MANURE MANAGEMENT IMPACTS ON PHOSPHORUS LOSS WITH SURFACE RUNOFF AND ON-FARM PHOSPHORUS INDEX IMPLEMENTATION. AN OVERVIEW OF ONGOING RESEARCH

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Introduction

Excessive phosphorus (P) application to many Iowa soils and inappropriate application methods have resulted in significant P loss from fields and water quality impairment. Excess P impairs water in streams and lakes through a process known as eutrophication, which occurs when P levels are too high and stimulate excessive algae growth. Excessive algae growth reduces water oxygen levels and creates ecological imbalances that reduce populations of desirable fish species as well as the drinking and recreational value of water resources. The P loss from fields cannot be appropriately assessed or predicted only from knowledge of soil-test P, manure or fertilizer P applied, and method or timing of P application. Although these factors are important, how much P moves off fields through various transport mechanisms is as important or even more important. Therefore, a new tool that integrates P source and transport factors was needed to estimate risk of P loss from fields. The Iowa phosphorus (P) index is an assessment tool that was developed to assess the long-term risk of P loss from fields to streams and lakes. Risk ratings can be used to prioritize fields or field zones for manure or fertilizer P application and for implementing improved management practices that maintain or reduce the risk of P loss.

Several research projects are being developed to learn more about P loss from fields and how to minimize the losses. Previous presentations have shown that increasing soil-test P values above optimum levels for crop production results in linear or exponential increases in P loss with surface runoff. This presentation summarizes results of ongoing projects to study the impact of rates and methods of P application on P loss with surface runoff and of P index on-farm implementation work.

Phosphorus in Surface Runoff as Affected by Management Practices

Manure and fertilizer P management systems.

A project being conducted in Northeast Iowa uses a field rainfall simulation technique to study P in surface runoff from a soil that has been managed with five nutrient and tillage management systems for corn-soybean rotations since 1999. The relevant treatments for the systems are shown in Table 1. Liquid swine manure from an underground pit always was injected into the soil. Fertilizer P was broadcast before fall tillage of corn residue and before spring field cultivation of soybean residue. The N-based manure rate was 150 lb N/acre (total manure N) and P application rates followed Iowa recommendations.

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Rainfall simulations were conducted once in each fall and spring season of 2 years. Simulations were conducted as soon as nutrient and tillage treatments were applied for each season. Runoff samples were collected and analyzed for total P, bioavailable P (iron-oxide impregnated filter paper method), and dissolved reactive P. The management systems resulted in different soil P levels, and results for Bray-1 P and total P in the top 2 inches of soil are shown in Fig. 1. Soil P was highest for the system using N-based manure for both crops, intermediate for the two systems using N-based manure for corn, and lowest for the systems using P-based fertilizer or manure for corn and P fertilizer for soybean.

Figure 2 shows the concentrations of total, bioavailable, and dissolved P lost during 30 minutes of spring runoff (averages of two seasons), when the likelihood of runoff events in Iowa is highest. Total runoff P was much higher than for other fractions, and was highest for the system applying N-based manure for both crops. It was followed by N-based manure only for corn, approximately similar for P-based manure or fertilizer, and N-based manure for no-till corn. Differences between systems for bioavailable P and dissolved P concentrations in runoff were proportionally lower than for total runoff P. Bioavailable P concentrations were highest for the system applying N-based manure for both crops, intermediate for systems applying fertilizer P or N-based manure for corn, and lowest for systems applying N-based manure for no-till corn or P-based manure for corn and P fertilizer for soybean. Dissolved P losses were highest for the system applying N-based manure for both crops and lowest for the system applying P-based manure for corn and P fertilizer for soybean.

Runoff P concentrations for total and bioavailable P fractions were highest for the two systems with the highest soil P levels. The no-tillage management significantly reduced total and bioavailable P in runoff compared with a similar N-based manure management for chisel-plow tillage. Although dissolved P concentrations also were highest for the system applying N-based manure for both crops, however, the lowest concentrations were lowest for the system applying P-based manure for corn and fertilizer P for soybean. This result confirms other results indicating that no-till management reduces total P loss significantly but does not necessarily reduce loss of dissolved P.

<u>Manure P surface application or incorporation into the soil</u>.
Surface application of P to sloping ground or where runoff flow concentrates can potentially result in large P losses with surface runoff. An ongoing field rainfall simulation project focuses on the study of P loss when manure is applied incorporated into the soil immediately after application or is not incorporated. The project also studies how the timing of a rainfall event influences P loss.

