Report as of FY2009 for 2008IA126B: "Biomass Harvest and Nutrient Management Systems Impacts on Water Quality."

Publications

Project 2008IA126B has resulted in no reported publications as of FY2009.

Report Follows

ANNUAL REPORT

Iowa Water Center Project
Biomass Harvest and Nutrient Management Systems Impacts on Water Quality.

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Prepared by Antonio P. Mallarino, Matt J. Helmers, and Mazhar U. Haq

Problem and Research Objectives

The general goal of this project was to evaluate impacts of selected crop, biomass harvest, and nutrient management systems on loss of N and P from fields with surface runoff and subsurface tile drainage. The two main objectives stated in the original proposal were the following:

1. Determine dissolved reactive P, total dissolved P, algal-available P, total P, and total N concentrations and loads in surface runoff from corn production systems harvested for grain using different tillage and fertilizer or manure P management systems and from continuous corn harvested for grain and cornstalks.

2. Determine loss of nitrate, dissolved reactive P, and total dissolved P through subsurface tile drainage from selected bioenergy production systems managed with fertilizer or manure N-P management systems.

Summary of Methodology

The field work for Objective 1 was conducted as planned for the runoff P study located in the Iowa State University (ISU) Northwest Research and Demonstration Farm. The experiment consisted of five treatments that include an N-based liquid swine manure management system for continuous corn managed with chisel-plow tillage, P-based fertilizer management for corn-soybean rotations managed with no-till or chisel-plow tillage, and P-based liquid swine manure management for corn-soybean rotations managed with no-till or chisel-plow tillage. Table 1 shows the systems evaluated and the abbreviations used in this report. Corn and soybean of Systems 1 through 4 were grown each year on adjacent plots, and crops were rotated each year. The crops of the corn-soybean rotations were harvested for grain, while the continuous corn was harvested for grain and also for cornstalks (baled after harvest). All systems were replicated three times, and there were 27 plots each measuring 20 by 100 feet. The amount of P needed by crops of the corn-soybean rotations was determined by soil testing and estimated P removal with harvest, and was applied only once in the fall before corn and the 2-year P rate averaged 100 lb P_2O_5/acre. Triple superphosphate was broadcast for all fertilizer P treatments, was not incorporated for the no-till systems, and was incorporated in the spring for the tilled systems. Liquid swine manure from an underground pit was injected into the soil in the fall for all plots of the manure-based systems. Fertilizer N (28% UAN solution) was injected in spring as needed for corn after soybean so that the total N applied was at least 150 lb N/acre and equal for all four systems. For System 5 (continuous corn), manure was applied at 200 lb total N/acre each fall. The runoff samples were analyzed for sediment, dissolved reactive P (DRP) in samples filtered at the field using a 0.45 um filter, bioavailable P (BAP) as estimated by the iron oxide-impregnated paper test), total N, and total P (TP). We also measured total dissolved P in filtered runoff samples from selected systems. Soil samples were collected from several soil depths and were analyzed for P by three routine tests (Bray-1, Mehlich-3, and Olsen), total P, and other nutrients.

The field work for Objective 2 was conducted at a site located in the ISU Agronomy and Agricultural Engineering Research Farm in central Iowa. Treatments were eight cropping and nutrient management systems that included three different cropping systems (continuous corn, corn/soybean rotation, and switchgrass) with varying nutrient management and harvest strategies. Table 2 shows the systems evaluated and the abbreviations that will be used in this report. Three systems involved continuous corn systems managed with N-P fertilizers and harvested for grain, partial stover removal, or total aboveground biomass removal. Two systems involved continuous corn systems managed with N-based liquid swine manure harvested for grain or total biomass. There was one corn-soybean rotation system managed with N-based liquid swine manure harvested for grain. There were two switchgrass systems harvested for total aboveground biomass. One was managed with N-P fertilizer and the other was established in plots with a history of large swine manure application rates and received no nutrient application during the study. Plots with corn were chisel-plowed and disked in spring, soybean residue was disked in spring, and both fertilizer and manure were applied in the spring and incorporated into the soil. Monitoring of drainage and collection of flow-weighted water samples was on-going on at least a weekly basis. Unfiltered tile drainage samples were analyzed for nitrate, reactive P (by the Murphy and Riley method), and total P. Soil samples were analyzed for P and other routine tests as described for the other study.

Principal Findings and Significance

The sample collection and analyses have been completed for both sites and the two years of the project. We are still summarizing a major portion of the laboratory results at this time, however. For the surface runoff study these include sediment loss, runoff total dissolved P, runoff total N, and soil samples taken in fall 2009. For the tile drainage study these include both nitrate and P in tile drainage water and soil samples taken in fall 2009. Also, we have not completed statistical analyses for most measurements and sampling dates. Therefore, in this report we show and discuss the most relevant of the available results and cannot have final conclusions.

