

# PLANT NUTRIENTS AND NUTRIENT CYCLES



Prof. B. C. WALPOLA

## PLANT NUTRIENTS AND NUTRIENT CYCLES

This emphasize the forms and availability of nutrients in soils, their movement and their uptake by roots, and the utilization of nutrient within plants.



# PLANT NUTRIENTS

- The success of farming depends largely on the growth of crops.
- Crop growth is influenced by a number of factors of including plant nutrients.
- Plant nutrient elements are broadly grouped in to two ways
  - Essential nutrients
  - Beneficial nutrients



# ESSENTIAL NUTRIENTS

- The completion of the life cycle of the plant cannot be achieved in the absence of such an element.
- Plays a specific role in the plant.
- Plants absorb or utilize more than 90 nutrient elements from the soil and other sources during their growth and development and about 64 nutrients have been identified in plants by their tissue analysis.
- But all are not essential for their growth and development. They require only 17 elements/nutrients. These 17 have been recognized as essential elements.



# **CLASSIFICATION OF ESSENTIAL NUTRIENTS**

- Essential nutrients are classified into two major groups based on relative utilization or absorption by the plants

## **❖ Macro or Major Nutrients**

**Basic elements:** C, H, O

**Primary Nutrient:** N, P, K (fertilizer elements)<sup>I</sup>

**Secondary Nutrients:** Ca, Mg, S

## **❖ Micro nutrients**

Fe, Mn, Zn, Cu, B, Mo, Cl and Ni.



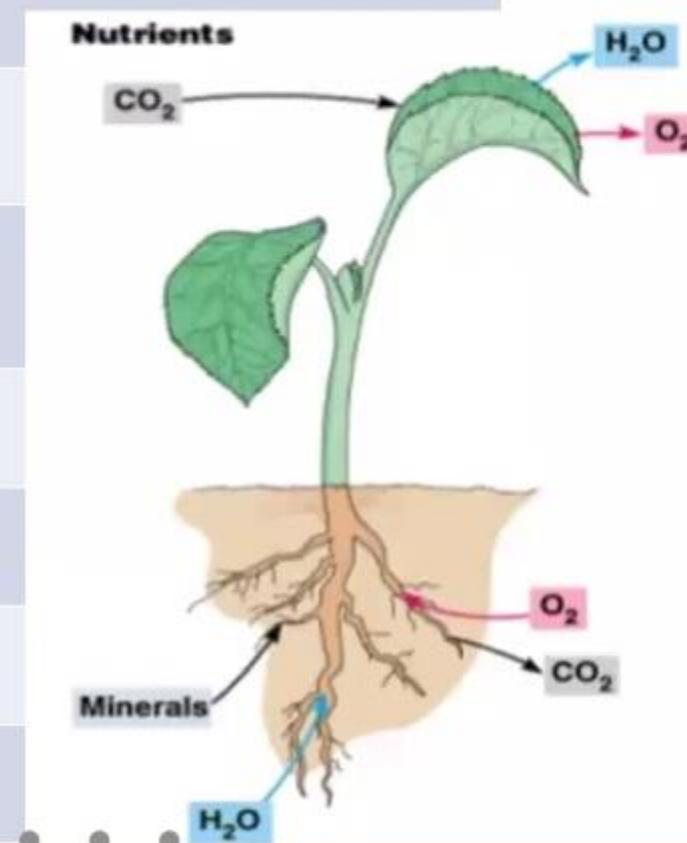
# DEFINITIONS

- **Macro or Major Nutrients:** They are the nutrients utilized by the plants in relatively large amounts (quantity) for their growth and development.  
Ex: C, H. O. N, P, K, Ca, Mg and S (C, H and O are abundantly present in the atmosphere and need not be applied through fertilizers).

