IMPACT OF TILE DRAINAGE ON NITRATE LEACHING

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Introduction

Subsurface tile drainage is a common water management practice in much of the Midwest. Although subsurface drainage has many benefits, it also may increase nitrate-N losses through the rootzone and out to surface waters. An appropriate balance between increasing drainage intensity (narrower spacing) to improve drainage and decreasing drainage intensity to reduce nitrate-N losses needs to be found in order to protect surface water quality. We have measured nitrate leaching into tile drains of three different spacings at a long-term research site in southeastern Indiana. Over the 15-yr period, we have sequentially changed management practices to try to reduce nitrate leaching from the rootzone. This report summarizes our major findings.

Site and Study Description

The study was conducted from 1984 to 1999 at the Southeast Purdue Agricultural Center (SEPAC) in Jennings County, Indiana. The soil is a light-colored, low organic matter, high silt soil (Clermont silt loam) with slow permeability and a high water table in spring. Tile drains (4-inch diameter perforated plastic drain tube) were installed in 1983 at three spacings (16, 33, and 66 ft) at a depth of 2.5 ft and a slope of 0.4%. From 1984 to 1993, continuous corn was grown with spring chisel tillage, while in 1994 a no-till soybean-corn rotation was begun with a winter wheat cover crop after corn to "trap" nitrogen remaining in the soil. Fertilizer N rates were decreased over the 15 years, as N fertilizer "philosophy" and recommendations changed. Preplant anhydrous ammonia rates were 250 lb/acre in 1984-88, 200 lb/acre in 1989-93, 175 lb/acre in 1995, and 155 lb/acre in 1997 and 1999, with small additional amounts of N applied as starter. Tile drainflow was monitored continuously and water samples were analyzed for nitrate-N beginning in 1985.

Rainfall and Drainflow

Annual rainfall varied from a low of 31 inches in 1987 to a high of 54 inches in 1995, with an average of 44 inches over the 15-yr period. Tile drainflow varied among years as a result of differences in annual rainfall and the timing of rainfall within each year. Tile drains removed between 2.6 and 12.8 inches of water per year, depending on drain spacing and rainfall. The narrower drain spacings removed more water per acre than the wider spacings, as expected. On average over the 15-yr period, the amount of annual rainfall removed by the tile drains was 20.6, 14.8, and 12.0% for the 16, 33, and 66 ft spacings, respectively.

Nitrate-N Concentrations

Nitrate-N concentrations in drainflow decreased greatly over the 15-yr period, as a result of the changes in management practices (Table 1). Concentrations were consistently in the 20 to 30 ppm range in the 1985 to 1988 period and in the 7 to 10 ppm range in the 1996 to 1999 period. Results show that on the low organic matter, silt loam soils at SEPAC, concentrations of nitrate-N

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in tile drainage can be reduced below the drinking water standard of 10 ppm, by a combination of lower fertilizer N rates and a winter cover crop after corn in a corn-bean rotation.

Year-to-year variations in nitrate-N concentrations were also caused by variations in weather and crop yields. During the first 5 yr of the study, preplant fertilizer N rates were 250 lb/acre. Several years of poor crop yields (1986, 1988) likely resulted in high amounts of N remaining in the soil, which contributed to an increasing trend in nitrate-N concentrations over the 1985 to 1989 period. Preplant fertilizer N rates were reduced from 250 to 200 lb/acre in the 1989 to 1993 period, and concentrations started to decrease in 1990, in the first "flow season" after the reduction in fertilizer rate. A rise in concentrations in 1992 probably reflects the poor crop yield in 1991, but concentrations decreased again in 1993 following a high crop yield in 1992. The 1994 change to a soybean-corn rotation and lower fertilizer N rates for the corn, did not result in an immediate decrease in concentration, but by 1996 the concentrations had declined again due to both the winter wheat "trap crop" after the corn and the lower fertilizer N rates.

Table 1. Drainflow, nitrate-N loads, and nitrate-N concentrations at beginning and end of 15-yr study period on tile drainage research site in southeastern Indiana.

	Drain spacing (ft)					
	1986-88			1997-99		
	16	33	66	16	33	66
Drainflow (% of rainfall)	20.2	13.7	10.4	20.4	18.6	14.8
Nitrate-N Load (lb/acre/yr)	43.9	32.5	23.2	14.1	13.8	11.2
Nitrate-N conc. (ppm)	26.9	29.2	27.1	7.6	8.0	8.1

Nitrate-N Loads

The total losses or "loads" of N are often of more concern than the concentrations, both from the agronomic efficiency perspective and for water quality concerns. The nitrate-N load is the product of the concentration times the total drainflow and is expressed in pounds of N lost per acre. Annual nitrate-N loads to drainage water decreased significantly over the 15-yr period, due to the large decrease in nitrate-N concentrations over the same time period. Annual nitrate-N loads averaged 33 lb N/acre in the 1986 to 1988 period and 13 lb N/acre in the 1997 to 1999 period. This 60% reduction in load occurred in spite of the fact that annual drainflow was 29% higher in the 1997 to 1999 period (7.2 inches) than in the 1986 to 1988 period (5.6 inches). The 71% decrease in concentrations, from 28 ppm (1986-1988) to 8 ppm (1997-1999) resulted in a large decrease in loads even with a moderate increase in flow in those years.

Generally the nitrate-N loads were greater from narrower spacings compared with wider spacings (Table 1), because the drainflow per acre was greater from the narrower spacings. The results suggest that wider drain spacings are preferable for reducing nitrate loads to surface waters, and that future drainage design should try to optimize drain spacing to reduce nitrate loads while providing adequate drainage for crop growth.

Seasonal Effects

The majority of the drainflow and nitrate-N loads occurred during the fallow season of November through March, prior to the start of any field work or fertilization for the next crop. This underscores the potential impact of growing winter cover crops as "trap crops" for N in the soil, by having a crop growing later in fall and earlier in spring than the typical corn-bean system.

Overall Conclusions

The primary findings from our site are:

- Nitrate-N concentrations and losses were significantly decreased over the 15-yr period, by a combination of reductions in N fertilizer rates, change in rotation and tillage, and growth of a winter cover crop as a "trap crop" after corn.
- Both drainflow volumes and nitrate-N loads were greater with more intensive drainage.
- The majority of the drainflow and nitrate-N loads occur in the fallow season. About 64% of the annual drainflow and nitrate-N loads occur in November through March, and 80% in November through April.
- Concentrations did not vary greatly by month within a year, but loads did vary due to the seasonal distributions of drainflow.

Current concerns about hypoxia in the Gulf of Mexico have focused attention on nitrate-N loads from tile-drained Midwestern soils. Some key points from our study that should be kept in context when comparing results across the Midwest region are highlighted here:

- The relatively shallow (2.5 ft) drain depth at our site, may affect concentrations and drainflow volumes, compared to sites where drains are installed at deeper depths (4 ft).
- The low organic matter content of this soil (~1.3%) contrasts with the dark "prairie" soils of much of the upper Midwest. The nitrate-N concentrations of less than 10 ppm achieved in the last 4 yr of our study may not be achievable on high organic matter soils growing the same rotation, due to higher mineralization rates from the soil organic matter.
- Drainage occurs all winter at our site. This contrasts with many Midwest drainage research sites (Minnesota, Iowa) where drainflow ceases during January through March.
- Fertilizer N is applied as spring preplant anhydrous ammonia, in the second half of April. This contrasts with sites receiving fall N applications or nitrate-containing fertilizers.

References

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