Phosphorus Basics

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Phosphorus-Basics

- Atomic number 15
- Atomic weight 30.974
- Two isotopes: \(^{32}\text{P}\) and \(^{33}\text{P}\)
- Density 1.82 g/cm\(^3\)
- Four allotropic forms (white, red, black and violet)
Phosphorus Basics

- Gr. Phosphoros-Light bearing
- Discovered in 1669 by Brand who prepared it from urine (by boiling, filtering, and further processing 60 buckets of human urine-dedicated scientist)
- Never found free in nature
- Must be kept under water in pure form
- Very poisonous 50mg fatal dose (white form)
- Phosphate rock (apatite, Ca$_3$(PO$_4$)$_2$) found in
  - Russia, Morocco, Fl, TN, UT, ID

Phosphorus

- Found in every cell
- 85% of P in body is in bones (hydroxyapatite)
- Phospholipids structural components of cell membranes
- Dietary P is absorbed in small intestine, excess is excreted by kidneys
P is essential element for metabolic processes

- Component of Adenosine tri and di phosphate ATP and ADP used in energy transformations
- Essential component of deoxyribonucleic acid DNA (genetic inheritance) and ribonucleic acid RNA (protein synthesis)

Soil P Forms

- Inorganic forms
  - Calcium phosphates
  - Fe and Al phosphates
- Organic forms (% of organic P)
  - Inositol C₆(PO₄)₆ (10-50%)
  - Nucleic acids (1-5%)
  - Phopholipids (.2-2.5%)
Most of the Earth’s P is in the form of very slowly soluble minerals: for example:

- Tricalcium phosphate $\text{Ca}_3(\text{PO}_4)_2$
- Fluorapatite $[3 \text{Ca}_3(\text{PO}_4)_2]\text{CaF}_2$
- Variscite $\text{AlPO}_42\text{H}_2\text{O}$

“Phosphate” = $\text{PO}_4^{3-}$
Phosphoric acid = $\text{H}_3\text{PO}_4$

In soil solution $\text{HPO}_4^{2-}$ and $\text{H}_2\text{PO}_4^-$
Soil pH affects mechanism of P fixation
# Soil P Forms

**Table 1.1**

Total Phosphorus Content of Soils from Different Areas and the Percentage of Total Phosphorus in the Organic Form

<table>
<thead>
<tr>
<th>Soils</th>
<th>Number of samples</th>
<th>Total P (mg/kg)</th>
<th>Organic fraction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Oregon soils</td>
<td>Hill soils</td>
<td>4</td>
<td>357</td>
</tr>
<tr>
<td></td>
<td>Old valley-filling soils</td>
<td>4</td>
<td>1479</td>
</tr>
<tr>
<td></td>
<td>Recent valley soils</td>
<td>3</td>
<td>848</td>
</tr>
<tr>
<td>Iowa soils</td>
<td>Mollisolns</td>
<td>2</td>
<td>613</td>
</tr>
<tr>
<td></td>
<td>Allisols</td>
<td>2</td>
<td>574</td>
</tr>
<tr>
<td>Arizona soils</td>
<td>Allisols</td>
<td>2</td>
<td>495</td>
</tr>
<tr>
<td></td>
<td>Surface soils</td>
<td>19</td>
<td>703</td>
</tr>
<tr>
<td></td>
<td>Subsoils</td>
<td>5</td>
<td>125</td>
</tr>
<tr>
<td>Australia soils</td>
<td>Spodosol</td>
<td>1</td>
<td>398</td>
</tr>
<tr>
<td></td>
<td>Vertisol</td>
<td>1</td>
<td>362</td>
</tr>
<tr>
<td></td>
<td>Mollisol</td>
<td>1</td>
<td>565</td>
</tr>
<tr>
<td>Hawaii soils</td>
<td>Hydrandept</td>
<td>1</td>
<td>4700</td>
</tr>
<tr>
<td></td>
<td>Haplustoll</td>
<td>1</td>
<td>2220</td>
</tr>
<tr>
<td></td>
<td>Gibbsoorthox</td>
<td>1</td>
<td>1444</td>
</tr>
<tr>
<td></td>
<td>Gibbsoorthox (Subsoil)</td>
<td>1</td>
<td>2575</td>
</tr>
</tbody>
</table>

Data for Oregon, Iowa, and Arizona from sources quoted by Brady (1974). Australia from Fares et al. (1974); Hawaii from Solaimpour et al. (1986).

