ESSENTIALS PHOSPHORUS

NO. 2

Phosphorus (P) has an essential role in every living cell. In plants, P is essential for photosynthesis - the process of converting the sun's energy into food, fiber and oil. It is also necessary for the metabolism of sugars, energy storage and transfer, cell division, cell enlargement, and transfer of genetic information.

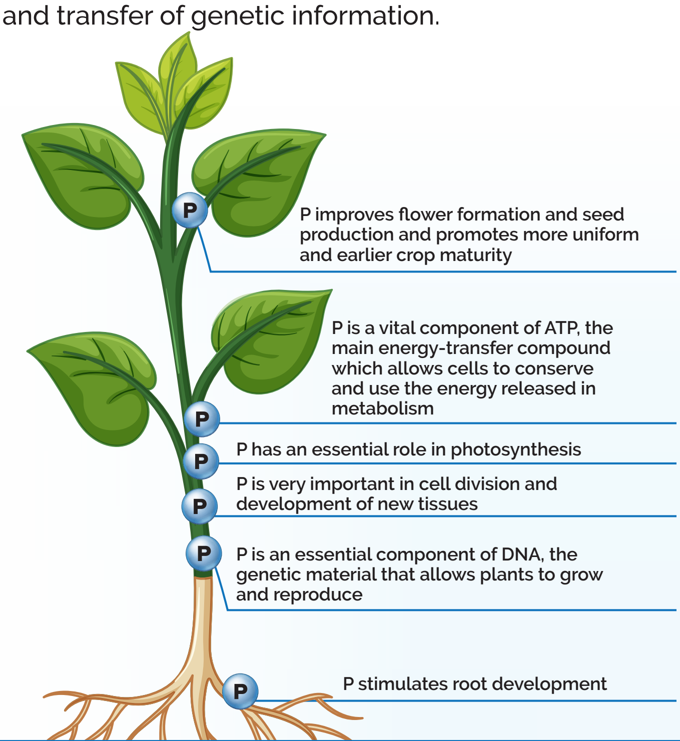

Figure 1. Some essential roles of phosphorus in plants.

Farmers relied primarily on animal manures to supply P to their crops until the 18th century, when animal bones were discovered to be a source of P. In the following years, bones were dissolved in sulfuric acid to make the P more soluble by producing calcium phosphate [$Ca(H_2PO_4)_2$], referred to as "superphosphate of lime".

Modern P fertilizers come from phosphate rock excavated from abundant sedimentary and igneous geologic deposits located around the world. A variety of soluble, concentrated, and affordable P fertilizers are now available for farmers to nourish their crops.

PHOSPHORUS IN PLANTS

Plants require a large quantity of P and the majority of the plant P is removed from the field with each harvested crop (**Table 1**). Plants with sufficient P have healthy root growth, earlier and more vigorous shoot growth, and enhanced quality of harvested crops. Adequate P improves the use of other plant nutrients (such as nitrogen), contributes to disease resistance, helps plants cope with stress, hastens plant maturity, and promotes seed formation.

Table 1. Phosphorus uptake and removal by common crops.

Crop	Uptake in above ground biomass, kg P_2O_5 per t	Removal in harvested product, kg P_2O_5 per t
Maize	9.6	6.3 (66%)
Rice	8.4	6.7 (80%)
Wheat	13	9.5 (73%)
Sorghum/Millet	13	7.8 (60%)
Beans	15	13 (87%)
Groundnuts	12	5.5 (46%)

APNI data. To convert P_2O_5 to P, multiply by 0.4364. Numbers inside parentheses indicate the % of total P uptake removed in harvested product.

PHOSPHORUS IN SOIL

Soil pH greatly influences the availability of P to plants, as it quickly reacts with common soil materials (fixation). In acid soils, P reacts with iron and aluminum to form low-solubility compounds. At high pH, P reacts with calcium to form insoluble minerals. Limestone is added to acid soils in order to raise the soil pH into the range where P is most available (i.e., between 5.5. and 7.5; **Figure 2**).

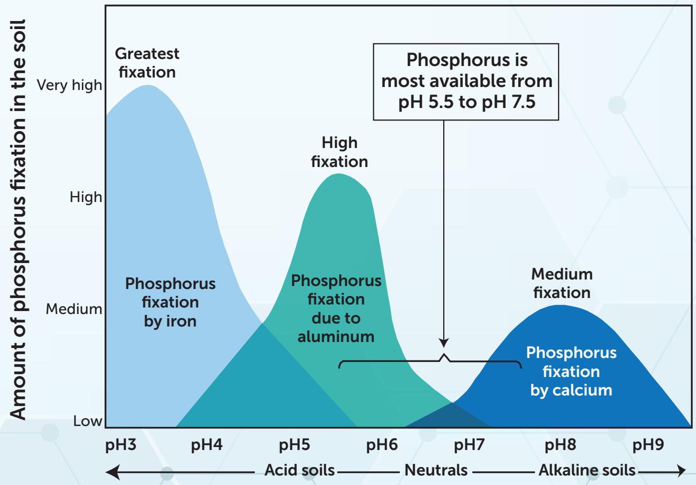

Figure 2. Effects of soil pH on P availability for plants.

