How can fertilizer and manure management practices reduce dissolved phosphorus loss from fields and improve water quality?

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Introduction

Phosphorus (P) usually is the nutrient that limits and controls algae growth and eutrophication in freshwater bodies. Public concerns about agriculture impacts on water quality and the likelihood of further government regulation have been increasing. A major portion of the public and some in regulatory agencies see reducing P fertilization rates as an effective way of reducing nutrient loss from fields. Economic considerations do not justify P fertilizer 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. Utilizing manure N as much as possible helps farm economics and the environment by reducing N inputs, and transport factors affecting soil and water loss from fields often are more important than soil P levels or P application rates at determining P delivery to water resources. This is the main science supported reason for using a comprehensive tool such as the P index to determine the risk of P loss from fields, instead of just using soil-test P or P rate as the main criteria. However, managing soil-test P and P application appropriately is important, and often is easy to implement and can actually increase profit from crop production.

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 soil P at optimum levels for crops. The P source (mainly fertilizer or animal manure), the placement method, and the time of the application can greatly affect P use efficiency by crops in some regions the US. However, research in Iowa has shown no difference 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). In Iowa, however, the loss of both dissolved and particulate P with surface runoff could be greatly 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 time of runoff after application

A study was 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 from a coordinated National Phosphorus Research Project being developed at the time, and the procedures followed the established guidelines.

The results were comparable for both fields, so Figure 1 shows the most relevant results for one field as an example. Incorporation of manure P into the soil by disking greatly reduced the P loss for a runoff event occurring immediately after the application. The benefit of incorporating the P was much less when the occurrence of rainfall and runoff was delayed, however. The effect of a runoff event delay of 15 days on dissolved reactive P (DRP) and total runoff P (which also includes both DRP and sediment-bound or particulate P) was proportionally greater for the non-incorporated treatment and the lower application rates. The DRP fraction is the most active at stimulating algae growth and eutrophication. With low P rates, the incorporation actually increased total P loss 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. 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.

