Phosphorus

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Essential Role Of Phosphorus (P) In Plants

Phosphorus is an essential nutrient both as a part of several key plant structure compounds and as a catalysis in the conversion of numerous key biochemical reactions in plants. Phosphorus is noted especially for its role in capturing and converting the sun’s energy into useful plant compounds. The two examples that follow illustrate how vital phosphorus nutrition is to normal plant development and production.

Phosphorus is a vital component of DNA, the genetic "memory unit" of all living things. It is also a component of RNA, the compound that reads the DNA genetic code to build proteins and other compounds essential for plant structure, seed yield, and genetic transfer. The structures of both DNA and RNA are linked together by phosphorus bonds.

Phosphorus is a vital component of ATP, the "energy unit" of plants. ATP forms during photosynthesis, has phosphorus in its structure, and processes from the beginning of seedling growth through to the formation of grain and maturity.

Thus phosphorus is essential for the general health and vigor of all plants. Some specific growth factors that have been associated with phosphorus are: stimulated root development, increased stalk and stem strength, improved flower formation and seed production, more uniform and earlier crop maturity, increased nitrogen N-fixing capacity of legumes, improvements in crop quality, and increased resistance to plant diseases.

Phosphorus deficiency is more difficult to diagnose than a deficiency of nitrogen or potassium. Crops usually display no obvious symptoms of phosphorus deficiency, other than a general stunting of the plant during early growth, and by the time a visual deficiency is recognized it may be too late to correct in annual crops. Some crops, such as corn, tend to show an abnormal discoloration when phosphorus is deficient. The plants are usually dark bluish-green in color with leaves and stem becoming purplish. The degree of purple is influenced by the genetic makeup of the plant, some hybrids showing much greater discoloration than others. The purplish color is due

to accumulation of sugars which favors the synthesis of anthocyanin (a purplish colored pigment) that occurs in the leaves of the plant.

Phosphorus is highly mobile in plants and when deficient it may be translocated from old plant tissue to young actively growing areas. Consequently, early vegetative responses to phosphorus are often observed. As a plant matures, phosphorus is translocated into the fruiting areas of the plant where high energy requirements are needed for the formation of seeds and fruit. Phosphorus deficiencies late in the growing season affect both seed development and normal crop maturity. The percentage of the total amount of each nutrient taken up is higher for phosphorus late in the growing season than for either nitrogen or potassium.

Table 6.1: Percentage of Each Plant Nutrient Absorbed by a 180 bu/acre Corn Crop During Successive Twenty-five Day Growing Periods

	First (early)	Second (growth)	Third (silk)	Fourth (grain)	Fifth (mature)	
N	8	35	31	20	6	= 100
P_2O_5	4	27	36	25	8	= 100
K_2O	9	44	31	14	2	= 100

Phosphorus in Soils

The total phosphorus content of most surface soils is low, averaging only 0.6% phosphorus. This compares to an average soil content of 0.14% nitrogen and 0.83% potassium. The phosphorus content of soils is quite variable ranging from less than 0.04% P_2O_5 in the sandy soils of the Atlantic and Gulf coastal plain to over 0.3% in soils of the northwestern United States.

Many factors influence the content of soil phosphorus. Among these are: (1) type of parent material from which the soil is derived; (2) degree of weathering; and (3) climatic conditions. In addition, soil phosphorus levels are affected by erosion, crop removal and phosphorus fertilization.

Soil phosphorus is classified in two broad groups, organic and inorganic. Organic phosphorus is found in plant residues, manures, and microbial tissues. Soils low in organic matter may contain only 3% of their total phosphorus in the organic form, but high organic matter soils may contain 50% or more of their total phosphorus content in the organic form.

Inorganic forms of soil phosphorus consist of apatite (the original source of all phosphorus), complexes of iron and aluminum phosphates, and phosphorus absorbed on clay particles. The solubility of these phosphorus compounds, as well as organic phosphorus is extremely low and only very small amounts of soil phosphorus are in solution at any one time. Most soils contain less than a pound per acre of soluble phosphorus, with some soils containing considerably less.

Through adequate phosphorus fertilization and good crop/soil management, soil solution phosphorus can be replaced rapidly enough for optimum crop production.

Soil Phosphorus Availability

Soluble phosphorus, either from fertilizer or natural weathering, reacts with clay, iron, and aluminum compounds in the soil and is converted readily to less available forms by the process of phosphorus fixation. Because of these fixation processes, phosphorus moves very little in most soils (less than an inch in most soils), stays close to its place of origin, and crops seldom absorb more than 20 percent of fertilizer phosphorus during the first cropping season after application. As a result, little soil phosphorus is lost by leaching. This fixed, residual phosphorus remains in the rooting zone and will be slowly available to succeeding crops. Soil erosion and crop removal are the significant ways soil phosphorus is lost.

