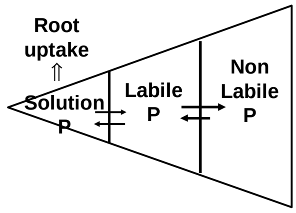
BIOL 695

PHOSPHORUS

Chapter 9
MENGEL et al, 5th Ed

PHOSPHORUS SOIL FRACTIONS



Over time, much of the labile P is converted to non labile P

Fig. 9.1 Schematic representation of the 3 important P soil fractions for plant nutrition.

Phosphorus Cycle

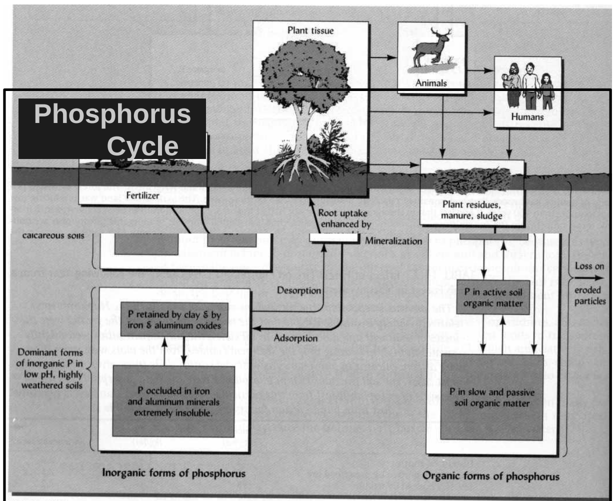


FIGURE 14.5 The phosphorus cycle in soils. The boxes represent pools of the various forms of phosphorus in the cycle, while th arrows represent translocations and transformations among these pools. The three largest white boxes indicate the principal groups o phosphorus-containing compounds found in soils. Within each of these groups, the less soluble, less available forms tend to dominat

PHOSPHATE SORPTION PROCESSES

- Labile P = sol Ca-PO_4 + sorbed PO_4
- P-sol'n vs P-sorbed follows
  Langmuir Equation
- Effect of pH:
  - stronger sorption at low pH
  - less strong at mod. to neutral
  - strong sorption at v. high pH
- Most sorption to Fe, Al oxides

PHOSPHORUS SOIL FRACTIONS

- P in soils mostly as orthophosphates
  X-PO_4^{-3} , X may be Ca, Na, H, combo
- Total P in soils ˜ 0.02-0.15%
- Organic P ˜û20-80% total P
- Important soil phosphate minerals:

Hydroxyapatite	- $Ca_5(PO_4)_3OH$
Fluorapatite	- $Ca_5(PO_4)_3F$
Dicalciumphosphate	- $CaHPO_4$
Tricalciumphosphate	- $Ca_3(PO_4)_3$

PHOSPHORUS SOIL FRACTIONS

- P-soil interaction:
  - both sorption and precipitation
  - sorption mostly to Fe-oxides
  - slow conversion to insol. Forms
  - formation of Ca-, Fe-, Al-phosphates
- OM decomposition releases PO_4
  - most P inform of inositol-P compds (synthesized by microbes)
  - phosphatase Rx'n liberates PO_4
  - phosphatase conc high in root cell walls & in rhizosphere

PO_4 IN SOIL SOLUTION

- Low levels (0.3 - 3 ppm)
- Low pH: predom. $H_2PO_4^-$
- High pH: predominately HPO_4^{2-}
- Beans abs PO_4 at pH 4 (10x) > pH 8.7
- Roots push thru soil & contact PO_4
- PO_4 gradient near root caused by absorption of PO_4 so more PO_4 moves in.

P DEPLETION ZONES

- 20% photosynthesate of wheat
  - released into soil
- Rape roots had P depletion zones
- Microbial activity at 30 - 45^oC
  - Favors organic P from tropical soil

PO_4 IN SOIL SOLUTION

- In addition there is some mass flow.
- Mycorrhizal fungi can take up PO_4 more rapidly than root.
- Microorganisms that produce acids and chelating agents aiding PO_4 abs:
  - *Aspergillus niger*
  - *Escherichin freandi*
  - *Penicillium sp. Pseudomonas sp.*

ABSORPTION & TRANSLOCATION

- PO_4 conc in root 100-1000 > conc soil
  - Metabolism drives active uptake
- 1st trans in xylem to young leaves 2nd in phloem as phosphoryl-choline and organic PO_4 to older leaves.
- Most P in plant in inorganic P (P_i) form.