<u>Highlights of Results for Objective 1 - Runoff Study</u>.

There were a total of 13 runoff events with measurable water or soil loss for most plots of the experiment. We summarize results by showing average annual runoff P concentrations and loads for DRP, BAP), and total P fractions. The DRP fraction is readily available for algae in streams or lakes, the BAP fraction estimates both P readily available and P becoming available over a short period of time (probably 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 DRP, intermediate for BAP, and highest for TP. Runoff P was 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 DRP and BAP, 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 DRP or BAP) was highest for FP-CH and lower with small differences for the other systems. In the soybean years (corn residue), DAP and BAP 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 loads, which integrate treatment effects on runoff (water and soil losses) and runoff P concentrations. In the corn years, DRP and BAP losses were highest for the no-till and fertilizer-based system (FP-NT) and lowest for MP-NT, with small or no differences between the other intermediate systems. The TP losses were highest for FP-CH and MP-CH, lowest for MP-NT, and intermediate with small or no differences for the other two systems. In the soybean years, there were small differences between systems for DRP and BAP, 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 this figure must be interpreted with care because the corn and soybean crops alternate over time but there is corn every year for the continuous corn. The available results suggest 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.

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 DRP and BAP losses were the highest for the no-till and P fertilizer based system in corn years, which probably is explained by broadcast fertilizer application before no-till corn. The differences with the other systems were smaller, however, and this higher loss of DRP and BAP for the no-till and P fertilizer based system was not observed in the soybean years. The total P losses for systems managed with tillage were much higher (two to four times higher) than the DRP and BAP losses but differences were much smaller for the systems managed with no-till, which was an expected result. 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.

Highlights of Results for Objective 2 - Tile Drainage Study.

Monitoring of drainage and collection of flow-weighted tile drainage water samples was at least on a weekly basis from April to November 2008 and then from March to November 2009. Approximately 600 to 700 water samples were collected each year.

Figures 3 and 4 show nitrate-N concentrations for 2008 and those available from 2009. In 2008, the highest nitrate concentrations were for the continuous corn plots fertilized with commercial fertilizer at 200 lb N/acre. Continuous corn plots with manure applied received an average of 211 lb N/acre while the corn-soybean rotation received 159 lb N/acre for corn. A significant spike was observed for the commercial fertilizer plots in June 2008 that continued into July, which likely was due to extreme rain events during these months. Average nitrate-N concentration was lowest for the switchgrass plots receiving commercial fertilizer. Results for 2009 again indicate the highest nitrate-N concentrations for continuous corn treatments receiving commercial fertilizer, particularly for grain and total biomass harvest systems. Continuous corn plots with manure applied received an average of 159 lb N/acre while the corn-soybean rotation received 117 lb N/acre for corn. Similarly to results for 2008, there was a pronounced increase in nitrate-N concentrations in June for systems managed with inorganic fertilizer. Nitrate concentration was lowest for the switchgrass systems. Further interpretation and confirmation of apparent differences will be possible after completing data from 2009 and statistical analyses.

Figures 5 and 6 show tile drainage water reactive P concentrations for 2008 and those for available from 2009. In both years reactive P concentrations for most samples were extremely low, less than 5 ug/L for most treatments and flow events. Spikes in concentration occurred in April or June of each year and in the fall of 2008 (data for fall 2009 were not summarized at this time). These isolated spikes were not clearly related to the treatments applied and may be explained by relatively higher rainfall amounts during those periods.

Data for total P in drainage water for 2008 and 2009 are shown in Figures 7 and 9, respectively. The total

P concentrations were higher than reactive P concentrations for all treatments in both years, and there were no clear or consistent differences between management systems. In 2008, the total P concentrations followed reactive P trends closely, but there was less agreement in 2009. Further analysis and interpretation of these results will be possible after completing analysis of water and soil samples collected in 2009 and corresponding statistical analyses. Data for 2008 in Fig. 9 clearly show the higher total P concentration than for reactive P for all treatments, which on average was two to four times higher. Although in this study we did not analyze the nature of this additional P and drainage water samples were not filtered, the samples seldom had any sediment and previous work with soil extracts suggest that it mainly represents P in labile organic and inorganic compounds that is not measured by the Murphy and Riley colorimetric method.

Significance of Results.

