soil Phosphorus

Soil Quality Kit – Guides for Educators

USDA NRCS
United States Department of Agriculture
Natural Resources Conservation Service

Phosphorus (P), next to nitrogen, is often the most limiting nutrient for crop and forage production. Phosphorus' primary role in a plant is to store and transfer energy produced by photosynthesis for use in growth and reproductive processes. Soil P cycles in a variety forms in the soil (Figure 1). Adequate P levels promote root growth and winter hardiness, stimulate tillering, and hasten maturity. Phosphate soil test levels are an excellent indicator of P-cycling in soils, and are an index of the likelihood of crop response to P fertilizer.

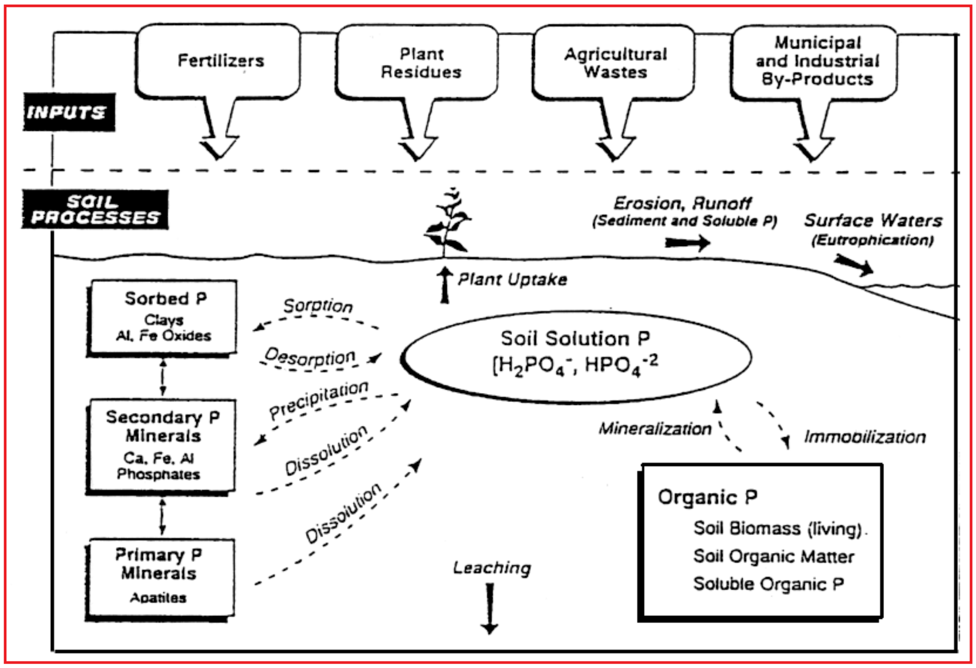

Figure 1. Soil phosphorus cycle (Pierzinski et al., 1994).

Inherent Factors Affecting Soil Phosphorus

Inherent soil properties and climate affect crop growth and how crops respond to applied P fertilizer, and regulate processes that limit P availability. Climatic and site conditions, such as rainfall and temperature, and moisture and soil aeration (oxygen levels), and salinity (salt content/electrical conductivity) affect the rate of P mineralization from organic matter decomposition. Organic matter decomposes releasing P more quickly in warm humid climates and slower in cool dry climates. Phosphorus is released faster when soil is well aerated (higher oxygen levels) and much slower on saturated wet soils.

Soils with inherent pH values between 6 and 7.5 are ideal for P-availability, while pH values below 5.5 and between 7.5 and 8.5 limits P-availability to plants due to fixation by aluminum, iron, or calcium (Figure 2), often associated with soil parent materials. Soil P cycles in many different forms some that are readily available and some that are not (Figure 1).

Phosphorus does not readily leach out of the root zone; potential for P-loss is mainly associated with erosion and runoff. Soils and sites that are most prone to erosion and runoff, or are in close proximity to streams, lakes and other water bodies need to be closely managed to avoid P loss.

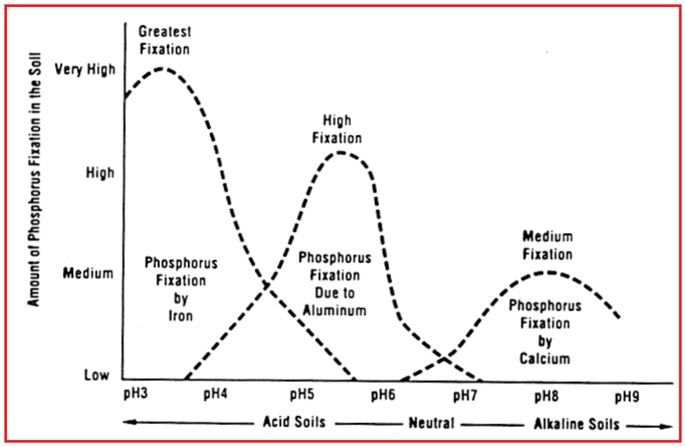

Figure 2. Phosphorus availability across pH ranges (California Fertilizer Association, 1995).

