Effects of Tillage and Phosphorus Source on Long-term Phosphorus Runoff Loss and Crop Yield

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Introduction

Excess sediment and phosphorus (P) impair many Iowa water resources and the Gulf of Mexico. Most of the sediment and P originate from agricultural fields and stream banks. Previous research on P loss with surface runoff in Northwest Iowa was based on rainfall simulations. This technique provides useful information about dissolved P loss but poorly estimates the long-term differences and total P loss from fields. Therefore, a long-term study based on large plots and natural precipitation was conducted at the ISU Northwest Research and Demonstration Farm from 2007 until 2012. The objectives were to study effects of corn and soybean production, tillage, and fertilizer or manure P management systems on yield and both soil and P loss with surface runoff.

Materials and Methods

The study evaluated 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-CC: Continuous corn managed with chisel/disk tillage, N-based manure, and baled stover.

The crop rotations and tillage systems were established in 2006 and the nutrient treatments were first applied for the 2007 crops. Corn and soybean of Systems 1 through 4 were grown each year on separate large plots, and the crops were rotated each year. All systems were replicated three times with 27 plots measuring 20 ft wide by 100 ft long.

The P needed by crops of the corn-soybean rotations was determined by soil testing and estimated P removal at harvest. P was applied in the fall only before corn. Initial Bray-1 soil-test P was 17 ppm (Optimum). A rate of 100 lb P_2O_5/acre as fertilizer or manure approximately maintained the initial soil-test P level. Triple superphosphate was broadcast for the P fertilizer treatments and was incorporated in the spring only for the tilled systems. Liquid swine manure from a pit was injected into the soil in the fall for the manure-based systems. Fertilizer N was applied for corn after soybean so that the total N applied to all plots (fertilizer or manure) of the four systems was at least 150 lb N/acre. For System 5 (continuous corn with N-based manure), manure was applied at 200 lb total N/acre each fall. Crops of the corn-soybean rotations were harvested for grain. For continuous corn the grain was harvested and the stover was baled. Adapted corn hybrids and soybean varieties were used.

Summary of Results

Crop Yield. Soybean yields were statistically similar across systems (Table 1), except for 2008 when yields were highest for the two fertilizer-based systems (FP-CH and FP-NT) and in 2012 when yields were highest for the FP-CH system. The lower yields were not explained by P applied or soil P availability because soil-test P was similar for the systems. The 6-yr averages showed very small and not statistically significant soybean yield differences.

Corn yields after soybean (Table 1) were similar between no-till and tillage in 2007 and 2011, but was lower for no-till in other years, including the very dry 2012 season. The 6-yr corn yield averages were 10 bushels/acre lower for no-till. On average, over the six years corn yield was statistically similar across all systems, including the continuous corn (although yields tended to be higher for corn after soybean and with tillage).

Soil erosion. Figure 1 shows average annualized soil loss for six years summarized for corn and soybean years separately, for the rotation, and for continuous corn. In corn (Figure 1A), soil losses were much more with tillage than with no-till, largest for fertilizer P, intermediate for P-based manure, and lowest for the continuous corn with N-based manure and baled stover. In soybean (Figure 1B), when tillage was applied to corn residue, there was much less soil loss than in the corn years, and the relative difference between tillage and no-till remained approximately the same. On average, for the corn-soybean rotation (Figure 1C) soil loss with tillage was 2.5 to 3 times more than with no-till, and also was more than the continuous corn with manure and tillage.

Runoff P. The 6-yr average annual runoff P loss for dissolved (DP), bioavailable (BP), and total P (TP) fractions are shown in Figure 2. 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 body properties.

In corn after soybean (Figure 2A), total P loss was more with tillage than no-till, and was similar for fertilizer or manure P within each tillage system.

Interestingly, total P loss was least for continuous corn managed with tillage, N-based manure, and baled stover. The DP and BP losses were largest and similar for corn after soybean managed using fertilizer with no-till, manure P with no-till, and manure with tillage. The DP and BP losses were smallest for corn after soybean managed with fertilizer P with tillage and for continuous corn managed with tillage and N-based manure. In the soybean years (Figure 2B), the runoff P losses for all fractions were much less than in corn years, and differences between treatments were small. However, losses were largest for fertilizer with tillage and smallest for manure P with no-till. The averages across the two years of the corn-soybean rotations (Figure 2C) tended to follow the trends of corn years, but P losses were slightly lower.

Conclusions

Soil and runoff P losses in corn-soybean rotations were greater in the corn year. This was explained by less cover with soybean residue from the prior year and because fertilizer or manure P was applied before corn. Also, both dissolved and bioavailable P losses were greatest for no-till with fertilizer P, mainly in corn years after soybean. However, no-till significantly reduced soil and total P loss.

Acknowledgements

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Table 1. Management systems effects on crop yield.