I



NUTRIENT	FORM TAKEN UP BY THE PLANTS
Carbon(C)	$\text{CO}_2, \text{HCO}_3^-$
Hydrogen(H)	$\text{H}_2\text{O}$
Oxygen(O)	$\text{O}_2, \text{H}_2\text{O}$
Nitrogen (N)	$\text{NH}_4^+, \text{NO}_3^-$
Phosphorous(P)	$\text{H}_2\text{PO}_4^-, \text{HPO}_4^{2-}$
Potassium(K)	$\text{K}^+$
Calcium	$\text{Ca}^{2+}$
Magnesium	$\text{Mg}^{2+}$
Sulfur	$\text{SO}_4^{2-}$



- **Micronutrients:** The nutrients which are required by plants in relatively smaller quantities for their growth and development, but these are equally important and essential to <sup>I</sup> plants as macronutrients. They are also called as trace/rare/nano elements.

Ex: Fe, Mn, Zn, Cu, B, Mo, Cl and Ni.



NUTRIENT	FORM TAKEN UP BY THE PLANTS
Iron(Fe)	$\text{Fe}^{2+}, \text{Fe}^{3+}$
Zinc (Zn)	$\text{Zn}^{2+}, \text{Zn(OH)}_2$ , chelate
Managanese (Mn)	$\text{Mn}^{2+}$ , chelate
Copper(Cu)	$\text{Cu}^+, \text{Cu}^{2+}$ , chelate
Boron(B)	$\text{B(OH)}_3(\text{H}_3\text{BO}_3), \text{H}_2\text{BO}_3^-$
Chlorine(Cl)	$\text{Cl}^-$
Nickel (Ni)	$\text{Ni}^{2+}$



# BENEFICIAL PLANT NUTRIENTS

- Several elements other than the essential nutrients have beneficial functions in plants.
- Although not essential (as the plant can live without them), beneficial nutrients can improve the growth of some crops in some respects.
- Some of these nutrients can be of great practical importance and may require external addition  
Ex:  $\text{Na}^+$ ,  $\text{Co}^{2+}$ ,  $\text{Al}^{3+}$



# NITROGEN



# NITROGEN (N)

- Very important and major limiting nutrient.
- Availability of Nitrogen
  - Surface mineral soils → 0.02–0.5%  
(1ha → 3.3Mg of N)
  - Atmosphere 78% by volume  
(Air above that 1ha of soil → 300 000 Mg of N)



## ROLE IN PLANTS

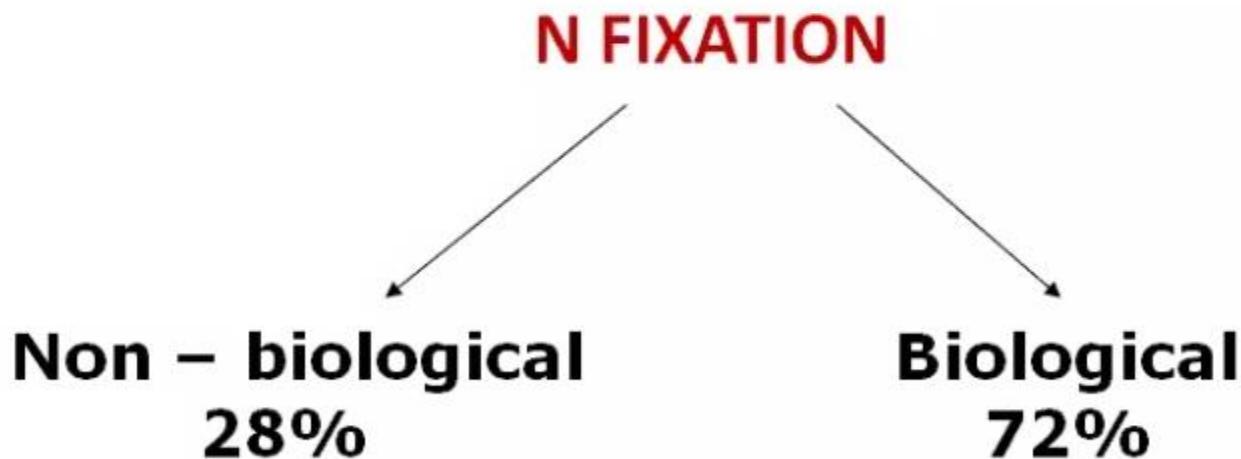
- Components of many essential compounds.  
Nuclear acid (10% of total N), protein (16-18% N), enzyme, lipid, chlorophyll (45-60% protein), phytochrome, plant hormone (IAA), vitamin (B<sub>1</sub>, B<sub>2</sub>, B<sub>6</sub>), alkaloid etc.
- Participation in metabolism and energy in plant  
High energy triphosphate components (<sup>I</sup>ATP, ADP etc) coenzymes (CoA, NAD).
- Essential for plant growth processes
- Essential for carbohydrate use within the plants
- Stimulate root growth and development as well as the uptake of other nutrients.



