AGRONOMY

Soil Phosphorus Reactions

Phosphorus is required by the plant to form vital compounds and to store and transfer energy for growth and reproduction. However, soil minerals and organic matter react quickly with soluble phosphorus fertilizer to create compounds with very low solubility. Because soil components and conditions significantly affect the amount of phosphorus available, the ability to estimate soil phosphorus reactions is crucial. The challenge is to manage these reactions so that crops have adequate supplies of available phosphorus.

Phosphorus Reactions with Soil Minerals

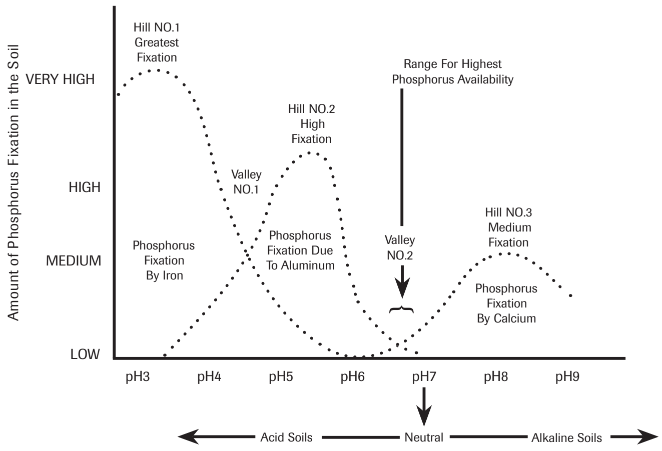
Availability of phosphorus is primarily dependent upon the pH of the soil. However, soil pH doesn't affect phosphorus availability directly. Instead, soil pH levels indicate how certain minerals – iron, aluminum, and calcium – interact with phosphorus in the soil, and it is this interaction that affects phosphorus availability.

Most soils contain abundant quantities of iron and aluminum; some soils, depending on soil pH, also contain an abundance of calcium. The amount of iron, aluminum, and calcium present in the soil are important because, in certain circumstances, each mineral is capable of "fixing" the phosphorus, making it unavailable to the crop.

In alkaline soils, iron and aluminum minerals are nearly insoluble, while soluble calcium is abundant. In acid soils, iron and aluminum concentrations are high because the minerals are soluble, while calcium concentrations are low because the mineral has been dissolved and leached out of the soil. High concentrations of any of these minerals will result in the phosphorus being fixed in the soil and unavailable to the crop.

Notice the hills and valleys of the phosphorus fixation graph in Figure 1. The highest fixation occurs in acid soils due to high iron concentrations when the pH is less than 5.
On the other end of the spectrum, alkaline soils also create phosphorus-fixation problems due to high concentrations of calcium. In the following paragraphs, you will see what can be done in each circumstance to reduce this fixation.

Figure 1. Phosphorus Fixation



When the soil pH is less than 5, iron and aluminum concentrations are very high and react very quickly with phosphorus, creating iron or aluminum phosphate minerals. The best way to correct this problem is to correct the pH with lime. Lime neutralizes the soil acidity and decreases the concentration of iron and aluminum in the soil solution. In short, lime reduces phosphorus fixation due to iron and aluminum.

When the soil pH is more than 7, calcium concentrations are very high. Therefore, phosphorus fixation due to calcium is a problem. The obvious solution is to lower soil pH. Unfortunately, the amount of acid needed to neutralize many alkaline soils is cost prohibitive. For example, a typical alkaline soil with 5% lime content would contain 50 tons of lime in the top 6 2/3 inches of soil. It would require 16 tons of elemental sulfur to neutralize 50 tons of lime. If the soil were 50% lime, that would be 500 tons of lime and 160 tons of elemental sulfur. However, more cost effective solutions do exist:

- Acknowledge the high pH, and plant a low-phosphorus-demand crop.
- Band-apply phosphorus fertilizer.
- When severe phosphorus stratification is evident, thoroughly incorporate the applied phosphorus throughout the root zone.

Phosphorus fixation occurs to some degree for all soils-even for pH levels from 6 to 7. This pH range is where phosphorus availability is at its highest and fixation due to iron, aluminum, and calcium is at its lowest. At this range and in the very best of circumstances, the crops may use 15% of the broadcast-applied phosphorus fertilizer and 30% of the band-applied phosphorus fertilizer. When the soil is acidic or alkaline, these numbers could drop to 5% for broadcast and 15% for banded.

The best way to know if your soil has a high phosphorus-fixation capacity is to monitor the rate at which the soil-test levels build when extra phosphorus fertilizer is applied.On the average, it requires 18 pounds of P2O5 to raise the soil test by 1 ppm for the Bray or Mehlich test and by 0.5 ppm for the Olsen test. If your soil requires more than 25 pounds of P_2O_5 to raise the soil-test levels, then perhaps normal fertilizer applications are insufficient for your situation. Instead, consider correcting soil pH and/or band-applying phosphorus fertilizer to meet your crop’s requirements.

Phosphorus Reactions with Soil Organic Matter

Soil microbes require phosphorus as a part of their diet. As a result, microbes compete with crops for soil phosphorus. This is especially true if a residue with a high carbon-to-phosphorus ratio has been applied to the soil. In this case, the microbes will need to use extra phosphorus from the soil solution to help them decompose the residue. During this decomposition, phosphorus is temporarily unavailable to the crop. This is called phosphorus immobilization. When decomposition nears completion and the microbial population declines, phosphorus will once again become available for plant uptake.

It is important to monitor phosphorus immobilization carefully because it can result in purple corn or similar deficiencies. If the residue has a high carbon to phosphorus ratio (e.g., 300:1), apply additional phosphorus fertilizer to prevent phosphorus deficiencies.

Conclusion

Soil minerals and organic matter react quickly with soluble phosphorus. In order for crops to have adequate supplies of available phosphorus, soil pH must be managed, and phosphorus immobilization must be monitored.