The last portion of data collected during 2009 has not been summarized and no statistical analysis has been conducted. Therefore, no strong conclusions can be drawn at this time. Results for the surface runoff study indicate that, as expected, less P loss with no-till than with tillage for soybean residue, but small and inconsistent tillage effects for corn residue and also inconsistent differences between the fertilizer and swine manure P management systems. Results for the tile drainage study suggest larger nitrate loss for the fertilizer management systems than for the swine manure systems, and lowest loss for the switchgrass systems. These results suggest that swine manure N was less available for leaching through the soil profile than the fertilizer N. There were small differences between the cropping and harvest systems that cannot be interpreted with certainty until more recent samples are analyzed and statistical analysis are completed. Nitrate and P loss among the lowest in the study for switchgass established on plots that had a long history of large swine manure application (where soil-test P was very high) shows the great potential of such a system to remediate soils with high N and P loss. Comparisons of analyses for reactive P and total P in drainage water indicate that the differences between these two P fractions varied across systems and flow events, but on average TDP were two to four times higher than DRP for all management systems. We will continue studying results for both studies, but such a difference is important because dissolved P that is not measured as reactive P can be available for algae growth over a very short period of time.

Student Involvement

One M.S. graduate student participated in the project and received training in all aspects of the study, from treatment application to data management. One postdoctoral associate helped plan and execute the project, and up to three undergraduate students also helped at different times. These undergraduate students helped mainly with field and laboratory work.

Outreach Activities and Publications

Two progress reports with preliminary results of each portion of the project, were prepared in March 2010, and were posted in the web site of the ISU Research Farms (see specific reference below). Preliminary results also were shared at field days or conferences (see below). We will continue sharing results of the project through various ISU Extension outlets in 2010 and beyond. We will begin preparing presentations for scenic national meetings and two articles for scientific journals (one for each portion of the project) once analysis of all data is completed.

Helmers, M., C. Pederson, A. Staudt, R. Christianson, and A.P. Mallarino. 2010. Impacts of crop, biomass harvest systems, and nutrient management on yield and subsurface drainage water quality. Agric.

Eng., Agronomy, and Central Iowa Research Farms. RFR-A9135. ISRF09-16, 30. Iowa State Univ., Ames, IA. http://www.ag.iastate.edu/farms/reports.html.

Mallarino, A.P., A. Andrews, M. Haq, and M. Helmers. 2010. Corn harvest and nutrient management systems impacts on phosphorus loss with surface runoff. Agric. Eng., Agronomy, and Central Iowa Research Farms. RFR-A9133. ISRF09-16, 30. Iowa State Univ., Ames, IA. http://www.ag.iastate.edu/farms/reports.html.

Mallarino, A.P., M.J. Helmers, M.U. Haq, A.A. Andrews, and C.H. Pedersen. 2009. Biomass harvest and nutrient management impacts on nutrient loss from fields. Presentation at the Iowa Water Quality Conference, March 10, 2009, Iowa State University, Ames.

Mallarino, A.P., M.J. Helmers, M.U. Haq, C.H. Pedersen, and A.A. Andrews. 2008. Water quality impacts of biomass production. Presentation at the Bioeconomy Conference, Sep. 7-10, 2008, Iowa State University, Ames.

Mallarino, A.P., M.J. Helmers, and M.U. Haq. 2008. Tillage and nutrent management systems impacts on phosphorus loss with surface runoff. Field day presentation at the Northwest Iowa State Univ. Research and Demonstration Farm. Sep. 2, 2008. Sutherland.

Table 1. Management systems evaluated at the Northwest Iowa runoff study site.

System	Rotation	Tillage	Nutrient Management	Abbreviation		
				Crop	Nutrient	Tillage
1	Corn-Soybean	Chisel plow	Fertilizer P	Cs or Sc	FP	CH
2	Corn-Soybean	No till	Fertilizer P	Cs or Sc	FP	NT
3	Corn-Soybean	Chisel plow	Manure P	Cs or Sc	MP	CH
4	Corn-Soybean	No till	Manure P	Cs or Sc	MP	NT
5	Continuous Corn	Chisel plow	Manure N	CC	MN	CH

Table 2. Management systems evaluated at the Central Iowa tile drainage study site.

