

Phosphate adsorption and transformations in soil

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Phosphate ions can be adsorbed on surface of several types of minerals occurring in soils as discrete particles or as coatings on other materials. Phosphate ions can be held at positively charged sites by simple anion exchange. Adsorption of phosphate above materials is considered to take place predominantly by specific adsorption mechanism. Such mechanisms involve the exchange of phosphate ions (H_2PO_4^- or HPO_4^{2-}) with surface Fe-OH, Al-OH, Fe-OH²⁺ and Al-OH²⁺ groups through ligand exchange reactions. Phosphate can be absorbed by phyllosilicate clay minerals, although in most soils the amounts adsorbed by these materials will be far smaller than by the hydrous oxides and short range order aluminosilicates. Adsorption by the phyllosilicate clays is thought to take place through Al-OH groups, where these are exposed at the edge sites of octahedral Al layers. E.g. in 1:1 clays, where octahedral Al layers are exposed at the crystal surface. Phosphate is adsorbed to a great extent by 1:1 clays like kaolinite than by 2:1 clays.

Phosphate adsorption can be classified into 2 types:

- Physical adsorption of phosphate: Phosphate held on the soil solid surface
- Chemical adsorption of phosphate: Retained phosphate penetrates more or less uniformly into the solid phase.

Phosphate adsorption: Phosphate adsorption takes on surfaces of constant charge such as crystalline clay minerals, which interact with phosphorus mainly through cations held tightly to their plate like surfaces and on surface of variable charge including the ferric (Fe^{3+}) and aluminium oxides and organic matter, for which H^+ and OH^- ions determine the surface charge. Calcite (CaCO_3), for which Ca^{2+} and CO_3^{2-} are responsible for charge development. Some clays like Kaolinite and allophanes are intimately associated with a hydroxy aluminium gel, which have pH dependent charge on their crystal edges and surface. Organic matter having pH dependent charge, reacts with phosphorus through its cations. The degree of adsorption has been found to be increased with increase in temperature and hence the adsorption reaction is chemical.

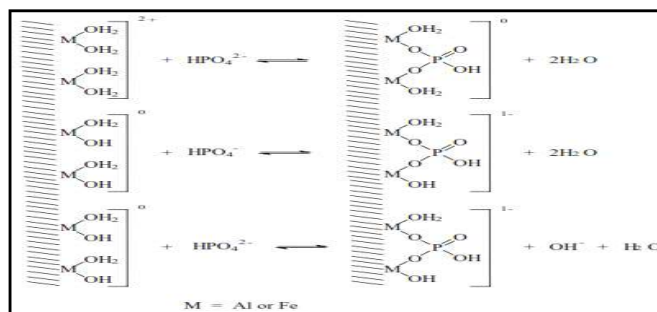


Fig. Mechanism of phosphate adsorption

Chemical absorption of phosphate :

– *Freundlich adsorption isotherm* $X = KC^{1/n}$

X = amount of phosphorus adsorbed per unit weight of soil

C = concentration of phosphorus in soil solution

K and n = constant (vary from soil to soil)

