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Phosphorus dynamics in different soils

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Abstract
Phosphorus (P) is essential to all known life forms because it is a key element in many physiological and biochemical processes. A component of every cell in all living organisms, phosphorus is indispensable and cannot be replaced by any other element. The name comes from the Greek word 'PHOSPHOROS', which means bringer of light, because of Phosphorous glows in the dark Phosphorous is a non-metal, solid at room temperature It was discovered around 1669 by a German chemist named Henning Brandt during an experiment where he was attempting to change silver into gold It is the 11 th most abundant element and it is found in all fertile soil and most natural water Phosphorus occurs in complex DNA and RNA structures which hold and translate genetic information and so control all living processes in plants, animals and man.

Keywords: Phosphorus dynamics, German chemist, mycorrhizal fungi

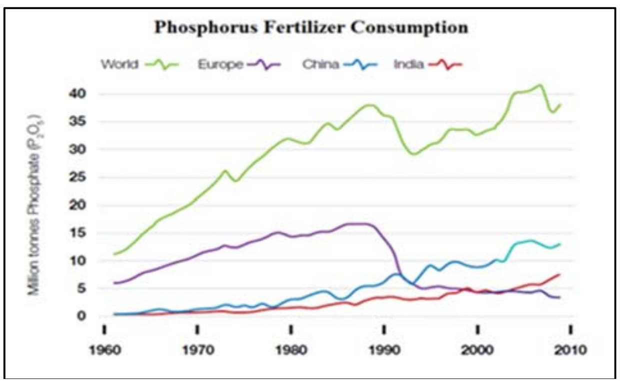
Introduction
Phosphorus (P) is the second most abundant macronutrient in plants after nitrogen the unique characteristic of P is its low availability due to slow diffusion and high Fixation in soils P can be one of the major limiting factors for plant growth. Mainly because of fixation of P in the soil. In the soils, it is mainly present in inorganic and organic forms Generally the concentration of P is ranges from 50 - 1500 ppm in surface soils, while in organic matter rich soils it is present as organic P complexes It is most studied element but the least understood due to its complex chemistry in the soil Most agricultural soils contain larger amount of fixed form of P than available P, a considerable part of which has accumulated as a consequence of regular applications of P fertilizers. However, a large proportion of soluble inorganic phosphate added to soil is rapidly fixed as insoluble forms soon after application and becomes unavailable to the plants. In acid soils, free oxides and hydroxides of Al and Fe fix P, while in alkaline soils it is fixed by Ca. Hence P availability in the soil to the crops is very low. Certain microorganisms such as phosphate solubilizing bacteria (Pseudomonas sp., Bacillus sp., Micrococcus sp. etc), fungi (Aspergillus sp. Pencillium sp. etc.), actinomycetes mostly those associated with the plant rhizosphere are known to convert insoluble inorganic phosphorus into soluble form that could be utilized by the plants. Among them, some phosphate-solubilizing bacteria (PSB) are being used as phosphatic bio fertilizers for crop production (Alam *et al*., 2002) [1]. They occur in soil but usually their numbers are not high enough to rhizosphere of plants. Therefore, for agronomic utility, inoculation of plants or seeds by PSB at a much higher concentration than those normally found in soil is necessary to take advantage of their beneficial properties for plant yield enhancement. Due to P insolubility and high sorption in soils, poor phosphate supply is one of the major constraints to plant growth. In order to enhance the availability of P, plants adopt different strategies like formation of mycorrhizal associations, rhizosphere acidification which can promote the release of P from soil minerals, and the exudation of phosphatases and organic acids that solubilize the complexed.. Several evidences showed that addition of organic acids, especially citric and oxalic acids to soils can solubilize significant quantities of fixed P and reduce the sorption of newly applied fertilizer P **(**Hocking, 2001).

Role of phosphorus
Great role in energy storage & transfer - 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 (H2PO4 -), but some is also absorbed as secondary orthophosphate (HPO4 =), 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), phosphor proteins, 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. Constituent of nucleic acid, phytin and phospholipids

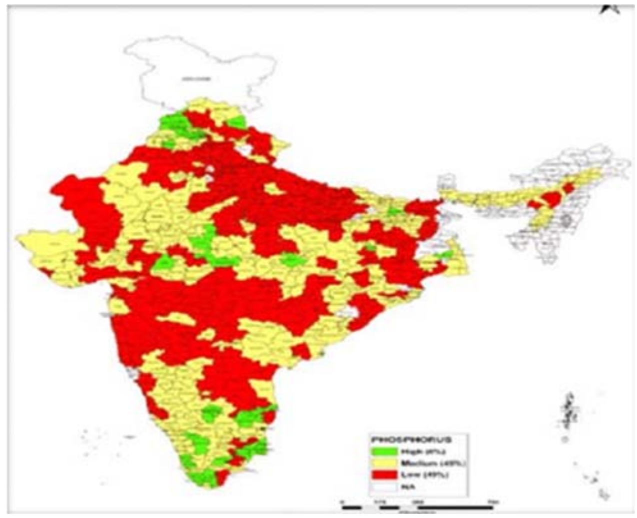
Nutrient Transport: Plant cells can accumulate nutrients at much higher concentrations than are present in the soil solution that surrounds them. This allows roots to extract nutrients from the soil solution where they are present in very low concentrations. Movement of nutrients within the plant depends 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.