System	Crop rotation	Harvest Practice	Nutrient Management	Abbreviation
1	Continuous corn	Grain only	Fertilizer NP	CCGr-F
2	Continuous corn	Grain only	Manure N	CCGr-M
3	Continuous corn	Aboveground biomass	Fertilizer NP	CCTot-F
4	Continuous corn	Aboveground biomass	Manure N	CCTot-M
5	Continuous corn	Grain and stover baling	Fertilizer NP	CCSt-F
6a	Corn before soybean	Grain only	Manure N	CsGr-M
6b	Soybean before corn	Grain only	None	ScGr-M
7	Switchgrass	Aboveground biomass	Fertilizer NP	Sw-F
8	Switchgrass	Aboveground biomass	Manure history	Sw-Mh

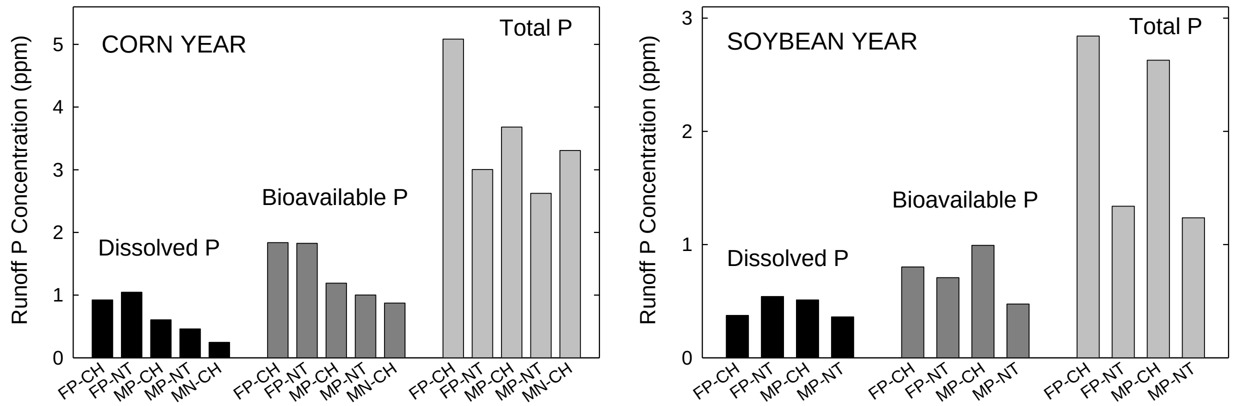

Figure 1. Runoff P concentrations for the corn and soybean years at the Northwest Iowa study (annualized averages).

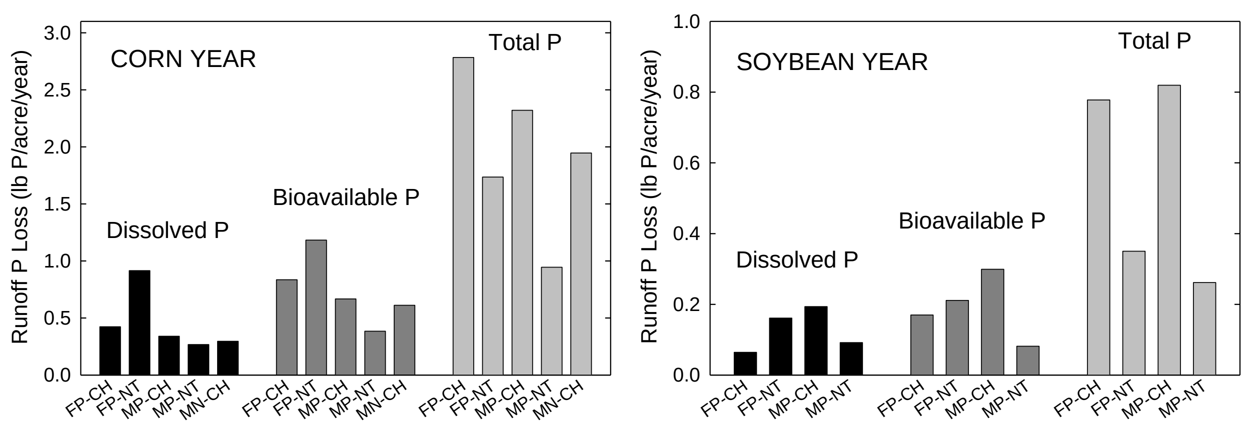

Figure 2. Runoff P loads for the corn and soybean years at the Northwest Iowa study (annualized averages).

