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Nitrogen – Transformation, factors affecting nitrogen availability ,deficiency and toxicity symptoms

Learning objectives

a. To understand the transformation of nitrogen
b. To know the factors affecting the availability of nitrogen
c. To understand the deficiency symptoms of Nitrogen and corrective measures

Nitrogen

The cheap source of N is the crop residues in temperate region. In tropical soils, the total N content is 0.03 - 0.1 %. Rainfall is also source of N at 4.6 kg of N / ha is received ha^{-1} yr^{-1}. It is converted to NO_3 during lighting addition of organic matter and fertilizer is other major sources. Nitrogen is an essential constituent of protein and also other non protein compounds of great physiological importance in plant metabolism. It is an integral part of chlorophyll, which is primary observer of light energy needed for photosynthesis. Nitrogen also imparts vigorous vegetative growth and governs the utilization of P,K and other elements

Forms of soil nitrogen

Inorganic forms N	**Organic forms of soil**
1. Ammonium NH_4^+	Amide form (NH_2)
2. Nitrite NO_2^-	Plant absorbs N as both
3. Nitrate NO_3^-	NH_4^-, NO_3^-.
4. Elemental N (No)	

Losses of Nitrogen

1. Crop removal
2. Leaching (or) drainage (11-18% loss)
3. Gaseous losses as NH_4 or elemental N_2
4. Volatilization.
5. Erosion (8 – 15 kg $ha^{-1}yr^{-1}$).
6. Ammonia fixation by clays
7. Immobilization in organic materials.

N transformations in soils

a. **N -** Mineralisation
b. Aminisation
c. Conversation of urea

d. N Immobilization.
e. N factor
f. Ammonification.
g. Nitrification
h. Denitrification
i. Organic fixation
j. Elemental N loss.
k. Nitrogen cycle.

N transformations in soils

Nitrogen mineralization

Mineralization is the conversation of organic N to NH_4^+ as a result of microbial decomposition. Mineralization increases with a rise in temperature and is enhanced by adequate, although not excessive, soil moisture and a good supply of O_2. Mineralization of organic N involves in two reactions.

i.e 1) Aminization 2) Ammonification.

Aminisation

Aminisation is the decomposition of proteins and the release of amines, amino acids and urea is called aminisation.

Bacteria NH_2 NH_2

| |

Proteins ⟶ R – C – COOH + R NH_2 + C = O + CO_2 + Energy

Fungi H_2O | |

H   amines NH_2

Amino acid   Urea.

The initial step in the decomposition of organic matter by the enzymatic digestion of proteins into amino acids like, peptones and amino acid. **Under aerobic** protolysis the major end products are CO_2 $(NH_4)_2$ SO_4 and H_2O. Under anaerobic conditions the end products are ammonia, amides, CO_2 and H_2S.

The organic compounds and proteins are mainly decomposed by various species of Pseudomonas,

Bacilli, clostridium, serrotia, Micrococcus

Generally in the neutral and sodic soils, bacteria are active and in acidic soils fungi are active.

Conversion of urea

Urea is a product of ammonization. The hydrolysis of urea by the action of increases enzyme is effected by Bacilli micrococcus, Pseudomonas, clostridium, Aeromobactor and coryne bactor.

$$Co\,(NH_2) + H^+ + 2H_2O \longrightarrow 2NH_4^+ + HCO_3^-$$

$$NH_4^+ \longrightarrow NH_3 + H^+$$

$$2NH_3 + H_2\,CO_3 \longrightarrow (NH_4)_2\,CO_3 \longrightarrow NH_4^+ + CO_3^{2-}.$$

The optimum H_2O holding capacity for these reactions is 50 – 75 and optimum temperature is 30 – 50°C.

The NH_4 can be utilized by microorganisams and root of higher plants. Some of the released NH_3 is fixed by clay especially illite. A major portion is oxidized to nitrate form. In the second reaction NO_2^- is further oxidized to NO_3^- by nitrobactor

$$2\,NO_2^- + O_2 \longrightarrow 2\,NO_3^-.$$

Nitrogen immobilization

"Immobilisation is the process of conversion of inorganic N (NH_4^+ or NO_3^-) to organic N and it is basically the reverse of N mineralization".

The Microorganisms accumulate NH_4 N and NO_3 – N in the form of protein, nucleic acid and other complexes. If C:N ratio is wider than 30, it favours immobilization and lesser C:N ratio encourage mineralization.

N factor

N factor is the No of units of in organic nitrogen immobilized for each 100 units of materials under going decomposition". The average values for the nitrogen factor vary from 0.1 or < to 1.3.

Ammonification

"Amines and Aminoacids produced during aminisation of organic N are decomposed by other heterotrophs with release of NH_4^+ is termed **Ammonifcation**

$$\longrightarrow$$

$R - NH_2 + H_2O \quad\quad NH_3 + R - OH + energy$

$H_2O \quad NH_4^+ + OH^-$

Nitrification

Nitrification is the process of biological oxidation by which the NH_4- Cal form of N converts to nitrate form of N. There are two steps. (a) NH_4 is converted first to NO_2^- and then to NO_3^-.

$$2NH_4 + 3O_2 \xrightarrow{\text{Nitrosomonas}} 2\,NO_2^- + 2\,H_2O + 4\,H^+$$

Nitrosomonas are obligate autotropic bacteria that obtain their energy from the oxidations of N and their C from CO_2.

