PHOSPHORUS LOSS WITH RUNOFF AFTER APPLYING FERTILIZER OR MANURE AS AFFECTED BY THE TIMING OF RAINFALL

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INTRODUCTION

Public concerns about agriculture impacts on water quality and the likelihood of further government regulation have been increasing. Phosphorus usually is the nutrient that limits and controls algae growth and eutrophication in freshwater bodies. The uninformed public and many in regulatory agencies see reducing fertilization rates as an effective way of reducing nutrient loss from fields and improving water quality, especially when animal manure is applied. Soil testing for P is a useful, although not perfect, diagnostic too that should be used in conjunction with P removal with crop harvest to decide fertilization rates and maintain available soil P at optimum levels for crops. Economic considerations do not justify fertilizer P application rates higher than needed to optimize crop yield. However, utilizing manure N and consideration of the cost of transporting manure may justify applying manure to high-testing soils when other site factors determine a low risk of P loss. This is the case because transport factors affecting soil and water loss from fields often are more important than soil-test P levels and application rates for P delivery to water resources.

The P source (mainly fertilizer or animal manure), the P placement method, and the time of the application are factors that can greatly affect P use efficiency by crops and P loss from fields in many ecoregions the US. However, Iowa research has shown no differences between fertilizer, liquid swine manure, and poultry manure P sources for crop production although the P availability of solid beef manure can be slightly lower. Also, Iowa research published in numerous articles has shown that broadcast or banded application of fertilizer or manure P in the fall or spring seasons do not have a major impact on P use by corn and soybean or the rate needed to optimize grain yield (even with no-tillage), except for a small complementary starter P rate in a few conditions. These results are reflected in current Iowa guidelines for fertilizer and manure P management (Sawyer and Mallarino, 2008; Mallarino et al., 2013). However, the loss of both dissolved and particulate P with surface runoff could be affected in different ways by the P source, the placement method, and the time of application in relation to the occurrence of runoff events. Therefore, this article highlights results of several research projects developed in Iowa to investigate some of these issues.

PHOSPHORUS RATE, TILLAGE, AND TIMING OF RUNOFF

A study we conducted in the middle 2000s to study the effects of various liquid swine manure P rates and management practices with the timing of runoff events. The results have been published (Allen and Mallarino, 2008) and a portion of them are relevant to understand the reasons for recent unpublished research. Liquid swine manure was applied at rates ranging from 0 to 100 lb P_2O_5/acre at two fields having soybean residues and 3 to 12% slope. The manure was broadcast with or without incorporation into soil by disking. Simulated rainfall was applied within 24 h of the application, after 15 days, or after 6 months. Any natural rainfall during the evaluation period was excluded from the plots. The rainfall simulator was built according to suggestions for a coordinated National Phosphorus Research Project being developed at the time,

and the simulation and runoff collection procedures followed the established guidelines.

The results were comparable for both sites, and Fig. 1 shows the most relevant results for one site. Incorporation of P into the soil by disking greatly reduced the P loss for the runoff event occurring shortly after application. The benefit of incorporating the P was much less when the occurrence of rainfall and runoff was delayed. The effect of a runoff event delay for 15 days on both dissolved reactive P (DRP) and total runoff P was proportionally greater for the non-incorporated treatment and the lower application rates. At low P application rates, the incorporation actually increased total P loss with runoff probably because of increasing soil and particulate P loss. Another significant result was that the percentage DRP of the total runoff P was higher without P incorporation, increased with the P rate, and decreased with a runoff delay. The DRP fraction is the most active at stimulating algae growth and eutrophication. These results are important because application of P fertilizer or manure to the surface in no-till or in the fall without tillage until spring is very common in Iowa and the Corn Belt.

