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Fertilizer and Swine Manure Management Systems Impacts on Phosphorus in Soil and Subsurface Tile Drainage

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Abstract

Swine manure and fertilizer can be used to supply the nitrogen (N) and phosphorus (P) needs of crops. Excess P application sometimes applied with N-based manure for corn increases the risk of P loss and water quality impairment. Poor water quality in Iowa streams and lakes due to excess P has prompted questions about the impact of cropping and nutrient management systems on P loss from fields.

Keywords

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Disciplines

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Introduction

Swine manure and fertilizer can be used to supply the nitrogen (N) and phosphorus (P) needs of crops. Excess P application sometimes applied with N-based manure for corn increases the risk of P loss and water quality impairment. Poor water quality in Iowa streams and lakes due to excess P has prompted questions about the impact of cropping and nutrient management systems on P loss from fields.

A long-term study at the ISU Northeast Research Farm, Nashua, Iowa with only N treatments was modified in 1993 to assess the effects of fertilizer or liquid swine manure management for corn-soybean rotations and continuous corn on yield and nutrient loss with subsurface tile drainage. The study includes 36 one-acre plots with 1 to 4 percent slope; Kenyon, Floyd, and Readlyn soils with loam to clay loam subsoil; and tiles installed at a depth of 4 ft spaced 95 ft. The effects of systems and practices on crop yield and nitrate loss have been summarized in previous reports.

This report summarizes drainage P results from 2000 until 2010 for the four systems most relevant to P issues and for which changes in P management from 2000 through 2010 varied little, had no change, or changes are not expected to influence interpretations. Three corn-soybean rotation systems involved N and P application using fertilizer according to current ISU guidelines or N-based liquid swine manure for corn after soybean. Another system applied N-based liquid swine manure to both crops of a corn-soybean rotation until 2006 and to continuous corn since 2007 (Table 1). The P fertilizer (triple superphosphate) has been incorporated by chisel plowing and disking except for one system managed with no-till. The manure had always been injected.

Results and Discussion

Effects on soil P. Several methods were used to measure soil P at various depths. All methods were similar at ranking the system effects, however, so Figure 1 only shows results for the Bray-1 method. The N-based manure application for corn after soybean increased soil P more than the fertilizer-based system. This result was explained by a lower N:P ratio in manure compared with the corn and soybean needs. Application of N-based manure to both corn and soybean (1999 to 2006) or to continuous corn (since 2007) applied much more P, which resulted in the highest soil P values. The excess P applied with N-based manure rates also increased P in the 6 to 12 in. subsoil layer, but not at deeper depths.

Effects of tile drainage P concentration. Figure 2A shows that the annual average dissolved P concentrations in tile drainage was very low for both crops of the corn-soybean rotations (<0.12 mg P/L), but was highest for the system with manure applied every year to corn and soybean or to continuous corn.

For the corn-soybean rotations, the P concentration was lowest for the system with fertilizer management and tillage, intermediate with N-based manure and no-till, and highest with N-based manure and tillage. However, these differences were statistically significant only in the years when corn was raised.

Effects on P loss through tile drainage. Figure 2B shows the annual average dissolved P lost through tile drainage, which combines management effects on both P concentration and water flow. The P loss for the soybean years of the corn-soybean rotations did not differ statistically between systems, but values were lowest for the fertilizer-based system and highest for the manure-N based system with no-till. This result coincides with similar and statistically significant results for drainage flow (not shown). The P loss in the corn years was the lowest for the system managed with fertilizer and tillage, intermediate for manure-N based systems for corn after soybean with or without tillage, and the highest for the system with N-based manure applied every year (to corn and soybean until 2006 and to continuous corn since then).

In spite of apparently large differences between the management systems compared, the P losses were very small. Even for the system applying manure every year at N-based rates, the average P loss was less than 0.05 lb P_2O_5/acre per year. Plots with soil-test P value five times the optimum level for crops in the top 6-in. layer lost almost as little P as plots that tested optimum (16-20 ppm for the Bray-1 or Mehlich-3 tests). Overall, there was no significant correlation between P in tile drainage and soil P except in 2008, which was a year with exceptionally high drainage flow. In 2008, P loss increased exponentially after a Bray-1 soil P level of about 70 ppm (not shown).

The results agree with the lack of treatment effects on subsoil P below a 1-ft depth (Figure 1) and with research showing that the subsoil of most Iowa soils has a large capacity to filter P moving laterally to tile drains.

Conclusions

Nitrogen-based manure applications have increased soil-test P in the top 6-in. layer to about five times the optimum levels for crops and also increased P loss with tile drainage compared with P-based fertilizer management. This was especially the case for swine manure applied annually to both crops of the corn-soybean rotation or to continuous corn. In all instances, however, the P losses were very small. This study confirms results of studies of P loss with surface runoff in that soil erosion and surface runoff are by far the most important pathways for P loss in the region.

Table 1. Selected phosphorus management systems summarized in this report.

