Functions of Phosphorus in Plants

Phosphorus is one of 17 nutrients essential for plant growth. Its functions cannot be performed by any other nutrient, and an adequate supply of P is required for optimum growth and reproduction. Phosphorus is classified as a major nutrient, meaning that it is frequently deficient for crop production and is required by crops in relatively large amounts. The total P concentration in agricultural crops generally varies from 0.1 to 0.5 percent.

Phosphorus (P) is vital to plant growth and is found in every living plant cell. It is involved in several key plant functions, including energy transfer, photosynthesis, transformation of sugars and starches, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next.

Uptake and Transport of Phosphorus

Phosphorus enters the plant through root hairs, root tips, and the outermost layers of root cells. Uptake is also facilitated by mycorrhizal fungi that grow in association with the roots of many crops. Phosphorus is taken up mostly as the primary orthophosphate ion ($H_2PO_4^-$), but some is also absorbed as secondary orthophosphate ($HPO_4^{=}$), this latter form increasing as the soil pH increases.

Once inside the plant root, P may be stored in the root or transported to the upper portions of the plant. Through various chemical reactions, it is incorporated into organic compounds, including nucleic acids (DNA and RNA), phosphoproteins, phospholipids, sugar phosphates, enzymes, and energy-rich phosphate compounds...for example, adenosine triphosphate (ATP). It is in these organic forms as well as the inorganic phosphate ion that P is moved throughout the plant, where it is available for further reactions.

Plant Energy Reactions

Phosphorus plays a vital role in virtually every plant process that involves energy transfer. High-energy phosphate, held as a part of the chemical structures of adenosine diphosphate (ADP) and ATP, is the source of energy that drives the multitude of chemical reactions within the plant. When ADP and ATP transfer the high-energy phosphate to other molecules (termed phosphorylation), the stage is set for many essential processes to occur.

Photosynthesis

The most important chemical reaction in nature is photosynthesis. It utilizes light energy in the presence of chlorophyll to combine carbon dioxide and water into simple sugars, with the energy being captured in ATP. The ATP is then available as an energy source for the many other reactions that occur within the plant, and the sugars are used as building blocks to produce other cell structural and storage components.

$$\text{Photosynthesis} = \text{Carbon Dioxide} + \text{Water} \xrightarrow[\text{Phosphate Energy}]{\text{Chlorophyll} \atop \text{Sunlight}} \text{Oxygen} + \text{Carbohydrates}$$

Genetic Transfer

Phosphorus is a vital component of the substances that are building blocks of genes and chromosomes. So, it is an essential part of the process of carrying the genetic code from one generation to the next, providing the "blueprint" for all aspects of plant growth and development.

An adequate supply of P is essential to the development of new cells and to the transfer of the genetic code from one cell to another as new cells are formed. Large quantities of P are found in seeds and fruit where it is believed essential for seed formation and development.

Phosphorus is also a component of phytin, a major storage form of P in seeds. About 50 percent of the total P in legume seeds and 60 to 70 percent in cereal grains is stored as phytin or closely related compounds. An inadequate supply of P can reduce seed size, seed number, and viability.

Nutrient Transport

Plant cells can accumulate nutrients at much higher concentrations than are present in the soil solution that surrounds them. This allows roots to extract nutrients from the soil solution where they are present in very low concentrations.

Movement of nutrients within the plant depends largely upon transport through cell membranes, which requires energy to oppose the forces of osmosis. Here again, ATP and other high energy P compounds provide the needed energy.

Phosphorus Deficiency

Adequate P allows the processes described above to operate at optimum rates and growth and development of the plant to proceed at a normal pace.

When P is limiting, the most striking effects are a reduction in leaf expansion and leaf surface area, as well as the number of leaves. Shoot growth is more affected than root growth, which leads to a decrease in the shoot-root dry weight ratio. Nonetheless, root growth is also reduced by P deficiency, leading to less root mass to reach water and nutrients.

Generally, inadequate P slows the processes of carbohydrate utilization, while carbohydrate production through photosynthesis continues. This results in a buildup of carbohydrates and the development of a dark green leaf color. In some plants, P-deficient leaves develop a purple color, tomatoes and corn being two examples. Since P is readily mobilized in the plant, when a deficiency occurs the P is translocated from older tissues to active meristematic tissues, resulting in foliar deficiency symptoms appearing on the older (lower) portion of the plant. However, such symptoms of P deficiency are seldom observed in the field...other than loss of yield.

Other effects of P deficiency on plant growth include delayed maturity, reduced quality of forage, fruit, vegetable, and grain crops, and decreased disease resistance. BC

World Production... *(continued from page 5)*

1975 to 1979 (**Figure 1**). Consumption declined to an average of 4.3 million tons yearly during the 1985-1989 period, but has since begun increasing, averaging about 4.5 million tons since 1995.

Illinois led the U.S. in phosphate consumption in 1997, followed by Iowa, Minnesota and Texas (**Table 3**). Others in the top 10 consuming states included Nebraska, California, Indiana, Kansas, Missouri, and North Dakota. These 10 states accounted for 55 percent of U.S. phosphate consumption.

Canadian consumption of fertilizer phosphate followed similar trends to the U.S., but reached a high of 798,164 tons of P_2O_5 in 1985 (**Figure 1**). Consumption declined to 637,175 tons in 1991, but has since increased to 775,370 tons in 1997. About 75 percent of Canada's phosphate consumption occurs in the prairie provinces (Alberta, Manitoba and Saskatchewan). BC

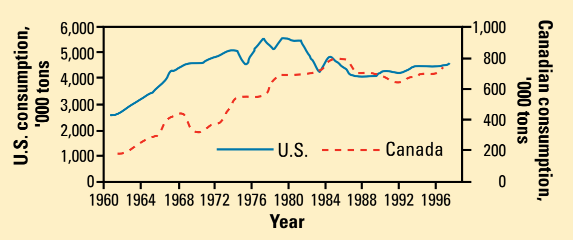

Figure 1. Consumption of P_2O_5 in North America.