Phosphorus Management

P availability can be managed by liming acid soils, using measures that increase organic matter, and proper placement of P fertilizer affecting how efficiently P is used by crops. P losses can be reduced by applying appropriate measures to reduce erosion and runoff.

Adequate P levels encourage vigorous root and shoot growth, promote early maturity, increase water use efficiency and grain yield. Thus, P-deficiency stunts vegetative growth and grain yield. Soil phosphorus is relatively stable in soil, and moves very little compared to nitrogen. This lack of mobility and low solubility reduces availability of P-fertilizer as it is fixed by soil P-compounds. Fixed P is not lost, it becomes slowly available to crops over several years depending on soil and P-compound type (Figure 1).

Purple leaf tissue is symptomatic of P deficiency (Figure 3). Phosphorus deficiency symptoms appear on lower leaf tips and progress along leaf margins until the entire leaf shows purpling. Lower leaves die when phosphorus deficiency is severe, especially when hot, dry, windy conditions persist. Emerging leaves are usually green, because plants mobilize available P to youngest leaves first.

Phosphorus deficiency symptoms often occur as young plants are exposed to cool/wet growing conditions, resulting in a phase where vegetative growth exceeds the roots' ability to supply P. Young plants are especially vulnerable because their root systems are small and P is immobile in soil solution. Any cultural or environmental factors which limit root growth aggravate deficiency symptoms. Example factors include: cool temperatures, too wet or dry, compacted soil, herbicide damage, insect damage, salinity, and root pruning by side-dressing knives or cultivators. Once favorable growing conditions prevail, leaves normally regain green coloration when further root growth occurs. However, P deficiency reduces yield by delaying maturity, stunting growth, and restricts energy utilization by the plant.

Figure 3. Phosphorus deficient corn characterized by purple color on lower leaves.

Phosphorus availability is controlled by three primary factors: soil pH, amount of organic matter, and proper placement of fertilizer phosphorus.

Acid soils should be limed to bring soil pH up to ideal levels (pH 6-7). Low soil pH severely limits P availability to plants, which may cause deficiency symptoms even where high soil test P levels exist. Soil pH less than 5.5 typically reduces availability of P in soil solution by 30 percent or more. Acidic soil also reduces root growth, which is critical to P uptake. Soil pH values below 5.5 and between 7.5 and 8.5 limit phosphate availability to plants (Figure 2).

Organic matter maintenance is an important factor in controlling phosphorus availability. Mineralization of organic matter provides a significant portion of P for crops.

P-fertilizer, manure or other organic amendments can be applied to remedy P deficiency, but careful management strategies must be implemented to increase P availability to plant roots, which must contact available P for uptake to occur. Phosphorus is often recommended as a row-applied starter fertilizer for increasing early growth, even if P is not deficient for grain yield. Another strategy is to place P two inches below the seed of row crops providing a ready source of P for young seedlings. Producers need to carefully evaluate cosmetic effects from P-fertilizer early in the growing season versus increased profits from yield increases at harvest time.

Four major P-management strategies are:

1) Lime acid soils to increase soil pH to between 6.5 and 7.0 (Figure 2.);
2) Apply small amounts of P fertilizer frequently rather than large amounts at one time;
3) Reduce P tie-up by banding/injecting P fertilizer or liquid manure; and
4) Place P fertilizers near crop row or in furrow where roots are most active.

Measuring Soil Phosphate

Materials Needed to Measure Phosphate

____ Plastic bucket and probe for gathering and mixing soil samples

____ Phosphate test strips

____ 1/8-cup (29.5 mL) measuring scoop

____ Calibrated 120-mL shaking vial with lid

____ Squirt bottle

____ Distilled or rain water

____ Pen, field notebook, sharpie, and zip lock bags

Considerations – Electrical conductivity (EC) measurements should always be measured first, before measuring phosphate on same sample. Soil nitrate/nitrite and soil pH can also be measured on the same sample using the following steps.

All soil tests used for P are of no value unless <u>correlated</u> and <u>calibrated</u> with crop response to applied P. **Therefore, all P soil tests are an "index" of relative** availability.

In-Field Quick Hand Test

1. <u>Soil Sampling:</u> Soil phosphate level is variable, depending on field location, past management and time of year. Examples include, P fertilizer placement (rows or between rows), soil texture, organic matter content, and applications of manure or fertilizer. Using a soil probe gather at least 10 small samples randomly from an area that represents soil type and management history to a depth of 8 inches and place in a small plastic bucket. Do not include large stones and residue in sample. Repeat this step for each sampling area.

2. Neutralize hands by rubbing moist soil across your palms and discard soil, then place a scoop of mixed soil in the palm of your hand and saturate with "clean" water (distilled or clean rain water).