# MAJOR STEPS OF THE N CYCLE

## NITROGEN FIXATION

- Conversion of molecular  $N_2$  to  $NH_3$  and subsequently into organic forms utilizable in biological process.



# NON – BIOLOGICAL N FIXATION

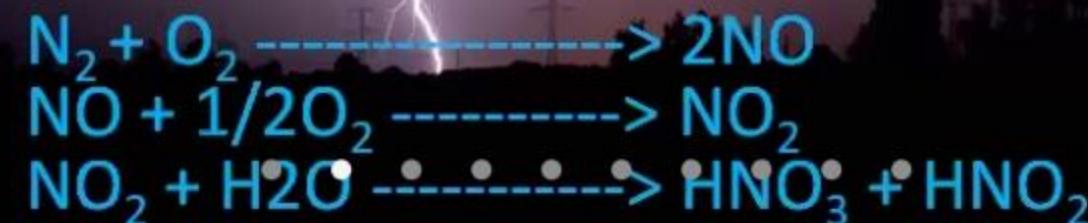
- ❖ Atmospheric fixation (Physical)
- ❖ Industrial fixation (Chemical)



## 1. Atmospheric Fixation

(Only 5 to 8% of the Fixation Process)

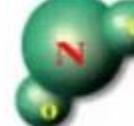
Nitrogen can be fixed by lightning converting nitrogen and oxygen into  $\text{NO}_2$  (nitrogen oxides).  $\text{NO}_2$  may react with water to make nitrous acid or nitric acid, which seeps into the soil, where it makes nitrate, which is of use to growing plants



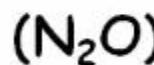
## Lightning "fixes" Nitrogen!



Nitrogen  
combines  
with Oxygen



Nitrogen oxides forms



Nitrogen  
oxides dissolve  
in rain and  
change to  
nitrates

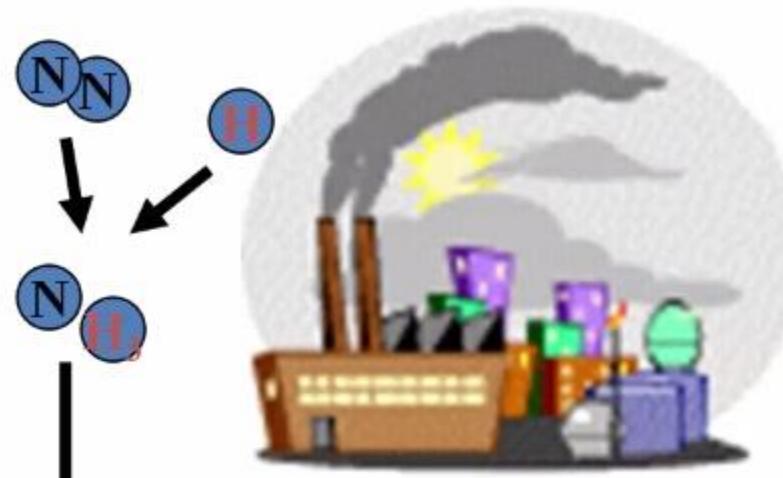
Plants use  
nitrates to grow!