Others autotrophic bacteria *Nitrosolobus, Nitrospira* and *nitroso vibrio* and to some extend heterotrophic bacteria also can oxidize NH_4^+ and other N reduces, compounds to NO_3^-.

Losses of Nitrogen

The major losses of N from the soil are due to (1) crop removal and leaching, however under certain conditions inorganic N ions can be converted to gases and lost to the atmosphere. The primary pathway of gaseous N losses are

1. Denitrification
2. NH_3 volatilization.

Denitrification

Denitrification is the biochemical reduction of NO_3N or NO_2N to gaseous N, either as molecular Nitrogen or an oxide of Nitrogen. The most probable bio chemical pathway is

$$NO_3 \longrightarrow NO_2 \longrightarrow NO \longrightarrow N_2O \longrightarrow N_2$$

Nitrate Nitrite Nitric oxide Nitrous oxide Nitrogen

Nitrogen fixation

The conversation of elemental nitrogen to organic forms readily use able in biological process. Vermicullite and illite are capable of fixing NH_4^+ by a replacement of K^- or Na^+ for interlayer cations in the expended lattice of clay minerals. The radius of NH_4 ion 0.143° A. K^+ ion 0.133°A.

Because of NH_4 and K have more or less same charge, they easily replace each other in the exchange sites.

Organic fixation

It the soil has more organic matter the NH_4 will lockup as a complex. There complex are called **Chelates**. It release the nutrients only after its molecular break down. The facultative aerobic bacteria tiles pseudomonas, bacillus, porococcus are responsible for denitrification. It also depends upon the texture of soil. In heavy clay soils loss is upto 50% of added fertilizer.

Elemental N loss

It is due to chemical reduction. If chemical fertilizer containing amide (or) NH_4 form of N, it may be oxidized to elemental N and lost.

$$2NHO_2 + CO(NH_2)_2 \longrightarrow CO_2 + 3H_2O + 2\ NH_2$$

Sources of N leading to N and NO_2 gaseous loss

1. Denitrification
   $NO_3^- \longrightarrow NO_2^- \longrightarrow NO \longrightarrow N_2O \longrightarrow N_2$

2. Nitrification
   $NH_4^- \longrightarrow NH_2OH \longrightarrow NO_2 \longrightarrow NO_3^-$

3. Nitrates and Ammonium
   $NH_4^+ + NO_2^- \longrightarrow N_2 + 2H_2O$

4. Nitriates and aminoacids.
   $HNO_2 + RNH_2 \quad N_2 \longrightarrow ROH + H_2O$

5. Lignin : HNO_2 + lignin $\longrightarrow N_2 + N_2O + CH_3O\ NO$

6. Phenols : Phenol $\longrightarrow N_2 + N_2O$ + Organic residue

7. Decomposition of nitrous acid / reaction with metal cations.

$$3\ HNO_2 \longrightarrow 2NO + 2\ HNO_3 + H_2O$$

$$Mn^{2+} + HNO_2 + H^+ \longrightarrow Mn^{3+} + NO + H_2O$$

$$Fe^{2+} + HNO_2 + H \longrightarrow Fe^{3+} + NO + H_2O$$

8. NH_3 Gas

9. Urea : $(NH_4)_2CO + H_2O \longrightarrow 2NH_3 + CO_2$

10. NH_4 Salts : NH_4 + OH → NH_3 + H_2O

11. Decomposition of residues and manures

Release and volatilization of NH_3

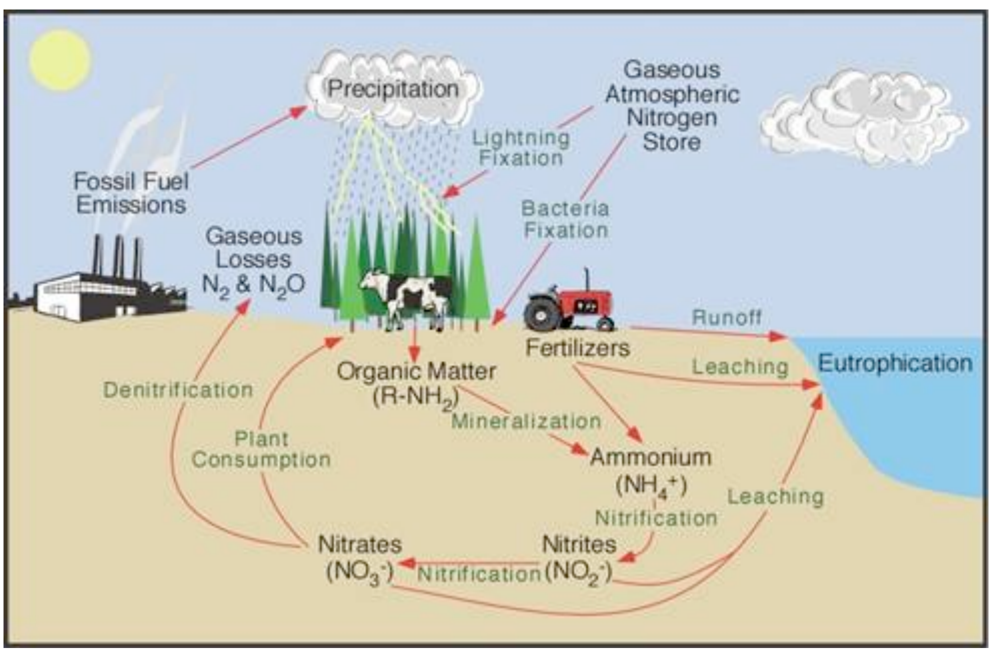
Nitrogen cycle

The cycling of N in the soil – plant – atmosphere system involves many transformations of N between inorganic and organic forms.