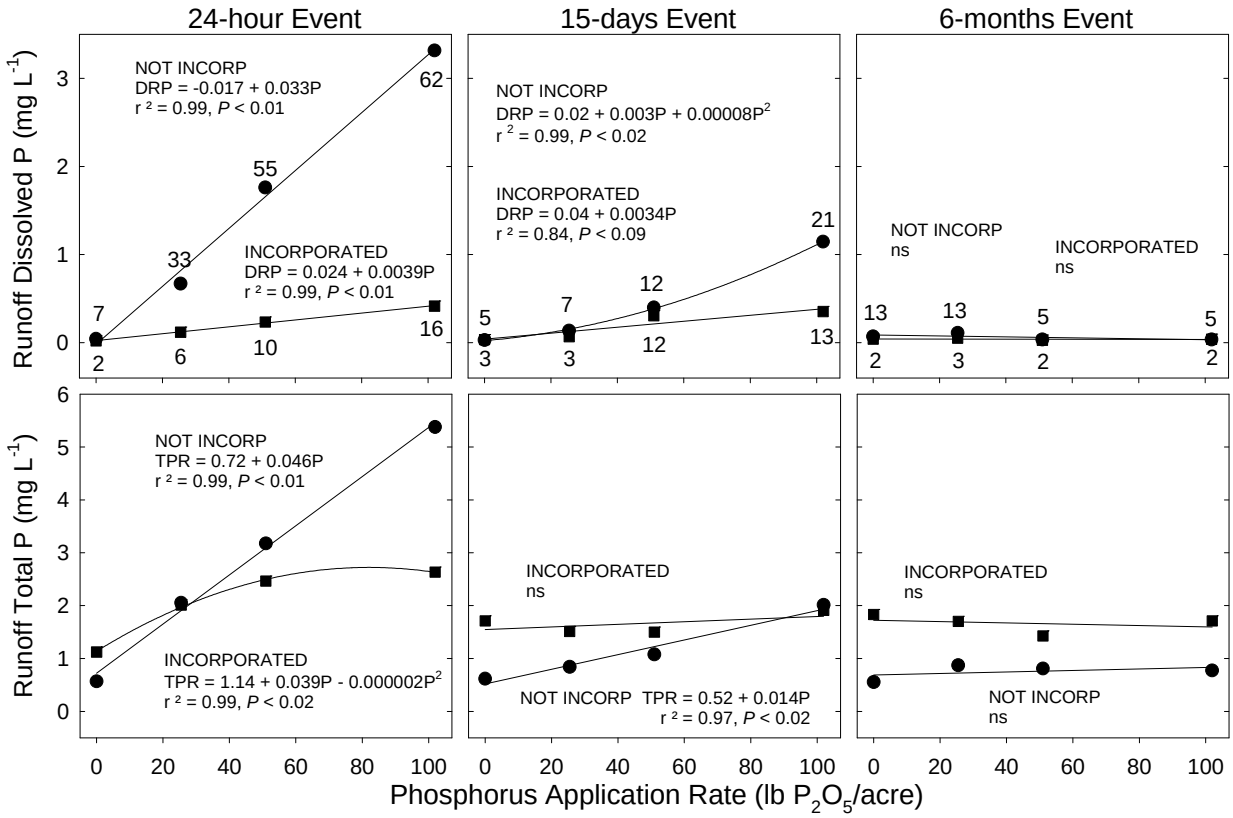

Fig. 1. Liquid swine manure P rate, incorporation, and time of rainfall effects on runoff P concentrations for an Iowa field. Numbers by the DRP data points indicate percent DRP of the total P. Adapted from Allen and Mallarino (2008).

FERTILIZER OR MANURE PHOSPHORUS AND TIMING OF RUNOFF

The results of the previous Iowa research with liquid swine manure suggested further research to study effects of different P sources on P loss with surface runoff interacting with the P application method and the timing of runoff events. We developed several projects utilizing similar field rainfall simulation techniques using single P application rates of fertilizer and various types of animal manures.