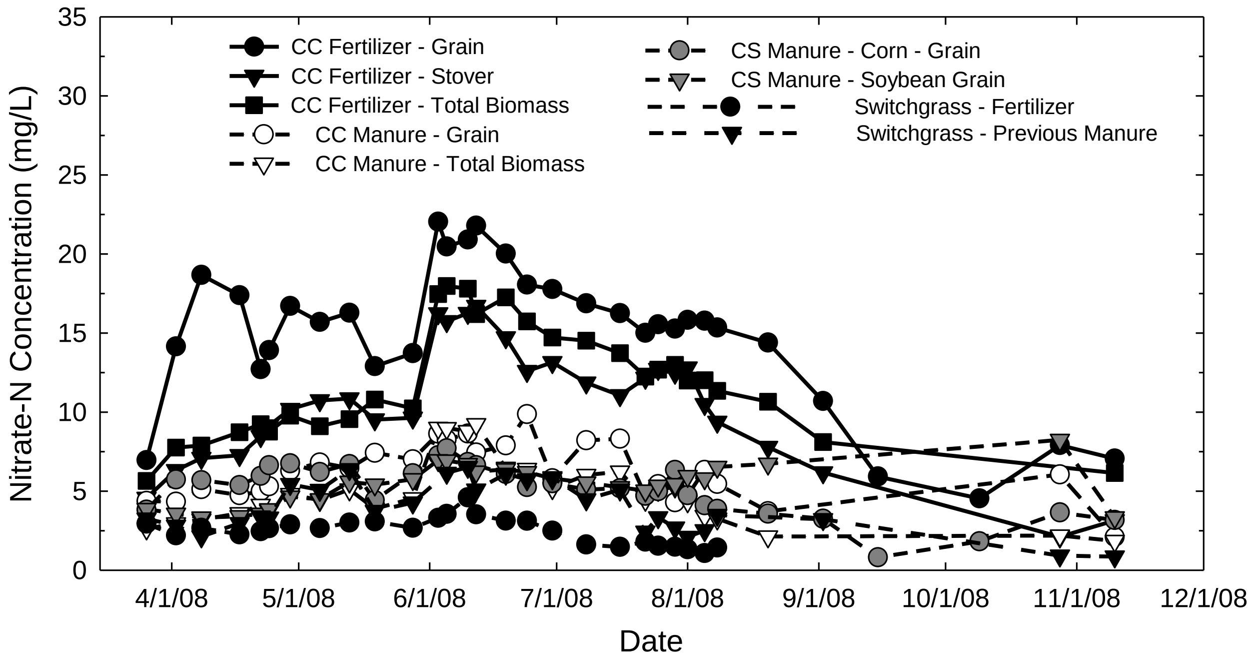

Figure 3. Nitrate-N concentrations in subsurface drainage water during 2008.

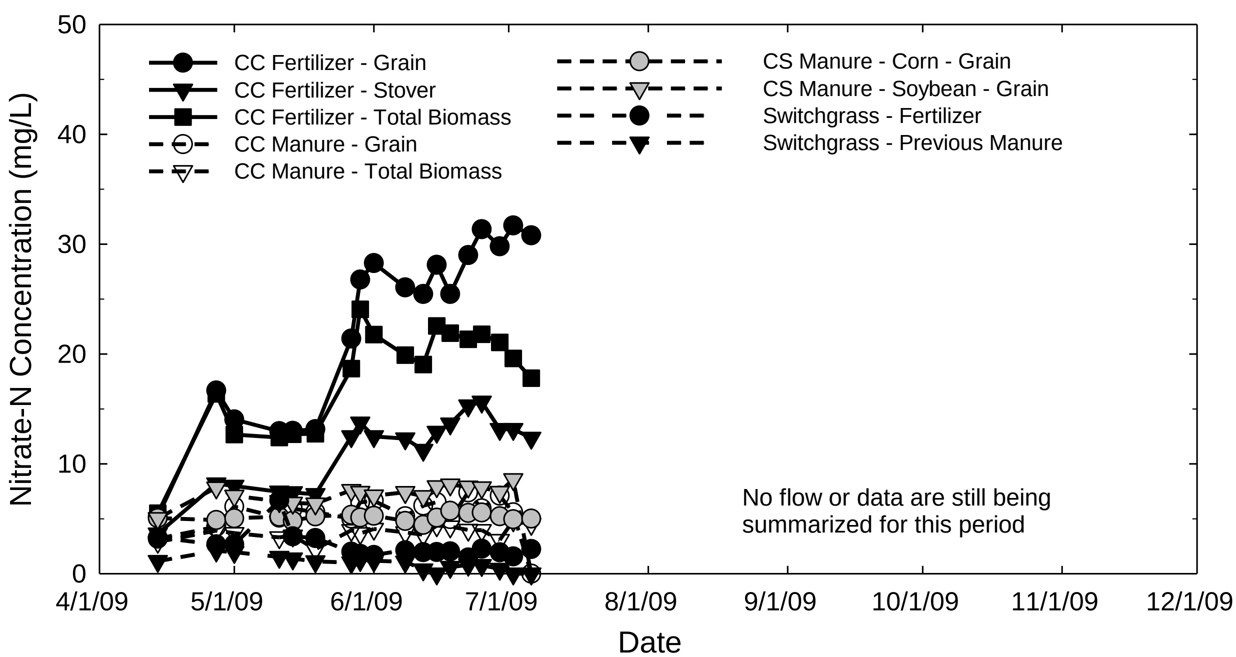

Figure 4. Nitrate-N concentrations in subsurface drainage water during 2009.