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.



Phosphate fertilizer consumption in world and in China, India and Europe From 1960-2010

Group of scientist they reported and explained the Phosphate fertilizer consumption in world and in China, India and Europe From 1960-2010 India and Europe already consume about 60% of the global use of phosphate fertilizer. China is the largest consumer of phosphorus fertilizers in the world with 34% of world total and India is second with 19% of global consumption between 2002 and 2009, global use of phosphate fertilizers increased by 12% India showed the largest increase in phosphate use, almost doubling in quantity between 2002 and 2009 (80% increase). China also showed strong increases with 20% growth in phosphorus consumption between 2002 and 2009. Europe, in contrast, decreased use by about 20% from 2002 to 2009, reflecting market price increases and environmental restrictions. On a worldwide scale, population growth, changes towards meat-rich diets and growing demands for bio-energy crops will push an increasing demand for phosphate fertilizers in the future. The installed capacity to manufacture phosphate fertilizers has reached to a level of 7.06 tonnes in respect of phosphate nutrient (P2O5) in the year 2014-15, making India the 3rd largest fertilizer producer in the world. The current consumption of phosphatic fertilizers (in terms of P2O5) is 6.89 million tonnes. The projected phosphate fertilizers (P2O5) requirement in 2020-21, 2025-26 and 2030-31 would be 7.83, 9.01 and 10.69 million tonnes, respectively.



Phosphorous status of Indian soils (Anon, 2012) [2]

Group of scientist they reported and explained the Phosphorous status of Indian soils in this figure red color indicates poor phosphorous status about 49% and yellow color indicates medium status of P in the soil 45% and green color indicates high P status of Indian soils.

Forms of P in soil

Organic P Forms: The proportion of organic P in mineral soils may vary between 20% and 80% of total P, depending on the age of the soil, organic matter content, and climate, vegetation, soil texture, land use. The share of organic P to total P on average varies from 16% to 46% in different states. Organic P compounds present in the soils are Inositol phosphates (10-50%) Phospholipids (1-5%) Nucleic acids (0.2-2.5%). Major advantages of organic P are its slow release which synchrony with crop uptake and also supply sizable quantity of P during a crop season.

Inorganic P Forms: Inorganic P constitutes a dominant part of total P and is considered to be the major contributor of P to the growing plants. In Indian soils the share of inorganic P in the total P content varies from 54% to 84%. P bound to Al-P, Iron-P, and Ca-P constitutes the major active form of inorganic P

Phosphorus reserves as phosphate rock in Sedimentary deposits- 80-90% of world production from USA, Africa, Igneous deposits- 10-20% from Russia, Canada, Brazil.

World: Rock phosphate:-85% of reserve is distributed in USA, Morocco and Africa In India Rock phosphate reserve of 14.7mt. – High grade rock phosphate 190 mt. – low grade rock phosphate totally 217.2mt. Out of which Rajasthan - 78.8mt.

Common P minerals in soils

Mineral	Chemical formula
Acid soils	
Strengite	$FePO_4.2H_2O$
Variscite	$AlPO_4.2H_2O$
Neutral and Calcareous soils	
Monocalcium phosphate (MCD)	$Ca(H_2PO_4)_2.2H_2O$
Dicalcium phosphate dehydrate (DCPD)	$CaHPO_4.2H_2O$
Dicalcium phosphate (DCP)	$CaHPO_4$
Octacalcium phosphate (OCP)	$Ca_4H(PO_4)_32\text{-}5H_2O$
B-tricalcium phosphate (b-TCP)	$Ca_3(PO_4)_2$
Hydroxyapatite (HA)	$Ca_5(PO_4)_3OH$
Fluorapatite (FA)	$Ca_5(PO_4)_3F$

These are all the important common P minerals present in acid, neutral and calcareous soils and Minerals are listed in order of decreasing solubility

Mechanism of P uptake by plants in soil

1. Mass Flow (2% of available P)
2. Diffusion (97 % of available P)
3. Root Interception (1% of available P)

Mechanism of P uptake by plants in soils through Mass Flow Diffusion and Root Interception is immobile nutrient in soil only mobile nutrients are absorbed with mass flow the P is taken by diffusion method P, K, Zn. Due to very low mobility of P plant absorbs it from soil by diffusion because of this P is generally recommended to apply in soil in full dose during final land preparation.