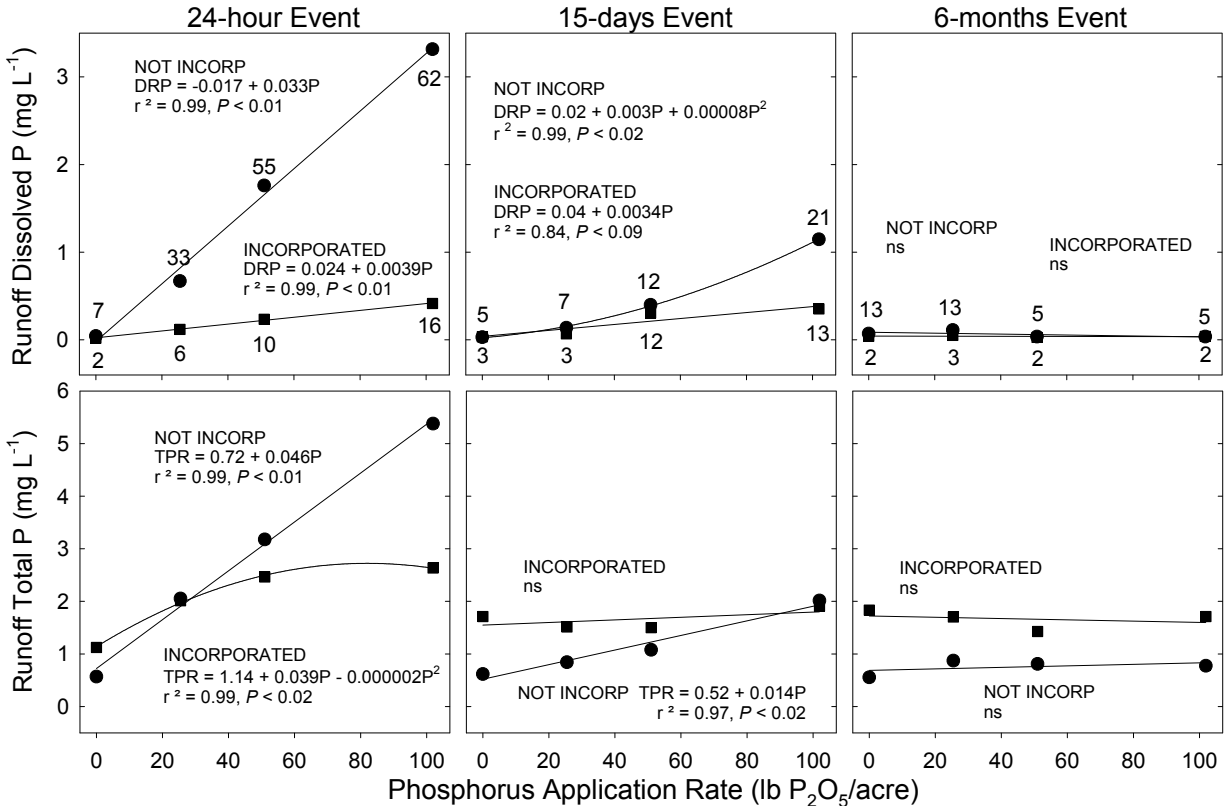

Figure 1. Liquid swine manure P rate, incorporation, and timing of rainfall effects on runoff P concentrations for an Iowa field. Numbers by the DRP points indicate percent DRP of the total P. Adapted from Allen and Mallarino (2008).

Fertilizer or manure P and time of runoff after application

The results of the research with liquid swine manure summarized above 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 was not tilled. The concentration of both 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 the average results shown for fertilizer and liquid swine manure were similar in all fields, but the ranking for beef and poultry manure switched in a few fields. Moreover, at some fields there were no statistical differences between the control, beef manure, and poultry manure. 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).

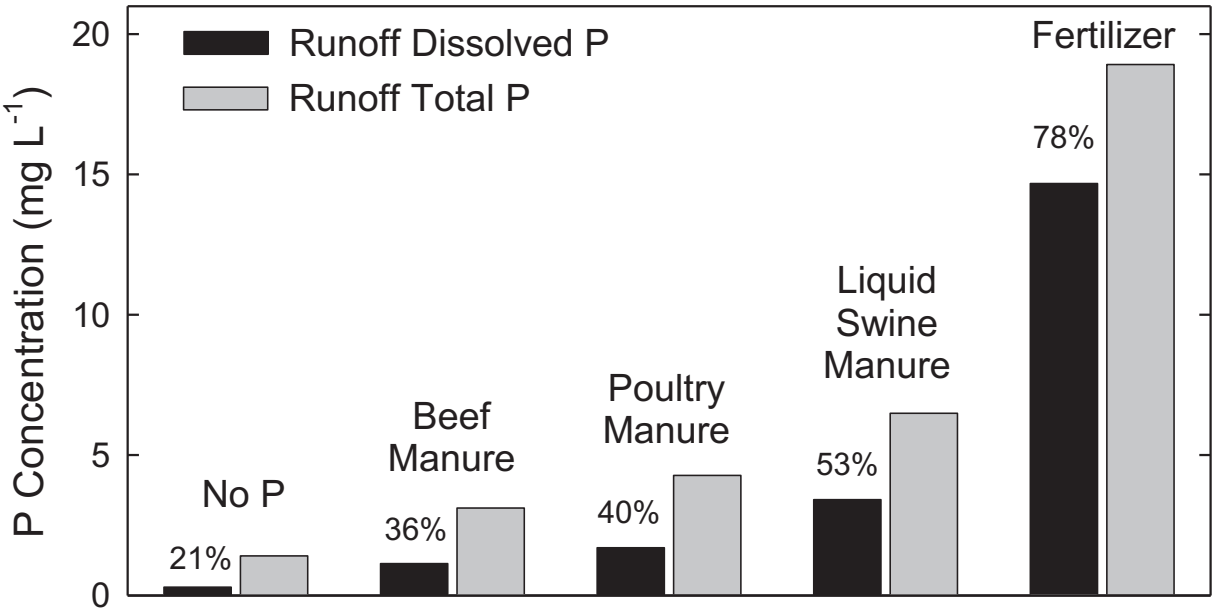

Figure 2. Runoff P for rainfall events within 24 hours of broadcast surface application of 100 lb P_2O_5/acre using several P sources across 21 Iowa sites. Numbers on top of the bars indicate percent DRP of the total P.

