Site-Specific Nutrient Management

For Nutrient Management Planning To Improve Crop Production, Environmental Quality, and Economic Return

Presentation Script: Phosphorus - Chapter 3

Written By:

Agustin Pagani, Post-Doctoral Fellow
John E. Sawyer, Professor
Antonio P. Mallarino, Professor
Department of Agronomy, Iowa State University

Developed in cooperation with:
Lara Moody, The Fertilizer Institute (TFI)
John Davis, Natural Resources Conservation Service (USDA-NRCS)
Steve Phillips, International Plant Nutrition Institute (IPNI)

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Phosphorus Management

Slide 1.

This module will cover the most important concepts of phosphorus management in agricultural systems for profitable and environmentally safe crop production. Since it is impossible to go through specific scenarios for all regions of the U.S., general concepts regarding phosphorus management will be presented. Even though these principles apply for most regions, viewers are encouraged to review locally developed phosphorus use recommendations.

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Phosphorus is an essential nutrient for crop production. It is involved in many functions of the plant such as energy transfer and protein synthesis, increases cell multiplication, and stem and root growth. This nutrient also increases the stem strength and biological nitrogen fixation in legumes.

When a plant is phosphorus deficient, it normally shows symptoms like stunting and dark green or purple coloration of leaves. In general, unless the phosphorus deficiency is severe, symptoms are not as easy to detect as for other nutrient deficiencies. The more a certain crop yields the more phosphorus it needs and is exported with harvest; in other words, there is a positive relationship between phosphorus uptake and removal and crop yield. For that reason, phosphorus removal can be used along with soil testing for deciding phosphorus applications. Phosphorus management is not only important from the agronomic point of view, but also from the environmental standpoint, because phosphorus losses from production fields can affect surface water quality. Excess phosphorus can cause eutrophication, which is over nutrient supply and excessive growth of algae, causing depletion of available oxygen for other organisms, such as fish.

Slide 3.

This table is adapted from an Iowa State University extension publication and shows the phosphorus removal with harvest for some important crops. As you can see, there are some species like alfalfa or tall fescue that have high phosphorus requirement and because of total biomass harvest, have high removal.

Slide 4.

Long-term fertilizer phosphorus and manure applications, especially in the most productive regions of the United States, have resulted in an increase in soil phosphorus levels. Certain areas have seen increases in soil P availability due to long-term application of P nutrients in excess of crop needs. This situation has increased the risk of phosphorus losses from agricultural fields which can have negative effects on water quality. In addition to field crop production, there has been an increase in the number and size of concentrated animal feeding operations across the country. These systems have generated localized surpluses of phosphorus inputs as fertilizer and feed, with resultant excess manure and associated phosphorus application in excess of crop needs. This situation has increased the risk of phosphorus loss from soil to water resources.

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The overall objective of phosphorus management is to balance phosphorus inputs and outputs to supply needed phosphorus to maintain soil fertility, maintain or increase crop productivity, while minimizing impacts on water quality. Some strategies to increase phosphorus use efficiency by crops include: the use of appropriate soil sampling and testing, use of locally developed recommendations to define phosphorus application rates, adoption of variable-rate application, transport of manure from areas with excess phosphorus to areas needing phosphorus, and the implementation of soil conservation practices to reduce soil erosion and surface runoff.

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Soil phosphorus testing is a very useful tool to determine phosphorus requirements by crops and help assess the risk of phosphorus loss. Many soil test methods have been adopted in different regions of the US. For example, the Bray-1 and the Mehlich-3 methods are used in many states, the Mehlich-1 method is used mainly in the southeast of the country, whereas the Olsen method is recommended in regions with calcareous soils. The normal sampling procedure is to collect soil samples from the top 6 to 8 inches of soil, since research has shown no significant improvement to sample at shallower or deeper soil layers. However, in some states, shallower depths are recommended for pastures and no-till. It is important to consider that soil test methods must be calibrated with crop yield response for soil with different properties, using the most appropriate sampling depth and time.

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Besides the aspects already discussed, researcher concepts and economic considerations also influence the recommended optimum soil-test levels for crops. In general, the optimum soil-test phosphorus level from an economic perspective varies with grain and phosphorus fertilizer prices, producer management philosophy, and other enterprise management decisions. Because of variations in soils, and both economic and philosophy considerations, the interpretation of test results for a specific soil-test method and the recommended application rates may vary greatly across regions.

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The recommended approach in most states is to apply phosphorus to low-testing soils in order to gradually increase soil phosphorus levels to the optimum. The selected rate depends on many factors such as soil test phosphorus value, the rotation and economic situation, and land tenure. Also, there should be consideration that the time to reach optimum phosphorus soil test levels varies across soils. Phosphorus rates should be based on crop removal when tests are at or near optimal ranges. It is always recommended to avoid excessive high soil test levels to reduce the risk of phosphorus losses. Producers have to take into account that soil test phosphorus levels can be managed over time in most soils. In this sense, soil test phosphorus can be increased, decreased, or maintained by managing phosphorus application and crop removal.