Soil P dynamics

P dynamics is not same for all the soils it varies from soil to soil and mainly pH also influence on the dynamics of P. dynamics which involves adsorption, desorption, precipitation, and transformation of P in the soil.

Phosphate adsorption: complex reaction between the components of soil and P source and involves both the adsorption and precipitation reactions adsorption dominates at low P concentration for shorter period

Phosphorus desorption: Reversible release of adsorbed P into the soil solution

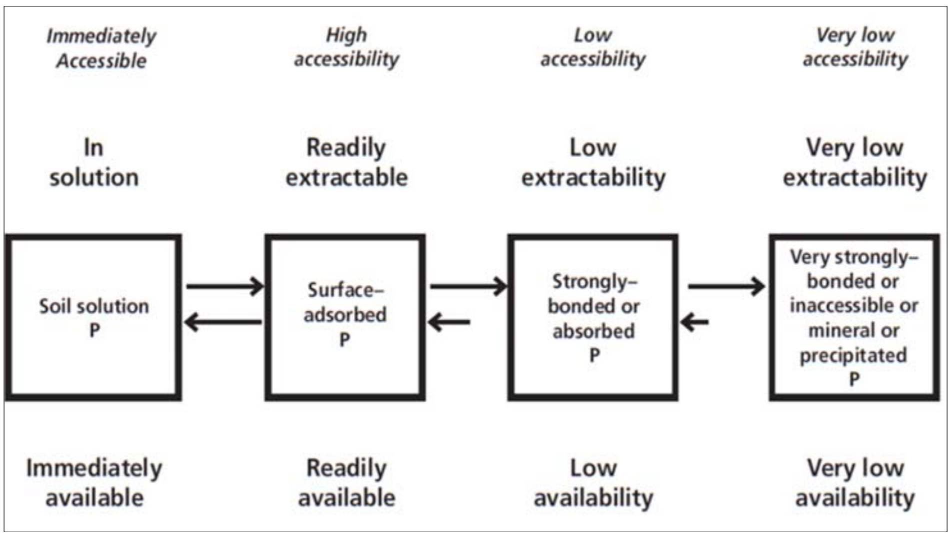


Fig 5: Conceptual illustration of different pools of inorganic P in soils Rome Syers *et al*. (2008) [4]

Syers and his co-workers during 2008 at Rome they gave the Conceptual illustration of different pools of inorganic P in soils in this figure there are four different pools of P are there in the soil solution first pool P is immediately available for uptake by the plant this is first pool. Readily extractable P held on the soil surface represents the second pool which is considered to be in equilibrium with soil solution P. The third pool represents less readily extractable P that is more strongly bonded to soil components as absorbed P. fourth pool is very low extractability and very slow availability because of bonding very strongly with soil components precipitation as partially soluble P compounds, P becoming a part of soil mineral components. P in the first pool and second pool is considered labile, fourth pool is non labile.

P dynamics in the soil

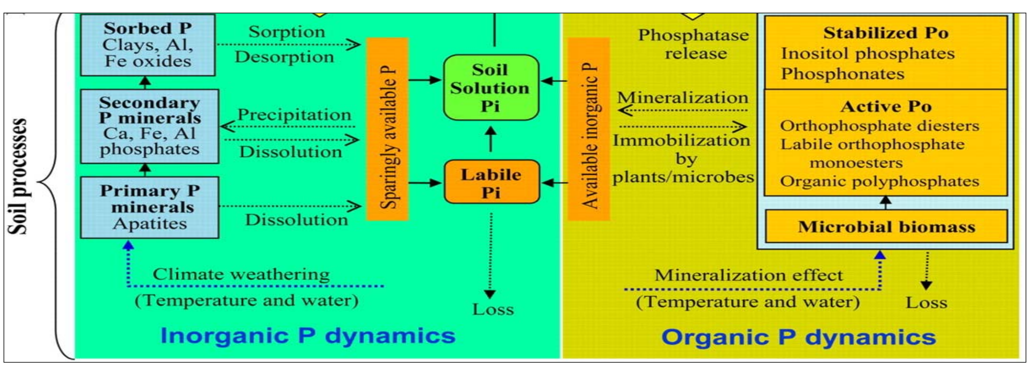


Fig 6: Phosphorus dynamics from soil to plant China Jianbo *et al*. (2008)

Jianbo and his coworkers during 2008 at china they gave the Phosphorus dynamics from soil to plant in soil P exists in various chemical forms including inorganic P and organic P these P forms differ in their behavior and fate in the soil.

Inorganic P dynamics: Primary P minerals including apatite's, strengite and varisite are very stable release of available P from these minerals by withering is generally too slow to meet the crop demand through direct application of P rock apatites has proved relatively efficient for crop growth in acid soils. Secondary P minerals including Ca, Fe, and Al vary in their dissolution rates depending on size of mineral particles and the soil ph. The P adsorbed on various clays Al and Fe oxides can be released by desorption reactions.