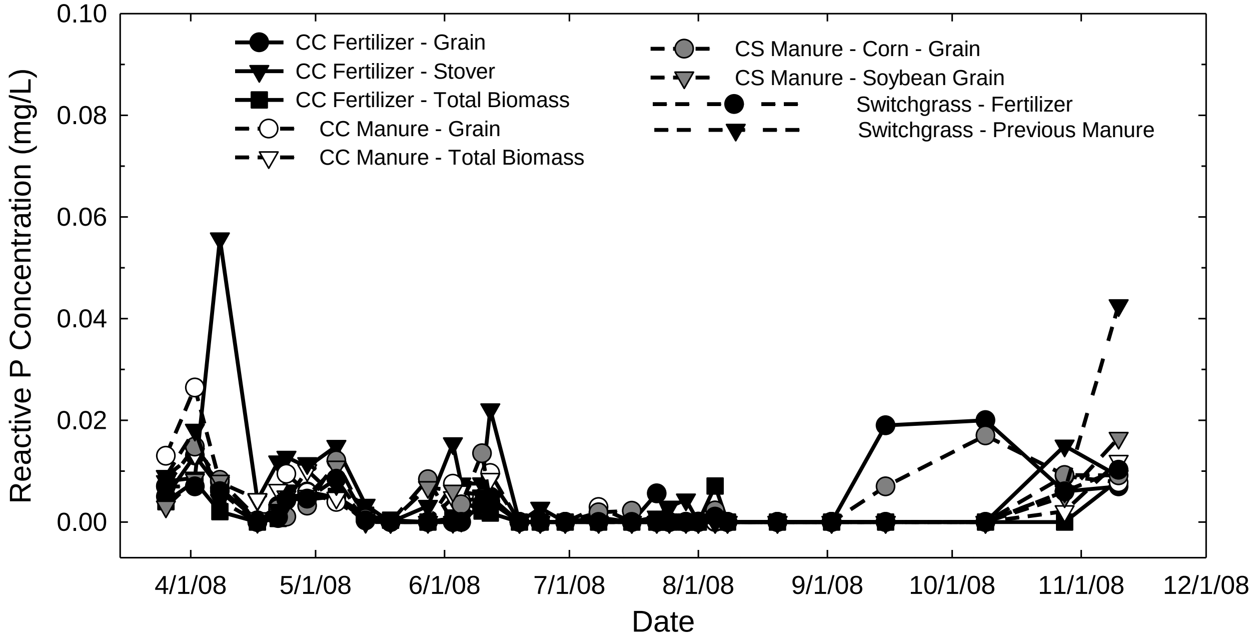

Figure 5. Reactive P concentrations in subsurface drainage water during 2008.

