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Crop Yields and Phosphorus Loss with Surface Runoff as Affected by Tillage Systems and Phosphorus Sources

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Abstract
Excess sediment, phosphorus (P) and/or nitrogen (N) impair many Iowa lakes and streams. Most of the sediment and P originate from fields and stream banks. Previous research was based on rainfall simulations. This technique provided useful information about potential differences between management practices, but estimated poorly long-term differences and total losses. Little work has been conducted elsewhere in Iowa to study P loss with surface runoff based on natural rainfall and large-scale plots. Therefore, a long-term study was established to investigate effects of corn and soybean production, tillage, and fertilizer or manure P management system on crop yield and loss of soil and P with runoff.

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Introduction

Excess sediment, phosphorus (P) and/or nitrogen (N) impair many Iowa lakes and streams. Most of the sediment and P originate from fields and stream banks. Previous research was based on rainfall simulations. This technique provided useful information about potential differences between management practices, but estimated poorly long-term differences and total losses. Little work has been conducted elsewhere in Iowa to study P loss with surface runoff based on natural rainfall and large-scale plots. Therefore, a long-term study was established to investigate effects of corn and soybean production, tillage, and fertilizer or manure P management system on crop yield and loss of soil and P with runoff.

Management Systems

The study evaluates the following systems:

1. FP-CH: Corn-soybean rotation managed with chisel/disk tillage and fertilizer P.
2. FP-NT: Corn-soybean rotation managed with no-tillage and fertilizer P.
3. MP-CH: Corn-soybean managed with chisel/disk tillage and P-based liquid swine manure.
4. MP-NT: Corn-soybean managed with no-tillage and P-based manure.
5. MN-CH: Continuous corn managed with chisel/disk tillage and N-based manure.

The crop rotations and tillage systems were first established in 2006 and the nutrient management systems were first applied for the 2007 crops. Corn and soybean of Systems 1 through 4 are grown each year on separate plots, and the rotation over time is achieved by switching crops each year. All systems are replicated three times. Therefore, the study includes 27 plots that are 20 ft wide by 100 ft long.

The P needed by crops of the corn-soybean rotations is determined by soil testing and estimated P removal with harvest, and it is applied only once in the fall before corn. Initial Bray-1 soil-test P was 17 ppm (Optimum), and a rate of 100 lb P_2O_5/acre as fertilizer or manure has maintained soil P levels. Triple superphosphate is broadcast for all fertilizer P treatments but incorporated in the spring only for the tilled systems. Liquid swine manure from an underground pit is injected into the soil in the fall for all plots of the manure-based systems. Fertilizer N (28% UAN solution) is injected in spring as needed for corn after soybean so that the total N applied is at least 150-lb N/acre and equal for all four systems. For System 5 (continuous corn), manure is applied at 200-lb total N/acre each fall. The crops of the corn-soybean rotations are harvested for grain, and the continuous corn is harvested for grain and cornstalks are baled. The corn hybrids are resistant to rootworm and corn borer and the soybean variety is resistant to glyphosate and soybean cyst nematode.

Summary of Results

Crop yield. Soybean yields have been statistically similar across systems (Table 1), except for 2008 when yields were highest for the two fertilizer-based systems (FP-CH and

FP-NT). Soybean yield has not been impacted by tillage, which agrees with results from the long-term tillage and fertilizer placement study at this farm. The lower yield for the manure P-based systems in 2008 is not likely explained by P applied or P availability because in fall 2007 and 2008 soil-test P was similar for the fertilizer and manure systems.

Corn yields often differed between systems. Yield of continuous corn managed with tillage (MN-CH) always was the lowest, being 20 and 13 bushels less than FP-CH and MP-CH. Yield differences for corn after soybean were less frequent. Apparent small differences due to tillage or P management in 2007 and 2008 were not statistically significant. But in 2009, yield was highest for FP-CH, intermediate for FP-NT, and lowest for the two manure-based systems.

Runoff P. There were six runoff events with measurable water or soil loss for most plots in 2007, six in 2008, and only one in 2009. We summarized results by showing average annual runoff P concentration and loss for dissolved (DP), bioavailable (BP), and total P (TP) fractions. The DP fraction is readily available for algae, the BP fraction results from a laboratory test that estimates both P readily available and P becoming available over a few weeks, and TP becomes available over a longer period of time depending on water properties and other factors. Figure 1 shows that average runoff P concentrations were lowest for DP, intermediate for BP, and highest for TP. The P concentrations were higher for the corn years (soybean residue in corn-soybean rotations) than for the soybean years (corn residue).

In the corn years the systems ranked similarly for DP and BP, with statistically higher concentrations for the fertilizer-based systems (FP-CH and FP-NT), intermediate for MP-CH, and lowest for the other systems. Total runoff P concentration (which reflects soil loss more than DP or BP) was highest for FP-CH and lower with small differences for the other systems. In the soybean years (corn residue), DP and BP concentrations were low and did not differ. The concentrations of TP were larger, however, and much higher for the tilled systems than for no-till.

