Soil and Phosphorus Losses with Surface Runoff from Corn-Soybean Rotations as Affected by Tillage, Cover Crops, and Phosphorus Placement Methods

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Introduction

Research has shown that no-till greatly reduces soil loss from surface runoff compared with tillage. Although no-till often reduces sediment-bound phosphorus (P) loss, it can increase the proportion of dissolved P in runoff or the amount lost. There is little information about how broadcast or subsurface banding of P influences P loss with runoff. Subsurface P banding with the planter may reduce P loss mainly from no-till fields because it should reduce the P accumulation in the soil surface layer. In Iowa and the Corn Belt, most farmers broadcast P in the fall (when the risk of runoff events is small) or band P with planters. The objective of this study was to evaluate soil and P loss with surface runoff in corn-soybean rotations as affected by the tillage system and these two commonly used P application methods.

Materials and Methods

The study was conducted from 2013 to 2018 under natural rainfall on plots measuring 20 ft x 100 ft in size. Plots were located in an area with Sac silty clay loam soil with 4.3–4.6 percent organic matter (6-in. depth) and 2.7–3.9 percent slope. The study evaluated five management systems for corn-soybean rotations with three replications. For four systems, both crops were grown each year on adjacent field areas (24 plots) for which previous management had resulted in the appropriate no-till or chisel-plow/disk tillage management and optimum-to-high soil-test P. These four systems were the combinations of no-till or chisel-plow/disk tillage and broadcast or planter-band P placement methods. The broadcast treatment consisted of 100 lb P_2O_5/acre applied in the fall before snow and only before corn. The planter-band treatment applied 50 lb P_2O_5/acre beside and below the seed furrow each year for both corn and soybean crops. The P fertilizer was granulated triple superphosphate (0-46-0). The amount of P applied broadcast or banded was the same over the two years of the rotation. For a fifth system, only one crop of the rotation was planted each year (began with soybean in 2013). The management consisted of no-till with a cereal rye cover crop every year and no P application, because these plots initially tested very high in P due to a history of nitrogen-based manure application for continuous corn. Soil samples were taken after each crop harvest from depths of 0–2 and 2–6 inches, and were analyzed for P (Bray-1). Automated devices monitored runoff flow and collected runoff samples. Unfiltered runoff was analyzed for total solids (soil) and total P. Samples filtered through a 0.45-um filter were analyzed for dissolved reactive P.

Results and Discussion

Crop yield. Table 1 shows the average crop yields across the six years of the study. As previous studies in Iowa have shown, corn yield was lower with no-till than with tillage (about 10 bu/ac lower). Soybean yield was not affected by the tillage system, and the P placement method did not affect yield with any tillage system.

The no-till corn yield for System 5 was midway between the corn yield for the tilled and no-till systems. However, the comparison is not equitable because System 5 corn was planted only in three years and its plots had a history of tillage and N-based swine manure application. The average annual rye cover crop dry matter yield and P content at the termination time in the spring were 1,022 lb/acre and 10.9 lb P_2O_5/acre, respectively. In the individual years, however, dry matter yield ranged from 161 to 1,928 lb/acre and P content ranged from 7.5 to 17.9 lb P_2O_5/acre.

Soil-test P. Figure 1 shows soil-test P values from samples taken in fall 2016 when the two placement methods applied the same amount of P (samples taken in fall 2018 are being analyzed at this time). Soil-test P was greater in the 0–2 inch depth than in the 2–6 inch depth for both tillage systems, but the difference was greater for no-till. The planter-band P reduced the accumulation of P in the surface soil layer compared with broadcast fertilization with both tillage systems.

Soil loss with runoff. Figure 2A shows the average annual soil loss across the six years of the study. As expected, soil losses were the greatest with tillage as opposed to no-till. The no-till system losses were the smallest for the system managed with a cereal rye cover crop. The average annual soil losses were small because in 2016 and 2017 spring rainfall was lower than normal or was distributed in several small events that resulted in little runoff. Soil losses were greater for the corn years, when corn was planted in soil with soybean residue (not shown).