Figure 2 summarizes results from a study in 21 Iowa fields that investigated the effect of several P sources on the P loss with runoff for events occurring within 24 hours of applying 100 lb P_2O_5/acre to the soil surface without incorporation into the soil. All fields had soybean residue and the soil had not been tilled. The concentration of both dissolved (DRP) and total P in the runoff was the highest for fertilizer (DAP), intermediate for liquid swine manure (from pits), and lowest for poultry (solid egg-layer manure) and beef manure (solid feedlot manure with little bedding). The ranking of results for fertilizer and liquid swine manure shown by averages in Fig. 2 were similar in all fields, but the ranking for beef and poultry manure switched in a few fields. Moreover, at several fields the results for the control receiving no P, beef manure, and poultry manure were statistically similar. Contrary to expectations, runoff volume was not clearly affected by the P source and, therefore, results for P loads were similar to concentrations but more variable (not shown).

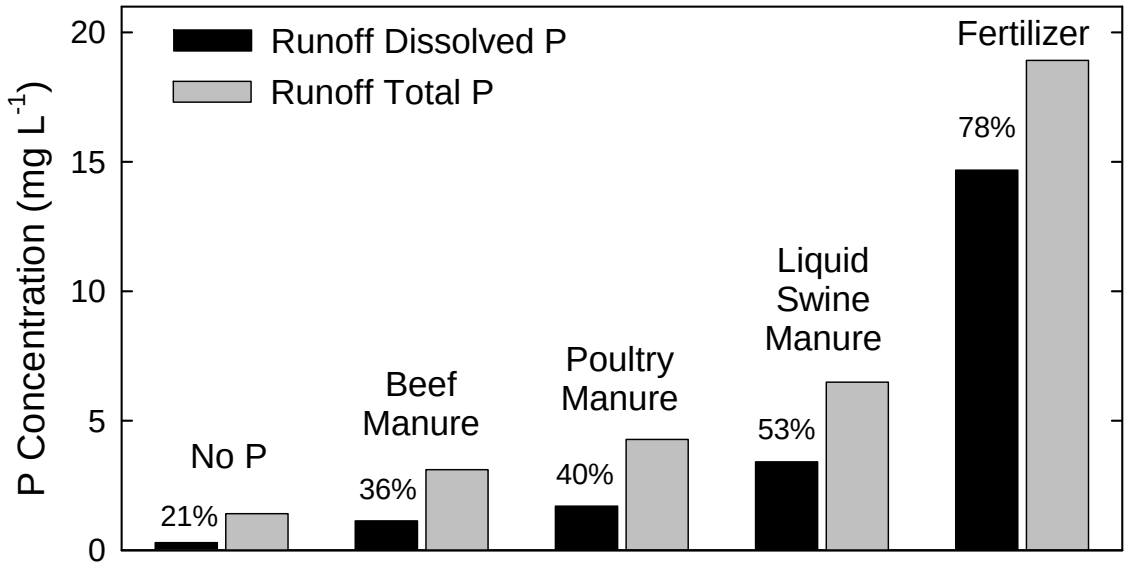

Fig. 2. Runoff P for rainfall events within 24 hours of broadcast surface application of 100 lb P_2O_5/acre using several P sources across 21 Iowa sites. Numbers on top of the bars indicate percent DRP of the total P.

Another significant result from this study was that the proportion of dissolved P in the runoff was the highest for fertilizer, intermediate for liquid swine manure, and the lowest and statistically similar for poultry and beef manures. Both results can be explained by the higher proportion of P immediately soluble in water in the fertilizer than in the manures (although highly it is variable). Therefore, when P is applied without injection or incorporation into the soil in periods of high probability of high intensity of rainfall such as in early spring, the risk of total and dissolved P loss is much higher for fertilizer than for manures.

Figure 3 summarizes results of another study that focused on assessing P loss with surface runoff as affected by the P source (three) and the timing of runoff (three) after applying P to the soil surface without incorporation by tillage or injection. The study was conducted on different areas of two fields during three years, and data shown are averages across years and sites. The P sources were DAP fertilizer, liquid swine manure from pits, and egg-layer manure. These P sources were applied at 100 lb P_2O_5/acre in the fall shortly after harvesting corn or soybean

grain. The times of runoff treatments applied to different plots after the one-time P application were within 24 hours, after 10 days with or without light rainfall since the P application that wetted the soil but did not cause runoff, and snowmelt runoff. The fall rainfall events were created by rainfall simulations, and the snowmelt runoff was collected during winter and until early March as it occurred naturally.