The N cycle can be divided into

1. N inputs or gains.
2. N outputs of losses
3. N cycling with in the soil.

1. N in plant and animal residues and N derived from the atmosphere through electrical, combustion, biological and industrial process is added to the soil.
2. N in the residues is mobilized as NH_4 by soil organisms as an end product of residue decomposition, plant roots absorb a portion of the NH_4.
3. Much of the NH_4 is converted to No_3^- by nitrifying bacteria in a process called nitrifications.
4. NO_3 is taken up by the plant roots and is used to produce the protein in crops that are eaten by humans or fed to live stocks.
5. Some NO_3 is lost to ground H_2O or drainage systems as a results of downward movement through the soil in perculating H_2O.
6. Some NO_3 is consorted by denitrifying bacteria in to N_2 and N_2O that escape into the atmosphere, completely the cycle.



The nitrogen cycle
Source: http://www.physicalgeography.net

Important microorganisms in BNF

Organisms	Properties	Active location
Azotobacter	Aerobic, free living	Soil, water, rhizosphere, leaf surface
Azospirillum	Micro aerobic rhizobacteria; free fixers	Free living in Rhizosphere; Colonize roots of cereals and also gives phytotonic effect
Rhizobium	Symbiotic	Root nodules of legumes
Actinomycetes, Frankia, Beijerinckia	Symbiotic	Non leguminous forest tree roots, leaf surfaces
Cyanobacteria	Photo autotrophic Anabaena - symbiotic	In wetland flood water; Anabaena associate with Azolla

Symbiotic N fixation

The symbiosis is the mutually beneficial relationship between host plant and bacteria. The location of association is in root or stem nodules, inside cavities, or by colonizing and penetrating plant tissue.

Legume (nodule forming)

Legumes and bacteria of the genera **Rhizobium** and **Bradyrhizobium** provide the major biological source of fixed N (40-60%) in agricultural soils. These organisms infect the root hairs and the cortical cells, ultimately inducing the formation root nodules that serve as the site of N fixation. The host plant supplies the bacteria with carbohydrates for energy and the bacteria reciprocate by supplying the plant with fixed N compound.

Effective nodules cluster on primary roots and have pink to red centers. The red colour of the nodule is attributed to the occurrence of **leghemoglobin**. The quantity of N fixed by properly nodulated legume averages about 75% of the total N used for the plant growth. The amount of BNF varies with Rhizobium strain, host plant, and environment.

Yield of non-legume crops often increase when they are grown following legumes (e.g. maize after soybean). Maximum N fixation occurs only when available soil N is at a minimum. When optimum conditions for N fixation is not prevailing, a legume crop can deplete soil N greatly, more than a cereal, if the legume grown is not incorporated into the same soil.

Fixer	Host plant
Rhizobium	Alfalfa, clover, peas, bean, soybean
	Gliricidia, Leuceana, Sesbania, Mimosa, Acacia 3 (3/4)
Bradyrhizobium	Cowpea, groundnut, red gram

Non-legume (nodule forming)

Roots of many species of angiosperm trees like casuarina in forests and wetlands form distinct nodules when infected with Actinomycetes of the genus **Frankia**.

Non-legume (non-nodule forming)

Azospirillum, **Azotobacter**, and **Azorhizobium**, dominant N fixers in cereals like rice, wheat, corn, sorghum, millets can grow on root surfaces and penetrate root tissues. The organisms use carbohydrates of root exudates as source of energy. They also induce crop growth by hormonal action. The organism **Beijerinckia** fixes N on leaf surfaces of tropical plants.

The **Anabaena** blue green algae (Cyanobacteria) inhabit cavities in the leaves of the floating water fern **Azolla** and fix quantities of N comparable to those of the better Rhizobium-legume complex. It could fix about 30-105 kg N/ season taking care of 75% N requirement of rice.

Nonsymbiotic N fixation

In wetland floodwater photoautotrophic **Cyanobacteria** independently do photosynthesis and fix N up to 20–30 kg N/ ha/ year. The excess ammonia is excreted in floodwater, which is beneficially absorbed by rice plants.

Free-living heterotroph bacteria like **Azotobacter** and **Beijerinckia** in aerobic upland soils and **Clostridium** in anaerobic wetland soils effectively fix N in pockets where O_2 supply is limited. Fixation depends upon the pH, soil N level, and source of organic matter.

