Soil Phosphorus Cycle

WHAT YOU'LL LEARN

- Phosphorus (P) is an essential nutrient needed for optimum corn and soybean growth and development.
- Understanding the P cycle can help producers make decisions regarding management.

INTRODUCTION

Phosphorus (P) is a macronutrient that plays a number of important roles in plants, including root development. Insufficient soil P can result in delayed crop maturity, reduced flower development, low seed quality, and decreased yield potential.

Phosphorus does not occur as abundantly in soils as nitrogen (N) and potassium (K). However, the quantity of total P in soils does not always have a direct relationship to the availability of P to plants.

Understanding the relationships and interactions of the various forms of P in soils and the factors that influence P availability can help producers make decisions regarding P management, both for farm profitability and protection of the environment.

THE PHOSPHORUS CYCLE

Phosphorus exists in different forms in the soil. The P Cycle (Figure 1) shows the forms of P and the pathways by which P may be taken up by plants or leave as P runoff or leaching. Phosphate can potentially be lost through soil erosion and to a lesser extent to water running over or through the soil. Phosphorus is taken up by plants in the ionic forms $H_2PO_4^-$ and HPO_4^{2-}. The soil solution only contains a small amount of available phosphorus at any one time. The general P transformation processes are: weathering and precipitation, mineralization and immobilization, and adsorption and desorption. Weathering, mineralization, and desorption increase the plant available P. Immobilization, precipitation, and adsorption decrease plant available P.

Once plant roots remove P from the soil solution, it is replenished by the residual P in the soil. Soil microbes transform organic forms of P in plant residues or organic soil amendments into plant-available P through the process of **mineralization**. The soil solution can also be replenished from several pools of inorganic (mineral) P in the soil. Solid P minerals in the soil can **dissolve** into the soil solution when concentrations of soluble P diminish. Phosphorus can be attached to soil particles such as clay or specific minerals that contain iron (Fe) or aluminum (Al). Phosphorus can detach from these soil particles, supplying P to the soil solution via a process called **desorption**. Finally, solid rocks can be a source of P as they break down into soil over a long period of time by a process called **weathering**.

Just as soil solution P can be replenished when the concentration of P becomes too low, P can be removed from the soil solution if the amount of P becomes too high. When concentrations of P in the soil solution are too high, some of the dissolved P will form solid P minerals by a process called **precipitation**. Maximum phosphorus availability occurs at a soil pH between 6.5 and 7.0. Depending on the soil pH, precipitation can result in the formation of solid calcium phosphate minerals (high soil pH) or aluminum and iron phosphate minerals (low soil pH). One of the most important benefits to liming acid soils is improving phosphorus availability. Conversely, P can be removed from the soil solution and attach to soil particles like clays or iron and aluminum-bearing minerals through **adsorption**.

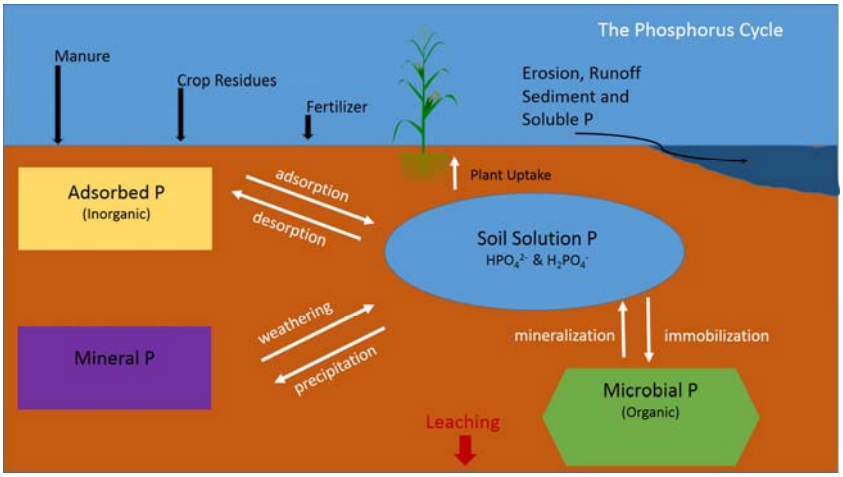

Figure 1. Simplified phosphorus cycle.

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FORMS OF PHOSPHORUS IN THE SOIL

Soil P is generally characterized into 3 types: solution P, labile P, and non-labile P.

Solution P is a very small part of the total soil P but it is the fraction taken up by plants. A growing crop would quickly deplete the P in the soluble P pool if the pool was not being continuously replenished.

Labile soil P is more plentiful than soluble P, but still only a small fraction of the total soil P. Labile P is not strongly sorbed in the soil and may enter the soluble phase fairly quickly.

Lastly, stable, **non-labile P** is in forms unavailable to plants and constitutes the greatest fraction of total soil P. With time, a small amount of non-labile P reacts chemically to become labile P and soluble P. Most non-labile P will remain non-labile indefinitely.

Soil solution P ⇌ Labile P ⇌ Non-labile P

The equilibrium relationship between non-labile (insoluble phosphorus forms) and labile phosphorus is affected by many factors such as the size of the slowly available pool, soil temperatures, compounds in the pool, type and amount of clay in the soil and the pH of the soil solution.

CROP UPTAKE

Crop response to P depends on the availability of P in the soil solution and the ability of the crop to take up P. Phosphorus is not very mobile in the soil and it does not move very far in the soil to reach the roots. Therefore, root growth is very important to P uptake. Any factor that affects root growth can affect the ability of the plant to explore the soil and receive adequate phosphorus. Soil compaction, herbicide root injury, and insect root feeding can all reduce the ability of the plant to uptake adequate P. Young seedlings can suffer from P deficiency even in soils with high P availability because they have limited root systems that are growing very slowly in cold, wet, early season soil conditions (Figure 2).

Figure 2. Phosphorus deficiency symptom in corn, older leaves turn purple in color.

MANAGEMENT

The most important tool in P management for crops is a soil test. Soil testing can reveal soil pH, soil P levels, and help determine the recommended application amount of phosphorus for the crop to be grown.

Understanding both crop nutrient uptake and removal can help a farmer better match plant nutritional needs for a target yield in a field environment. For corn, each bushel harvested per acre removes approximately 0.43 lbs/acre of P_2O_5.[6] For soybeans, each bushel harvested per acre removes approximately 0.85 lbs/acre of P_2O_5. Crops cut for silage remove significantly more, approximately 3 lbs of P_2O_5/ton of 67% moisture silage, because the majority of the aboveground tissue is harvested.

Soil fertility tests should be conducted at least every other year to verify that appropriate fertility levels are maintained. If there is concern about fertility, especially due to very high or very low yields, soil tests can aid with fertility decisions. It is important to apply fertilizers based on the values of the soil test.

Table 2. P_2O_5 Nutrient Removal.*

Crop (units)	Removal P_2O_5, lb/unit
Corn (bu)	0.35
Corn Silage (ton—67% moisture)	3.1
Alfalfa (ton)	12
Winter Wheat (bu)	0.48
Soybean (bu)	0.73

* Nutrient removal coefficients may vary regionally depending on growing conditions. Use locally available data whenever possible. Source: 2014. Nutrient removal in the harvested portion of selected crops. Table 4.5. International Plant Nutrition Institute. http://www.ipni.net

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