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 a study that assessed 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 treatments were DAP fertilizer, liquid swine manure from pits, and egg-layer manure; all applied at 100 lb P_2O_5/acre in the fall shortly after harvesting corn or soybean grain. The times of runoff treatments were within 24 hours of the P application in the fall, after 10 days with or without light rainfall since that wetted the soil but did not cause runoff, and snowmelt runoff during winter and early spring. The fall rainfall events were created by rainfall simulations, and the snowmelt runoff was collected as it occurred naturally.

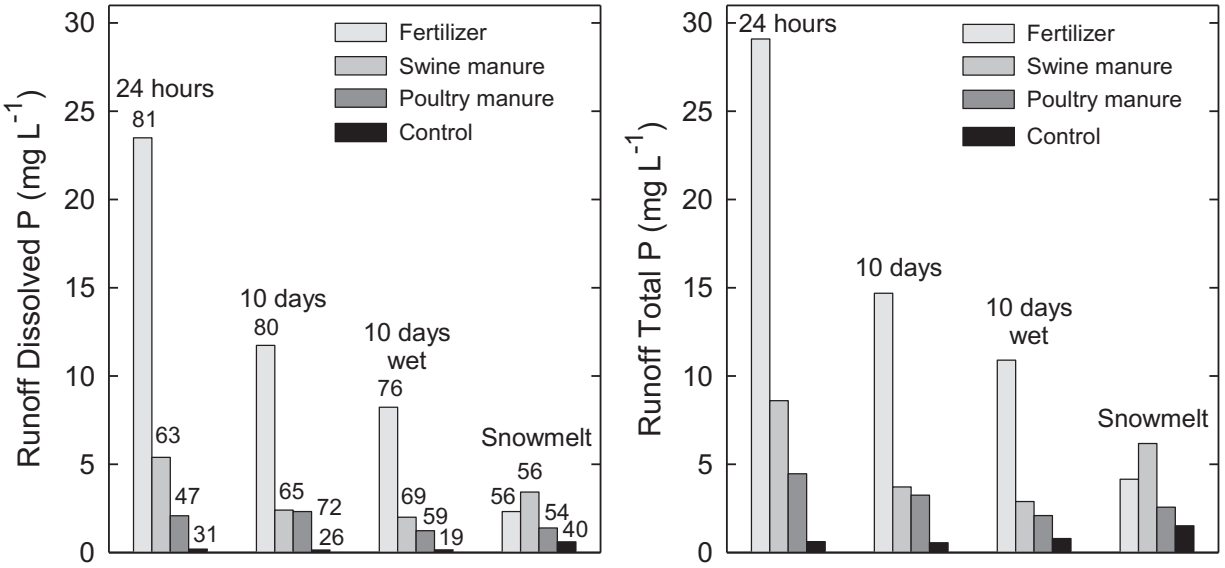

Figure 3. Dissolved and total P concentration in runoff after applying three P sources in the fall with runoff occurring within 24 hours, 10 days after, 10 days after and light rainfall the wetted the soil, and in winter as snowmelt. Numbers on top of the bars indicate percent DRP of the total P.

In the fall runoff events, the concentrations 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 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, 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 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. Two additional set of plots without P incorporation into the soil was used to study effects of delaying the runoff event for 10 days in the fall or until snowmelt runoff. In addition, all sources were applied to another set of plots using a similar P rate in January to snow-covered and frozen ground that had not received P or tillage in the fall. Snowmelt runoff was collected during winter until early April.

Figure 4 shows that for runoff events occurring within 24 hours of P application without incorporation

into the soil, runoff DRP and total P for the fertilizer were much greater than for either manure, but the differences between fertilizer and the manures were much smaller 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 manures compared with the 24-hour runoff event, but reduced runoff P from the fertilizer to one-fourth of that 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 event 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 the 10-day runoff, however, the proportion of DRP was similar for the fertilizer and liquid swine manure.

