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# PHOSPHORUS MANAGEMENT ON HIGH PHOSPHORUS SOILS

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## Introduction

Soil phosphorus (P) is important for crop production. Phosphorus is extensively involved in energy transfers within plants and plants require P early in growth for the proper development of reproductive systems. In general, adequate soil P causes an increase in root growth allowing the plant to explore more soil volume for water and nutrients.

While P is necessary for crop production, managing P properly is a responsibility of farmers and home owners. Too little soil P causes land degradation through poor ground cover and erosion and reduces economic returns to farmers. Too much soil P causes the eutrophication of lakes and streams when runoff high in P leaves the soil and enters waterways.

Balancing the inputs and removals of P on each field or farm should be a goal of every producer. When the amount of P entering the soil (from fertilizers or manure) is the same as the amount leaving the soil (in crop removal), soil test P values should neither increase or decrease. Managing nutrients in this way minimizes potential negative impacts on water quality. However, balance may not be possible on some farms because the land base is too small for the number of animals present. With soils that are already high in P, management options are less flexible than those for soils with low soil test P levels. However, carefully thought-out decisions can provide options for the producer other than the financial strain induced by buying more land in which to dispose of manure or reducing the number of livestock.

This publication is intended to provide suggestions for producers and nutrient management planners who have determined that the soils they have to deal with fall into a high soil test P level and therefore present greater environmental risks. Although the ultimate solution is to achieve input/ output balance, we have also attempted to identify least risky alternatives to those operations that are still working toward a whole farm P balance lower than crop P removal.

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## What is Considered a High Soil Test P Site?

Soil test phosphorus (STP) is determined when a soil sample (field cores from the top 6 to 7 inches) is analyzed in a lab for P availability. In Wisconsin, STP is measured using the Bray-Kurtz $P_1$ extractant. Results of these tests are reported in concentration of P as parts per million (ppm). For environmental purposes, a high STP site is one in which the soil test level is above 100 ppm. For crop production, a "high" soil is one where the chance for responses from added fertilizer is relatively low (<30%). This typically is at soil test P levels ranging from 20 to 30 ppm. Guidelines for P application according to the NRCS 590 standard for nutrient manage-ment suggests the following:

(A) **50 ppm P or less:** Manure applications allowed up to the rate that meets the crop N need;
(B) **50 to 100 ppm P:** P applications shall not exceed crop removal of P over a 4-year rotation;
(C) **100 ppm P or greater:** Eliminate P applications if possible, but must apply at rates lower than crop removal.

## Approaches to Improving Phosphorus Balance

### (1) Dietary Considerations

**Dairy** — For dairy producers, a first step in balancing P inputs and outputs is to examine the amount of P being supplied in the dairy diet. In January 2001, the National Research Council (NRC) published their most recent recommendations for dairy dietary P intake. Varying with milk production, the NRC recommends a diet with 0.32 to 0.38% P (Table 1). Studies have shown that these levels of P are adequate for high milk production and successful reproduction. Adding more P increases the P excreted in the manure, and thus the potential for P loss when the manure is land applied. Producers can evaluate the supplements they use in the dairy diets to more carefully monitor for the amount of P being supplied by each (Table 2). By monitoring protein supplements and inorganic P additions, producers can keep the dairy diets close to the recommended levels and minimize the amount of P being spread when manure is land applied.

Table 1. Feed recommendations of the National Research Council, January 2001.

| Milk production level | Dietary P level |
|---|---|
| lb/day | % |
| 55 | 0.32 |
| 77 | 0.35 |
| 99 | 0.36 |
| 120 | 0.38 |

Table 2. Examples of protein supplements indicating crude protein content and %P (from the National Research Council, 2001).

| Protein supplement/ by-product feed | % Crude protein | % Phosphorus |
|---|---|---|
| Blood meal | 95.5 | 0.30 |
| Soybean meal (expellers) | 49.9 | 0.70 |
| Cottonseed | 23.5 | 0.60 |
| Corn distiller's grain | 29.7 | 0.83 |
| Wheat bran | 17.3 | 1.18 |
| Porcine meat & bone meal | 54.2 | 4.73 |