## INDUSTRIAL FIXATION

- Under great pressure, at a temperature of 600 °C, and with the use of a catalyst, atmospheric nitrogen ( $N_2$ ) and hydrogen are combined to form ammonia ( $NH_3$ ). Ammonia can be used as a fertilizer.





Industrial Plant combines  
nitrogen and hydrogen



Ammonia is formed

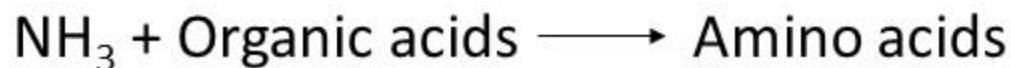
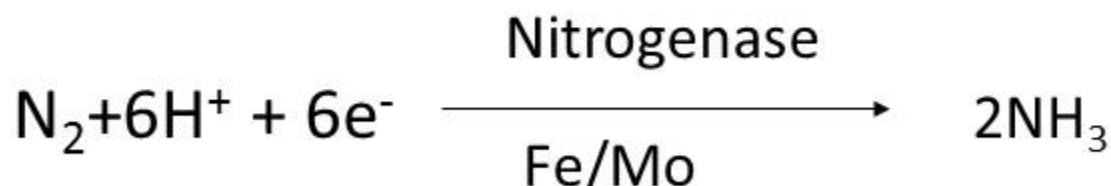