Results of experiments with liquid swine manure at two fields showed that incorporation (by disking) of the manure into the soil within 24 hours of application greatly reduces all forms of runoff P loss during an immediate runoff producing rainfall (Fig. 3). Results for bioavailable P were similar to those for dissolved P and are not shown. The effect of manure incorporation can be explained by a reduction of manure P concentration near the soil surface. Runoff P usually increased linearly with increasing manure application rate. When the manure was incorporated there was very small or no increase in runoff P. Treatment effects on runoff P loads usually were

similar to results for runoff P concentrations, but because of large variation in runoff volume the manure rate effects were more poorly defined.
A delay in runoff producing rainfall greatly reduced both dissolved and total P concentrations in runoff when the manure was not incorporated (there was no rainfall during those 10 days). A rainfall delay also reduced the effect of higher manure P rates on increasing runoff P concentrations and P loads. The sharp decrease in runoff P 10 days after surface manure application without incorporation can be explained by increased P reaction and retention by the soil. Postponing rainfall 10 days after application did not significantly change runoff P concentrations when the manure was incorporated. Moreover, in one field the total P concentration in runoff and the P load were higher when manure was incorporated, likely because of increased soil loss.

Results of the study with poultry manure also showed that large P loss observed when the manure is not incorporated after application for an immediate runoff event (Fig. 4). However, in contrast to results for liquid swine manure, a 10-day rainfall delay did not reduce dissolved or total runoff P compared with immediate rainfall. We believe that low moisture in the poultry manure limits the manure P retention by soil as was observed for liquid manure. The results also showed that at low manure application rates incorporation sometimes increases total runoff P because of increased soil loss. Current investigation is studying the effects of low rainfall occurring a few days before the runoff producing rainfall.

The results of these experiments demonstrate that the probability of runoff producing rainfall after manure application, manure rate, and tillage are major factors determining short-term P loss from fields. Results suggest that incorporating both poultry or liquid swine manure immediately after application to sloping ground always is important when the probability of an immediate runoff event is high (such as in spring or to frozen/snow covered ground). However, results showed that incorporation of liquid swine manure immediately after application is not as critical as for poultry manure when the probability of an immediate runoff event is low (such as in the fall). Additional research is being conducted for these manure sources and for P fertilizer.

On-Farm Phosphorus Index Implementation Project

We developed a three-year project in cooperation with Iowa NRCS and IDNR to implement the Iowa P index on farmers' fields. The objectives of the project were to learn about the index application to field conditions, demonstrate its use, see what ratings are obtained for a variety of conditions, and to study its application to entire fields and to field zones. We collected field information and calculated P index ratings from 33 fields grouped in six clusters having different soils and management practices. Clusters were in Adams (southwest), Buchanan (northeast), Crawford (west), Plymouth (northwest), Cerro Gordo and Hancock (north), and Des Moines Jefferson, and Washington (east-southeast) counties. The production systems at the farms involved only row crops or both livestock (cattle, poultry, or poultry) and rows crops (27 fields). Twenty fields were managed with corn-soybean rotations, two with continuous corn, and nine with hay or pasture. Table 2 provides summarized information about soil-test P levels, slopes, and estimates of erosion across the fields. These values indicate that the fields under study encompassed a wide variety of conditions commonly found in Iowa.

As expected, the P fertilization rates that would be needed varied greatly across fields. The amount of manure needed to supply N and P needs of crops also varied greatly depending on field characteristics conditions and the criteria used to decide the application rates. For example, current Iowa State University recommendations provide nutrient application rates needed to produce or maintain economically optimum crop yields. However, IDNR guidelines for manure management plans include nutrient application rates based on nutrient removal with harvest. Data in Table 3 provides a summary of the average P and liquid swine manure rates that would be applied across all fields according to different criteria used. The very low average P rate that would be applied if P recommendations for crop production were used reflects generally high-testing soils across the fields. The average amount of manure that would be applied differed greatly between N-based and P-based recommendations but also between recommendations for crop production and those based on nutrient removal. Recommendations to supply P needs of crops would result in very little or no manure applied to most fields. Recommendations based on N removal with harvest would use the highest amount of manure.