MYCORRHIZAL FUNGI & P UPTAKE

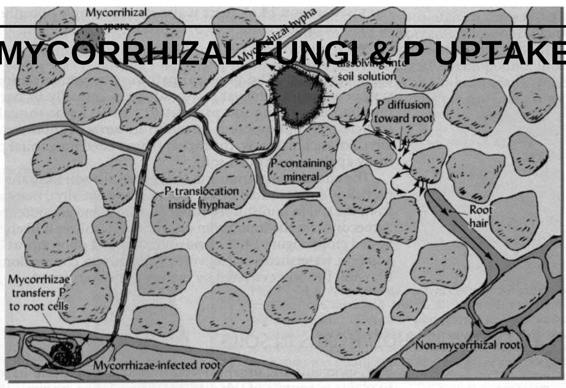


FIGURE 14.7 Roles of diffusion and mycorrhizal hyphae in the movement of phosphate ions to plant roots. In soils with low solution phosphorus concentration and high phosphorus fixation, slow diffusion may seriously limit the ability of roots to obtain sufficient phosphorus. The hyphae of symbiotic mycorrhizal fungi are particularly beneficial to the plant where phosphorus diffusion is slow, because phosphorus is transported inside the hyphae by cytoplasmic streaming, making the plant much less dependent on the diffusion of phosphate ions through the soil.

P NOT REDUCED

- Remains in oxidized form (P_i) after uptake as $H_2PO_4^-$
- May be esterified thru hydroxyl group to carbon chain C-O-(*P*) as PO_4 ester
- Attached to another pyrophosphate by energy-rich bond *P* ~ (*P*) e.g., ATP

(*P*) - Organic P

EXCHANGE RATE

- Frequent exchange between P_i & Ⓟ
  - P_i taken up by roots in Ⓟ in few min
  - Then released in few min as P_i into xylem
- Another type of bond is diester state C -Ⓟ- C which is relatively stable.

PHOSPHOLIPID BIOMEMBRANE

- Ⓟ diesters form bridge between
  - diglyceride and
  - another molecule e.g.
    - amino acids
    - amine
    - alcohol
- phosphatidylcholine (lethicin)

P AS STRUCTURAL ELEMENT

- Nucleic acids
  - DNA carrier of genetic information
  - RNA - translation of genetic inform
  - Ⓟ forms bridge between ribonucleoside units to form macromolecules
  - (Section of RNA molecule, Fig 9.7)

ROLE IN ENERGY TRANSFER

- Metabolic mechanisms of cells
  - Phosphate esters (C -Ⓟ)
  - Energy rich phosphates (Ⓟ-Ⓟ)
- 2 of most important esters:
  - glucose-6-phosphate
  - Phosphoglyceraldehyde
- Energy for metabolic functions (ATP)

Ⓟ RESPONSIBLE FOR ACIDIC NATURE OF NUCLEIC ACIDS

- Exceptionally high cation conc in DNA and RNA
- Ⓟ high in meristems
- Ⓟ low in storage tissue

P SUPPLY

- P required for optimum growth
  - 0.3 - 0.5% of plant DM during vegetative growth
- P toxicity if > 1% plant DM
  - But Pigeon Peas P toxicity at 0.3 to 0.4% plant dry matter

P DEFICIENCY

- Autotropic growth (req C & N) requires PO_4 export from chloroplasts.
  - Influences
    - Protein synthesis
    - Nucleic acid synthesis

PHOSPHOTASE ACTIVITY

- Higher in low Ⓟ plant
  - High rates P can lower Zn, Fe, Cu
  - Very high PO_4 retards uptake & translocation of Zn, Fe, Cu

P DEFICIENT PLANTS

- P_i depressed but Ⓟ is unchanged
  - Thus plant growth retarded. Why?
  - Low shoot/root ratio
    - Fruit trees show
      - Reduced shoot growth
      - Retarded bud opening
      - Fruit & seed form depressed

P CROP REQUIREMENTS

- 10^{-4} *M* PO_4 in soil solution adequate
- If P buffer cap is high, then the P content of sol'n may be opt at lower conc'n
- Crops with high growth rates need more P
  - Potatoes
  - Tomatoes
  - Cabbage

DEFICIENCY SYMPTOMS

- First in older leaves
  - Is P_i and/or Ⓟ ion mobile or not?
- Leaves - Dark green ⇒ Necrotic mar ⇒ Abscise prematurely
- Stems - Reddish from anthrocyanin

P FERTILIZERS

See Text, Table 9.4 for PO_4 fertilizers

Raw material is rock phosphate

$3[Ca_3(PO_4)_2] \cdot CaF_2 + 7H_2SO_4 \Rightarrow$

$3Ca(H_2PO_4)_2 + 7CaSO_4 + HF_{(g)} \uparrow$

monocalcium phosphate

P FERTILIZERS

IN SOIL:

$Ca(H_2PO_4)_2 + Ca^{+2} \rightarrow 2CaHPO_4 + 2H^+$

Mono-Ca-phosphate Di-Ca-phosphate

$3CaHPO_4 + Ca^{+2} \rightarrow Ca_4H(PO_4)_3OH + 2H^+$

Octo-Ca-phosphate

$Ca_4H(PO_4)_3OH + Ca^{+2} + H_2O \rightarrow Ca_5(PO_4)_3OH + 2H^+$

Hydroxy apatite

PHOSPHATE APPLICATION

- PO_4 mobility comparatively low
- Need to apply to root zone of crop
  - lettuce: 0-18 cm depth
  - carrots: 30-40 cm depth
- Placed (banded) application may be better than broadcast
- Apply at any time of year, except in soils of high P-fixing capacity