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This figure shows a schematic representation of the relationship between relative crop yield and phosphorus loss. As can be seen, the soil phosphorus level that maximizes productivity also results in low potential phosphorus losses. As soil phosphorus level exceeds that critical value, phosphorus losses increase exponentially. Therefore, the recommendation is to maintain soil test levels at or slightly above the critical value to maximize crop productivity and minimize environmental impacts.

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The figure shows an example of how soil phosphorus levels can be managed over time. The graphs show the soil phosphorus level over time for a corn soybean rotation in Iowa for different rates of phosphorus fertilizer applied annually. This relationship is shown for different initial levels of soil test phosphorus. For the lowest initial soil phosphorus levels, there is slight decrease in the soil test phosphorus over time when no phosphorus is applied due to continuous crop removal, but that decrease turns to an increase as the rate annually applied increases. The situation is different for the intermediate initial soil test phosphorus, where only the maximum annually applied rate produces soil phosphorus increase and all other rates produce a decrease, indicating that crop removal is higher than annual application. Furthermore, for the highest initial soil phosphorus level, the highest annually applied phosphorus rate is only enough to maintain soil test phosphorus, but with the rest of the rates the soil test phosphorus decreases from the initial test levels. It also is important to point out the magnitude of the year-to-year variability in soil test levels. This means it is difficult to manage slight changes in soil test level in the short term, but can be done on the long-term. An important aspect of soil phosphorus management is that if takes more phosphorus input to maintain a high soil test than a low test.

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Different phosphorus sources are used in crop production. The two most common commercial phosphorus fertilizers in the U.S. are monoammonium phosphate and diammonium phosphate. Research has shown that both sources have similar agronomic efficiency. Use of triple superphosphate has greatly decreased during the last two decades, and is difficult to find in many regions. Ammonium polyphosphate and other polyphosphates in fluid fertilizers are very common in the U.S. Rock phosphate, which is comprised of apatite and fluorapatite, is used only infrequently in the U.S. due to the low solubility, especially when soil pH is neutral to alkaline. Organic producers frequently use this form of raw, unprocessed phosphorus mineral as a nutrient source, but at very high rates and pulverized into fine particles due to its low solubility and low available phosphorus concentration.

Applying manure to cropland sometimes presents different management issues and options from those for phosphorus fertilizers. If manure is applied to meet crop nitrogen needs, more phosphorus may be applied than is necessary to meet crop requirements. However, this varies greatly with the animal species and both feeding and manure handling systems. Therefore, long-term manure applications may increase soil test phosphorus levels well above critical levels, especially when applied to continuously to cereal crops to meet nitrogen fertilization requirements.

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When considering phosphorus application rates, one needs to understand that there is no agricultural justification for increasing soil test phosphorus levels higher than optimal levels for crop production. However, if manure is utilized as a nitrogen source, it might be reasonable to further increase phosphorus levels in areas with low risk of phosphorus loss as indicated by the phosphorus index.

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In situations where soil test phosphorus is above the optimum, phosphorus application rates can be reduced to a starter rate or eliminated, until the soil test values decreases to the optimum level or slightly above. Surface application of phosphorus or banding usually increases phosphorus use efficiency and crop yield in comparison with broadcast application, especially in situations where the soil strongly retains or transforms applied phosphorus into less available forms, when the soil is dry, or in wet soil with high amounts of surface residue. Subsurface banding is also recommended where erosion and surface runoff is a major concern.

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The mobility of phosphorus within the soil is lower than for nitrogen and other nutrients, and for that reason, surface phosphorus application increases soil test levels at the soil surface in reduced and no-till systems or when no phosphorus incorporation occurs. The total amount of phosphorus runoff may or may not be reduced with incorporation or surface application of manure or fertilizer because phosphorus losses also depend on factors affecting soil erosion and surface runoff. These factors include slope, soil hydrology, soil disturbance, and residue offset with incorporation or injection.

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This figure shows the effects of phosphorus rate, incorporation into the soil, and days after the application on the risk of phosphorus loss with surface runoff for an Iowa soil. Reduced phosphorus loss occurs with lower phosphorus rates, a delay in runoff events after application due to time for phosphorus retention by soil constituents, and incorporation into the soil. Similar results were observed for inorganic fertilizer and poultry manure. Phosphorus loss can be greatly reduced by incorporation of large phosphorus applications into the soil, but only when the tillage operation does not significantly increase erosion and surface runoff.