**Swine/Poultry —** For non-ruminants (monogastric) animals such as swine and poultry, dietary P manipulations are also possible. These techniques attempt to reduce the P content in manure by improving the efficiency that the animal extracts P from feed. This can significantly reduces the need for inorganic P supplements in these diets. One strategy is to reduce the phytate level of feed grains by use of low-phytate, high available-P varieties. In corn and other feed grains, P is stored as phytate that is largely unavailable to non-ruminant livestock, and as a result, inorganic P is often added to the diets as an inorganic P supplement. The unutilized phytate P from the plant is excreted by the animals, resulting in manure that is enriched in P content. Using corn hybrids that have been develop-ed to contain lower amounts of phytate and that store more P in the available phosphate form will increase the P uptake efficiency of a non-ruminant animal, thus decreasing the amount of P excreted in manure.

Another option for reducing the P content of manure from monogastric livestock is the use of commercially produced phytase enzymes as a feed supplement. Phytase enzymes are capable of releasing phytate P from plants into animal-available forms. Phytase enzymes occur naturally in some microorganisms, plants, and ruminant animals. Monogastric animals lack phytase and can only poorly utilize the P reserves in many grains. By adding phytase enzymes to non-ruminant animal feed, the efficiency of P uptake during digestion can be increased, thus lowering the amount of P excreted in the manure.

**(2) <u>Reduce or Eliminate Other P Inputs</u>**

**Follow Soil Test Recommendations —** In addition to imported feed, the other major input to Wisconsin farms is purchased fertilizer. Applying only the amount needed by the intended crop can eliminate P buildup and improve farm profits. Following a well-calibrated soil test recommendation program is essential to aligning application rates with crop needs. At optimum soil test levels, the recommended nutrient additions are approximately equal to anticipated crop removal. To avoid over-fertilization with P and other nutrients, fertilizer and manure additions should be made according to soil test results. It is recommended that soil tests be taken at least every 3 to 4 years and preferably every other year on sandy and other soils of low buffering capacity.

Soil test P levels should be used to help prioritize fields for manure applications. Although this is not the only factor to consider (crop to be grown, runoff risk, spreading restrictions, and hauling conveniences are a few others), it should be remembered it is the lowest testing fields that are most likely to respond to applied nutrients, including those from manure.

**Credit All Nutrient Sources —** To determine the need for commercial fertilizer application rates, it is critical that nutrient contributions from all sources, including those in the soil and manure additions, are credited. Both economic and environmental benefits can result if the nutrient supplying capacity of all nutrient sources is correctly estimated. Environmentally, the prevention of nutrient over-fertilization reduces potential threats to water quality. The use of appropriate nutrient credits is of particular importance in Wisconsin where manure applications to cropland, legume crop pro-duction, and the land application of organic wastes are common.

Manure can supply crop nutrients as effectively as commercial fertilizers in amounts that can meet the total N and P requirements of crops. To utilize manure efficiently, the nutrient content and the application rate need to be estimated. The most effective method of gauging the nutrient content of manure is to have samples analyzed by a commercial or university laboratory. Large farm-to-farm variation in nutrient content can occur due to manure storage, handling, livestock feed, or other farm management differences. In instances when laboratory analysis is not convenient or available, estimates of crop nutrients supplied by animal manures should be made. Table 3 summarizes the University of Wisconsin estimates of first-year available nutrient values for various livestock manures. Manure application rates can be determined through the calibration of the manure spreading equipment.