Industrial fixation of N

Commercially produced N is the most important source of plant nutrient in agriculture. Industrial N fixation is by Haber-Bosch process, in which H_2 and N_2 gases react to form NH_3 under high temperature (1200^{O} C) and pressure (500 atm). Anhydrous NH_3 can directly be used as fertilizer or combined to other ions as solid forms.

N additions from atmosphere

Ammonia escapes in to atmosphere from soils, manures, and industries because of volatilization. Organic N compounds remain in fine dust of air lifted from earth surface. Rainfall brings down to soil NH_3, NO_3^-, NO_2^-, N_2O, and organic N. About 10 to 20% of the NO_3^- in the rainfall is due to fixation of N_2 by energy of lightning.

Deficiency and toxicity symptoms of Nitrogen in plants

Deficiency of N:

1. Plants are stunted and yellow in appearance.
2. The loss of protein N from chloroplasts. In older leaves produces the yellowing or chlorosis. It appears first on the lower leaves, the upper leaves remain green, while under severe N deficiency lower leaves will turn brown and die.
3. The necrosis begins at the leaf tip and progress along the midrib until the leaf is dead. In cauliflower - young leaves turn pale yellow and old leaves become orange.

In coffee - Veins becomes yellow and new leaves are very small.

Tomato - Stem become purple and hard. Flower buds become yellow and flower dropping rate also increases

Excess of Nitrogen (Toxicity of nitrogen)

a. Causes excess vegetative growth, dark green leaves, lodging, maturity is delayed with increases susceptibility to pest and disease.

b. In cotton, weak fibre are resulted. In rice, lodging is common.

c. Lengthening of crop duration and narrow leaf.

d. Slender shoot, profuse vegetation, thick peel and skin will be rough and leathery in the case of citrus.

e. Excess N in coffee plant, interferes the K uptake causing imbalance between N and K.

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Questions to ponder

1) How does the soil pH affect the nitrogen availability?
2) What climatic factors influence nitrogen availability to crops?
3) What is nitrogen fixation?
4) What is C: N ratio?
5) How does salinity affect nitrogen availability?

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Phosphorus – Transformation, factors affecting Phosphorus availability, deficiency and toxicity symptoms

Learning objectives

a. To understand the transformation of phosphorus
b. To know the factors affecting the fixation of phosphorus
c. To understand the deficiency symptoms of Phosphorus

Phosphorus

Phosphorus is taken up by the plant in the form of $\mathbf{H_2PO_4^-}$ $\mathbf{HPO_4^=}$ $PO_4^{-=}$ through **diffusion** and **mass flow** action.

The P availability mainly depends on pH. In acid soils **(Al & Fe)** the presence of Al, Fe, Mn, P gets fixed as $AlPO_4$, $FePO_4$ and not available to the plants. Some times as $CaPO_4$. these are insoluble in H_2O.

Under hilly areas (or) high rainfall areas, all the cations will be leached leaving Fe, Al and Mn. The P availability will be reduced.

Ideal pH for available P = 6.5 - 7.5. If pH > 8.5 the fixation will be more. < 6.5 the fixation will be more.

Forms of P

Organic P : Nucleic acid and Phospho lipids

Rock Phosphate - acid soluble. If the organic matter content is high the availability of P is more since it is soluble in acid. It is highly suited to **plantation crops.** Rock Phosphates is black in colour. Roots also exudates acids, which will solublises the P.

Fixation is high so the P_2O_5 deficiency is 15 – 35%.

P is present as Apatities

1. Chlor - $Ca_{10}(PO_4)_6Cl_2$.
2. Fluor - $Ca_{10}(PO_4)_6F_2$.
3. Carbonate - $Ca_{10}(PO_4)_6Co_3$.
4. Hydroxy - $Ca_{10}(PO_4)_6(OH)_2$.

Based on solubility the P fertilizers can be grouped into 4 groups.

1. H_2O soluble : (i) SSP 16% P as H_2O soluble

   P : (ii)TSP 45% P as H_2O soluble

2. Citrate soluble : Dicalcium PO_4 34% P_2O_5.

   P : Tricalcium PO_4 24%

3. Acid soluble P : Anhydrious Rock phosphate 16 - 18 %

4. Both H_2O and citrate soluble P: Kotka PO_4 25% P_2O_5.

Rock phosphate is obtained in Bihar: Singlahe

Rajaithan: Udaipur

Uttar Pradesh: Mussoorri

Andhra Pradesh: Kasi pattinam

Phosphorus occurs in most plants in concentrations between 0.1 and 0.4%. Plants absorb either $H_2Po_4^-$ or H + PO_4^{2-} ortho PO_4 ions Absorption of $H_2PO_4^-$ is greatest at low pH values, where as uptake of HPO_4^{2-} is greater at higher values of soil pH, plant uptake of HPO_4^- is much slower than $H_2PO_4^-$.

Functions of P

1. It has a greater role in energy storage and transfer.
2. It is a constituent of nucleic acid, phytin and phospholipids
3. It is essential for cell division and development
4. P compounds act as energy currency within plants. The most common P energy currency is that found in ADP and ATP. Transfer of the energy rich PO_4 molecules from ATP to energy requiring substances in the plant is known as **"Phosphorylation"**
5. It stimulates early root development and growth and there by helps to establish seedlings quickly.
6. It gives rapid and vigorous start to plants strengthen's straw and decreasess lodging tendency.
7. It is essential for seed formation because larger quantities of P is found in seed and fruit-phytic acid is the principle storage from of phosphorus in seeds.
8. It increases the activity of Rhizobia and increases the formation of root nodules.