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From a nutrient use efficiency perspective in humid regions, the time of phosphorus application before crop planting generally is a much less important factor than the time of nitrogen application. With the exception of regions that have soils with very high phosphorus retention capacity, or crops with very limited root growth and poor uptake, the timing of phosphorus application before planting has little or no impact on phosphorus use efficiency by crops. In soils that retain or transform applied phosphorus into forms of low crop availability, however, application well in advance of crop growth may reduce phosphorus use efficiency and there are often large differences due to placement method. On the other hand, in-season phosphorus application is not recommended, except for forages crops and pastures.

The time of phosphorus application to the soil surface or of tillage to incorporate broadcast phosphorus may have a significant impact on runoff phosphorus loss shortly after application. As was shown in the previous figure, phosphorus loss with runoff from surface phosphorus application decreases significantly with a delay in the runoff event. A few days are needed so that soluble phosphorus reacts with the soil and the phosphate concentration in solution decreases. Therefore, the importance of incorporation and potential for loss are higher when the phosphorus is applied during periods of high probability of rainfall and surface runoff, or with significant snow cover. The probability of large runoff events typically is greatest in the spring due to snowmelt in northern areas and frequent high-intensity rainfall in most humid regions of the U.S.

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Dense soil sampling from many fields has shown very large within-field spatial variability of soil-test phosphorus and crop yields. Precision agriculture technologies available to producers or custom applicators facilitate application of fertilizer and manure at rates adequate for different parts of a field based on soil-test phosphorus and estimated phosphorus removal. For example, research in Iowa has shown that grid or zone soil sampling methods combined with variable rate application of fertilizer or manure phosphorus may not always increase crop yield or increase profits compared with traditional application methods because the average effects on yield and amount of phosphorus applied depends on the overall level and distribution of soil-test phosphorus. Also, soil testing seldom is performed on an annual basis, there is always a certain degree of sampling error, and research has shown that relationships between phosphorus removal and soil-test phosphorus are good over several years but not necessarily from year to year. Therefore, even with annual variable-rate application, use of this technology is not perfect. However, on-farm research has shown that variable-rate application of phosphorus fertilizer or phosphorus-based manure almost always minimizes or avoids phosphorus application to high-testing areas, reduces soil test phosphorus variability within fields, and, as a consequence improves phosphorus use efficiency and reduces risk of phosphorus loss by minimizing phosphorus application to high-testing field areas.

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This figure shows that use of variable-rate technology is an effective tool to improve phosphorus management. The change in soil-test phosphorus was measured after applying phosphorus-based liquid swine manure for corn after three corn-soybean rotation cycles. Similar results were observed with fertilizer application. In addition, variable-rate phosphorus application can be practically implemented on the basis of phosphorus-index ratings for field zones, not just based on soil test phosphorus or estimates of phosphorus removal. Variable rate application of fertilizer phosphorus is common in the Great Plains and the Corn Belt, and custom manure applicators also are beginning to apply manure at variable rates.

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Even though it is usually not best to make generalizations in term of nutrient management, there are some useful phosphorus management practices that apply in most regions. In terms of the selection of the phosphorus rate to apply, it is recommended to sample soil as frequently and as densely as economically possible and using appropriately calibrated soil-test methods. It is important to consider crop phosphorus removal, which depends mainly on yield level, across and within fields to help maintain optimum soil-test phosphorus levels and avoid excess or too low application. Fertilize phosphorus deficient soils or maintain optimum soil-tests using environmentally and economically sound agronomic practices. Divide large, non-uniform fields into smaller fertility management units based upon yield potential, soil tests, and relevant soil properties.

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Also, consider all available phosphorus from manures and other organic sources. Use manure nutrient analysis and a phosphorus risk assessment tool in order to utilize as much manure nutrient as much as possible without increasing the risk of phosphorus loss and water quality impairment. Refer to local research and guidelines concerning phosphorus placement methods appropriate for the region. Incorporate, band, or inject high rates of inorganic or organic phosphorus sources into the soil where the risk of surface runoff or soil erosion is high. Keep in mind that the timing of P application is not as important as for other nutrients in most soils as long as sufficiency of P is assured before the crop growing season begins.

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In summary, proper phosphorus management is essential to maximize the profitability of crop production, maximize efficiency of a non-renewable resource, reduce impacts of phosphorus use in crop production on surface water quality, and avoid increased regulation. The goal of sound phosphorus management in most regions of the U.S. should be to keep the soil-test phosphorus level at optimal ranges for maximum economic crop yield and utilize application methods and timing that optimize phosphorus use efficiency and economic profitability, and minimize water quality impairment. Large within-field variability of phosphorus soil-test levels and phosphorus removal with harvest in most agricultural areas justifies the use of appropriate soil sampling, soil testing, application methods, and variable-rate application technology to increase phosphorus use efficiency and reduce the risk of phosphorus loss to water resources.