Farmers add P to the soil when the native supply is too low to support healthy crop growth. Roots generally absorb P as inorganic orthophosphate ions ($H_2PO_4^-$ or

AFRICAN PLANT NUTRITION INSTITUTE
BENGUÉRIR, MOROCCO
WWW.APNI.NET | INFO@APNI.NET

HPO_4^{2-}) when they are dissolved in soil water. 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 by extending the root system further into the soil and excreting organic compounds that aid in solubilizing soil P minerals (**Figure 3**).

In some soils, organic matter can provide a large reserve of P. However, P in organic compounds is generally not available for plant uptake until soil microbes convert (mineralize) them into simple inorganic phosphate.

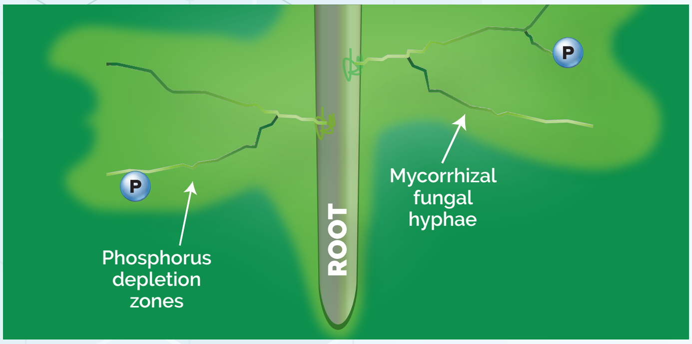

Figure 3. Plants acquire P from a small volume of soil immediately surrounding the root. Mycorrhizal fungi grow in close association with roots and extend the volume of soil that can be explored and excrete organic compounds that solubilize P.

PHOSPHORUS DEFICIENCY SYMPTOMS

The first indication of a P shortage is often a stunted and dark green plant, which can be difficult to diagnose. Leaf shapes may also be distorted. Areas of brown (necrotic) tissue may develop on leaves, fruits and stems. Older leaves first display deficiency symptoms because P is internally redistributed towards more actively growing tissue.

Some plants, such as maize, display a purple or reddish color on the lower leaves and stems when P concentrations are low. This condition is associated with accumulation of sugars in P-deficient plants, especially in cool temperatures. A shortage of P will reduce crop yields, quality and profitability even before symptoms are visible.

J. Kelly/M. Mozaffari/APNI Photo

Phosphorus deficiency symptoms showing in a maize crop.

PHOSPHORUS MANAGEMENT

Phosphorus is added to the soil in many forms, including commercial fertilizers, rock phosphate, animal wastes, biosolids, crop residues, or other by-products. Phosphorus recycling from wastes is important, but the demand for P in modern food production systems far surpasses what organic resources can supply. When feasible, often a combination of fertilizer P and organic matter achieve the best yields in African soils.

Table 2. Common sources of phosphorus.

	% P_2O_5	% P
Monoammonium phosphate (MAP)	52	23
Diammonium phosphate (DAP)	46	20
Triple superphosphate (TSP)	45	20
Phosphate Rock (examples)		
Minjingu PR	23-30	10-13
Tilemsi PR	24	11
Manure		
Cattle	0.5	0.2
Poultry	3.5	1.5

In cropping systems where more P is removed from the soil during harvest than is replaced, soil P concentrations 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. Without proper management, excessively high P concentrations can sometimes lead to unwanted nutrient loss to surface water and stimulate algae growth. Minimizing P loss from farmland involves managing the appropriate P source, rate, time and placement to eliminate P loss through runoff and erosion.

Added P fertilizer quickly 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 zones, 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 planted crops (called starter or pop-up fertilization), even when sufficient P is available for growth later in the season.

Many African soils are acidic and have a high P-fixation capacity that results in wide-spread P deficiencies. A combination of lime and P fertilizer application improves the soil fertility and plant health in these situations. The response of maize to P fertilizer additions in two different soils in south-western Kenya is shown in **Figure 4**.

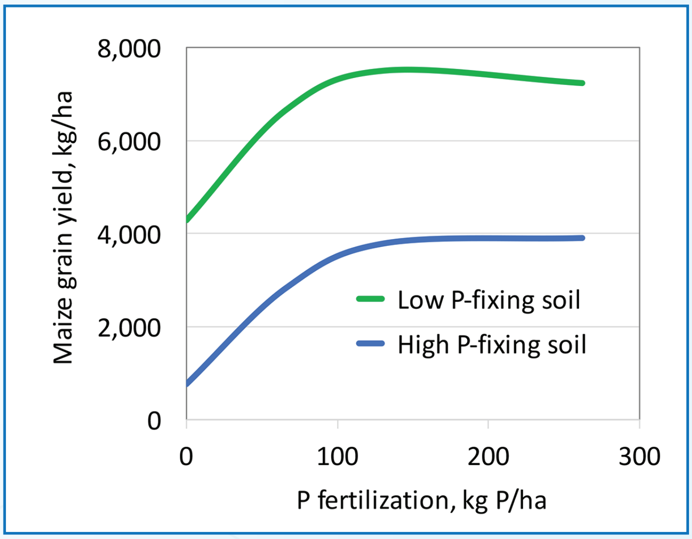

Figure 4. The response of maize grain yield following P fertilization of two soils in south-west Kenya[1] (averaged over three growing seasons). van der Eijk, D et al. 2006. Agric Ecosyst Environ 116:104-120.