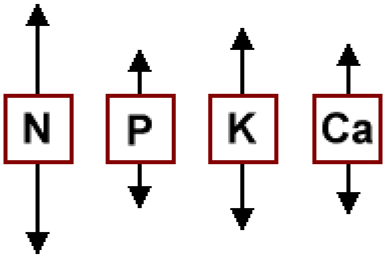

Figure 6.1 Relative Movement of Nutrients in the Soil

Phosphorus availability varies with the following factors:

Soil pH

Precipitation of phosphorus as slightly soluble calcium phosphates occurs in calcareous soils with pH values around 8.0. Under acid conditions, phosphorus is precipitated as Fe or Al phosphates of low solubility. Maximum availability of phosphorus generally occurs in a pH range of 6.0 to 7.0. This is one of the beneficial effects of liming acid soils. Maintaining a soil pH in this range also favors the presence of $H_2PO_4^-$ ions which are more readily absorbed by the plant than $HPO_4^=$ ions which occur at pH values above 7.0.

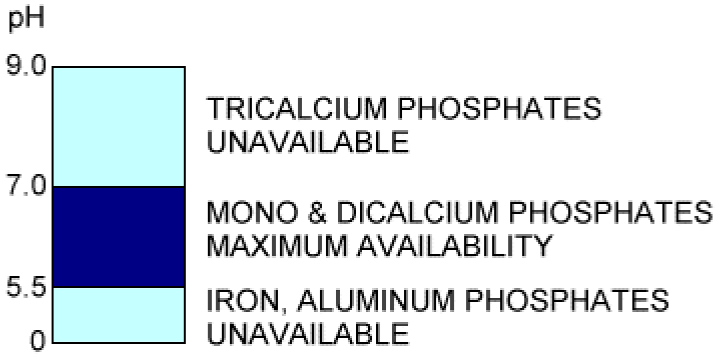

Figure 6.2 Soil pH Affects Phosphorus Availability

Other Nutrients

Adequate supplies of other plant nutrients tend to increase the absorption of phosphorus from the soil. Application of ammonium forms of nitrogen with phosphorus increases phosphorus uptake from a fertilizer as compared to applying the phosphorus fertilizer alone or applying the nitrogen and phosphorus fertilizers separately. Applications of sulfur often increase the availability of soil phosphorus on neutral or basic soils where the soil phosphorus is present as calcium phosphates.

Organic Matter

Soils high in organic matter contain considerable amounts of organic phosphorus which are mineralized (similar to organic nitrogen), and provide available phosphorus for plant growth. In addition to supplying phosphorus, organic matter also acts as a chelating agent and combines with iron, thereby preventing the formation of insoluble iron phosphates. Heavy applications of organic materials such as manure, plant residues, or green manure crops to soils with high pH values not only supplies phosphorus, but on decomposition provides acidic compounds which increase the availability of mineral forms of phosphorus in the soil.

Type of Clay

Clay particles tend to retain or fix phosphorus in soils. Consequently, fine-textured soils such as clay loam soils have a greater phosphorus fixing capacity than sandy coarse-textured soils. Clays of the 1:1 type (kaolinite) have a greater phosphorus fixing capacity than the 2:1 type clays (montmorillonite, Illite, vermiculite). Soils formed under high rainfall and high temperatures contain large amounts of kaolinitic clays and therefore have a much greater fixing capacity for phosphorus than soils containing the 2:1 type clay. High temperatures and high rainfall also increase the amount of iron and aluminum oxides in the soil which contributes greatly to the fixation of phosphorus added to these soils.

Application Timing

Fixation of soil phosphorus increases with time of contact between soluble phosphorus and soil particles. Consequently, more efficient utilization of fertilizer phosphorus is generally obtained by applying the fertilizer shortly before planting the crop. This practice is especially effective on soils with high phosphorus-fixing capacities. On coastal plain areas, fertilizers may be applied several months before planting with little or no decrease in availability of the fertilizer phosphorus to the crop. Banding of fertilizer for row crops is also much more likely to increase the efficiency of fertilizer phosphorus on soils of high phosphorus-fixing capacity than on soils of low phosphorus-fixing capacity.

Soil Temperature/Aeration/Moisture and Compaction

Phosphorus absorption by the plant is decreased by low soil temperature and poor soil aeration. Starter fertilizers containing water-soluble phosphorus are much more likely to increase crop growth during cool weather. Excessive soil moisture or soil compaction reduces the soil oxygen supply and decreases the ability of the plant roots to absorb soil phosphorus. Compaction reduces aeration and pore space in the root zone. This reduces phosphorus uptake and plant growth. Compaction also decreases the soil volume that plant roots penetrate, limiting their total access to soil phosphorus.

Soil Test Phosphorus Levels

Crop responses to fertilizer phosphorus will be greater and occur more frequently on soils testing low in phosphorus than on high testing soils. However, yields on soils with high P soil test levels usually are higher. The response to phosphorus fertilizer on high testing soils is increasing and it is important to maintain high soil phosphorus levels to support optimum crop production.