Table 3. Estimated available nutrient content of solid and liquid manure from various livestock species.

| | Solid | | | Liquid | | |
|---|---|---|---|---|---|---|
| Livestock | Nitrogen† | Phosphate ($P_2O_5$) | Potash ($K_2O$) | Nitrogen | Phosphate ($P_2O_5$) | Potash ($K_2O$) |
| | ------------------ lb/ton‡ ----------------- | | | -------------- lb/1,000 gal‡ ------------ | | |
| Dairy | 3/4 | 3 | 7 | 7/10 | 5 | 16 |
| Beef | 4/5 | 5 | 9 | 5/7 | 5 | 16 |
| Swine § | | | | | | |
| Lagoon | — | — | — | 17/22 | 10 | 16 |
| Indoor pit | — | — | — | 25/33 | 25 | 24 |
| Poultry | 20/24 | 24 | 24 | 8/10 | 6 | 10 |

† Use higher value for manure that is incorporated within 3 days of application.
‡ Values rounded to the nearest whole pound.
§ Values for finishing operations.

If manure application rates are limited to P removal or less, due to soil test P levels greater than 50 ppm, supplemental N application may be required to meet the N needs of the crop. Knowing the nutrient values of your manure will allow the most efficient use of the resources on the farm, while supplying crop needs and protecting the environment.

**Use Starter Fertilizer Judiciously** — A minimal amount of starter fertilizer is recommended for most row crops planted in Wisconsin. For corn grown on medium- and fine-textured soils, a minimum application of 10 lb N, 20 lb $P_2O_5$, and 20 lb $K_2O$ per acre is recommended as a starter. In most corn fields, all the recommended $P_2O_5$ and $K_2O$ can be applied as starter fertilizers. On soils with test levels in the excessively high range, starter fertilizer applications in excess of 10 lb N, 20 lb $P_2O_5$, and 20 lb $K_2O$ per acre should be avoided.

Corn yield responses to starter fertilizer additions can still occur on soils that are excessively high in P and K. The probability of a yield response can be estimated using site-specific information about individual fields. Crop yield increases with starter additions to excessively high soils is much more likely if soil test K levels are less than 140 ppm and/or the combined effect of corn hybrid relative maturity (RM) and planting date result in an inadequate growth period for the crop to achieve its full yield potential. Specifically, responses are more likely with late planting dates and long-season RM hybrids. The probability of response to starter fertilizer on excessively high testing soils at a range of hybrid RM and planting dates is shown in Table 4.

## (3) Increase the Land Base Over Which the Manure Is Spread

For most dairy operations, about 1.5 to 2.0 acres of cropland is needed per cow for manure applications where manure is applied to meet the P crop need. Several approaches can be used that effectively increase the farm's land base that do not involve purchasing additional land. These include: (a) ensuring that all crop land receives manure at some time during the rotation; (b) applying manure to rented land; and (c) obtaining manure application rights from neighboring grain farmers.

Table 4. Probability of obtaining a positive economic return from starter fertilizer for several corn relative maturity ratings at various planting dates on soils with excessively high P and K levels. †

| Relative | Planting date | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| maturity | 4/25 | 5/1 | 5/5 | 5/10 | 5/15 | 5/20 | 5/25 | 5/30 |
| | --------------------------------- % probability ------------------------------------- | | | | | | | |
| 90 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
| 95 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| 100 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 |
| 105 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 |
| 110 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 |

† This table does not alter current recommendations for early planting and selection of corn hybrids with appropriate relative maturities for the production zone.