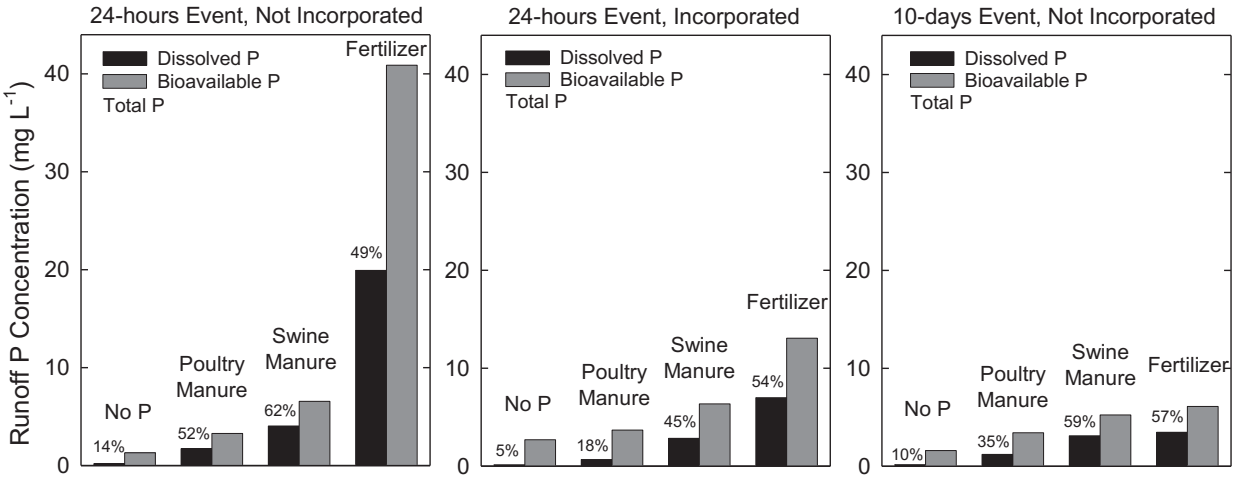

Figure 4. Dissolved reactive P and total P in runoff as affected by the P source, incorporation, and the timing of a runoff event shortly after applying 100 lb P2O5/acre. Numbers on top of the bars indicate percent DRP of the total P.

Figure 5 shows results for snowmelt runoff in this study. The rankings of the P sources were similar to those found for the fall runoff events, 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.

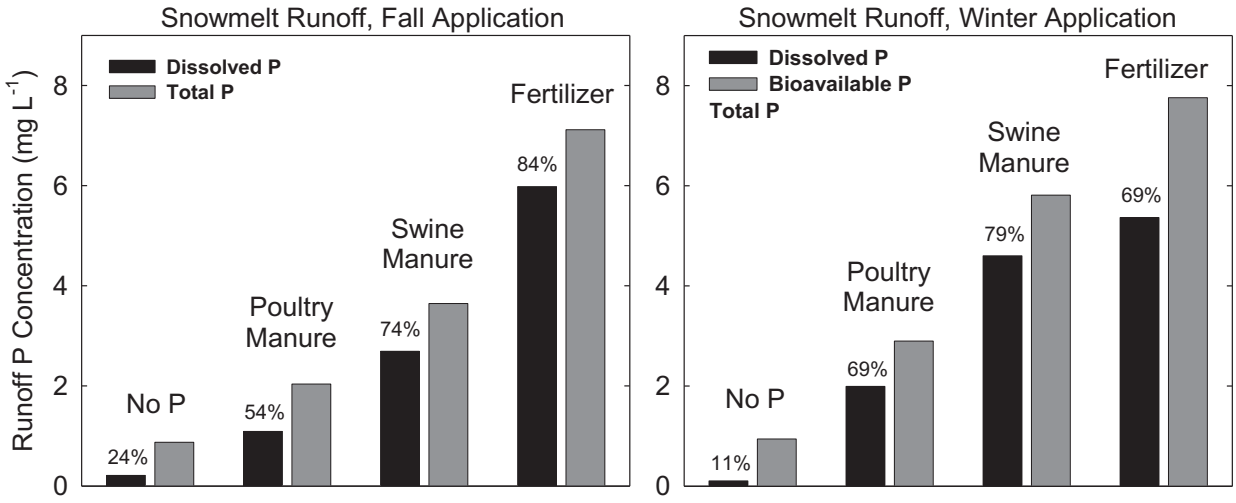

Figure 5. Dissolved reactive P and total P in snowmelt runoff after applying 100 lb P2O5/acre in the fall or early winter to snow-covered ground using several P sources. Numbers on top of the bars indicate percent DRP of the total P.

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 fertilizer or liquid swine manure P without incorporation into the soil were much larger than for solid poultry or beef manure P. Incorporating fertilizer or liquid manure reduced dissolved P loss during runoff events immediately after the 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 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 manure than for solid manure.

Therefore, application to the soil surface of 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.

References

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