Phosphorous and Potassium

Phosphorous

Second to N as limiting nutrient

Importance of P to Plants

In plants, P occurs in ATP, nucleic acids and phospholipids. Deficiency symptoms are stunted growth, early senescence and purplish color.

Soil Fertility and Environmental Problems Associated with P

Fertility

The supply of P in soil typically is small. Furthermore, availability is low (even of fertilizer P) and natural inputs are almost nil. However, loss due to leaching is slight.

Environmental

The over-application of P may lead to freshwater eutrophication due to soluble P in runoff and sorbed P on eroded material. More P has often been added to the soil than removed in harvest to compensate for P fixation in soil. Also, when organic materials are used for fertilizers the rate of application is based on N needs of crop, therefore, excessive P is added.

Regarding losses of P in runoff and with eroded soil:

Losses of P are low from forest soils and grasslands
Greater from agricultural soils
Total P losses with conventional-till are greater than with no-till

Organic Forms of P

20 to 80 % of P is in organic combination. The orthophosphate, $H_2PO_4^-$ and HPO_4^{-2}, taken up by plants, in part comes from the mineralization of organic P. Whether net mineralization or immobilization occurs depends on the C / P. Net mineralization occurs if C / P < 200 but net immobilization if C / P > 300. Typically, mineralization releases 5 to 20 kg / ha annually.

Inorganic P

Low solubility of P minerals and high fixation of P keeps P concentrations low, only about 0.001 ppm to 1 ppm. This is due to the low solubility of inorganic P compounds and surface adsorption reactions. Mycorrhizae help offset low solubility of P in soil by increasing the uptake of P.

Solubility of P decreases with increasing pH due to precipitation as Ca phosphates. $Ca(H_2PO_4)_2$ and $CaHPO_4$ are soluble but at high pH are converted to insoluble $Ca_3(PO_4)_2$.

$Ca(H_2PO_4)\ H_2O + 2CaCO_3$ 6

$Ca_3(PO_4)_2 + 2CO_2 + 3H_2O$

Further reaction converts tricalcium phosphate to even more insoluble minerals. Apatite minerals are very insoluble

$[Ca_3(PO_4)_2]CaX$ X = O, $(OH)_2$ ... F_2

Solubility of P decreases with decreasing pH due to precipitation with Al and Fe to give $Al(OH)_2H_2PO_4$ and $Fe(OH)_2H_2PO_4$. Low pH increases acidic cations solubility so precipitation increases as pH decreases.

$$Al^{3+} + H_2PO_4^- + 2H_2O \rightarrow Al(OH)_2H_2PO_4$$

Note that anaerobic conditions increase P solubility due to reduction of Fe^{3+} to Fe^{2+}.

Across a wide range of pHs, P is also surface-bound to Al and Fe oxides and layer silicates, especially, 1:1 type minerals. Adsorption reactions include:

Anion exchange

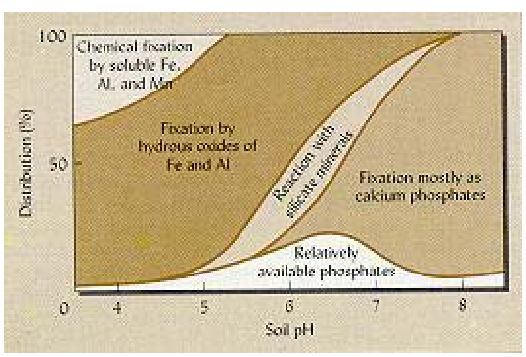
$$XCl + H_2PO_4^- \rightleftharpoons XH_2PO_4^- + Cl^-$$

P adsorbed by anion exchange is slowly available.

Displacement of bound OH or H_2O

$$Al\text{-}OH_2^+ + H_2PO_4^- \rightarrow Al\text{-}H_2PO_4 + H_2O$$

Once bound, P release is very slow.



Summary of P fixation processes. Which of these control P solubility depends on pH.

