Phosphorus Basics – The Phosphorus Cycle

Phosphorus, Crops and the Environment

This agronomy fact sheet provides a brief overview of the important components of the phosphorus (P) cycle. Understanding the P cycle can help producers make decisions regarding P management on the farm, both for farm profitability and protection of the environment.

Most plants are only about 0.2% P by weight, but that small amount is critically important. Phosphorus is an essential component of adenosine triphosphate (ATP), which is involved in most biochemical processes in plants and enables them to extract nutrients from the soil. Phosphorus also plays a critical role in cell development and DNA formation. Insufficient soil P can result in delayed crop maturity, reduced flower development, low seed quality, and decreased crop yield. Too much P, on the other hand, can be harmful in some situations; when P levels increase in fresh water streams and lakes, algae blooms can occur. When algae die, their decomposition results in oxygen depletion which can lead to the death of aquatic plants and animals. This process is called "eutrophication" (see Agronomy Fact Sheet #13: Phosphorus Runoff, for additional information).

Crop Uptake

One goal with field crop management is to optimize crop uptake of available P. A typical corn silage crop will remove about 4.3 lbs of P_2O_5 per ton of silage (35% dry matter). Soil testing of available P can help avoid application of fertilizer P that is not needed for optimum production. Applying fertilizer beyond crop needs is a waste of time and money, and can be harmful to the environment.

Phosphorus Cycle

Phosphorus exists in many different forms in soil. For practical purposes, we can group these sources into four general forms: (1) plant available inorganic P, and three forms which are not plant available: (2) organic P, (3) adsorbed P, and (4) primary mineral P. The P cycle in Figure 1 shows these P forms and the pathways by which P may be taken up by plants or leave the site as P runoff or leaching. The general P transformation processes are: weathering and precipitation, mineralization and immobilization, and adsorption and desorption. Weathering, mineralization and desorption increase plant available P. Immobilization, precipitation and adsorption decrease plant available P.

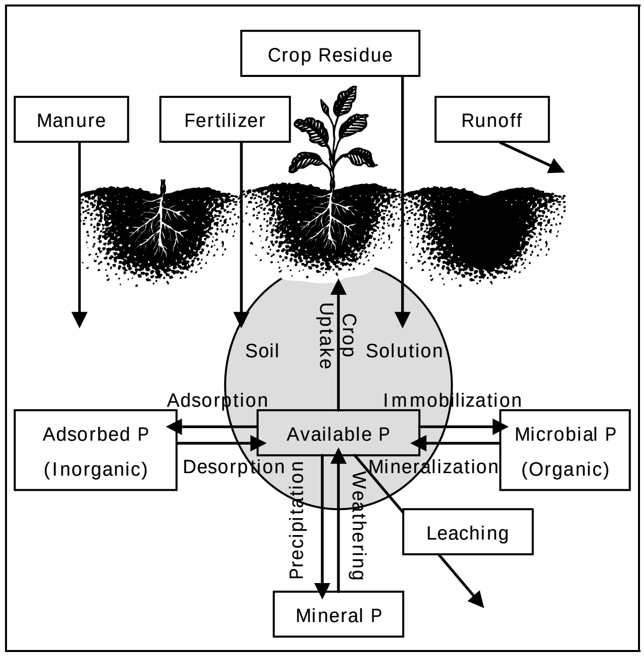

Figure 1: Simplified phosphorus cycle.

Weathering and Precipitation

Soils naturally contain P-rich minerals, which are weathered over long periods of time and slowly made available to plants. Phosphorus can become unavailable through precipitation, which happens if plant available inorganic P reacts with dissolved iron, aluminum, manganese (in acid soils), or calcium (in alkaline soils) to form phosphate minerals.

Mineralization and Immobilization

Mineralization is the microbial conversion of organic P to $H_2PO_4^-$ or HPO_4^{2-}, forms of plant available P known as orthophosphates.

Immobilization occurs when these plant available P forms are consumed by microbes, turning the P into organic P forms that are not available to plants. The microbial P will become available over time as the microbes die.

- Maintaining soil organic matter levels is important in P management. Mineralization of organic matter results in the slow release of P to the soil solution during the growing season, making it available for plant uptake. This process reduces the need for fertilizer applications and the risk of runoff and leaching that may result from additional P.
- Soil temperatures between 65 and 105˚F favor P mineralization.

Adsorption and Desorption

Adsorption is the chemical binding of plant available P to soil particles, which makes it unavailable to plants. Desorption is the release of adsorbed P from its bound state into the soil solution.

- Adsorption (or "fixing" as it is sometimes called) occurs quickly whereas desorption is usually a slow process.
- Adsorption differs from precipitation: adsorption is reversible chemical binding of P to soil particles while precipitation involves a more permanent change in the chemical properties of the P as it is removed from the soil solution.
- Soils that have higher iron and/or aluminum contents have the potential to adsorb more P than other soils.
- Phosphorus is in its most plant available form when the pH is between 6 and 7 (Figure 2). At higher pH, P can precipitate with Ca. At lower pH, P tends to be sorbed to Fe and Al compounds in the soil.

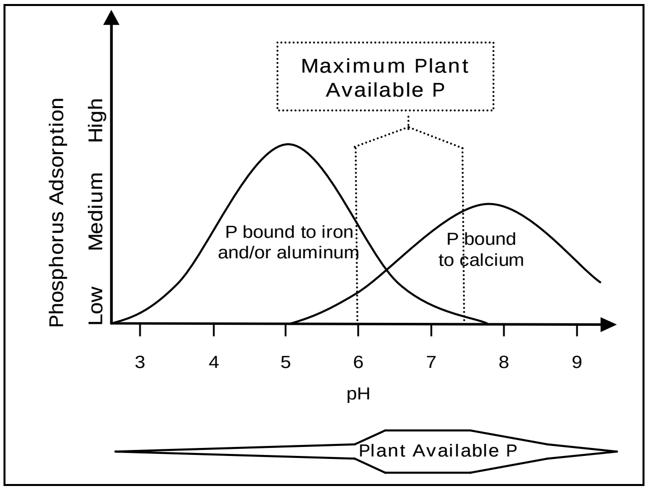

Figure 2: Soil pH impacts P availability.

- Every soil has a maximum amount of P that it can adsorb. Phosphorus losses to the environment through runoff and/or leaching increase with P saturation level.
- Precise fertilizer placement can decrease P adsorption effects by minimizing P contact with soil and concentrating P into a smaller area. Band application of fertilizer is a common example of this (see Agronomy Fact Sheet #8: Starter P Fertilizer for Corn).

Runoff

Runoff is a major cause of P loss from farms. Water carries away particulate (soil-bound) P in eroded sediment, as well as dissolved P from applied manure and fertilizers. Erosion control practices decrease P losses by slowing water flow over the soil surface and increasing infiltration.

Leaching

Leaching is the removal of dissolved P from soil by vertical water movement. Leaching is a concern in relatively high P soils (near or at P saturation), especially where preferential flow or direct connections with tile drains exist.

Summary

Crop uptake is the goal of applying P fertilizer or manure to the soil. If soil test P levels are already optimum, P additions through fertilizer or manure should not exceed crop removal. If additional P is needed (soils testing low or medium in P), P adsorption can be minimized by band applications and by maintaining an optimum pH. Naturally occurring immobilization of P by microbes can help ration plant available P to crops over the course of a growing season. Steps should be taken to reduce losses in order to maximize the efficiency of fertilizer and manure applications.

For more information

Cornell University Cooperative Extension

Nutrient Management Spear Program
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