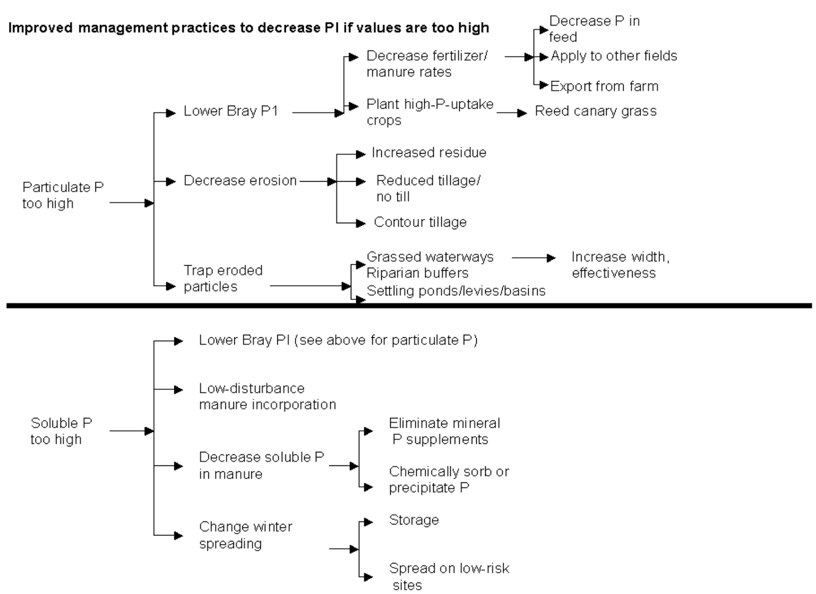
Managers can make applications to meet the P needs of crops for the length of the rotation. For example, research has shown that manure applications at high rates prior to seeding alfalfa can actually benefit the crop while reducing the need for topdress fertilizer and eliminating the risk of runoff P losses from annual topdress manure or fertilizer applications. However, a major caution to growers considering this practice is that they must be prepared to deal with the potential flush of annual weeds.

## Management to Reduce Phosphorus Losses

### (2) Identifying Low Risk Sites

The risk due to P loss from a site is controlled by the source and quantity of P at the site and how readily that P is transported to a vulnerable water system. Source and transport are site-specific factors, meaning that they vary from field-to-field. For nutrients (specifically P) to be released to water, there must be a source - soil test P levels that are high or manure and fertilizer applications. Transport of P occurs through runoff, erosion, and occasionally leaching. Sites located adjacent to or near waterways, streams, and lakes are more susceptible to transporting P off the fields and into surface water. Fields with highest risk for P loss are those with both source and transport factors, i.e. those with high soil test P and located near water. If a site has high soil test P or high amounts of nutrient addition from manure or fertilizer but is not located near a lake or stream, the risk for P loss to water is much less. Likewise, if a field is located next to a stream but has low levels of soil test P, risk for P loss is also low.

The P index is a management tool that is being developed in many states that considers both P source and P transport criteria when ranking the susceptibility of a landscape for P loss. Specifically, the Wisconsin P index considers the soil test P for a site, the expected erosion loss for the crop rotation in place, the slope, the magnitude, form, placement and soil condition (frozen or unfrozen) of P additions, distance to concentrated flow, soil type, and residue management practices in place. It calculates a P index that typically ranges from 1 to 12. For values that are greater than 6, improved management is recommended. The P index also identifies whether the likely risk is associated with potential particulate or soluble P losses. This knowledge can guide specific management to reduce these losses as shown in the figure below.




**Improved management practices to decrease risk from particulate or soluble P**

By accurately identifying lower risk sites, the manager may then choose to allow P to build on very low risk sites while minimizing or eliminating manure or fertilizer P applications on very high risk areas. Areas of particular concern include those within a 10-year flood plain or within 1,000 feet of lakes or 300 feet of streams unless incorporation follows as soon as possible. Other guidelines suggest not applying manure to frozen soils in these areas, using buffer strips to slow runoff velocity and deposit nutrient and sediment loads, not applying manure to the soils associated with these land areas when they are saturated, and not applying manure to grassed waterways, terrace channels, open surface drains or other areas where surface flow may concentrate.

**(3) Timing of Manure Applications**

Manure application timing is an important management practice for minimizing P contributions to surface waters. Manure should not be spread on sloping lands any time a runoff-producing event is likely. Unfortunately, runoff-producing events are impossible to predict and the elimination of manure applications to sloping lands is seldom a practical option for landowners. Also, if winter applications of manure must be made, the risk should be minimized to the greatest extent possible. Manure applications to frozen soils should be limited to slopes of less than 6%. Preferably these soils are corn stalk covered, roughly tilled, or protected from up-slope runoff. Winter applications should not be on alfalfa or other vegetation-covered, smooth-surfaced fields. If applications of manure to frozen soils with slopes of 6 to 12% must be made, conservation measures need to be in place in order to protect surface waters. Grassed waterways must be well established and maintained and not have manure applied. Terraces should be in place, if appropriate, or fields contoured and strip-cropped with alternate strips in sod. If fields are farmed on the contour, they should be protected with an adequate residue cover from the previous year's crop. Manure should not be applied to frozen soils on slopes greater than 12%.