Code	Source †	Crop	Tillage	Target N rate	Actual P rate
				lb N/ac/year	lb P_2O_5/ac/year
FP-CS	Fertilizer	Corn	Chisel/disk	150	52
		Soybean	Disk	none	none
MN-CS	Manure	Corn	Chisel/disk	150	50
		Soybean	Disk	none	none
MN-CSNT	Manure ‡	Corn	No-till	150	44
		Soybean	No-till	none	none
MN-2CSCC §	Manure	CS-CC	Chisel/disk	150-200	150

†Liquid swine manure always was injected.
‡Applied in spring from 1999 until 2006 and in the fall since then.
§Manure N-based to corn (150 lb N) and soybean (200 lb N) from 1999 to 2006 (CS) and to continuous corn since 2007 (CC).

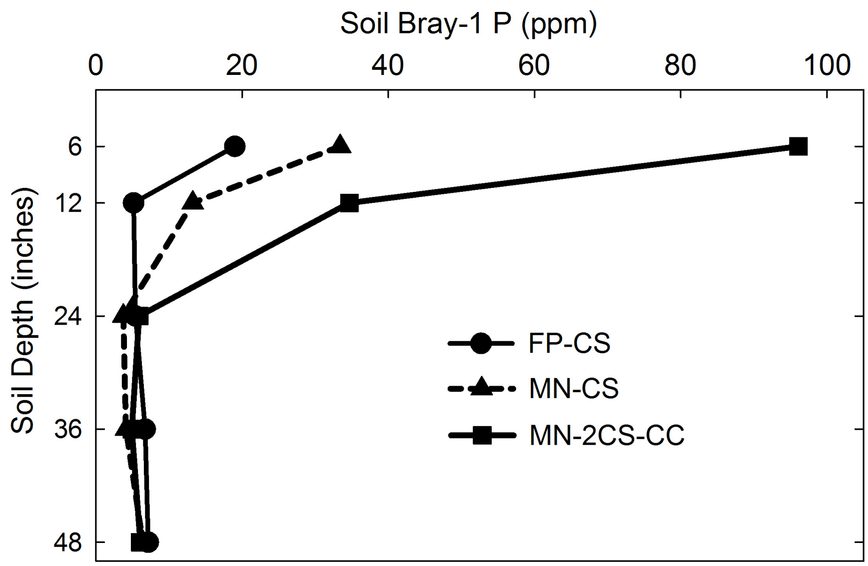

Figure 1. Soil profile P after 11 years of P-based fertilizer (FP-CS) for a corn-soybean rotation, N-based liquid swine manure for corn after soybean average for tillage or no-tillage (MN-CS), or N-based manure every year (MN-2CSCC).

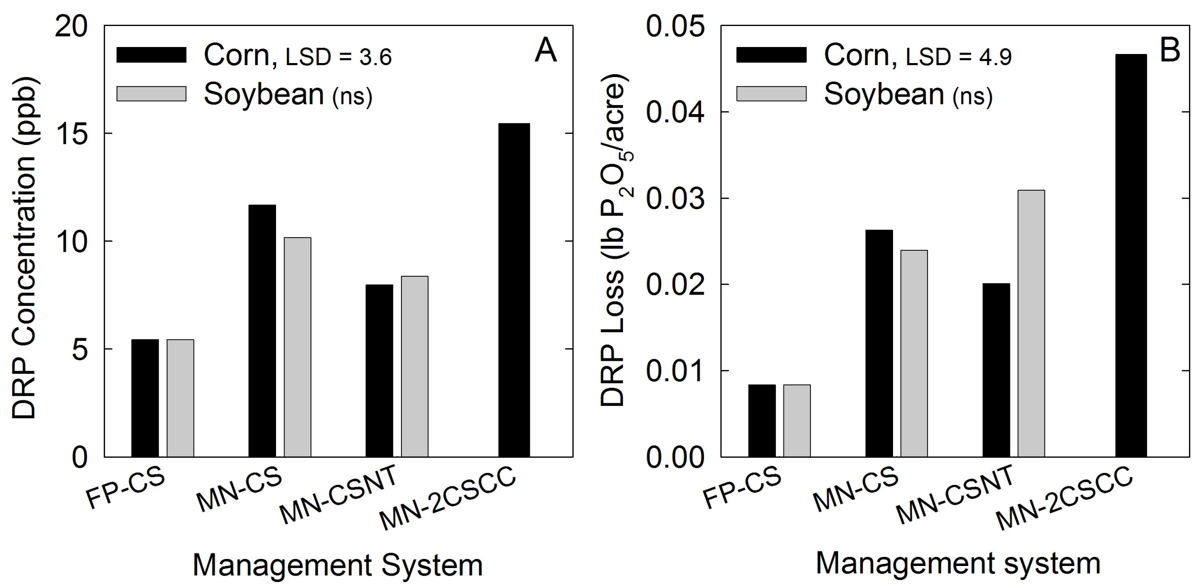

Figure 2. Average annual P concentration in tile drainage (A) and P loss (B) during 11 years of P-based fertilizer for a corn-soybean rotation (FP-CS), N-based liquid swine manure for corn after soybean with tillage (MN-CS) or no-till (MN-CSNT), or N-based manure every year (MN-2CSCC).