Figure 2 shows the P losses, which integrate treatment effects on runoff (water and soil losses) and runoff P concentrations. In the corn years, DP and BP losses were highest for the no-till and fertilizer-based system (FP-NT) and lowest for MP-NT, with no statistical differences between the other intermediate systems. The TP losses were highest for FP-CH and MP-CH, lowest for MP-NT, and intermediate with no statistical differences for the other two systems. In the soybean years, there were no statistical differences between systems for DP and BP, although losses of both fractions seemed highest for MP-CH. The TP loss was much larger with tillage than with no-tillage for fertilizer- or manure-based systems.

The P loss data in Figure 2 must be interpreted with care because the corn and soybean crops alternate over time but there is corn every year for the continuous corn. We do not show or discuss sums of P loss over years across crops because we do not have two complete corn-soybean rotation cycles for all plots. The available results suggest, however, that the P loss over a 2-year period was about similar for the systems managed with tillage, with small or no difference between the P-based and manure-N based systems.

Preliminary Conclusions

The results for these early years should be interpreted with caution because the systems were recently established, and in 2009 there was only one runoff event. One consistent result was, however, that losses of all runoff P

fractions in corn-soybean rotations were much higher for the corn year. This is reasonable because the fertilizer or manure P was applied before corn, and also because runoff was higher since there was less water infiltration where soybean was the previous crop. Another clear result was that dissolved and bioavailable P losses were the highest for the no-till and P fertilizer based system in corn years, which is explained by broadcast fertilizer application before no-till corn. The differences with the other systems were smaller, however, and this result was not observed in the soybean years. On the other hand, the total P losses were two to three times higher than the dissolved and bioavailable P losses. Overall there was a much higher total P loss with tillage than with no-till with small or no differences between fertilizer and manure management systems. We should continue evaluating this study so that the systems become more stable and provide more reliable results.

Acknowledgements

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Table 1. Management systems effects on yield.

Management system †			Grain yield		
Crop	Source	Till	07	08	09
			------- bu/acre ------		
Cs	FP	CH	184	166	194
Cs	FP	NT	180	160	177
Cs	MP	CH	177	175	170
Cs	MP	NT	177	158	170
CC	MN	CH	169	152	163
Sc	FP	CH	51	48	46
Sc	FP	NT	50	48	47
Sc	MP	CH	50	41	46
Sc	MP	NT	49	44	48

† Crop: Cs, corn after soybean; Sc, soybean after corn. Source: FP, fertilizer P; MP, manure P; MN, manure N. Tillage: CH, chisel/disk; NT, no-till.

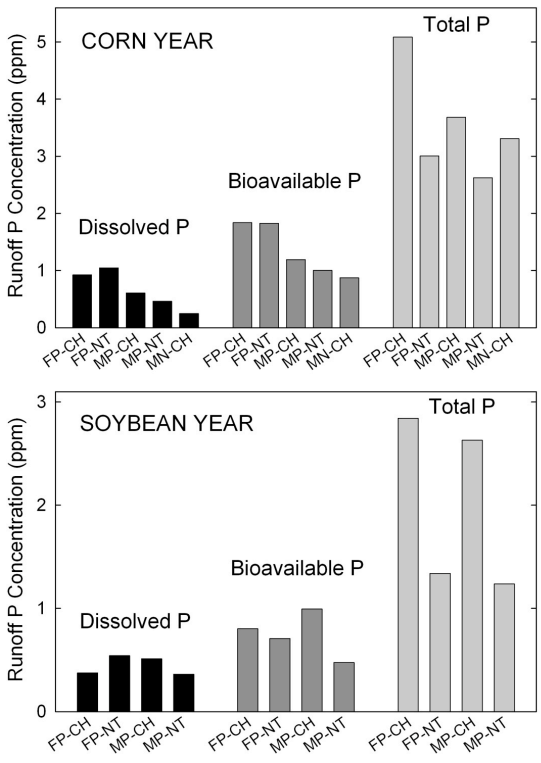

Figure 1. Mean runoff P concentrations.

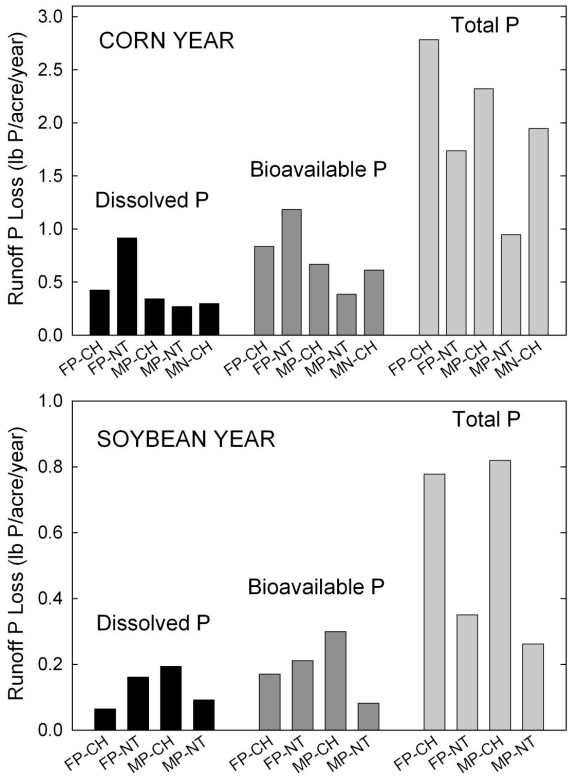

Figure 2. Annual runoff P losses.