Organic P dynamics: Soil P mainly exists in stabilized forms as inositol phosphates

Soil P mainly exists in stabilized forms as inositol phosphates and phosphonates active forms as orthophosphate diesters, labile orthophosphate monoesters and organic polyphosphate the P can be released through mineralization process mediated by soil organisms and plant roots and organic polyphosphate the P can be released through mineralization process mediated by soil organisms and plant roots in association with phosphatase secretion these process are highly influenced by soil moisture, temperature, surface physical chemical properties and soil pH and Eh and also P transformation has grew influence on the overall bio availability of P in soil.

Soil Phosphorous

Inorganic

PO_4^{-3}

(Orthophosphate)

H_3PO_4 $H_2PO_4^-$ HPO_4^{-2}

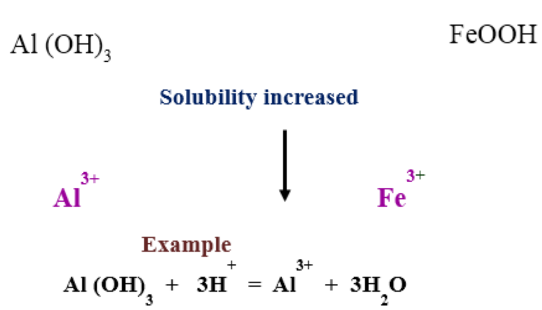
	Most Available	
H_2PO_4	———	**HPO_4^{-2}**
	pH 6-8	
pH 3-6		**pH 8-11**

Optimum pH = 6.5 for mineral soils

In soil P is available in different forms H_3PO_4 $H_2PO_4^-$ HPO_4^{-2} depending on the pH of the soils at pH 6-8 most available form of is available. Optimum pH is 6.5 for mineral soils

Acid Soils (Low pH)

Aluminum and Iron availability increased at low pH



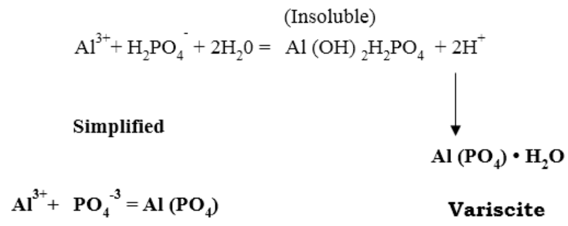
In higher pH value the iron and Al combines with OH hydroxide ions to form iron and Al oxides. In lower pH value increase the activity of hydrogen ion it combines with Fe and Al oxides and release the free Al and iron so it increase the availability of iron and Al.

Aluminum Precipitation at Low pH

In low pH value P availability in the form $H_2PO_4$of it combines with free Al^{3+} and Fe^{3+} to form a insoluble iron and Al phosphates which is slowly available depending upon the management practices

Form of available P at low pH $H_2PO_4^-$(pH 3-6)

$H_2PO_4^-$ combines with free Al^{3+} and Fe^{3+}



Alkaline Soils (High pH)

Calcium Binding in Basic Soils

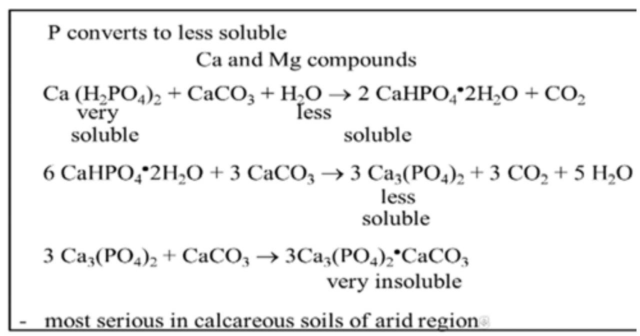
$CaCO_3$ (higher calcium availability)

$H_2(PO_4)^-$ is the available form of P

$CaCO_3 + 2H_2(PO_4)^- = Ca\ [H_2(PO_4)]_2 + CO_3^{2-}$

In alkaline soils availability of calcium carbonate is higher it combines with phosphate to form a monocalciam phosphate which is less soluble

Reactions at High pH Values



In higher pH value availability of Ca and Mg higher the Ca combines with phosphate to form a monocalciam phosphate is very soluble. This is very soluble monocalciam phosphate combines with calcium carbonate because in higher pH value availability of Ca carbonate is more to form a dicalciam, phosphate. Dicalciam combines with calcium carbonate because in higher pH value availability of Ca carbonate is more to form a dicalciam phosphate and again dicalciam combines with calcium carbonate to form a tricalciam phosphate again tricalciam phosphate combines with calcium carbonate to form the hydroxy apatite which is less insoluble.

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