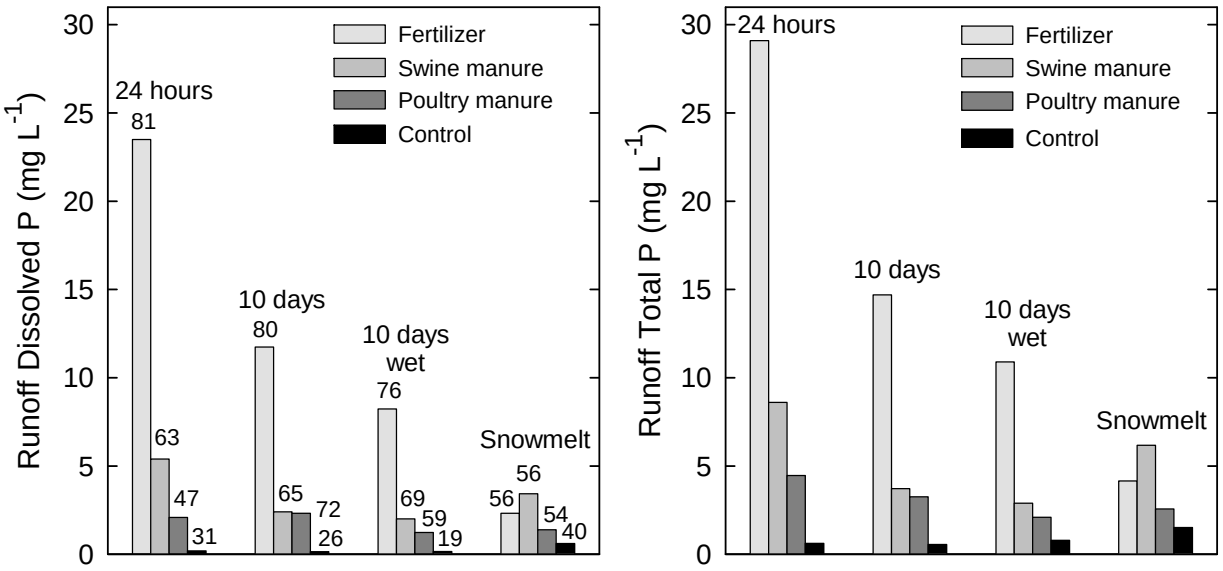

Fig. 3. Dissolved and total P concentration in runoff after applying three P sources in the fall with runoff occurring within 24 hours, 10 days after, 10 days after and light rainfall the wetted the soil, and in winter as snowmelt. Numbers on top of the bars indicate percent DRP of the total P.

In the fall runoff events, the concentrations of dissolved (DRP) and total P in surface runoff were greatly affected by the P source and the timing of a runoff event. Runoff P was the greatest for fertilizer, intermediate for liquid swine manure, and lowest for poultry manure. A delay in rainfall reduced runoff P for fertilizer significantly compared with the 24-hour runoff event, and also but to a lesser extent for liquid swine manure. The runoff delay effect was more pronounced after light rainfall that did not cause runoff. The runoff P for poultry manure was the smallest of all sources, and a runoff delay reduced little the already small P loss. The runoff volume was not clearly affected by the treatments, and results for P loads were similar to concentrations but more variable (not shown). The proportion of DRP of the total P in the fall season runoff tended to be the greatest for fertilizer, intermediate for liquid swine manure, and the lowest for poultry manure but was less clearly affected by the timing of the runoff event. For snowmelt runoff, most of which occurred two to four months after the P application in the fall, runoff DRP and total P were statistically similar for the three P sources as was the DRP proportion of the total runoff P. A remarkable result of the snowmelt runoff from the fertilizer plots was that the P loss was much smaller than for the fall rainfall events and became similar to the loss from the manure plots, which likely is explained by retention of the soluble fertilizer P by the surface soil.