3. Squeeze soil gently until a water slurry runs out into the cup of your hand on the side.

4. Touch phosphate test strip into soil water slurry such that the tip is barely wet until the liquid is drawn up at least 1/8" to 3/16" beyond the area masked by soil (Figure 4).

5. After 1 to 2 minutes, measure the phosphate by comparing the color of the wetted test strips to the color scale on the test strip container (Figure 5). The color that most closely matches that of the test strip is the amount of phosphate in water saturated soil. Record value in Table 1.

Figure 4. Quick hand test.

Figure 5. Phosphate color scale.

1:1 Soil-Water Soil Phosphate Test in Classroom

1. <u>Soil Sampling</u>**:** Same as step 1 shown in "In Field Hand Test".

2. Add one sampling scoop (29.5 ml) of mixed soil that has been tamped down during filling by striking carefully on a hard level surface. Then add one scoop (29.5 ml) of water to the same vial resulting in a 1:1 ratio of soil: water, on a volume basis.

3. Tightly cap vial and shake 25 times, let settle for 1 minute, remove cap, and decant 1/16" of soil 1:1 suspension carefully into lid.

4. After setting for 2-3 minutes in the lid, immerse end of phosphate test strip 1/16" into 1:1 soil water mixture until liquid is drawn up at least 1/8 to 3/16" beyond area masked by soil (Figure 6).

5. After 1 to 2 minutes, measure phosphate by comparing color of wetted test strips to color picture scale on bottle in which test strips were stored (Figure 5). The color that most closely matches the test strip is the index value of phosphate in water saturated soil. Record value in Table 1.

Figure 6. 1:1 soil water test.

Interpretations

Compare water soluble phosphate (PO_4) levels to other P-test methods, PO_4 categories, and recommended fertilizer rates in Table 1 and answer discussion questions. Fertilizer recommendations and PO_4 categories will vary by crop type and Land Grant University.

Table 1. Phosphorus test results and recommendations for corn in Nebraska soils based on standard extractable P tests and water soluble PO_4 test for a 1:1 soil:water mixture.

Site	**Water Soluble PO_4 Test Reading for 1:1 Soil:Water Mixture**		**Soil P Test relational values (ppm) by P-test Method**			**PO_4 Categories**	[3] Recommended Fertilizer to Apply to Corn*, lb P_2O_5/acre & (P/ac)	
	PO_4 (ppm)	**Relative PO_4 Level**	[1] **Water Soluble PO_4**	[2] **Olsen P**	[2] **Bray 1-P**	**Relative PO_4 Level**	**Broadcast**	**Band**
Ex.1	16 ppm	High	**0-5**	0-3	0-5	Very Low	35 (80)	17 (40)
			5-10	4-10	6-15	Low	17 (40)	9 (20)
			10-15	11-16	16-24	Medium	0	0
			15-20	17-20	25-30	High	0	0
			>20	>20	>30	Very High	0	0

[1] Water soluble P (PO_4) test (Hach trademark) for 1:1 soil:water mixture based on comparison with Bray-1 and Olsen P tests for 19 benchmark soils (Bray 1 for soils with pH <7.2; Olsen for soils pH >7.2). Water soluble Aquachek based P recommendations agreed for twelve soils (63%), were borderline for three (total 79%). Four 1:1 soil water mixture/water soluble PO_4 tests indicated higher available P than standard Bray 1 & Olsen P tests.

[2] Based on Nebguide "Fertilizer Suggestions for Corn" G74-174-A, Revised Sept. 2001.

[3] Recommendations are based on use of synthetic P fertilizer but can be used for ***organic sources** of P such as rock phosphate or soft phosphate which can supply equivalent levels of available P over time. NOTE - Most soils fertilized with animal manure or compost will generally test in the M (medium) to VH (very high) range and do not need supplemental fertilization.

Are soil phosphate levels adequate? What are relative P levels and recommended rate of P_2O_5 fertilizer to apply using Table 1?

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Do management measures and practices being used limit phosphorus losses from erosion and runoff?

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Are appropriate management measures being used to properly manage soil pH, salinity, organic matter, and placement and amount of P-fertilizer or manure? Why or why not?

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Glossary

Immobilization – Temporarily "tying up" of water soluble P by soil microorganisms decomposing plant residues. Immobilized P will be unavailable to plants for a time, but will eventually become available again as decomposition proceeds.

Mineralization – Nutrients contained in soil organic matter (e.g., phosphorus, nitrogen, and sulfur) are converted to inorganic forms that are available to crops that occurs during respiration.

Phosphorus Cycle – P cycles between many different forms in soil, some that is plant available and some that are not plant available such as those fixed to iron, aluminum, and calcium minerals (Figure 1).

Phosphorus Fixation – Fixation of phosphate to iron, aluminum, and calcium minerals and sorbed on clay minerals are considered fixed. Fixation and P-availability vary across pH ranges (Figure 2).

Soil Phosphate – Plant available form of P expressed as PO_4.