– *Langmuir adsorption equation* $X/X_0 = KC/(C_1 + KC)$

X = amount of cations adsorbed per unit weight of exchanger

X₀ = total exchange capacity

C₁ = concentration of added cations in moles per L

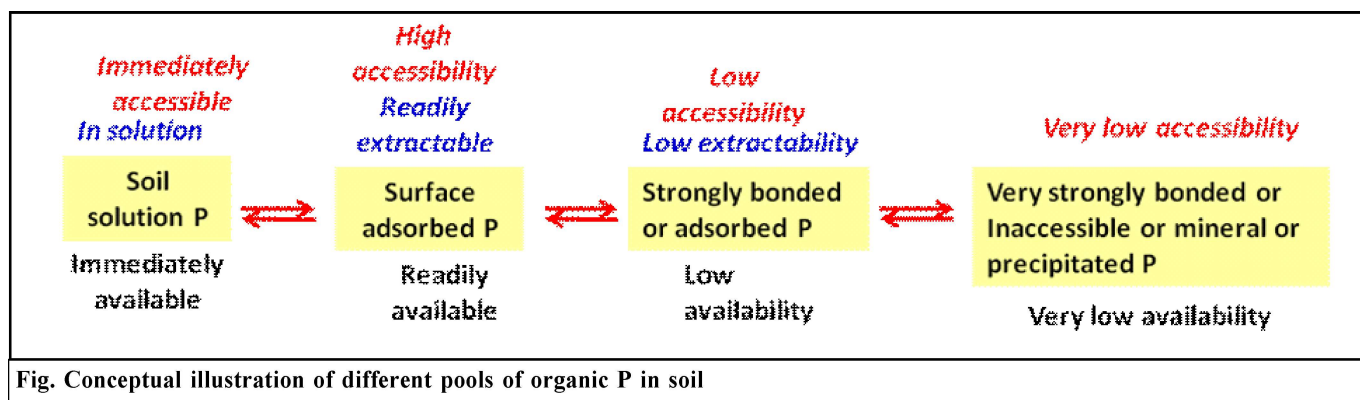
K = affinity co-efficient

Transformation of phosphate in soil:

- Soil phosphorus pools
- Fertilizer phosphorus
- Effect of moisture regime
- Transformation in cropping system.

Soil phosphorus pools : Inorganic P is more likely to be retained by soil components with a continuum of bonding energies, thus more strongly bound P is less available for uptake by plant roots and vice versa. Sorbed P has varying extractability or availability, related to the nature of its physical association with retaining components in soil. Based on accessibility by roots and extractability, and thus availability to the plants, P is considered to be four different pools.

Inorganic P forms in soils are the compounds associated mainly with aluminium, iron and calcium. Their relative abundance and solubility is controlled by a number



of factors including soil pH. Organic forms do contribute to plant nutrition through mineralization of soil organic matter. Inorganic forms of P in soil, calcium phosphates are normally the dominant group in young soils in the initial stages of weathering, and for a given site in the sub-soil. During soil weathering process under adequate rainfall, bases are leached out of the soil leaving behind a material more acidic in character, and under such conditions, a part of the calcium phosphates may get converted to phosphates of aluminum and iron. Soil P system contains a large number of compounds of differing reactivity which are sparingly soluble in water or soil solution, but nevertheless play an important role in crop nutrition.

Fertilizer phosphorus: When phosphate fertilizer is applied to soil, all its phosphorus being water soluble immediately enters the soil solution and readily forms new compounds with calcium, aluminium, iron, manganese gets out of the solution as soon as the newly formed compounds are precipitated. These sparingly soluble compounds are initial reaction products. All these reactions take place in close proximity of the site of placement of phosphatic fertilizer and are fairly rapid. Rate of reaction and volume of soil affected are strongly influenced by the water soluble component of P. These reactions take place

in close proximity on the site of placement of a phosphatic fertilizer and are fairly rapid. Rate of reaction and the volume of soil affected are strongly influenced by the water soluble components of P.

Effect of moisture regime : Moisture regime during cropping also influences transformations fertilizer P in soil. Flooding and submergence of soils with a wide range of pH create reducing conditions which lead to reduction of ferric phosphate to ferrous phosphate, resulting in greater availability of P in the soil. Organic acids formed under submerged conditions also solubilize phosphates.

Cropping sequence : Application of fertilizer P to wheat produces a better residual effect on the following rice crop. Al-P declines sharply after kharif rice and this decline is greater in high P soils. Fe-P gets depleted under rice but it improves after maize and millets, especially in low P soils. The reaction products containing iron assume special significance in rice nutrition. The efficiency of a fertilizer may thus depend upon the degree and duration for which its reaction products can serve as sources of plant-available-phosphorus. Ca-P continues to decrease due to cropping and the extent of decline is greater in rice-wheat rotation compared with rice-maize or rice-millet rotation.

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