Soil Quality Institute Technical Pamphlet No. 2

PHOSPHOROUS
In
AGRICULTURE

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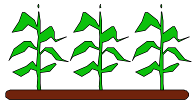

Role of Phosphorus in Agriculture

Phosphorus (P) is one of the key essential elements in modern agriculture. Fertilization of crops comprises the largest proportion of P used in agriculture. Phosphorous use has become increasingly prevalent during recent decades due to its depletion in soils used for crop and hay production. The importance of P to crop production systems is illustrated by the amount of fertilizer-P used during the last 35 years, which has doubled since 1960, stabilizing at slightly under two million tons/year over the last 10 years.

Importance to Plant Growth

Phosphorus has many important functions in plants, the primary one being the storage and transfer of energy through the plant. Adenosine diphosphate (ADP) and adenosine triphosphate (ATP) are high-energy phosphate compounds that control most processes in plants including photosynthesis, respiration, protein and nucleic acid synthesis, and nutrient transport through the plant's cells.

It is also known that Phosphorous:

- is essential for seed production;
- promotes increased root growth;
- promotes early plant maturity (less time for grain ripening);
- promotes stalk strength;
- promotes resistance to root rot diseases;
- promotes resistance to winter kill.

In addition to the importance of P in plant functions, the agronomic literature is full of examples of grain, fiber and forage yield increases due to proper maintenance of P fertility. Clearly, P is a necessary and beneficial input for modern crop production systems.

Livestock and Phosphorous

Crop production is not the only segment of agriculture that uses P. Confined livestock producers use P as a diet supplement to improve animal performance in addition to P contained in feeds. Many confined animal operations are located in grain deficient areas where feed is not produced locally and must be imported. Manure from livestock operations must be disposed and in most cases is applied to the land. Consideration must be given to the amount of land available to absorb P from livestock in an environmentally and agronomically acceptable manner and avoid excessive buildup of soil-P on lands surrounding confined animal farms.

Environmental Impacts of Agricultural Phosphorus

Although the benefits of P on agricultural production are evident, this element can be a pollutant if it moves from the site. The main concern is P transport from soils to streams, rivers, lakes, and eventually oceans. Phosphorus transported from agricultural soils can promote *eutrophication*, which is enrichment with nutrients that leads to increased algal growth, and decreased dissolved oxygen. Although no clear guidelines exist regarding the concentration of P in runoff considered eutrophic, recommendations have been made to critical P concentrations expected to cause noxious aquatic growth in downstream waters (See Table).

Harmful Effects of Eutrophication:

- Depletion of dissolved oxygen promotes conditions that convert many dissolved compounds to potentially toxic forms (e.g., nitrate to ammonia, sulfate to hydrogen sulfide, carbon dioxide to methane, etc.) that may harm wildlife and livestock.
- Increased cost and difficulty in purifying drinking water
- Replaces high quality edible fish, submerged macrophytes and benthic organisms with coarse, rapid-growing fish and algae.
- Increases sedimentation and impairs navigational and recreational use: lake depths are reduced; enhanced vegetative growth blocks navigable waterways.
- Decaying algae produces surface scums and undesirable odors (hydrogen sulfide, methane, etc.).
- Populations of insect pests such as mosquitos are increased

The Phosphorus Cycle

To understand how P can escape from agricultural land and become a pollutant, it is necessary to examine the P cycle (See Figure) beginning with sources of P in soil systems :

- Phosphorus enters the soil solution via either: dissolution of minerals, desorption of P from clay and mineral surfaces, and biological conversion of P in organic materials to inorganic forms (mineralization).

- P is moved into runoff from agricultural fields by dissolution and erosion. Dissolution of P from a thin zone of surface soil and vegetative material yields dissolved P; immediately available for uptake by aquatic biota (Sharpley et al, 1996).
- Erosion via surface runoff transports P attached to soil and in vegetation. It becomes available to aquatic biota as the dissolved P is consumed. Thus, *bioavailable P* includes dissolved P and a portion of particulate P. Once bioavailable P moves from agricultural fields into receiving waters it can contribute to eutrophication.
- Although generally considered a less important mechanism than surface runoff, P leaching followed by shallow lateral subsurface flow can contribute dissolved P to surface waters under high water table conditions. This mechanism becomes more important in soils with large accumulations of P that saturates surface soil sorption capacity leading to downward movement of P.

Managing Agricultural Phosphorus: The Role and Value of Soil Testing

Farmers, soil scientists and agronomists are faced with a dilemma over the coupling of agronomic and environmental concerns regarding levels of soil P. Soil P must be managed at concentrations that allow for good crop production, adequate animal waste disposal, and prevent the escape of P to surface water bodies. Escape of soil P to surface waters is affected by a host of soil management practices (e.g., tillage method, cover crops, riparian zones, terracing, etc.). However, the soil P concentration that correlates with P bioavailability is the greatest determinant of the balance between adequate soil P fertility and off-site P escape. In that regard, soil testing is currently the best management tool available to ensure that crops are provided adequate soil P. Moreover, soil testing is likely the best management tool available to ensure that soils do not become overloaded with P, which increases the likelihood of their contribution to pollution of downstream water.

