Fertilizer and Swine Manure Management Systems: Impacts on Crop Production and Nitrate-Nitrogen Leaching with Subsurface Drainage

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Introduction

Nutrient losses from row-crop land can cause nonpoint source water quality problems and "impaired waters." Nitrogen (N) losses due to nitrate (NO_3) leaching cause drinking water problems and possibly increase hypoxia (low oxygen) problems in the Gulf of Mexico. Phosphorus (P) losses can cause euthrophication problems in surface waters (lakes, streams, and reservoirs) in Iowa where algal blooms decrease oxygen, kill fish, and result in murky and bad tasting water. The U.S. EPA and the Iowa Department of Natural Resources are developing nutrient criteria/standards and implementation plans to address TMDL's (Total Maximum Daily Load) and to improve the quality of impaired waters. These plans need to be based on sound information. To address the need for information about water quality impacts from the use of swine manure as a source of nutrients (N and P), a field study was funded by the Leopold Center for Sustainable Agriculture in 1999. Properly managed, swine manure can supply N and P needed by corn and soybeans. This study is being conducted at the Northeast Research Farm on 36 one-acre plots that are instrumented to monitor subsurface drainage for continuous water quality assessment.

Objectives of the Study

- To study the impacts of alternative fertilizer and swine manure application management practices for the corn-soybean rotation on crop yields and water quality.
- To study the effects of over-application of swine manure on N and P leaching.
- To study the effects of spring and fall injection methods of swine manure application on crop yields, and N, P, and bacteria concentrations in subsurface drainage.
- To develop and recommend appropriate manure and nutrient management practices to reduce the water contamination potential from manure and N fertilizer application.

Progress

Table 1 shows various experimental treatments (systems) for this study. Table 2 presents the crop yield information, and Table 3 presents the corn stalk and soil test NO_3-N data for the period 2000–2002. Crop yields have been good, with yields on manured plots as good as or better than for plots receiving UAN. The stalk NO_3-N results have been mixed, but effects of applying manure to both corn and soybeans (system 4) resulted in higher values, still within the optimum range in 2001 and 2002; this effect does not show in the LSNT soil NO_3-N concentrations. The LSNT soil NO_3-N concentrations do show the effects of pre-test applications of N relative to the post-test application for system 5.

Tables 4 and 5 show NO_3-N concentrations and losses in subsurface drainage for corn and soybean plots. Concentrations have generally been high (> 10 mg/L), but have trended downward during the three years, whereas nitrate loss amounts have increased. These kinds of trends are more weather than management related, where precipitation, N mineralization, crop yield/uptake, denitrification, and leaching (all weather related) combine to affect the amount of NO_3-N in the soil at any time. Concentrations for manured plots are usually ≤ those for plots receiving equal amounts of N as UAN. Concentrations for system 4, receiving more than twice the applied N of other systems, had the highest concentrations. Losses follow a similar pattern, being the greatest for system 4. The overall average loss is 13.0 lb/acre. Reducing nitrate losses by 30% is a goal of the EPA Clean Water Action Plan for hypoxia. If this was done, the 4 lb/acre saved would only represent about $1/acre; therefore, forces other than economic incentive may be needed to achieve this reduction.

Table 1. Experimental treatments at the Nashua site for the manure management study.

Systems/ treatments	Application timings and source of N	Crop	Application rate, lb/acre	
			N-based rate	P-based rate
1	Spring UAN	Corn	150	As needed*
				As needed
	-	Soy	-	
2	Fall manure	Corn	150	-
				As needed
	-	Soy	-	
3	Fall manure	Corn	150	P-based **
				As-needed
	-	Soy	-	
4	Fall manure	Corn	150	
				-
	Fall manure	Soy	200	
5	Sidedress (UAN) LCD***			-
	-	Corn	150	As needed
		Soy	-	
6	Spring manure	Corn	150	-
		Soy	-	As needed

*As needed: application rate of P fertilizer based on need as determined by soil P test interpretation

** P-based: application rate of P from swine manure on the basis of P removal by corn

*** LCD: Localized compaction and doming applicator

Table 2. Corn and soybean yields for various N treatments.

System	Corn yield, bu/acre			Soybean yield, bu/acre		
	2000	2001	2002	2000	2001	2002
1	164	163	192	54.9	45.9	53.9
2	171	177	195	57.5	51.3	55.8
3	166	173*	191	58.4	42.9	57.2
4	154	181	194	71.0	56.3	59.4
5	161	159	189	58.0	45.6	53.6
6	159	169	192	53.9	44.3	52.8

*Excludes Plot 6 due to cutworm damage.

Table 3. Stalk and soil LSNT concentrations.

System	Basal stalk NO_3-N ppm			Soil LSNT NO_3-N ppm		
	2000	2001	2002	2000	2001	2002
1	284	245	626	23	44	32
2	1022	282	862	26	19	23
3	182	677	839	19	16	33
4	308	1087	1872	24	18	24
5	182	79	746	10	12	16
6	20	100	661	20	25	43

Table 4. Effects of experimental treatments on average NO_3-N concentrations with subsurface tile drain water.

Yearly average NO_3-N concentration, mg/l						
System	2000		2001		2002**	
	CS	SC	CS	SC	CS	SC
1	21.7	18.9	14.1	18.9	11.3	15.8
2	17.8	16.0	25.7	14.8	15.2	14.6
3	16.6	17.2	16.3	12.3	9.7	14.7
4	38.6*	25.7	25.7	31.4	30.7	18.6
5	11.9	17.3	13.9	16.9	9.8	7.8
6	14.5	13.2	12.2	8.4	8.5	9.7

*Under continuous corn rotation 1993-1999.
**Preliminary data set pending completion.

Table 5. NO_3-N losses with subsurface tile drain water.

Yearly average NO_3-N loss, lb/acre				
System	2000		2001	
	CS	SC	CS	SC
1	8.1	4.8	9.2	15.4
2	10.6	4.8	17.3	25.3
3	1.9	6.2	13.8	10.0
4	13.0	6.6	19.4	37.1
5	5.3	5.4	12.1	24.8
6	10.2	10.1	18.6	15.4