Field-average P index values across fields ranged from 0.5 (very low risk class) to 8.8 (high risk class). About one-half of the fields were classified as very low or low, 11 as medium, and four as high. Therefore, one average approximately 50% of the fields had medium or high risk of P loss and careful consideration should be given to management practices to maintain or reduce the risk. Another important result was related to the contribution of each index component to the overall index value for a field. Results summarized in Table 4 indicate that partial index values for erosion and runoff components were much larger than for the subsurface drainage component in most fields. This is the result of much greater total P loss through erosion (P bound to soil particles) and surface runoff (P dissolved in water) compared with loss through subsurface drainage (dissolved P). Results clear indicate that emphasis should be given to control soil erosion and surface runoff to reduce P loss from fields. Controlling soil erosion through conservation structures (terraces, ponds, vegetative filter strips, etc.), better tillage and crop residue management practices and by avoiding too high soil-test P levels will result in a significant reduction of total P loss. In addition, avoiding application of fertilizer or manure to frozen, snow-covered, or water-saturated ground will result in a significant reduction of dissolved P loss.

Determining P index ratings for different zones within a field resulted in a wide range of risk ratings and more frequent occurrence of very low and very high values. The index ratings for some soil map units were as high as 20. The consequences of zoning on resulting P index ratings varied greatly across fields depending on variation in field characteristics because of landscape forms and history of management practices. In 18% of the fields either the field was uniform (reasons to establish zones were not obvious) or the zones had approximately similar ratings. In 61% of the fields one zone had a significantly higher or lower ratings than all other zones in the field. In 21% of the fields one zone had a clearly higher rating and one zone had a clearly lower rating while other zones had intermediate ratings.

The results demonstrate the benefit of zoning fields for P index calculation. Large variation in P index ratings within zones in many fields should be expected because of large variation in the source or transport factors that determine risk of P loss. In a few fields zoning may not be relevant because either the field is uniform or the index rating for different zones may fall into the same risk rating class. Therefore, in most instances field zoning for index calculation should provide useful information to make decisions about soil conservation or P management practices to be implemented. The reasons for so large and frequent variation in P index ratings between zones were different depending on the field and location in the state. However, large changes in index ratings across zones within a field most often were explained by large change in erosion rates or the presence of terraces or grass filter strips in some field areas. Other reasons were differences in the distance from the center of the zone to the nearest perennial or intermittent stream and differences in soil-test P.

Many criteria can be used to delineate zones. Presence of terraces, contour cropping, tiles, flood plains, and other structures or management practices relevant to soil or water loss should be used. Information available in Iowa soil survey maps includes soil series names as well as erosion and slope phases. This information can be combined with other field information, such as soil-test P, and used to delineate zones for index calculation. The resulting P index ratings can be used to decide not to apply manure or to apply a lower rate to the more critical areas (areas with high soil P levels, near waterways, steep slopes, high flood risk, etc.) when soil-test P is above optimum for crop production. Soil survey maps sometimes do not include sufficient detail due to the scale used for their preparation, so information collected using precision agriculture technologies can be used to improve the information provided by the soil survey maps. A previous presentation in the ICM conference discussed the value of using this type of information to delineate management zones for soil sampling and fertilization purposes. Yield maps, high-precision elevation maps, electrical conductivity maps, and aerial or satellite images of bare soil or crop canopy can complement information from soil survey maps.

Summary

Producers can use Iowa P index ratings and knowledge of factors that influence P loss to identify causes of high P loss in their fields and to choose among alternative soil conservation and P management practices that minimize P loss. Study of factors determining high partial index values will reveal the management practices that cause a high risk of P loss for a specific field or one. Such a study will also suggest on a field-specific basis the most economically effective management practices for reducing the risk of P loss. Results for many Iowa fields show that loss of sediment-bound P through erosion is the most common mechanism explaining high P loss. Excessive fertilizer or manure P application increases the risk of P loss through increased soil P. Surface application of manure P to sloping ground without incorporation into the soil (by tillage or injecting) greatly increases the risk of P loss with surface runoff when the probability of an immediate runoff event is high. Although P incorporation by tillage usually reduces dissolved P loss, it may not affect or even increase total P loss when P application rates are low and soil erosion is increased. Research continues at this time to validate various portions of the Iowa P index and to study management practices effects on P loss with surface runoff and tile drainage.

Table 1. Nutrient and tillage management systems used in a study of P concentration in with surface runoff (results are shown in Fig. 1).