Ammonia is used a fertilizer in soil

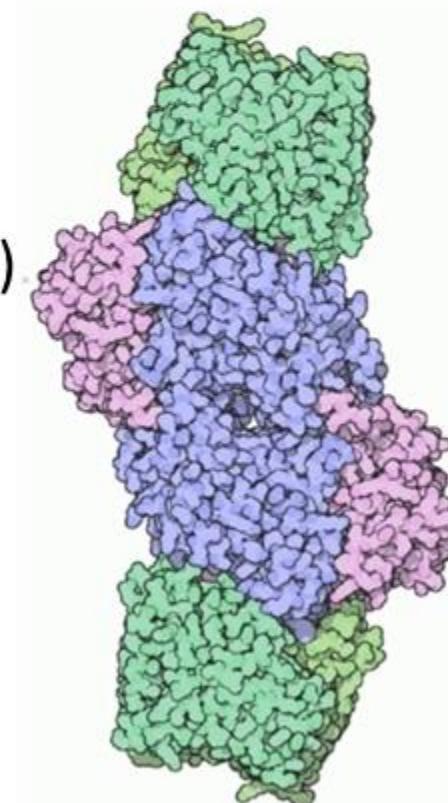


# BIOLOGICAL N FIXATION - BNF

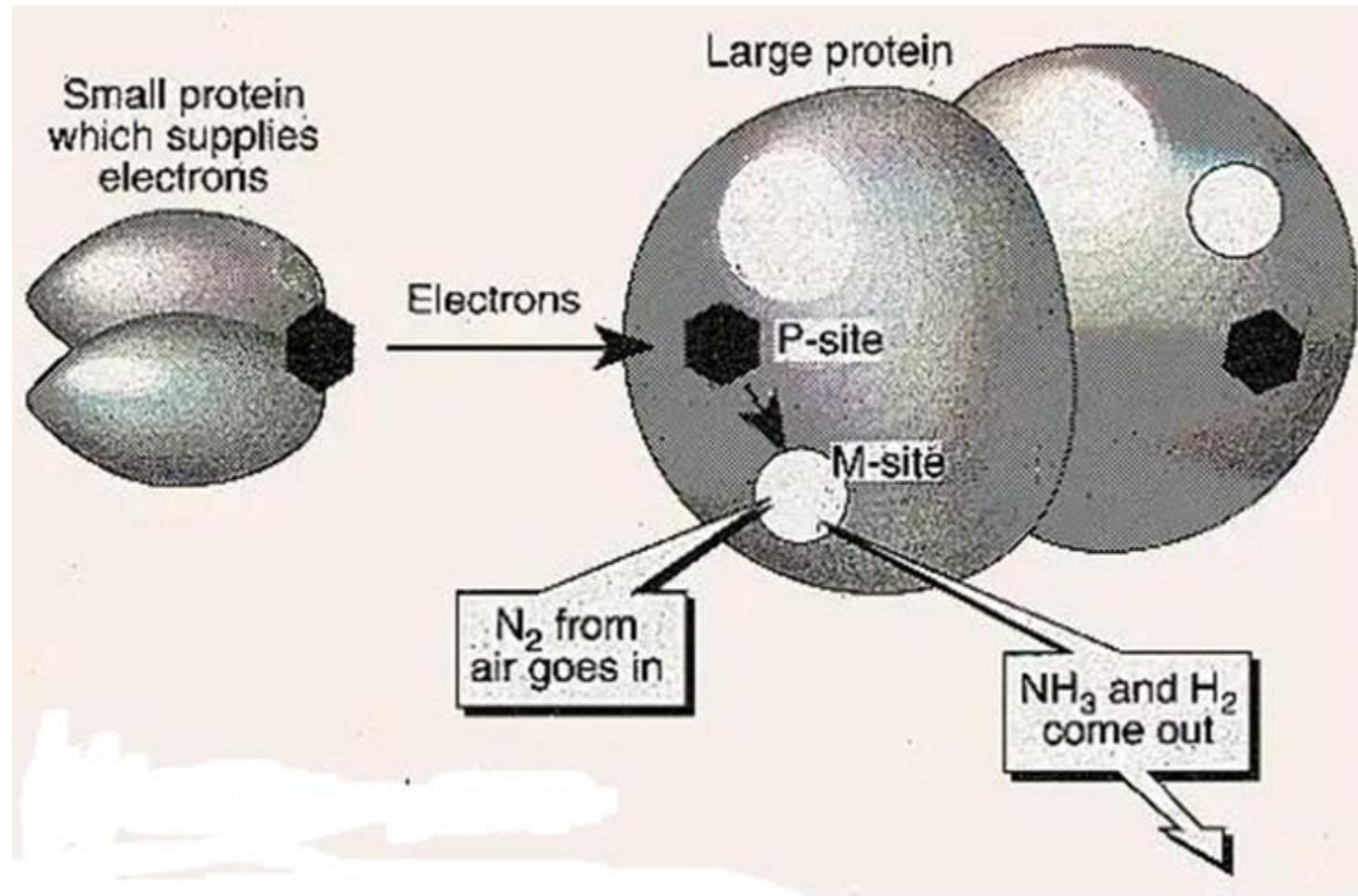
- Large amount of N is added to soil through procedure of BNF.
- BNF is probably the most important biochemical reaction for life on earth.
- Through this process (BNF) certain organisms convert the inert  $N_2$  gas of the atmosphere to N-containing compounds ( $NH_3$ )
- The key enzyme of BNF is nitrogenase



Proteins



The nitrogenase enzyme with the MoFe protein in blue and purple and the Fe proteins in green



# **IMPORTANT FACTS ABOUT NITROGENASE ENZYME AND ITS FUNCTIONS**

1. The reduction of  $N_2$  to  $NH_3$  by nitrogenase required a great deal of energy to break the triple bond between the N atoms. Therefore, the process is greatly enhanced by association with higher plants, which can supply this energy from photosynthesis.

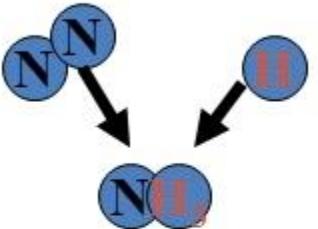
2. Nitrogenase is destroyed by free O<sub>2</sub>, So organisms that fix N must protect the enzyme from exposure to O<sub>2</sub>. when N fixation takes place in root nodules, one way of protecting the enzyme from free O<sub>2</sub> is the formation of leghemoglobin.
3. The reduction reaction is end product inhibited
4. N fixing organisms have a relatively high requirement for Mo, Fe, and S (Co is also required by certain organisms).