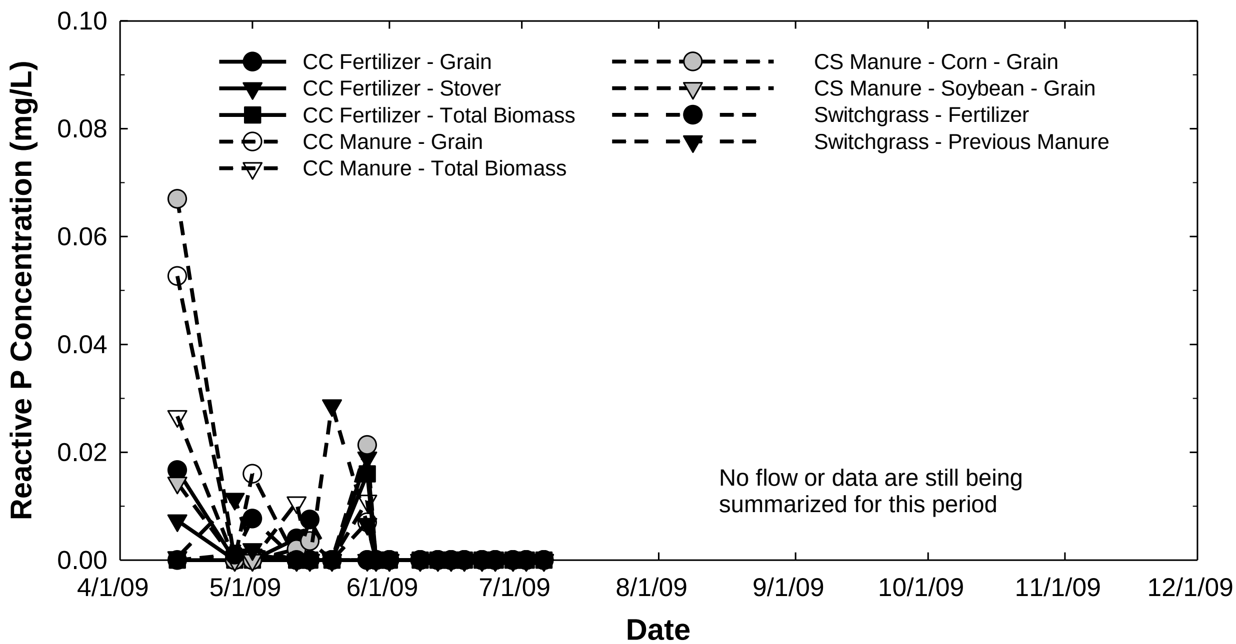

Figure 6. Reactive P concentrations in subsurface drainage water during 2009.

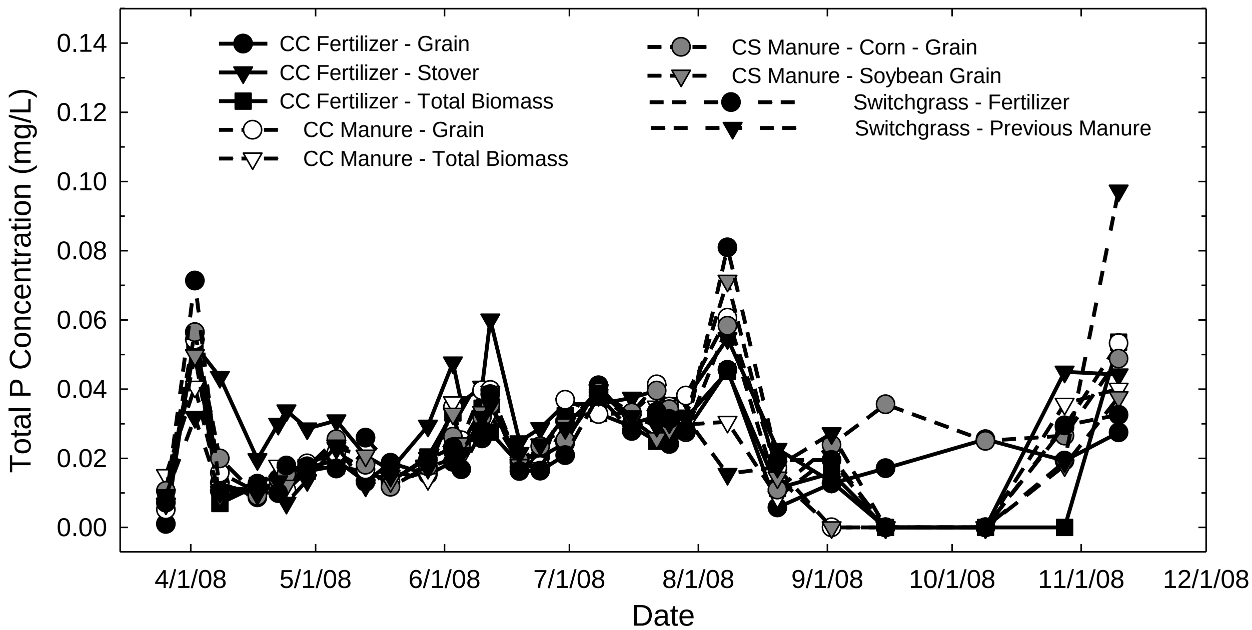

Figure 7. Total P concentrations in subsurface drainage water during 2008.