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# Concentration of Phosphorus in Soil Solution That Provided 95% of Maximum Yield of Several Crops in Hawaii

<table>
<thead>
<tr>
<th>Crop</th>
<th>Soil</th>
<th>Approximate P in soil solution (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava</td>
<td>Halii</td>
<td>0.005</td>
</tr>
<tr>
<td>Peanut</td>
<td>Halii</td>
<td>0.01</td>
</tr>
<tr>
<td>Corn</td>
<td>Halii</td>
<td>0.05</td>
</tr>
<tr>
<td>Soybean</td>
<td>Halii</td>
<td>0.20</td>
</tr>
<tr>
<td>Cabbage</td>
<td>Kula</td>
<td>0.04</td>
</tr>
<tr>
<td>Tomato</td>
<td>Kula</td>
<td>0.20</td>
</tr>
<tr>
<td>Head lettuce</td>
<td>Kula</td>
<td>0.30</td>
</tr>
</tbody>
</table>

From Fox (1981).
Two Contrasting Soils for P Buffering Capacity

• Soil A
  • Sandy soil (low in P-binding compounds)
  • Little buffering

• Soil B
  • Finer textured soil (high in Fe, Al, Mn, Mg, and Ca)
  • Highly buffered

The Phosphorus Cycle

- Animal manures and biosolids
- Crop harvest
- Atmospheric deposition
- Mineral fertilizers
- Runoff and erosion
- Mineral surfaces (clays, Fe and Al oxides, carbonates)
- Secondary compounds (CaP, FeP, MnP, AlP)
- Soil solution phosphorus $\text{H}_3\text{PO}_4^{2-}$ $\text{H}_2\text{PO}_4^{1-}$
- Primary minerals (apatite)
- Plant uptake
- Immobilization
- Mineralization
- Leaching (usually minor)
- Weathering
- Adsorption
- Desorption
- Dissolution
- Precipitation

Component: Input to soil | Loss from soil
Soil Test P and Crop Response

What is “soil test P” and which forms does it measure?
How does soil test P compare with soil TOTAL P?
Soil Phosphorus Forms

Non Labile P

inorganic

organic

Labile P

slow

inorganic

organic

Soluble P (%)

P in Crop Production

Relative Yield, (%)

50 70 90

Low Med High Very High

Soil Test P

Phosphorus Basics - Moncrief
Soil Test Phosphorus

Determined by chemical procedures that extract a portion of the soil P and are used to estimate plant availability.

Soil pH determines the appropriate phosphorus extracting solution.

<table>
<thead>
<tr>
<th>Soil pH</th>
<th>Soil P Compounds</th>
<th>Extractant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acidic &lt;6.0</td>
<td>Al, Fe, and Mn</td>
<td>Bray, Mehlich</td>
</tr>
<tr>
<td>Near Neutral  6.0-7.4</td>
<td>Al, Fe, Mn, Mg, and Ca</td>
<td>Bray, Mehlich, Olsen</td>
</tr>
<tr>
<td>Calcareous &gt;7.4</td>
<td>Ca and Mg</td>
<td>Olsen</td>
</tr>
</tbody>
</table>
Distribution of N, P, and K between urine and feces for Cow, Sheep, and Pigs

Phosphorus and Eutrophication

- P is most often the limiting nutrient in freshwater systems
- Lake water concentrations >0.02 ppm generally accelerate eutrophication
- Soil solution concentrations - 0.2 to 0.3 ppm
Phosphorus and Eutrophication

Concentration of P in Cropping System Components

<table>
<thead>
<tr>
<th>P source</th>
<th>ppm P</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>fertilizer</td>
<td>200,000</td>
<td>concentrated, metered precisely</td>
</tr>
<tr>
<td>manure</td>
<td>20,000</td>
<td>slow release, ideal mix of nutrients</td>
</tr>
<tr>
<td>plant tissue</td>
<td>2,000</td>
<td>cost effective way to control particulate losses, snow melt losses?</td>
</tr>
<tr>
<td>soil solution</td>
<td>.2</td>
<td>plants need energy to take up soil P</td>
</tr>
<tr>
<td>lakes</td>
<td>.02</td>
<td>critical level is relatively low for</td>
</tr>
<tr>
<td>algae</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P Basics - Summary

- P is an essential nutrient for plants and animals
- P is primarily found in insoluble mineral and organic forms
- P management is critical for agricultural production and for environmental quality