What are the critical soil test levels for Phosphorous?

The amount of P a soil can hold or its Phosphorous adsorption capacity is directly related to the type and amounts of clay, iron oxide content, and organic matter. Mullins and Hajek, 1996, studying soils receiving poultry litter found when P adsorption was related to clay content, adsorption and desorption was essentially the same per unit of clay for soils with kaolinitic mineralogy. Their study suggested that as a critical level of 300mg/kg is approached, management measures should be taken to limit further P buildup. It was also shown that 20 year simulations with the EPIC model compared favorably with data from an earlier study (Kingery, et al. 1994). The use of models such as EPIC could provide an evaluation of proposed and recommended practices for P management based on real onsite climate, soils, and other agronomic factors.

Literature Cited and Additional Reading

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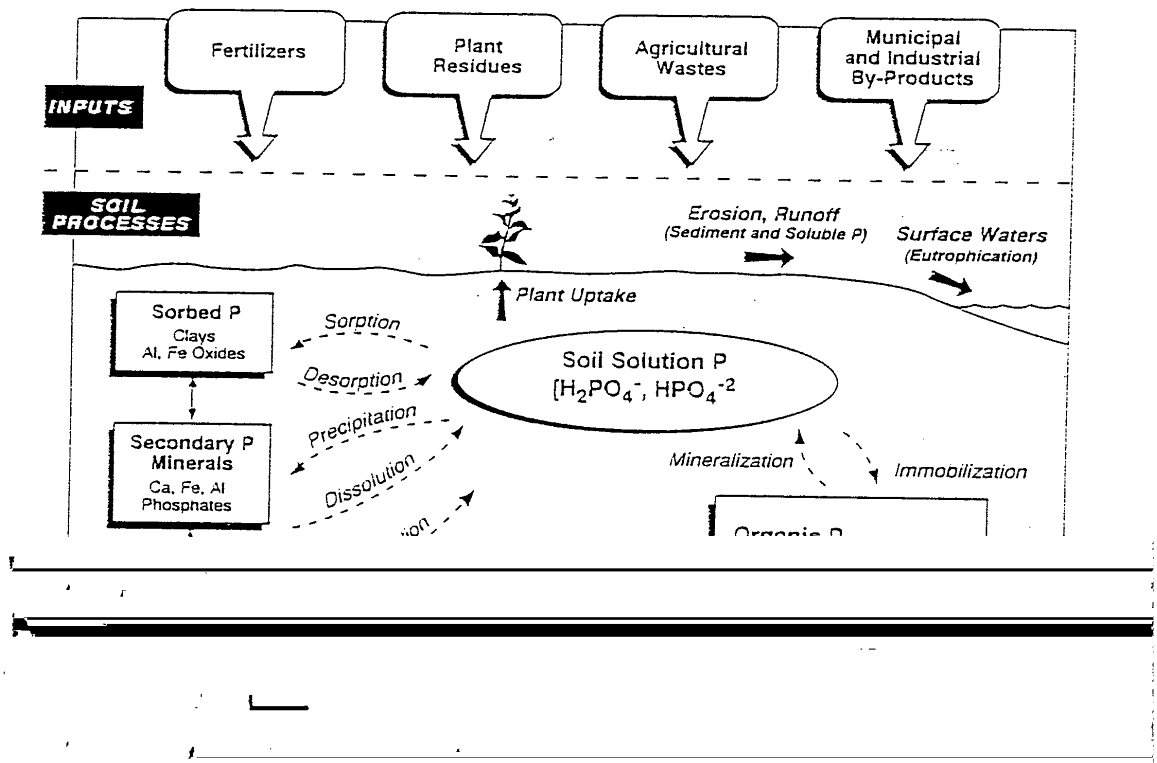
Table. Critical P concentrations for surface waters.†

Concentration (µg/L)	Comment	Source(s)
10	Dissolved P - critical concentration for lakes	Sawyer (1947) Vollenweider (1968)
100	Total P - critical concentration for streams	USEPA (1986)
50	Total P - critical concentration for lakes	USEPA (1986)
50	Dissolved P - concentration allowed to enter Florida Everglades	USA vs South Florida Water Management District (1994)
10	Dissolved P - target concentration allowed to enter Florida Everglades by the year 2000	USA vs South Florida Water Management District (1994)
1000	Flow-weighted-annual dissolved P - proposed allowable limit for agricultural runoff	USEPA (1986)

† Adapted from Sharpley

P CYCLE

From Pierzinski et al., 1994



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The institute focuses on soil quality resource concerns that have national and multi-state applicability. These resource concerns include, but are not limited to aggregate stability, infiltration, organic matter loss, nutrient cycling and losses, acidity, salinity, erosion and deposition. The institute seeks out current and emerging technologies for incorporation into Natural Resources Conservation Service (NRCS) programs. Soil quality inventory, assessment and management technologies will be developed for multiple scales including on-site, watershed and ecosystem/regional/national levels. Activities of the SQI are carried out through collaborative efforts and partnerships with the research community, other federal and state agencies, land managers and other NRCS staff.