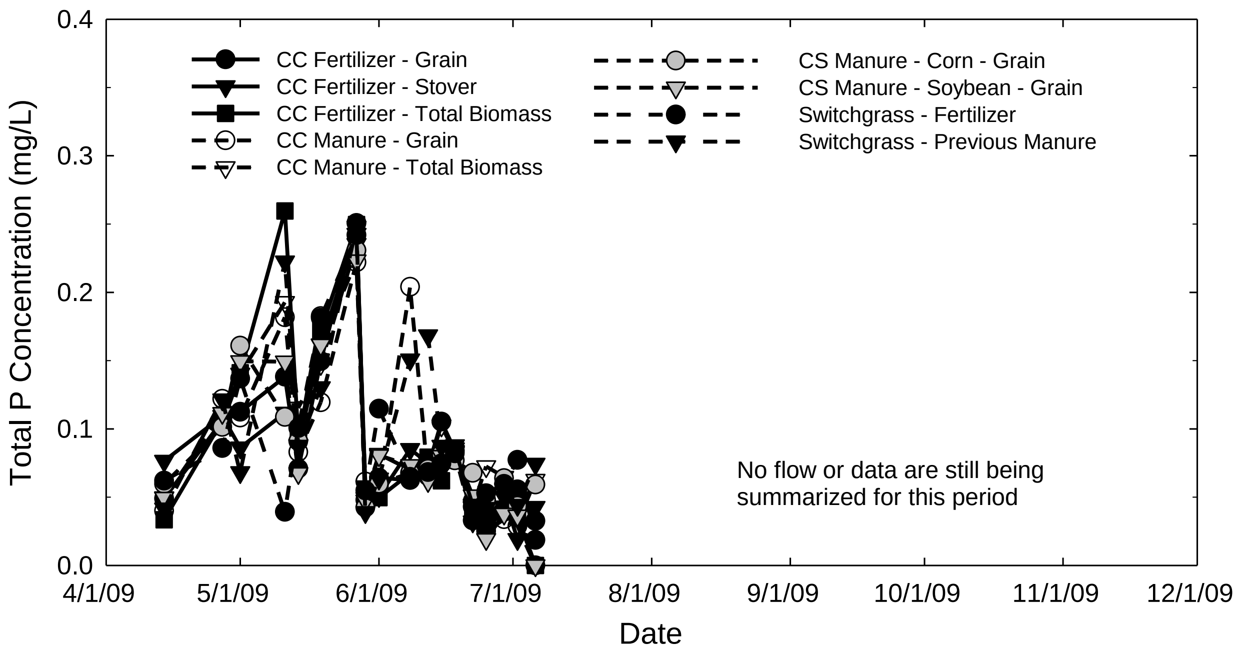

Figure 8. Total P concentrations in subsurface drainage water during 2009.

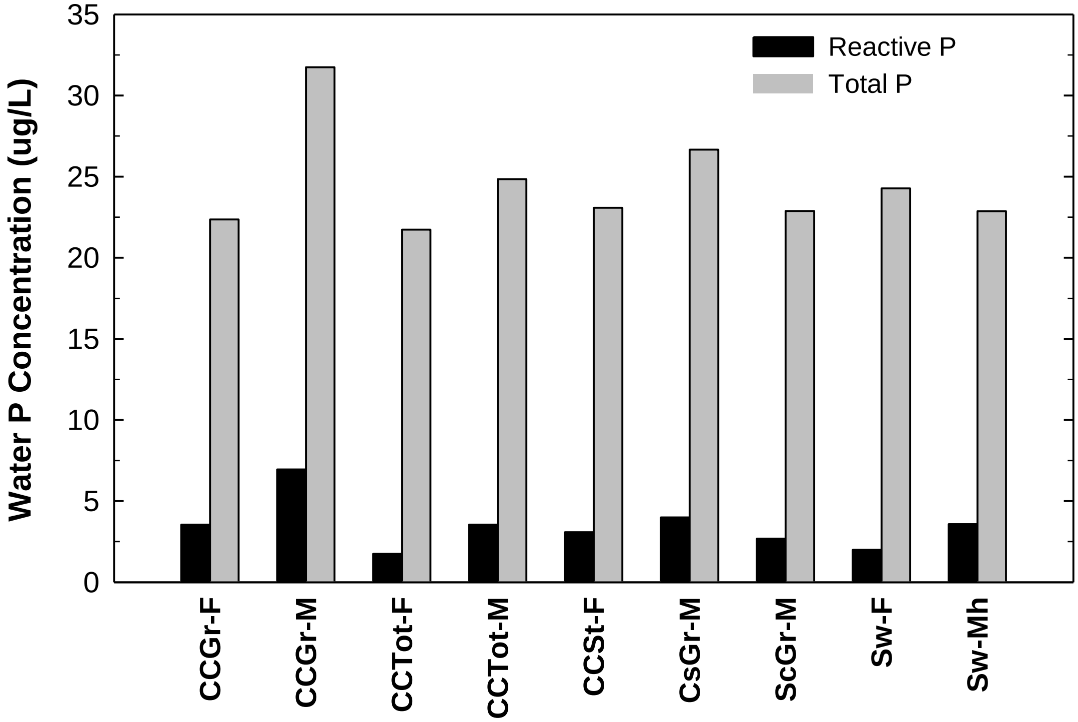

Figure 9. Comparison of reactive P and total P in tile drainage water for samples collected in 2008.