Another rainfall simulation study was conducted to investigate how selected non-factorial treatment combinations of the time of application of three P sources, incorporation into the soil, and time to a runoff event affect P loss with surface runoff. The study was conducted on different

areas of three fields having soybean residues during two years, and data shown are averages across sites and years. Fertilizer (DAP), liquid swine manure, and egg-layer manure were applied at 100 lb P_2O_5/acre in the fall with disk tillage to incorporate the P or without tillage, and simulated rainfall was applied within 24-hours of application. One additional set of plots without incorporation into the soil was used to study effects of delaying the runoff event for 10 days and another set was used to study the effect of delaying runoff until snowmelt. Also, all sources were applied using a similar P rate in January to snow-covered and frozen ground that had not received P or tillage in the fall. Naturally occurring snowmelt runoff was collected during winter until early March.

Figure 4 shows that for runoff events occurring within 24 hours of P application without incorporation into the soil, runoff dissolved (DRP) and total P for fertilizer were much greater than for either manure, but were only slightly greater with incorporation by tillage. Moreover, tillage greatly reduced P loss for the fertilizer but only slightly for either manure. A 10-day delay in the first runoff event without tillage had little effect on runoff P for the manured plots compared with the 24-hour runoff event, but reduced runoff P from the fertilizer plots to about one-fourth the runoff P concentration for the 24-day event without tillage and to one-half with tillage. The proportion of DRP of the total runoff P for the 24-hour runoff events was greater without incorporation into the soil than with incorporation and was the greatest for fertilizer, intermediate for liquid swine manure, and the lowest for poultry manure. For a runoff event delayed 10 days, however, the proportion of DRP was similar for the fertilizer and liquid swine manure treatments.

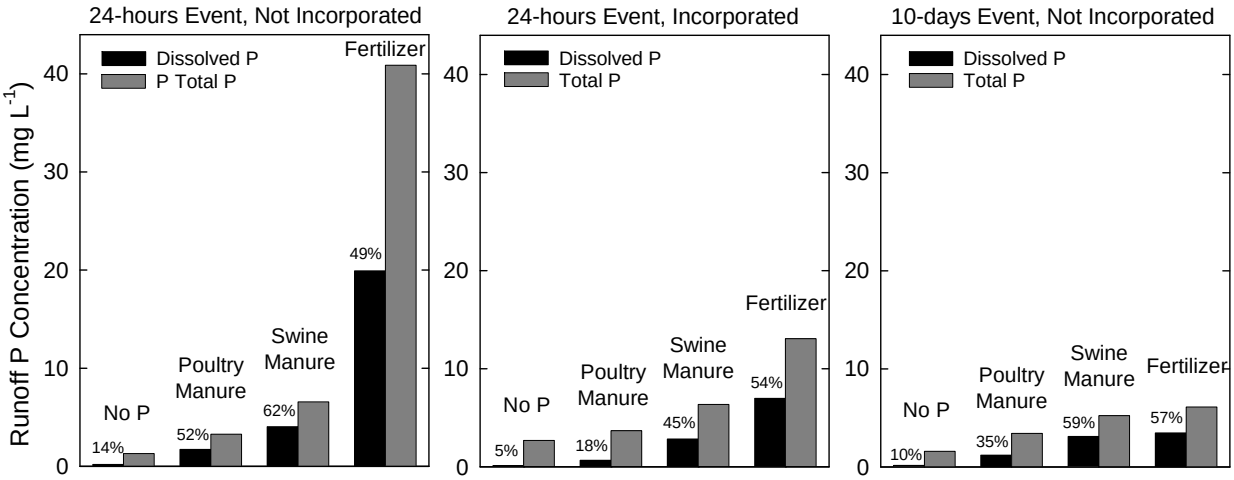

Fig. 4. Dissolved reactive P and total P in runoff as affected by the P source, incorporation, and the timing of a runoff event shortly after applying 100 lb P_2O_5/acre. Numbers on top of the bars indicate percent DRP of the total P.