Soil P its origin and Nature

Soil P exists in many primary and secondary compounds. The **apatite** group of primary mineral is the original source i.e. 55% of soil P.

a) Aluminium and Iron Phosphates

In the initial stages of acid weathering Po_4 becomes increasingly bound to Fe^{3+} and Al^{3+} ions released from silicate minerals by replacing OH^- from **hydroxyl minerals** or oxygen from **oxide minerals.** $FePO_4$ and $ZnPO_4$ has been found in H_2O logged or poorly drained soils, sand and silt fraction of some soils.

Calcium phosphates

The group of compounds form an important category in the young soils and the matured soils of **neutral** to **alkaline** pH ranges. The $CaPO_4$ found either in **stable** or **metastable** state in the soil fertilizer reaction zones.

Eg. Fluorapatite	-	$Ca_{10}(PO_4)_3$ Fe
Carbonate apatite	-	$Ca_{10}(PO_4)_3$ Co_3
DIcalcium Po_4	-	Ca HPO_4 $2H_2O$
Monocalcium Po_4	-	CaH_2PO_4 H_2O.

Organic phosphates

It is derived secondarily by the addition of organic matter to the soil through the growth of plants and the deposition of plant residues. The soil micro organic synthesize organic PO_4 compounds and accumulate in the soil mixed with derived from plant tissues. It constitute 20 – 30% of total soil P. The major classes of organic compounds in soils are

a. Phospholipids (0.6 – 0.9%)
b. Phospho proteins of nucleic acid (0.6 – 2.4%)
c. Phosphorylated sugar
d. Phytin and Inositol PO_4

The ideal C : N : P : S ratio in soils are

a. Calcarious	113	10	1.3	1.3
b. Non calcarious	147	10	2.5	1.4
c. Indian soils	144	10	1.4	1.8

Chemistry of solid phosphorus compounds and their equilibrium

The PO_4 concentration in soil solution is governed by the heterogenous equilibrium.

P adsorbed in soil Po_4 $\longrightarrow$ P in soil solution $\longrightarrow$ P' precipitated in soil solution.

The reactions involved in soil Po_4 equilibrium are **dissolution, precipitation, solubility product principle.**

By using radio active p^{32} Larsen (1952) characterized the total soil PO_4 into L**abile** and **Non labile** fractions and found the size of the labile pool primarily depended on soil properties and not a function of the total content of inorganic P. he correlated and equilibrium of

Non labile soil P $\rightleftarrows$ Labile soil P $\rightleftarrows$ P in soil solution.

Fixation of phosphorus in soil

"It is the way of removal of PO_4 from solution by soil which reduces the amount that plant roots can absorb".

The factors affecting P fixation are.

1. **clay minerals**

The PO_4 is fixed by clay minerals by reacting with soluble aluminum which originates from the exchanges sites or from lattice dissociation to from a highly **insoluble $AlPo_4$.**

2. **Iron and Aluminum (fixation in acid soils)**

The formation of Iron and aluminium PO_4 in the soil results from the combination of P with these metals in solution and their oxides hydroxides in acid soil.

$$2Al + 3\,H_2Po_4 \rightarrow Al_2\,(PO_4)_3 + 2\,H_2O + 2H^+$$

3. **Exchange cations and calcium carbonate (Fixation alkaline soils)**

In calcareous soils, free Ca CO_3 is a potent sources for 'P' fixation. P fixation in calcareous soil involved a rapid monolayer sorption of P in dilute concentration In $CaCo_3$ surfaces and form less soluble compounds of di and tricalcium PO_4.

$$Ca(H_2\,Po_4)_2 + 2\,CaCo_3\;\; Ca_3(Po_4)_2 + 2Co_2 + 2\,H_2O$$

4. Organic matter

Organic Po_4 can be fixed by soil organic matter also influences in Organic Po_4 fixation. The acids produced during the transformations of Organic matter could decreases the pH and increases fixation by the solubilization of Fe and Al.

P Fixation in soil in affected by

1. Nature and Amount of soil minerals

Soils have high amount of Fe and Al oxides, crystalline hydrous metal oxides are usually capable of retaining more P than amorphous forms. P adsorbed to a greater extend by 1 : 1 than 2: 1 clays. The greater amounts P fixed by 1 : 1 clays is probably due to the higher amounts of Fe and Al oxides, associated with kaolinite clays that are predominate in highly weathered soils. Soils containing large quantities of clay will fix more P than soils with low clay content.

2. Soil pH

a. Fixation of P by Fe and Al oxides decreases with increasing pH.

b. P availability is more in soils at a max in the pH range of 5.5 to 6.5

c. At low pH values, Fe and Al ions reacts with to from al Po_4 and $FePo_4$ oxides.

d. As the pH increases, the activity of Fe and Al decreases and the results of higher amount of P librates into soil solution.

Above pH 7.0, Ca^{2+} can precipitate with P as Ca –PO4

mineral and P availability again decreases.