Management System†			Grain Yield						
Crop	Source	Till	2007	2008	2009	2010	2011	2012	Avg.
					-------------------- bu/acre --------------------				
Cs	FP	CD	184	166	194	209	189	136	180
Cs	FP	NT	180	160	177	202	190	116	171
Cs	MP	CD	177	175	170	206	180	145	175
Cs	MP	NT	177	158	170	166	190	130	165
CC	MN	CD	169	152	163	201	176	129	165
Sc	FP	CD	51	48	46	55	54	39	49
Sc	FP	NT	50	48	47	56	51	31	47
Sc	MP	CD	50	41	46	55	54	30	46
Sc	MP	NT	49	44	48	56	57	29	47

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

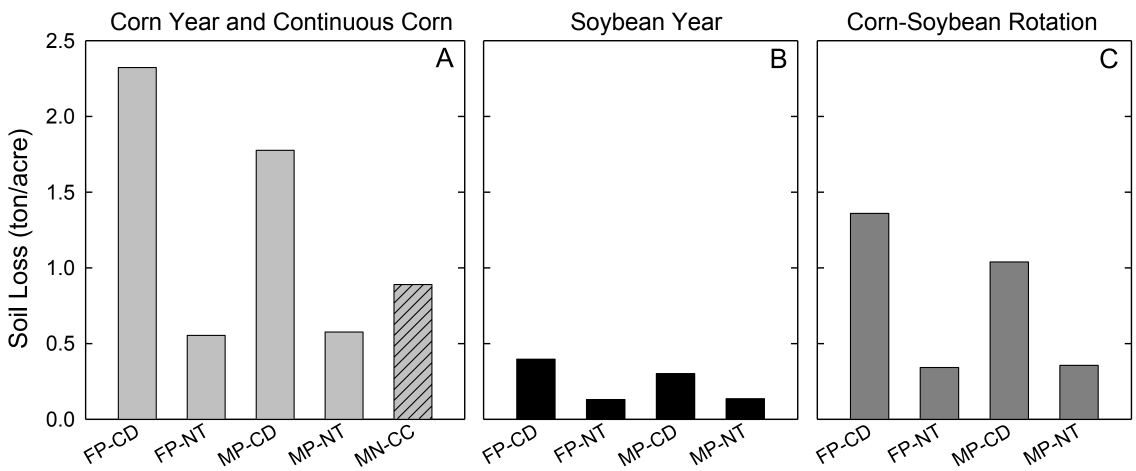

Figure 1. Amount of soil loss (6-yr averages). FP, fertilizer P; MP, manure P; CD, chisel/disk; NT, no-till; MN-CC, N-based manure for continuous corn with tillage.

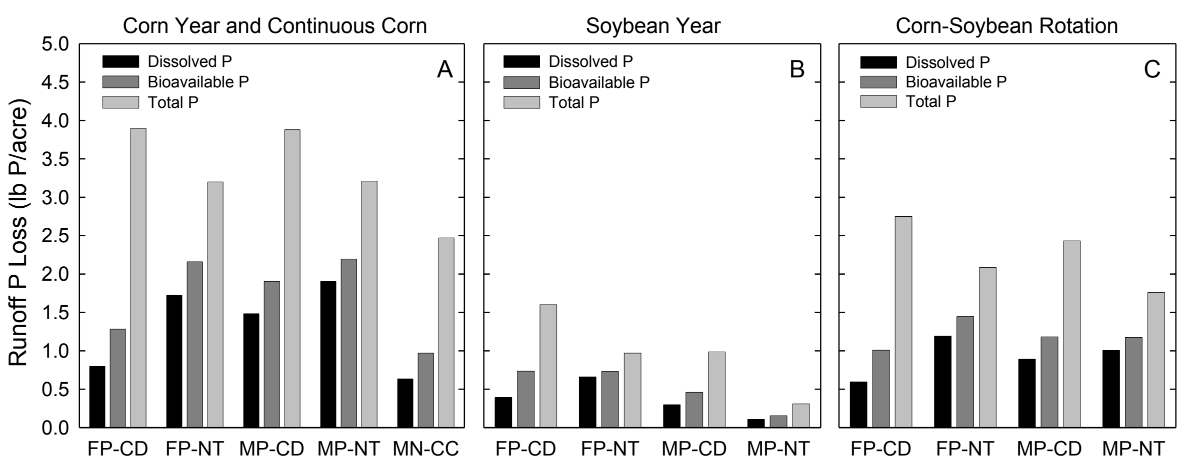

Figure 2. Dissolved reactive, bioavailable, and total P loss with surface runoff (6-yr averages). FP, fertilizer P; MP, manure P; CD, chisel/disk; NT, no-till; MN-CC, N-based manure for continuous corn with tillage.