Figure 5 shows results for snowmelt runoff. The rankings of the P sources were similar to those found for the fall rainfall simulations, but snowmelt runoff P for fall-applied fertilizer without incorporation was about one-fourth of that observed in the fall 24-hour event with the same treatment. This figure also shows that both DRP and total P for the P application in early winter to frozen and snow-covered ground were only slightly greater than for the application in the fall without incorporation into the soil. The proportion of DRP of the total snowmelt runoff P for the fall incorporation time was the greatest for fertilizer, intermediate for liquid swine

manure, and the lowest for poultry manure. With application in winter, however, the proportion of DRP of total snowmelt runoff P was not clearly different for the three P sources.

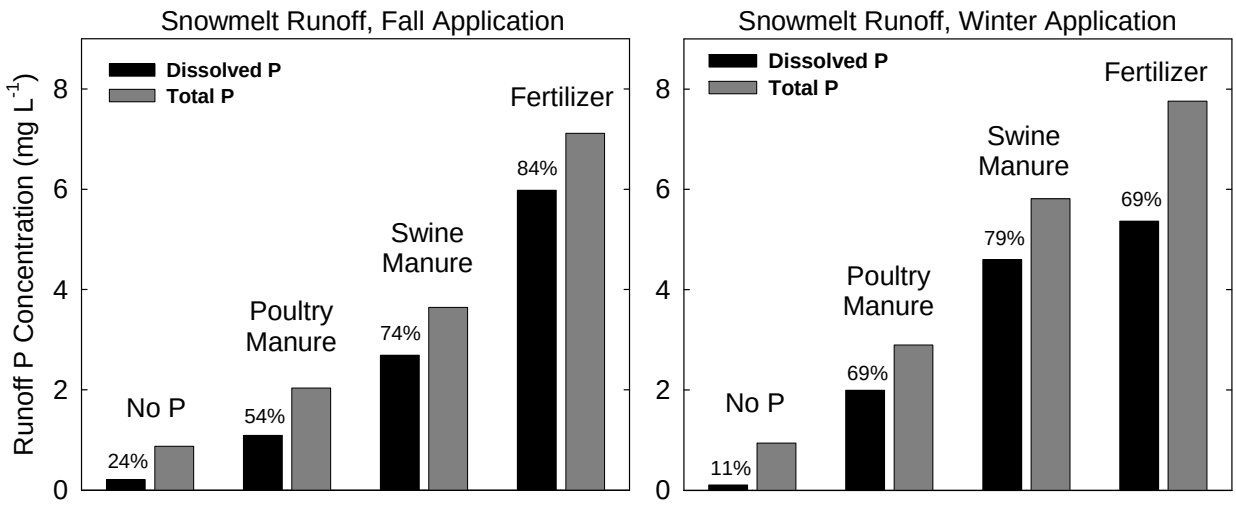

Fig. 5. Dissolved reactive P and total P in snowmelt runoff after applying 100 lb P_2O_5/acre in the fall or early winter to snow-covered ground using several P sources. Numbers on top of the bars indicate percent DRP of the total P.

SUMMARY AND CONCLUSIONS

The results of several studies showed that the P loss with surface runoff and the proportion of dissolved P for events shortly after applying inorganic fertilizer or liquid swine manure without incorporation into the soil were much larger than for solid poultry or beef manure. Incorporating fertilizer or liquid manure reduced dissolved P loss during runoff events immediately after the P application, but reduced total P loss only with the highest rates used.

A delay in a runoff event as short as ten days after P application to the soil surface without incorporation greatly reduced both dissolved and particulate P loss compared with runoff events immediately after application. The effect of a runoff event was much more pronounced for inorganic fertilizer than for manure. Longer runoff delays reduced dissolved and total P loss further and to levels comparable to or even lower than with a runoff event immediately after incorporation into the soil by disking. Among the manures evaluated, the reduction due to a runoff delay was more pronounced for liquid swine manure than for solid poultry manure.

Therefore, application to the soil surface of inorganic fertilizer or liquid swine manure with anticipation of periods with likely runoff events can significantly reduce potential loss of dissolved P, which is the runoff P fraction most active at encouraging algae growth and eutrophication of water resources. Late winter and early spring is the period with most likely high intensity rainfall and surface runoff in Iowa conditions.

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