Fertilizer Phosphorus Management Considerations

Conservation Tillage

Conservation tillage practices are increasing. Factors associated with the various conservation tillage practices are a lower soil temperature at planting, a higher soil moisture content, an increased possibility of soil compaction, and an accumulation of soil acidity near the soil surface. Each of these factors increase the possible response of fertilizer phosphorus, especially starter phosphorus. This occurs even at high soil test levels. Adequate phosphorus fertilization is

essential for rapid early growth and high yields when using conservation tillage systems. Responses to applied phosphorus at high soil test levels have been noted in numerous research studies conducted on several crops.

Table 6.2: Response to Applied Phosphorus at High Soil Test Levels

			Yield		
Location	Crop	Soil Test P Level	Without P	With P	
Louisiana	Cotton	High	949	1,073	lb/acre lint
Arkansas	Cotton	High	1,402	1,638	lb/acre lint
South Dakota	Corn	High	124	145	bu/acre
Wisconsin	Corn	High	122	149	bu/acre
Minnesota	Corn	High	89	100	bu/acre
Kansas	Wheat	High	23	41	bu/acre
New York	Barley	High	70	100	bu/acre

Early Planting

Earlier planting dates for corn and some other crops increase yield potential. More and more farmers can benefit from this advantage as they have upgraded equipment and reduced the number of trips over the field prior to planting. Earlier planting dates means cooler soils and less movement of soil phosphorus and a higher potential for response at high soil test levels.

Soil Drainage

Crops on poorly drained soils often show phosphorus response even at high soil test levels. Low oxygen availability in poorly drained soils reduces root growth rates and limits their ability to absorb and translocate phosphorus. The higher soil moisture content also tends to keep these soils cooler in the spring, further reducing phosphorus uptake.

Balanced Nutrition

Balanced nutrition is a must for realization of the full phosphorus response potential of crops. Insufficient levels of other nutrients can substantially reduce response to phosphorus. For example, a long-term Kansas study showed that response of irrigated corn to phosphorus continually increased with increasing nitrogen rate until the optimum nitrogen level was reached. Using soil tests to maintain adequate levels of all nutrients plus lime requirements helps maintain phosphorus efficiency.

Table 6.3: Response Of Irrigated Corn To Phosphorus

Annual N Rate lb/acre	Annual P_2O_5, lb/acre 0 (10-Year Average Corn Yield, bu/acre)	40	Average Response bu/acre
0	82	87	5
40	109	131	22
80	115	150	35
120	114	166	52
160	120	177	57
200	119	173	54

Phosphorus Placement

If a grower is looking for maximum return from high phosphorus investment on low testing soils, band application is best. Where conservation tillage is practiced, combinations of both band and broadcast applications of phosphorus may be needed. This insures an early, accessible phosphorus supply for developing seedlings and a nutrient reserve later in the growing season when phosphorus demands remain strong.

Several advantages for broadcast/plowdown phosphorus applications are; (1) High rates can be applied without injuring the plant; (2) Nutrient distribution throughout the root zone encourages deeper rooting, while band placement causes root concentration around the band; (3) Deeper rooting permits more root-soil contract, providing larger reservoir of moisture and nutrients; (4) A practical way to apply fertilizer to forages; and (5) Helps insure full-feed fertility to help the crop take full advantage of favorable growth conditions throughout the growing season.

Dual application of anhydrous ammonia and ammonium polyphosphates at seeding of wheat has been found to be superior to broadcast or band applications of ammonium polyphosphates.

Placement directly under the drill row (band seeding) for forage crops has proven superior to broadcast or side placement. Tomatoes and onions have responded best to phosphorus placed directly below the seed or set.

Diammonium Phosphate (DAP) 18-46-0
Diammonium Phosphate 2x4 (DAP) 18-46-0

Diammonium phosphate, $(NH_4)_2HPO_4$, is manufactured by the reaction of ammonia and phosphoric acid. Its nitrogen to phosphate ratio makes it an excellent direct application product or one that blends well with other fertilizer materials to produce a variety of NPK fertilizers.

DAP is typically 90% water soluble (expressed as a percentage of available P_2O_5). The typical pH of the product is 7.5 when it is measured on a saturated slurry of the product. In the soil, the initial stages of the product's breakdown releases ammonia (NH_3) and causes a small zone around the DAP particles in the soil to have a pH of about 8.0. After a short time and as the DAP continues to break down, the product has a net effect of acidifying the soil. The general guideline is that 1250 to 1550 pounds of calcium carbonate will be required to neutralize the acidity of one ton of DAP added to the soil. Because of this recognized acidifying characteristic of DAP and its potential for seedling injury when placed too close to the plant, the recommended placement techniques include the standard 2x2 sidedress, broadcast or deep placement.

Granular Monoammonium Phosphate (GMAP) 11-52-0

Monoammonium phosphate, $NH_4H_2PO_4$, is a fertilizer manufactured from phosphoric acid and ammonia. It is an excellent product for direct application and is particularly well suited for row application. It is an ideal product for dry bulk blending with other fertilizer materials. MAP is a product-of-choice for manufacturing fluid blends or suspension fertilizers.

Links to other sections of the EFFICIENT FERTILIZER USE MANUAL
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