth and N uptake also strongly contributed to reduced N leaching under orchardgrass.

Losses under grass peaked in the winter 1999-2000 season following a dry growing season during which researchers continued to apply fertilizer after a second cut despite limited accumulated growth of the crop. The researchers suggest that real-world management could have adjusted to prevent the high residual soil N levels.

Timing of Application

Nitrate-N concentrations followed a consistent pattern related to the timing of manure applications to the corn plots. Early fall applications resulted in higher levels than for late fall applications. Researchers suggest the lower losses in the late fall are likely associated with lower soil temperatures and N mineralization and nitrification rates.

All fall manure applications resulted in levels above EPA-acceptable levels. Elevated nitrate levels following fall application of manure to corn plots was immediately measurable in shallow groundwater.

Losses from both soil types varied with precipitation levels.

Researchers suggest that the very high NO_3-N concentrations in fall and winter 1999-2000 are the result of high residual soil N levels as a result of limited crop uptake during the very dry 1999 growing season.

In all seasons, spring applications of manure resulted in lower nitrate concentrations than for fall applications.

Still, concentration levels pose some cause for concern.

The results of this study agree with the recommendation of Hansen et al, 2004, who suggested that manure should be applied to corn crops in spring to achieve optimum use of manure N.

In all seasons, spring applications of manure resulted in lower nitrate concentrations than for fall applications. Still, concentration levels pose some cause for concern.

A delay in application in the spring season did not result in lower leaching losses, presumably due to slow N mineralization in the early growing period (Durieux et al., 1995).

The results of this study agree with the recommendation of Hansen et al, 2004, who suggested that manure should be applied to corn crops in spring to achieve optimum use of manure N.

Nitrate-N leaching losses from the orchardgrass plots were similar across all spring treatments and remained below the level of concern.

Leaching losses were lower for manure application than for fertilizer-only treatment on both soil types. This is attributable to a higher total N application with the fertilizer-only treatment and possibly to the loss through ammonia volatilization of larger fractions of manure N after surface application.

Elevated concentrations under grass were only measured after the unusually dry growing season of 1999. Levels may have been biased by the rigid manure application regimen.

Conclusions

The following conclusions are drawn from this three-year study:

- nitrate leaching losses are strongly affected by soil type
- nitrate leaching losses are twice as high for loamy sand soil compared to clay loam soil
- the magnitude of leaching losses is affected by precipitation patterns
- generally, concern for high nitrate leaching losses is greater for corn production than for grass production, presumably the result of a combination of factors, including higher ammonia volatilization losses due to lack of manure incorporation and longer periods and higher rates of N uptake by grass
- nitrate leaching losses from fall application of manure on corn on both loamy sand and clay loam are higher than for spring applications, and especially pose concern with the coarse-textured soils

- delaying manure application into late fall reduces N leaching losses to some degree compared to early fall application
- delaying manure application in spring through sidedressing does not appear to reduce N leaching losses
- concern for N leaching losses increases during periods that follow dry growing seasons because high residual N levels cause high leaching losses. Reducing N application rates in such cases may reduce losses.

Table 1. Flow-weighted mean (FWM) nitrate leaching losses for drain flow periods at the clay loam and loamy sand sites, and average corn silage yield (65% moisture).

CLAY LOAM mg L^{-1}

CORN

	3-yr FWM	Average Silage Yield
Early fall	15.4a	13.0b
Late fall	11.8b	16.0a
Early spring	6.2c	11.5b
Early+late spring	7.2c	12.7b
Mean	10.2	13.3

GRASS

	3-yr FWM
Early fall+late spring	1.0b
Early+late spring	1.6ab
Fertilizer only	2.1a
Mean	1.6
Site mean	5.9

LOAMY SAND mg L^{-1}

CORN

Early fall	23.4a	17.0a
Late fall	19.3b	16.6a
Early spring	11.8c	16.5a
Early+late spring	12.6c	18.0a
Mean	16.8	17.0

GRASS

	3-yr FWM
Early fall+late spring	2.6b
Early+late spring	2.1ab
Fertilizer only	6.3a
Mean	3.7
Site mean	10.3

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The Northern New York Agricultural Development Program provided funding support for this study.

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