P Fixation Capacity of Soils

Factors affecting P fixation include

Amount of clay

Mineralogy

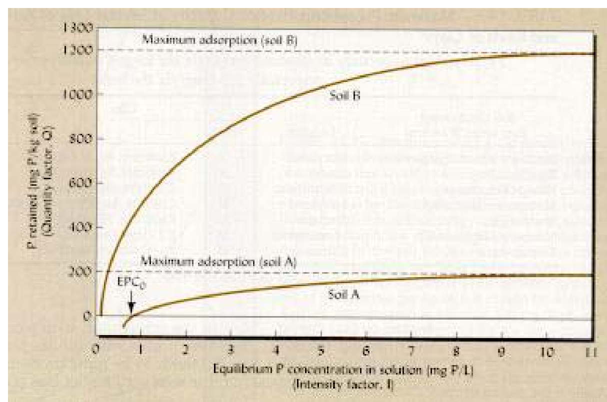
Amorphous Al and Fe oxides >
Crystalline Al and Fe oxides >
Carbonates >
1:1 layer silicates >
2:1 layer silicates

pH

Least fixation at near neutral pH (6 to 7)

Organic matter

Occlusion of P sorption sites by surface bound organic matter



Example P sorption isotherms.

P Management

Entails adding P and controlling fixation reactions. Alternative strategies include:

Add a lot of P to saturate fixation capacity
Add less but place it near plant roots by banding fertilizer application
Control soil pH (6 to 7) such that fixation is minimized

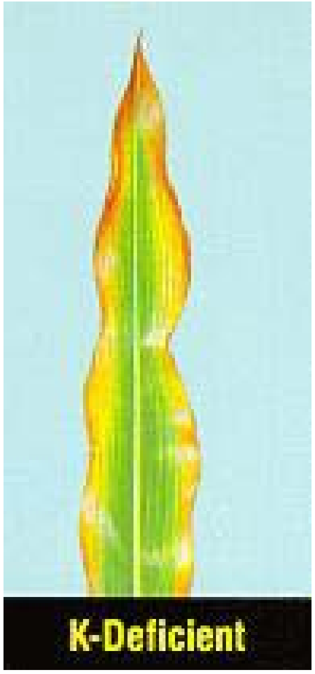
Potassium

After N and P, K is the most likely macro-nutrient to limit productivity.

Nutritional Roles of K

Potassium is not incorporated into organic compounds but is involved in enzyme activation including photosynthesis, starch synthesis, protein synthesis and many other systems. Good K nutrition also is important for resistance to several environmental stresses including drought, lodging, diseases and insects.

Concentration of K varies from 1 to 4 % in leaf tissue. Deficiency symptoms appear on older tissue (like with N or P) because K is easily translocated. Symptoms include chlorosis, then necrosis of leaf tips and margins (ragged appearance).

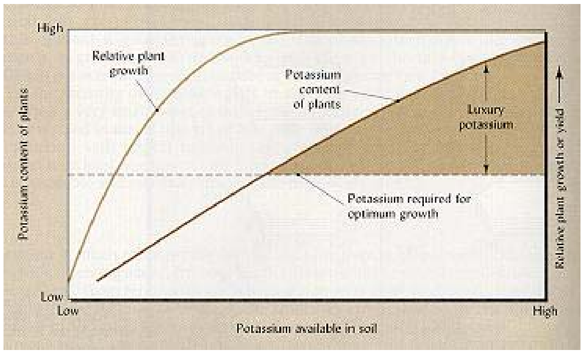


K Dynamics

K is abundant in soil but different sources vary in availability to plants

Source	*Availability*	*Amount*
Micas Feldspars	Unavailable	90 to 98 %
2:1 minerals (illite, especially)	Slowly	< 10 %
Exchangeable	Available	1 to 2 %

Despite usually large amount of K in soil, a high rate of harvest removal may exceed release of K^+ by weathering so that additions may be necessary. Plant uptake is high (= N removal) and depletes available soil K^+. This problem may be aggravated by *luxury consumption* -uptake in excess of crop needs.



Concept of luxury consumption.

K fixed in interlayer position of 2:1 minerals is nonexchangeable but represents a slow release reservoir. It may be considered in equilibrium with exchangeable and solution K, as

Slow *Fast*

Nonexch $\rightleftharpoons$ Exch $\rightleftharpoons$ Solution

The tendency for K fertilizer to become trapped in interlayer positions depends on several factors, one of which is clay mineralogy. Fixation follows the sequence,

vermiculite > illite > smectite