# NON – SYMBIOTIC N FIXATION

- Several kind of heterotrophic bacteria are act as N fixers.
- This type of N fixation is minor important for agricultural soils.
- These organisms are not directly associated with higher plants.

Ex: *Azotobacter* - Aerobic

*Clostridium* - Anaerobic



Free-living bacteria live  
in soil and combine  
atmospheric nitrogen  
with hydrogen



Nitrogen changes  
into ammonia



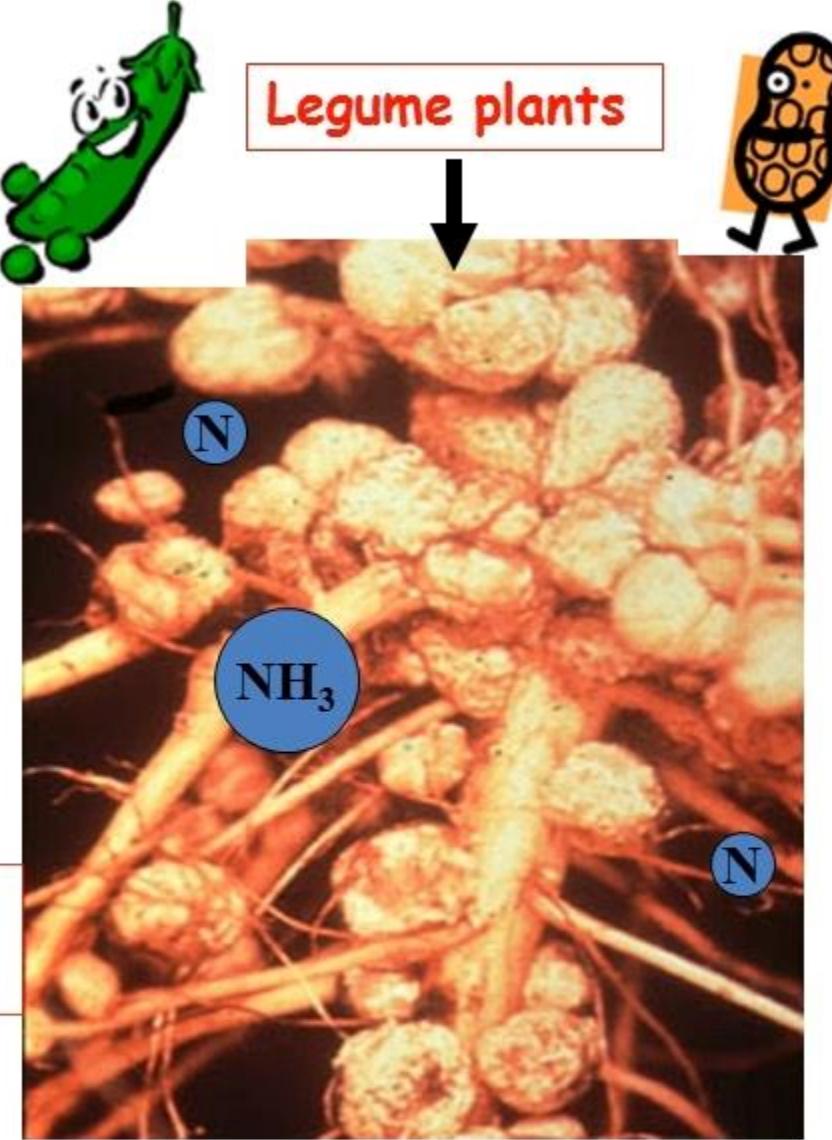
Bacteria

## SYMBIOTIC N FIXATION

- Symbiotic nitrogen fixation is the fixation of atmospheric nitrogen by symbiotic bacteria that live in the root nodules.
- These bacteria maintain mutually beneficial relationships with plants such as legumes, pod-bearing plants such as peas, beans, alfalfa and clovers.
- The fixed nitrogen can be used by the next generation of legumes in the same soil.
- The symbiosis of legumes and bacteria of the genera *Rhizobium* and *Bradyrhizobium* provide the major biological source of fixed nitrogen in agricultural soils.