System and code in Fig. 1	Residue	Tillage System	P application
1. P-based fertilizer for both crops (Fert P)	Corn	Fall chisel, spring disk	Fall P fertilizer
	Soybean	Spring disk	Fall P fertilizer
2. N-based manure for corn (M N-base)	Corn	Fall chisel, spring disk	None
	Soybean	Spring disk	Fall manure
3. N-based manure for corn managed with no-till (M N-base NT)	Corn	No-till	None
	Soybean	No-till	Spring manure
4. P-based manure for corn and fertilizer for soybean (M P-base)	Corn	Fall chisel, spring disk	Fall P fertilizer
	Soybean	Spring disk	Fall manure
5. N-based manure for both crops (M for 2 crops)	Corn	Fall chisel, spring disk	Fall manure
	Soybean	Spring disk	Fall manure

Table 2. Summary of selected field characteristics and P index results.

Measurement	Field Average Range	Highest Zone Value
Soil-test P (Bray-1)	8 - 218 ppm	230 ppm
Slope	1.1 - 14 %	25 %
Erosion (RUSLE)	0.6 - 7.4 ton/acre/year	19.2 ton/acre/year
P index rating †	0.5 - 11	20

† P index classes are 0-1 Very Low, 1-2 Low, 2-5, Medium, 5-15 High, and >15 Very High.

Table 3. Average P and manure that would have been applied across all fields for various nutrient management recommendation systems.

Recommendation system	P Supplied	Manure Needed
	lb P_2O_5/acre/year	gallons/acre/year
Agronomic P Recommendation	2	74
P-Removal Manure Plan	50	1,647
Agronomic N Recommendation	76	2,530
N-Removal Manure Plan	148	4,784

Table 4. Contribution of erosion, runoff, and subsurface components of the P index to the overall P index rating across all 33 fields.

	Partial Index Component Contribution (%)	
Index Component	Average Across Fields	Range
Erosion	73	31 - 91
Surface runoff	24	7 - 58
Subsurface drainage	3	2 - 7

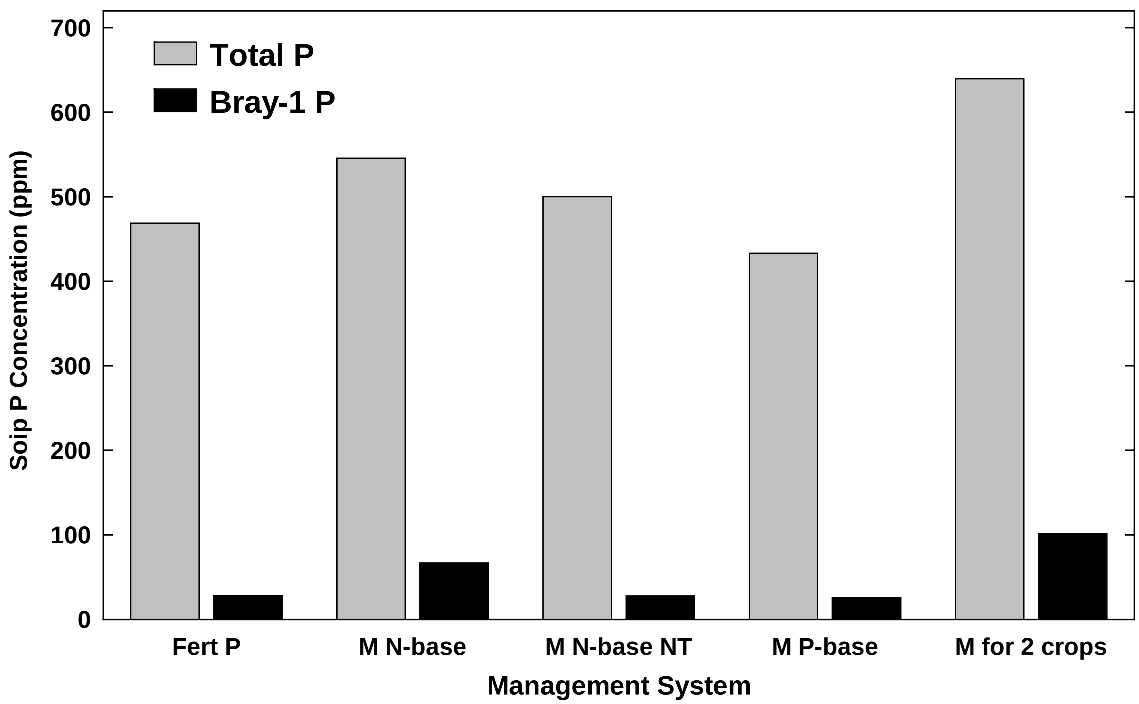

Figure 1. Total P and soil-test P (Bray-1) in the top 2 inches of soil managed with different nutrient and crop management systems (see Table 1 for codes) for several years.