3. Cation effects

Divalent cations enhance the P fixation than monovalent cations.

4. Anion effects

Both organic and Inorganic anions can compete with P for adsorption sites, resulting in decreases the fixation of P.

5. Organic matter

Addition of organic matter to soils increased P availability by

a. Formation of organoPo_4 complexes that are more easily assimilate by plants.
b. Anion replacement of $H_2Po_4^-$ on adsorption sites.
c. Coating of Fe and Al particles by humus to form a productive cover and thus reduce the P fixation.

6. Temperature

The rate of most chemical and biological reactions increases with increasing temperature. Mineralization of P from soil organic matter is dependent on soil biological activity an increases in temperature.

7. Flooding

In most soils there is an increases in available P after flooding largely due to conversion of Fe^{3+} PO_4 to soluble Fe^{2+} PO_4 and hydrolysis of Al PO_4 and thereby prevent the fixation of P in soils.

8. R_2O_3 : P_2O_5 (Ratio)

"R_2O_3 : P_2O_5 (Ratio) is a measure of amount of P present in the soil". A wide ratio indicates a small P fixation and vice versa. When the ratio is narrow P fixation is more.

9. Addition of Zn So_4

It may also cause P deficiency since it forms insoluble complex with P. This can be averted by addition of $ZnSo_4$ more and more.

P Cycle

"Process by which P moves form solid and liquid phase and transformation is called P cycle". P is taken mostly by diffusion in plants.

I. The decreases in soil solution P concentration with absorption by plants roots is buffered by both inorganic and organic fractions in soils.

Primary and secondary P minerals dissolve to re supply $H_2PO_4^-$ / $HPO_4^=$ in soluble.

Inorganic P adsorbed on mineral and clay surfaces as $H_2PO_4^-$ or $HPO_4^=$ (liable inorganic P) also can desorbs to buffer decreases in soil solution P. Numerous soil micro organic digest plant residues containing P and produce many organic plant compounds in soil and it can be mineralized through microbial activity to supply solution P.

H_2O soluble fertilizer P applied to soil readily dissolves and increases the concentration of soil solution.

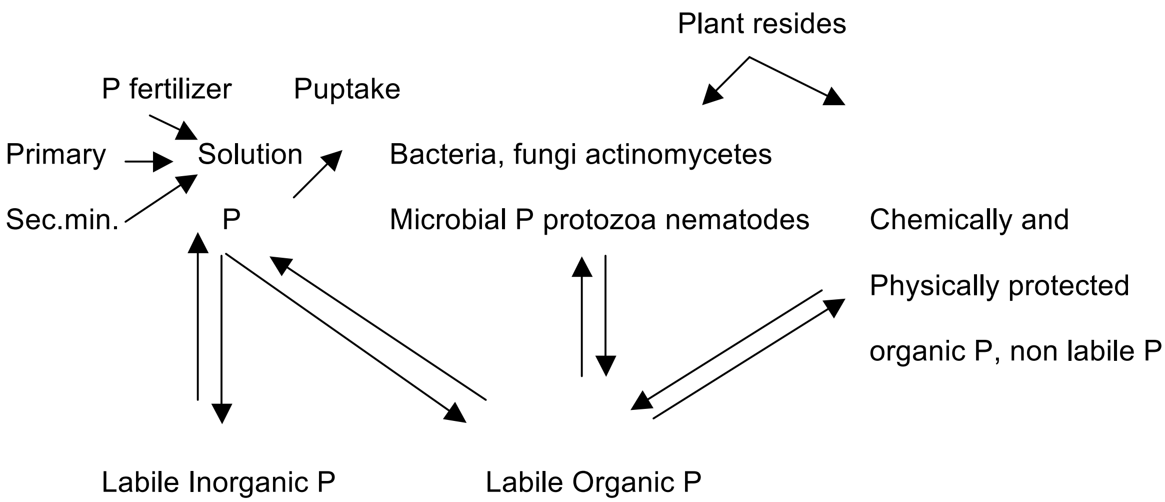
II. In addition to uptake of P by roots, solution P can be adsorbed on minerals surfaces and precipitated as organic P and these organic P compounds are more resistant to microbial degradation.

