Phosphate

The element P is present in every living cell, both plant and animal. The light energy captured by photosynthesis would not support any of the necessary plant functions if compounds which contain P were not present as "energy packaging" structures. Phosphorus is indeed the energizer in plant production.

Crop Demands for Phosphorus

Plants take up large amounts of P from the soil as various forms of phosphate. In an average year in the US, the crops of corn, wheat and alfalfa remove a total of nearly 1.5 billion pounds of P from the soil. Nitrogen (N) and potassium (K) are the only other essential plant food nutrients taken up in greater quantities than P.

The magnitude of P removal is even more impressive when the limited amount of plant-available P in soils and the plant's ability to find that P are considered. Phosphorus must be dissolved in the water that bathes soil particles and plant roots. This provides a soil-plant connection and allows the nutrient to be taken up and used by crops. Because P is relatively insoluble in water, the water in most agricultural soils contains only about one tenth of a pound of P per acre. This means that, for a crop such as corn, soils must completely replace all the P in the soil water 6 or 7 times each day when averaged over the entire growing season.

Plant roots occupy about one percent or less of the soil volume, so much of the soil P is too far from any root to be taken up in any one season. Therefore, P in the soil water near roots must actually be replaced many more than 6 or 7 times per day. If this is to occur, the soil must have an adequate reservoir of P to supply the crop's need over a normal growing season.

The Importance of Phosphorus in Crop Health, Quality and Our Environment

"Sickly," "stunted," "spindly," "weak" and "barren" are all adjectives used to describe P-deficient plants. They emphasize the importance of P in crop health. Some plants show obvious deficiency symptoms, while others may suffer growth reduction without apparent deficiency symptoms.

Due to the many vital plant functions influenced by P, crop yield losses can occur even though no distinctive deficiency symptoms are present, a condition referred to as “hidden hunger.” Plants suffering from hidden hunger will use available water less efficiently and be more susceptible to yield- and quality-depressing diseases. They also tend to take longer to mature, are more susceptible to cold temperatures, and have lower nutritional value.

Photosynthesis is the basic food production process in growing plants. Photosynthesis requires P compounds for growing plants, for energy transfer as carbon dioxide from the air and water from the soil are converted to simple sugars. Once the sugars are formed, P is again needed for utilization of the sugars by the plant.

Root uptake of all plant food nutrients is dependent, in part, on an adequate supply of P. It is not surprising that the P status of the plant frequently influences utilization of other nutrients such as N. Fixation of N from the air by legumes is also dependent on P. Nitrogen fixation takes place in the soil and is carried out by bacteria, usually living in nodules on leguminous plant roots. Nitrogen fixed in this manner is available for use by the legume or by crops that follow the legume. Crop plants cannot use atmospheric N, even though nearly 80% of the air we breathe is N.

Phosphorus is a part of the building blocks of genes and chromosomes. It is intimately involved in providing the "blueprint" for all aspects of plant growth and development and in the germination process of the seed which passes the "blueprint" on to the next generation.

Phosphorus is as vital to agriculture as is the sun. Without P, the sun’s bountiful energy would never be packaged in a loaf of bread or a juicy orange. Phosphorus is an integral part of a profitable, environmentally sound agriculture.

The early growth enhancement frequently associated with P fertilization has benefits other than increased yield. Rapid early growth allows for quicker closing of the crop canopy, which serves as an umbrella to protect soil from erosion. Also, the amount of unused N at the end of the growing season is usually less with adequate P. Unused N not only represents a potential economic loss to the farmer, but is also a potential contributor to water contamination by leaching and erosion.

Where Do Plants Get Phosphorus?

Plants take up P from soil water. Because of the small amounts found there, the P must be continually replenished by soil particles. Nearly all soils have naturally available P levels that are too low to support the needs of modern, high yielding crops without fertilization.

Soil particles contain some minerals comprised of P in combination with other elements. When these minerals dissolve, P is released into soil water much like sodium (Na) is released when salt is added to water. However, P minerals are less soluble and dissolve very slowly.

Some soil particles have P attached to their surfaces. It can be detached from the particles and move into soil water to replace the P being used by plants.

Soil organic matter is another source of P for plants, but this P is not available until soil microbes break the organic matter down into simple nutrients that roots can take up. The speed of that breakdown is affected by soil temperature, moisture, and the supply of oxygen and other factors.

If the various forms of soil P do not supply adequate P to the plant, supplemental P should be added. The two most common forms are animal manures and commercial fertilizer. Legumes do not add P to the soil, only N. Manure does not represent a net gain of P to a farm unless large amounts of purchased feeds (from other farms) are being used for the livestock that produce the manure. Manure use is an excellent way of recycling some of the P removed from soil in feed grains and forages (soil-animal-manure-soil).

The only significant net input of P into North American crop production is from commercial fertilizer. Phosphorus fertilizer in the United States is manufactured from naturally occurring mineral deposits (phosphate rock) mined in Florida, North Carolina, Idaho, and Utah, plus some imported phosphate minerals. These minerals have very low water soluble P contents and are poor P sources for plants until they are further processed into P fertilizers.

Fertilizer P is used to increase the amount of P in the soil to the point where P demands by crop plants can be met. Phosphorus removed in grain, forages, meat, milk and fiber, plus that which is lost by erosion, must be replaced or soil fertility and productivity will decline. The consequence of not balancing the nutrient budget (deficit farming) is a certain decline in productivity. This decline may not be noticed for several years in a fertile soil because soil particles act as a P "reservoir." However, the eventual result is poorer plant growth, declining production, less soil protection from rainfall, and increased erosion.