Total P loss with runoff. Figure 2B shows the annual average total P loss (which includes dissolved and soil-bound P) was the greatest for the system managed with tillage and broadcast P (System 1), and the lowest for the system managed with no-tillage, rye cover crop, and no P application because of initially high tests in soil-test P (System 5). The total P loss differences between the three other systems were very small and not statistically significant.

Dissolved P loss with runoff. Figure 2C shows the average annual loss of dissolved reactive P was remarkably different from results for total P loss. The dissolved P losses were the greatest for the two systems managed with no-tillage and broadcast P (System 2) or planter-band P (System 4), and the smallest for the system managed with tillage and planter-band P (System 3). The dissolved P losses for Systems 1 (tillage with broadcast P) and 5 (no-tillage with initially high soil P, rye cover crop, and no P applied) were intermediate with small differences among them.

The dissolved P loss expressed as the percentage of the total P loss (Figure 2) was the smallest for the two systems managed with tillage (Systems 1 and 3), and the highest for the three systems managed with no-tillage (Systems 2, 4, and 5). The difference between the broadcast and banded placement methods for the tillage management was very small (26 and 30%). The dissolved P percentage of total P for the three no-till systems was almost identical (48 or 49%). This is explained by no-till reduction of soil and sediment-bound P, but not necessarily dissolved P. Therefore, although the proportion of dissolved P for the system with initially very high soil-test P (which management changed to no-till with a rye cover crop and no P application) had results as high as the other no-till systems, the actual dissolved P loss was lower and comparable with that observed for the two systems managed with tillage.

Conclusions

The study showed no-till reduces soil loss with erosion compared with tillage. The use of a rye cover crop for no-till further reduces soil loss, and the soil loss is greater in the corn year (planted on soybean residue) than in the soybean year (planted on corn residue). The total P loss was the greatest for the system managed with tillage and broadcast P application, and the smallest for soil with initially very high soil-test P managed as no-till with a rye cover crop and no P application. The total P loss was intermediate for systems managed with tillage and banded P and the two systems managed with no-till with broadcast or band P application.

However, the dissolved P loss was the greatest for the no-till systems managed with broadcast or banded P. This runoff P fraction is the most readily available for algal consumption, which can result in excessive algae growth and subsequent water quality impairment.

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Table 1. Average corn and soybean grain yields from 2013 through 2018.

Management system	Corn yield*	Soybean yield
	---------- bu/ac	-------------
1 (CH broad P) chisel-plow/disk, broadcast P	214a	63.5a
2 (NT broad P) no-till, broadcast P	192b	60.7a
3 (CH band P) chisel-disk/disk, planter-band P	213a	62.7a
4 (NT band P) no-till, planter-band P	194b	62.3a
5 (NT cover cover) very high initial soil P, no-till, rye cover crop, no P†	210a	62.1a

*There were statistically significant differences only for tillage in corn.
†Caution must be used when interpreting differences between yields for System 5 and the other systems because corn and soybean were not planted each year as done for the others and the plots had different initial soil-test P levels and previous management history.