**(4) Placement of Phosphorus Fertilizer**

The placement of P-containing materials directly influences the amount of P transported to lakes and streams by runoff. When P fertilizer is broadcast on the soil surface and not incorporated, the concentration and loss of available P in runoff water can rise sharply and have a greater potential impact on surface water quality than from soil surfaces where P was incorporated. Phosphorus is strongly bound to soil particles; however, adequate soil P contact must occur to allow for adsorption. Incorporation by tillage or subsurface band placement of fertilizer is a very effective means of achieving this contact. To avoid enriching surface waters with soil nutrients, it is recommended that annual fertilizer applications for row crops such as corn be band-applied near the row as starter fertilizer at planting. Annual starter applications of P can usually supply all of the P required for corn. This practice reduces the change for P enrichment of the soil surface and reduces P loads in runoff from crop land.

**(5) Soil Conservation/Erosion Control**

One key to minimizing nutrient contributions to surface waters is to reduce the amount of runoff and eroded sediment that reaches surface waters. Numerous management practices for the control of runoff and soil erosion have been researched, developed, and implemented. Runoff and erosion control practices range from changes in agricultural land management (cover crops, diverse rotations, conservation tillage, contour farming, and contour strip cropping) to the installation of structural devices (buffer strips, diversions, grade stabilization structures, grassed waterways, or terraces). The most commonly used, widely adopted, and easily accomplished conservation practice is the main-tenance of surface residue through various types of conservation tillage.

## (6) Manure Incorporation?

Until recently, the recommendation for land-applied manure was to incorporate it within 3 days of application. While research has shown that incorporation reduces dissolved P and bioavailable P concentrations and loads in runoff, incorporation has also been shown to increase the risk of total P (soluble P + particulate P) losses through increased soil erosion. Recent Wisconsin findings suggest that the long-established management recommendation for incorporating manure may not minimize cropland P losses if total P reductions are the objective. Unincorporated manure applications tend to reduce total P losses by lowering soil erosion but increase dissolved P losses, while incorporating manure with tillage may lower dissolved P losses but tends to increase total P losses. Since regulatory agencies are leaning towards using total P as the parameter on which to base regulations, a general recommendation to surface apply manure without incorporation with conservation tillage practices in place to reduce soil erosion is appropriate. As a general practice, using conservation tillage, whether no-till or reduced tillage, will help keep soil particles on the field and as a result lower the loss of P in runoff to lakes and streams.

## (7) Buffer Strips

Maintaining or establishing strips of close-growing vegetation adjacent to water bodies is a practice that can reduce the sediment and nutrient content of runoff waters reaching them. The velocity of runoff is reduced when passing through a buffer strip as is its capacity for transporting sediment and nutrients. Sediment is deposited and runoff infiltrates or passes through the buffer strip with a substantially reduced nutrient load. Buffers as narrow as 15 feet have been shown to reduce the particulate P load by 80% and soluble P load by 50%. However, buffers are most effective when combined with up-slope practices that manage erosion and sediment nutrient loss.

## Summary

The previous pages provide a brief summary of agricultural management practices available to Wisconsin crop and livestock producers for reducing the impact of P on water quality while protecting farm profitability. Selection of appropriate P management practices for individual farms needs to be tailored to the specific conditions existing at the farm or field within a farm. However, an overall goal of any agricultural operation should be to balance inputs of P (fertilizer, feed, etc.) with outputs (crop and animal products) and to manage fields in ways that retain soil nutrients on the land.