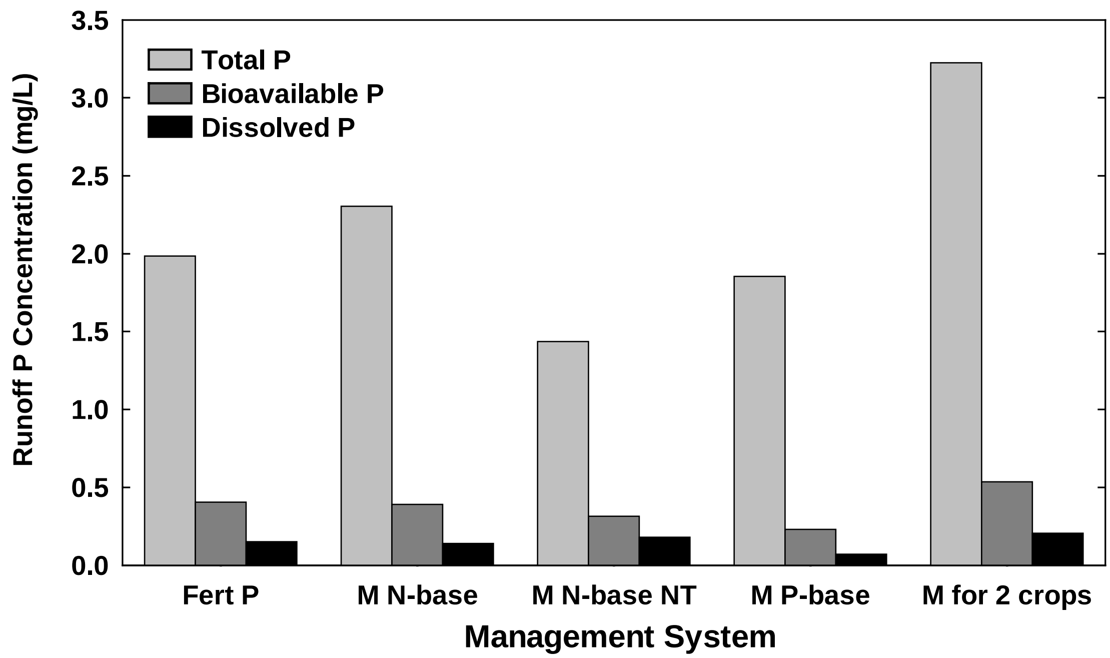

Figure 2. Phosphorus concentration in surface runoff from soil managed with different nutrient and crop management systems (see Table 1 for codes) for several years.