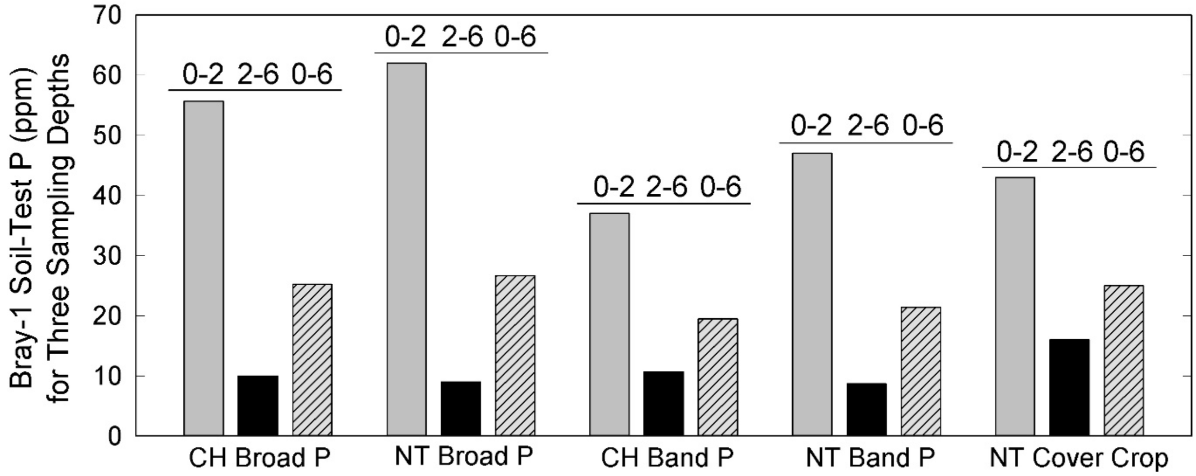

Figure 1. Soil-test P (Bray-1) at three soil sampling depths for five management systems in the fall of 2016, when all systems have received a similar amount of P fertilizer across four years. Caution must be used when interpreting differences between results for the NT cover crop system and the other systems because the plots had different initial soil-test P levels and previous management history.
CH = chisel tillage, NT = no-till, Broad = broadcast P, Band = planter-band P.

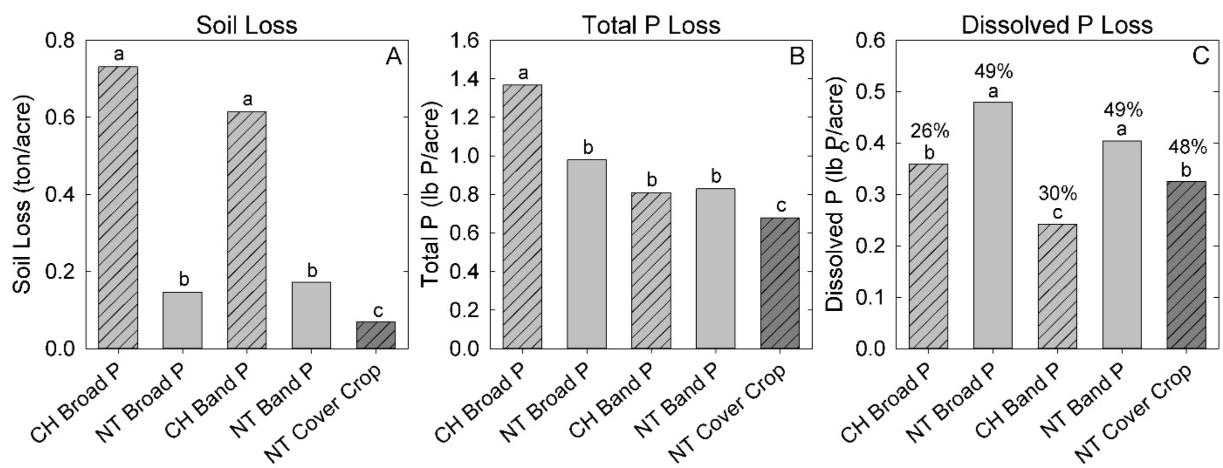

Figure 2. Annual average soil (A), total P (B), and dissolved P (C) losses with runoff across six years. Numbers on top of the dissolved P bars indicate percent dissolved P of the total P loss. Different letters on top of the bars of each graph indicate statistically significant differences. Caution must be used when interpreting differences between results for the NT cover crop system and the other systems because the plots had different initial soil-test P levels and previous management history.
CH = chisel tillage, NT = no-till, Broad = broadcast P, Band = planter-band P.