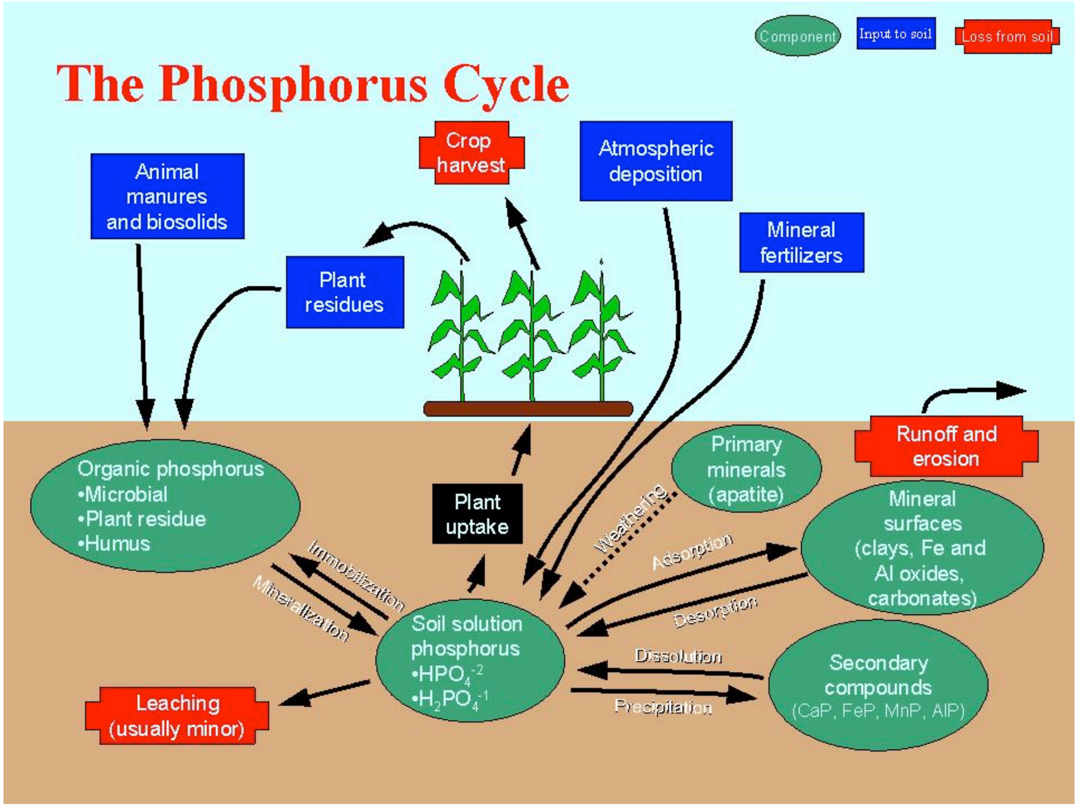
Soil solution P is called **Intensity factor,** while organic and inorganic labile P fractions are collectively **Quantity factor.**

Maintenance of solution P concentration for adequate P nutrition in the plant depends on the ability of labile P to replace soil solution P. "The ratio of quantity to intensity factor in called the **capacity factor, "which express the relative ability of the soil to buffer changes in soil solution".**

P cycle can be simplified to Soil solution → labile P → Non labile P

(Inorganic) (Organic)





Source: http://phsgirard.org/Biology/Ecology/PhosphorusCycle.jpg

Y value / L value (Larsens Value)

Larsen measured the quantity of soil P involved in the isotopic dilution of applied radio active P during a growing season. It is used to calculate P supply of the soil.

$$L \text{ (or) } Y = K \times \frac{(Co - C)}{C}$$

Where, L = Avail P in soil

Co = K x total P in the Plant

C = K x P taken by the plant

K = Proportionality constant.

Deficiency symptoms

P is mobile in plants and when a deficiency occurs it is translocated from older tissues to the active meristematic regions.

1. It arrests metabolism resulting in reduction of total N of Plants.

2. Reduced sugar content.

3. Premature leaf fall.

4. Develops necrotic area on the leaf petiole and in the fruit

5. Leaves will show characteristic bluish green colour.

Toxicity of phosphorus

a. Profuse root growth i.e. lateral and fibrous root lets.
b. It develops normal growth having green leaf colour.
c. It may cause in some cases trace elements deficiencies i.e. **Zinc and Iron.**

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http://phsgirard.org/Biology/Ecology/PhosphorusCycle.jpg

Questions to ponder

1) What is the role of soil pH in P availability?
2) P fixation is a blessing in disguise.How?
3) What are the natural sources of P?
4) What is C: P ratio?
5) How does calcareousness affect P availability?

9.

Potassium – Transformation, factors affecting Potassium availability, deficiency and toxicity symptoms

Learning objectives

a. To understand the transformation of Potassium
b. To study the forms of K and factors affecting K availability
c. To understand the deficiency symptoms of Potassium

Potassium

The potassium ion (K^+) is actively taken up soil solution by plant roots. The concentration of K^+ in vegetative tissue ranges from 1 to 4% on dry matter basis.

Functions of potassium

1. Essential for photosynthesis, development of chlorophyll.
2. It improves vigour of the plants to enable to with stand adverse climatic conditions.
3. Reduces lodging in cereal crops.
4. It regulates stomata opening and closing.
5. It regulates the movement of ions with in the plants and hence it is called **traffic policeman** of the plant.
6. Activation of enzymes, enzyme synthesis, peptide bonds synthesis.
7. Regulates H_2O imbalance within the plant.

Sources of K

The micas and fieldspars constitute the major K bearing minerals which on weathering slowly release K to the soil.

(Muscovite and biotite) (Orthoclase and microcline)

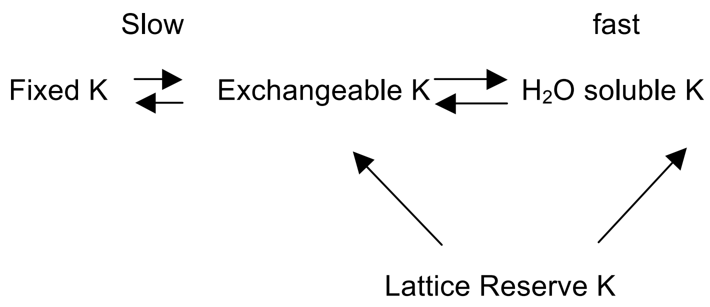
K-Feldspar: $KAlSi_3O_{10}$.