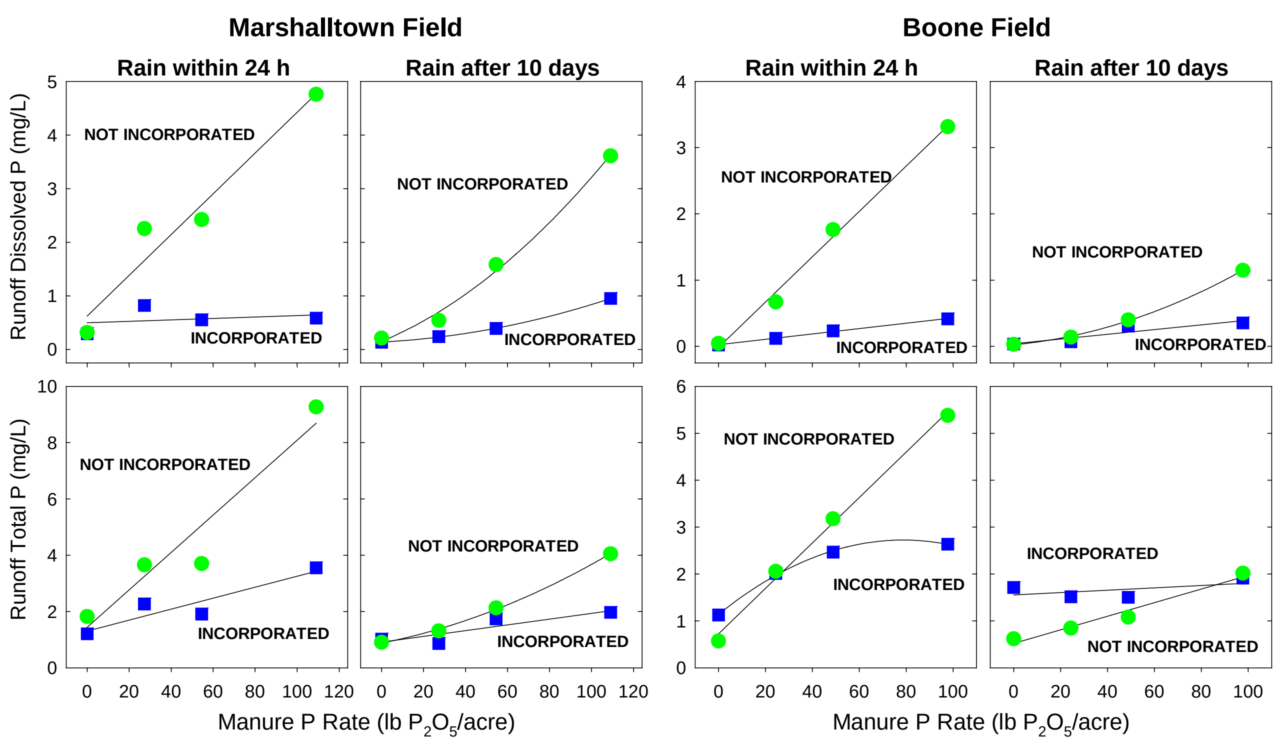

Figure 3. Effects of liquid swine manure P rate, incorporation, and time of runoff producing rainfall on dissolved and total P concentrations in surface runoff.

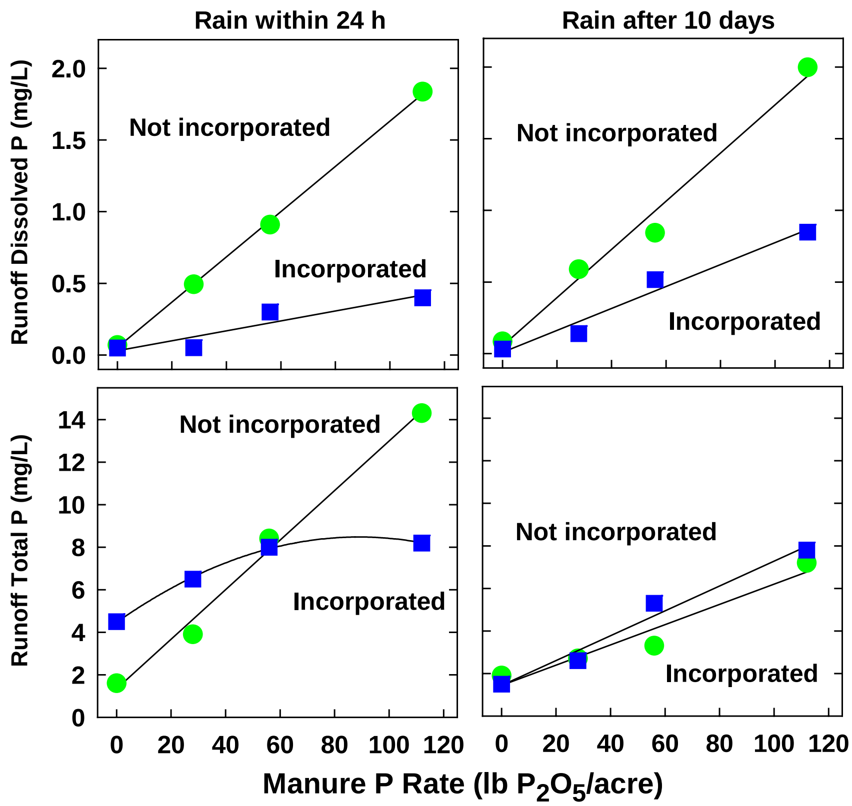

Figure 4. Effects of poultry manure P rate, incorporation, and time of runoff producing rainfall on dissolved and total P concentrations in surface runoff.