Phosphorus

ESSENTIAL ELEMENTS

THE FERTILIZER INSTITUTE

Phosphorus (P) is present in every living cell, both plant and animal. No other nutrient can be substituted for it when it is lacking. Phosphorus is one of the 17 essential nutrients that plants need for growth and reproduction. Phosphorus is considered one of the three major nutrients along with nitrogen (N) and potassium (K). They are termed major nutrients because of the relatively large amounts utilized by plants (**Table 1**) and the frequency with which their deficiencies limit plant growth.

Table 1. Phosphorus uptake and removal by crops.

Crop	Yield Level	P_2O_5 uptake	P_2O_5 removal
		--- lb ---	
Alfalfa (DM)	8 tons	96	96
Coastal Bermudagrass	8 tons	96	96
Corn	160 bu	90	56
Cotton	1,500 lb lint	63	42
Grain Sorghum	130 bu	84	51
Peanuts	4,000 lb	46	22
Potato	500 cwt	105	75
Rice	7,000 lb	59	47
Soybeans	60 bu	66	44
Tomatoes	40 tons	104	37
Wheat, Spring	60 bu	46	34
Wheat, Winter	60 bu	41	29

Note: To convert P2O5 to P, multiply by 0.4364
DM = dry matter (0% moisture) basis
For more crops, visit http://ipni.info/nutrientremoval

Phosphorus must be added to the soil when the native supply is too low to support healthy crop growth. Maintaining an adequate supply of P is essential for plant health and high yields.

Phosphorus in Plants

Phosphorus is a vital component in the process of plants converting the sun's energy into food, fiber, and oil. Phosphorus plays a key role in photosynthesis, the metabolism of sugars, energy storage and transfer, cell division, cell enlargement, and transfer of genetic information.

Phosphorus promotes healthy root growth, promotes early shoot growth, speeds ground cover for erosion protection, enhances

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Phosphorus-deficient corn plants.

the quality of fruit, vegetable and grain crops, and is vital to seed formation. Adequate P increases plant water use efficiency, improves the efficiency of other nutrients such as N, contributes to disease resistance in some plants, helps plants cope with cold temperatures and moisture stress, hastens plant maturity, and protects the environment through better plant growth.

Phosphorus in Soils

Plant roots can only acquire P from the soil when it is dissolved in soil water. Since only very low concentrations of P are present in the soil water, P must be continually replenished from soil minerals and organic matter to replace the P taken up by plants. Plant roots generally absorb P as inorganic orthophosphate ions (HPO_4^{2-} or $H_2PO_4^{-}$). Phosphorus present in soil organic matter is not available for plant uptake until soil microbes convert the organic compounds into simple inorganic phosphate.

Many soil factors affect P availability to plants, including the type and amount of clay minerals, P concentration, factors affecting root activity (such as aeration and compaction), soil moisture content, temperature, adequate supply of other essential plant nutrients, and the root properties of the crop. Additionally, soil pH (acid or alkaline) greatly influences the availability of P to plants **(Figure 1)**.

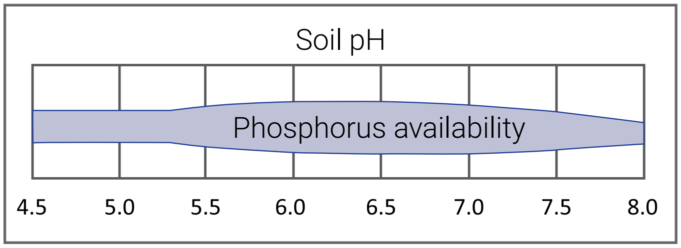

Figure 1. Effects of soil pH on P availability for plants.

The presence of mycorrhizal fungi growing in association with plant roots can enhance P uptake in many situations. The fungi do not provide any additional P to the soil, but can sometimes assist in P recovery.