Courtesy: http://ocw.mit.edu/ans7870/12/12.108/f04/imagegallery/lab3/lab3-32.html

Forms of potassium in soils

a. Water soluble K.
b. Exchangeable K.
c. Fixed or Non exchangeable K.
d. Lattice or Mineral K.

The different forms are in **dynamic equilibrium** with one another and represented as follows.



Water soluble K

The Concentration of H_2O soluble K in soil depends on (a) type of day (b) H_2O content (c) Intensity of leaching (d) Amount of exchange K (e) Kind and concentration of other ions.

The dilution of the soil, increases the concentration of H_2O soluble K and drying decreases it. The uptake of K is influenced by the presence of other cations, ie Ca^{2+} and Mg^{2+}, Al^{3+} (acidic soils) and Na^+ in salt affected soils.

The activity ratio $(AR_e^K) = \dfrac{\text{Activity of } K^+}{\sqrt{\text{activity of } Ca^{2+} \text{ and } Mg^{2+}}}$

(or)

$$= \frac{ak}{\sqrt{{}^aCa\text{- }Mg}}$$

2. Exchangeable K

The K adsorbed on soil clay complex and replaceable with neutral salts in relatively short time. The Cl reacts with soil Ca and form Ca Cl_2 which is leached by high rainfall. Hence **K is called** as **Decalcifier**

3. Non exchangeable or Fixed K

Added K which is firmly bound by the soil and not immediately replaceable with neutral salts.

4. Lattice K or Mineral K

Muscovite, biotite and K feldspar. The capacity of soils to release lattice K by weathering depends on the content of K minerals and soil texture.

Potassium fixation

The important of K fixation is to regulate the supply of the soil a for the plants and protects it against loss through leaching.

In the dynamics of soil Potassium, the phenomenon of fixation of exchange K and the liberation of non-exchange K play an important role. K ions are relatively small to enter the silica sheets where they are held firmly by **electrostatic forces**. The presence of K^+ ions can block the release of fixed NH_4^+ and vice visa.

Factors affecting K fixation.

1. **Soil texture** : Increases the texture grater will be fixation and vice visa.
2. **Wetting and drying:** Fixation is more under dry condition than wet condition.
3. **Type of day min:** Fixation is more in 2:1 type than 1: 1 type
4. **Freezing and thawing :** Enhances the fixation of K depends their clay mineralogy and degree of weathering
5. **Soil pH :** A decreases in pH reduces the K fixation either as result of competition of H_3O^+ for the inter layer exchange position. Liming also favors for the fixation of K.

Factors affecting K availability in plants

a. *Kind of clay minerals*: Soils containing vermiculite or montmorilonite will have more K than kaolinite clay soils.

b. *Cation exchange capacity*: Increases texture soils having higher CEC and can hold more exchange K.

c. *Amount of exchangeable K*: More K in soil solution leads to

Higher fixation.

d. *Subsoil K and rooting depth*: Low soil temperature may exhibit K release and diffusion, thus increasing crop response to K

e.*Soil moisture*: fertilization increasing K levels or moisture contain will accelerate K diffusion.

6. **Soil temperature :** The reduced temperature slow down plant process plant growth and rate of K uptake.
7. **Soil aeration** : Under high moisture levels or incompact soils root growth is restricted, O_2 supply is lowered and absorptions of K is slowed.
8. **Soil pH :** In very acid soils, toxic amount of exchange Al^{3+} and Mn^{2+} create unfavorable root environment for uptake of K and other nutrients.
9. **Ca and Mg :** K uptake would be reduced as Ca^{2+} and Mg^{2+} are increased or uptake of these two cations would be reduced as the available supply of K is increased.
10. **Tillage:** Tillage is increased that K availability is reduced because of increases compaction, less aeration and lower temperature.

Plant factors affecting K availability

1. CEC of Roots :Important for determining the ability of plants to absorb like more slowly available forms of soil K.

2. Root system and crop :Higher root density, higher the removal of exchange K and soil solution K. Fibrous root system absorbs more K than tap root system.

3. Variety or Hybrid :Hybrid absorbs more K than variety.

4. Plant population :Higher plant population and closer spacing increased the K removal.

Deficiency symptoms

1. Plant becomes stunted in growth with shortening of internodes and busy in appearance.
2. K deficiency in plants show reduced rate of photosynthesis.
3. Chlorosis, yellowing of leafs and leaf scarch in case of fruits trees.

Rice : The leave tips will dark brown in colour and blades will blueish green, chlorotic and necrotic are seen.

Banana : Deficiency is seen in the margin and bottom of leaves.

Grapes : Leaves are yellow with brown spots which are necrotic, brittle with uneven ripening.

References

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Questions to ponder

1) What is luxury consumption?
2) What is activity ratio and what does it measure?
3) How does CEC affect the amount of K in solution?
4) What is the effect of K: Ca ratio in K availabity?
5) Does fixed K tend to become available to plants?