Phosphorus: What happens in the Soil?

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Worldwide and in our region of the high plains, phosphorus (P) is regarded as the second most important nutrient in crop production. Soil P availability is often deficient for profitable wheat production in our calcareous soils. This deficiency or low availability doesn't mean that P is not present in our soils. It does means that much of the P that is in our soils is not in an available form. This inavailability comes from the interaction of P fertilizer with water and soil-calcium, and the slow formation of P compounds that are less available to plants than fertilizer P.

Most P fertilizers that come from the factory are made to be water soluble (they will dissolve in water) and convert easily into the **orthophosphate** form. It is the **orthophosphate** form that is actually taken up by plants roots. Other forms of phosphate can not be easily absorbed by plant roots.

What actually happens to P fertilizer when it is added to a soil? For about 7 to 14 days most of the fertilizer P is still in its original fertilizer P form. Liquid P sources (like 10-34-0) that form is usually ammonium poly-phosphate (AP) and some orthophosphate. Actually about 30 % of 10-34-0 is orthophosphate. With solid fertilizer P (like 11-52-0 and 18-46-0) the original form is a very soluble, readily available formof triple (also called treble) super phosphate (TSP), concentrated super phosphate (CSP) or mono-calcium phosphate (MCP). After a time, if conditions of pH, calcium concentration and water are adequate, fertilizer P will convert into forms that are not readily available. This happens to fertilizer P when it is applied to soils, and the process is variously called fixation, adsorption, sorption, precipitation, or reversion. Simply stated, the solid soluble ortho-phosphate reacts with soil-calcium to form P compounds that are stable and insoluble. If enough time goes by they eventually form hydroxyapatite (HAP) or rock phosphate. Because HAP is very insoluble, P availability decreases to the point that the growing crop can't get enough and will show deficiency. (Eq. 1).

AP,MCP,CSP,etc. ----> DCPD (diCa-P dihydrate) ----> OCP (octoCa-P) ----> HAP Eq. 1

Obviously, fixation is greater where fertilizer-P interacts with more soil surface. This is the main strategy behind banding as opposed to broadcast applications, and for this reason broadcast rates are 2 to 5 times greater than banding rates. What happens to the P fertilizer when it is placed into the soil? **Most** of it is eventually fixed, some is taken up by plants, some by microbes, under sandy conditions some can be washed by rain or irrigation down into the soil profile, and some is eroded away with wind or water eroded soil. If the fixation is on clay surfaces (adsorption), some remains in equilibrium with P in the soil solution, and contributes to the values found in soil testing.

Many pressing questions exist for the producers. Are the reactions different for granules versus liquids fertilizers such as 10-34-0, or P in manures? What are polyphosphates (10-34-0), and how are they different from regular phosphates, sometimes called orthophosphates? Are they superior to TSP? How does P interact with other nutrients such as N and micronutrients? How much P is removed by grain each year (minimum P replacement value)? What does the term residual P mean? Vesicular arbuscular mycorrhizae (VAM)? And what is organic P and how available is it to crops? These questions will be discussed during the break out sessions.

Today with no-till and longer rotations than wheat-fallow, P cycling and chemistry are changing. We do not mix the soil as often, so we have more P stratification at the soil surface, and also a pool of crop residue (surface and roots) producing through decomposition, available P.

How does this new paradigm change soil testing and P requirements? Generally P availability and uptake is influenced primarily by five factors:

1. Amount and distribution of solid phase P (P not in solution, but on soil surfaces)
2. Rate of solution of solid phase P (solubility of the mineral)
3. P concentration of the soil solution (function of 1 and 2)
4. Rate of P diffusion in the soil solution (function of texture, compaction, etc)
5. Rate of root absorption of soluble P (function of crop, temperature, and 1, 2, 3, and 4).

Soil tests values is an index of available P from 1 and 3, but soil sampling procedures must reflect the increasing use of banded P.

Colorado uses the sodium bicarbonate-extractable P (Olsen-P) soil test or its modification, the AB-DTPA test, but some places use a Bray-1 P test or a Mehlich test. What causes these differences in soil tests? Since the test is supposed to correlate with plant P uptake, and calibrated against field yields, P extractability and subsequent uptake by crops will be primarily influenced by soil pH. These tests reflect that chemistry. The Olsen test is used primarily in neutral to calcareous (alkaline, Ca-dominated) soils, and the Bray-1 test in acid soils. Others like the Mehlich is used in both soils. Invariably, crops respond more when soil tests are in the medium to low category. However, responses, especially under cool conditions and soil compaction, have also been shown with starter-P for high testing soils.

Current thoughts about P fertilization in The high plains region

The following table can be used to make recommendations for fertilizer P in wheat and corn. It is based on soil tests that have been calibrated at UNL and CSU and is adapted from Hergert et al.1995; and from Mortvedt et al 1996. The extracted P levels by the various tests are indicators of P availability and have been calibrated to fertilizer application and crop response through field and lab research. They are not the complete answer but they are still better than just guessing.

Phosphorous Soil test, ppm P, 0-6 inch sample			Relative Level	Amount to apply annually (P_2O_5), lbs/acre			
				corn		wheat	
Bray-P-1*	SB-P†	AB-P**		Broadcast	Band	Broadcast	Band
0-5	0-6	0-3	very low	80	40	40	40
6-15	7-14	4-7	low	40	20	20	20
16-24	15-22	8-12	medium	0	0	20	20
>25	>22	>12	high	0	0	0	0

*Bray P-1. This method is not recommended for calcareous soils, Ok for acid to neutral soils.
†SB-P is the sodium bicarbonate test for calcareous soils
** AB-P is the ammonium bicarbonate test also calibrated for calcareous soils.

In general, responses to P fertilizer have been more dramatic for winter wheat at the same given soil test level than they have been for corn. In other words, when soil test levels are medium to low,yield responses to added P fertilizer are likely to be more economically favorable more often with winter wheat than they will be with corn.

References

Hergert, G.W. R.B. Ferguson and C. A. Shapiro, 1995. Nebguide G74-174-A. Fertilizer suggestions for corn.

Mortvedt J.J., D.G. Westfall and J.F. Shanahan. 1996. Soil Crop Series 3/96 fertilizing Wheat.

Biographical data for Merle F. Vigil

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