Fertilizing Soils with Phosphorus

Very few soils contain an adequate supply of all of the mineral nutrients required for unrestricted crop growth. Soil and plant analysis can be used to assess if the need exists for supplemental P fertilizer.

Extensive research has established the relationship between P concentrations in the soil and the need for additional P fertilizer to achieve optimal growth. Similarly, research has identified the concentration of P required in plant tissue to sustain healthy plant growth. Both soil and plant diagnostic tests can be used as guides for fertilizer decisions.

In cropping systems where more P is removed from the soil during harvest than is being replaced, soil P concentrations will gradually decline over time. On the other hand, if more P is added than is removed, it will accumulate, and soil P concentrations will increase.

Careful nutrient management should accompany the use of all plant nutrients, including P. Without proper management, excessively high P concentrations can sometimes lead to unwanted nutrient loss to surface water, where stimulated algae growth may occur. Minimizing P loss from farmland involves consideration of P in the field (source) and transport (such as runoff and erosion loss).

Phosphorus is added to the soil in many forms, including commercial fertilizers, animal wastes, biosolids, crop residues, or other by-products. Phosphorus recycling from wastes has been practiced for centuries, but current demands for P in modern food production far outstrip these organic resources.

The P fertilizer industry was developed in the 19th century to better meet crop nutritional needs and to provide readily available forms of P that can be easily transported and applied to soil. Rock phosphate is mined from geologic deposits around the world and processed into many types of solid and fluid fertilizer. As with all earth minerals, P must be managed carefully to avoid waste and promote long-term resource stewardship.

In earlier times, fertilizer P was expressed as P_2O_5, and this notation has been maintained. Since P_2O_5 contains only 44 percent P, this notation sometimes can cause confusion.

Added P fertilizer chemically reacts with soil minerals, gradually reducing its solubility. Applying P fairly close to the time of crop utilization can improve P recovery by plants. When P fertilizer is applied beneath the soil surface in concentrated bands, these reactions are slowed. Environmental stress conditions that depress P availability to plants (such as cold soils) can be countered by placement of P close to the seed of crop plants (called starter or pop-up fertilization), even when adequate P is available for growth later in the season.

Phosphorus Deficiency Symptoms

The first indication of a P shortage is often a stunted plant, which is difficult to diagnose. Leaf shapes may be distorted. With severe deficiency, dead areas may develop on leaves, fruit and stems. Older leaves are affected before younger ones because of P redistribution within the plant. Some plants, such as corn, may display a purple or reddish color on the lower leaves and stems when P is low. This condition is associated with accumulation of sugars in P-deficient plants, especially during times of low temperature. A shortage of P can serve to reduce crop yields, quality, value, and profitability.

Crop Response to Phosphorus

Phosphorus fertilization increases yields and farmer profits in many soils around the world. Data in **Table 2** illustrate the importance of P for increasing crop yields, improving N use efficiency, lowering production costs per unit and increasing crop profitability.

References

1. Havlin, J.L., and A.D. Halvorson. 1990. MEY Wheat Management Conference. Denver, CO. pp. 82-95.

Further Reading

Shen, J. et al. 2011. Plant Physiol. 156:997-1005.
Syers, K. 2008. FAO Fertilizer and Plant Nutrition Bulletin 18.

Table 2. Adequate P increases wheat yields, improves N use efficiency, lowers production costs per bushel, and improves crop profits[1].

Fertilizer N, lb/A	Fertilizer P_2O_5, lb/A	Yield, bu/A	N use efficiency, bu/lb N	Fertilizer cost, $/bu	Net profit, $/A
75	0	35	0.47	1.29	200
75	20	51	0.68	1.12	300
75	30	58	0.77	1.09	343
75	40	69	0.92	1.00	414
75	50	67	0.89	1.12	394

Soil test P was low; Cost of fertilizer P_2O_5 = \$0.60/lb; N = \$0.60/lb; Wheat grain price = \$7.00/bu.

This information was originally developed by the International Plant Nutrition Institute.