How Are Plant Phosphorus Needs Determined?

Soil testing is used to determine if a specific area of land has an adequate P-supplying ability and to determine if the P nutrient budget is balanced. If more P is being removed from the soil than is being replaced, soil test levels will drop over time. On the other hand, if more P is being applied than is being removed, soil test levels will increase over time. Based on US Department of Agriculture (USDA) statistics, crops produced in the US took up more P than was applied to the soil each year since 1980. This is a troublesome statistic because it suggests that on the average soil fertility levels in the US may be declining. Such a change will eventually result in decreased productivity. It places an additional burden on future generations. They will be forced to repay the "debt" in order to regain the lost productivity. The problem can be prevented by proper management, including an adequate P fertilizer program.

Sources of Fertilizer Phosphorus

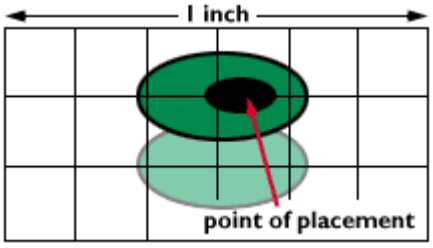
Several procedures are used to convert mined phosphate rock into usable fertilizers. Each process produces a fertilizer material with unique characteristics. The final product may be a dry granular material or a liquid. Following are descriptions of the most important commercial P fertilizers.

Concentrated superphosphate is a high analysis fertilizer containing from 44 to 53 percent P_2O_5. (The term P_2O_5 is an expression used to describe P contents of fertilizers, including manures and commercial fertilizers.) It is used extensively for legume forage fertilization since it does not contain N, as do most of the other P fertilizers. (Legumes fix their own N, so they do not usually need N from fertilizer.)

Ammonium orthophosphates are the dominant P fertilizers used in North America today. They range in P_2O_5 content from 46 to 53 percent and N content from 10 to 19 percent. They have the advantage of providing two needed nutrients, N and P. The ammonium N in these fertilizers may enhance the uptake of P by plant roots.

Ammonium polyphosphates contain ammonium N and complex phosphate molecules (polyphosphates). Most liquid P fertilizers contain some polyphosphates. Polyphosphates are excellent P sources and have the characteristic of allowing higher concentrations of other nutrients such as zinc (Zn) and iron (Fe) to be added to the liquid fertilizers.

What Happens to Phosphorus When It Is Added to the Soil?



Phosphorus fertilizer moves very little in the soil, so it must be placed where the plant roots can intercept it. This grid illustration represents a small area in a soil profile, showing the limited downward movement after application 17 days earlier.

A fascinating, complex series of chemical events takes place when a soluble P fertilizer contacts the soil. Almost immediately the P is converted to the most stable form possible in the soil to which the fertilizer was applied. These stable forms are less available to plants, because they do not dissolve easily in the soil water. Instead they react with other soil components and become part of the soil solids. In essence, the fertilizer P becomes soil P. The conversion from "fertilizer" P to "soil" P is called fixation.

In some soils the fixation process is very rapid, and the final forms of soil P are quite unavailable to plants. In most soils the conversion occurs more slowly, and the final forms are more available. Phosphorus from fertilizer is most available immediately after application. However, residual benefits occur in most soils for many years.

Phosphorus from livestock manure reacts similarly. However, most of the P from the source is in organic forms and must be broken down by microbes to be available to plants. Once this breakdown occurs, the P from manure is subject to the same chemical reactions in the soil as is fertilizer P. Also, at this point, there is no difference in the P derived from soil

organic matter and manure and that supplied in commercial fertilizer.

The tendency of P to react quickly with the soil greatly limits its motility in the soil. It does not move appreciably from the point of application and is not subject to being leached from the root zone. It is lost only through crop removal and soil erosion.

Best management practices (BMPs) for P vary, depending on the characteristics of the specific soil in question.

Helping Plants Obtain Phosphorus

The basic management strategy in crop production is to build soil test levels to a point where plant needs are generally met by the soil. Once this point is reached, additional P is applied in quantities necessary to maintain the soil at the level, approximately the amount removed in the harvested portion of the crop.

In many cases at least a portion of the maintenance P requirement should be applied in a concentrated zone near the seed at planting. This is called “starter” fertilizer and assures sufficient P for early growth. Most annual crops have a very high requirement for P early in their growth because of a limited root system. This early requirement is so high that in many cases it can only be met by use of commercial fertilizer in a concentrated band placed near the young plant.

Normally, the factor having the greatest impact on the amount of P a crop plant can obtain from a given soil or fertilizer treatment is the size of the root system. Therefore, it is vital that the crop be managed such that all controllable factors are near optimum. The goal should be vigorous, healthy plants with well-developed root systems that can forage effectively for nutrients, produce high, profitable yields and at the same time sustain environmental quality.

Summary

Phosphorus is a vital component in the process of converting the sun’s energy into usable forms for the production of food and fiber. Fertilizer P is an essential ingredient in North American agriculture if the productive capacity of the system is to be sustained or improved and if it is to remain competitive in a global economy. Soil testing is a critical tool to help determine if nutrient budgets are being balanced or if management adjustments are necessary to maximize crop production efficiency and protect the environment.

Crops supplied with adequate P are more efficient and more profitable. Vigorous, healthy growth helps reduce soil erosion and increases the efficiency of fertilizer N utilization. To be most successful, sound P practices must be used in a program incorporating an entire set of finely tuned BMPs that support the most profitable yields while providing environmental protection.