*Roots with nodules  
where bacteria live*



*Nitrogen changes into  
ammonia.*

There are two types of “Nitrogen Fixing Bacteria”



Free Living Bacteria  
("fixes" 30% of N<sub>2</sub>)



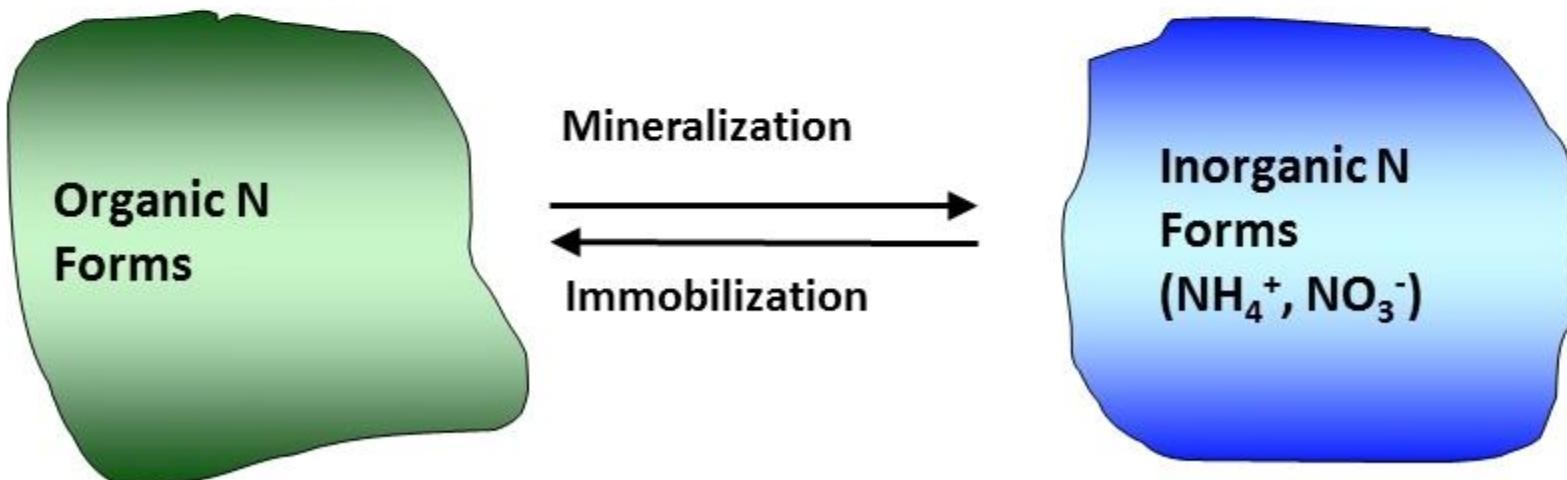
Symbiotic Relationship  
Bacteria  
("fixes" 70% of N<sub>2</sub>)

# SYMBIOTIC NITROGEN FIXATION AND NON SYMBIOTIC NITROGEN FIXATION

SYMBIOTIC NITROGEN FIXATION	NON SYMBIOTIC NITROGEN FIXATION
A part of a mutualistic relationship in which plants provide a niche and fixed carbon to bacteria in exchange for fixed N	A process of biological N fixation performed by a group of autotrophs bacteria living free in the soil either aerobically and not depend on plants
Symbiotic nitrogen fixation bacteria live in a mutualistic relationship with plants	Non-symbiotic nitrogen fixation bacteria are free living in the soil
Ammonia, amino acids and ureides are formed	Ammonia, nitrites and nitrates are formed
Symbiotic bacteria produce nitrogen for its host	Non-symbiotic bacteria make nitrogen available in the soil
Ex: <i>Rhizobium leguminosarum</i>	Ex: <i>Azotobacter</i> spp.

# MINERALIZATION

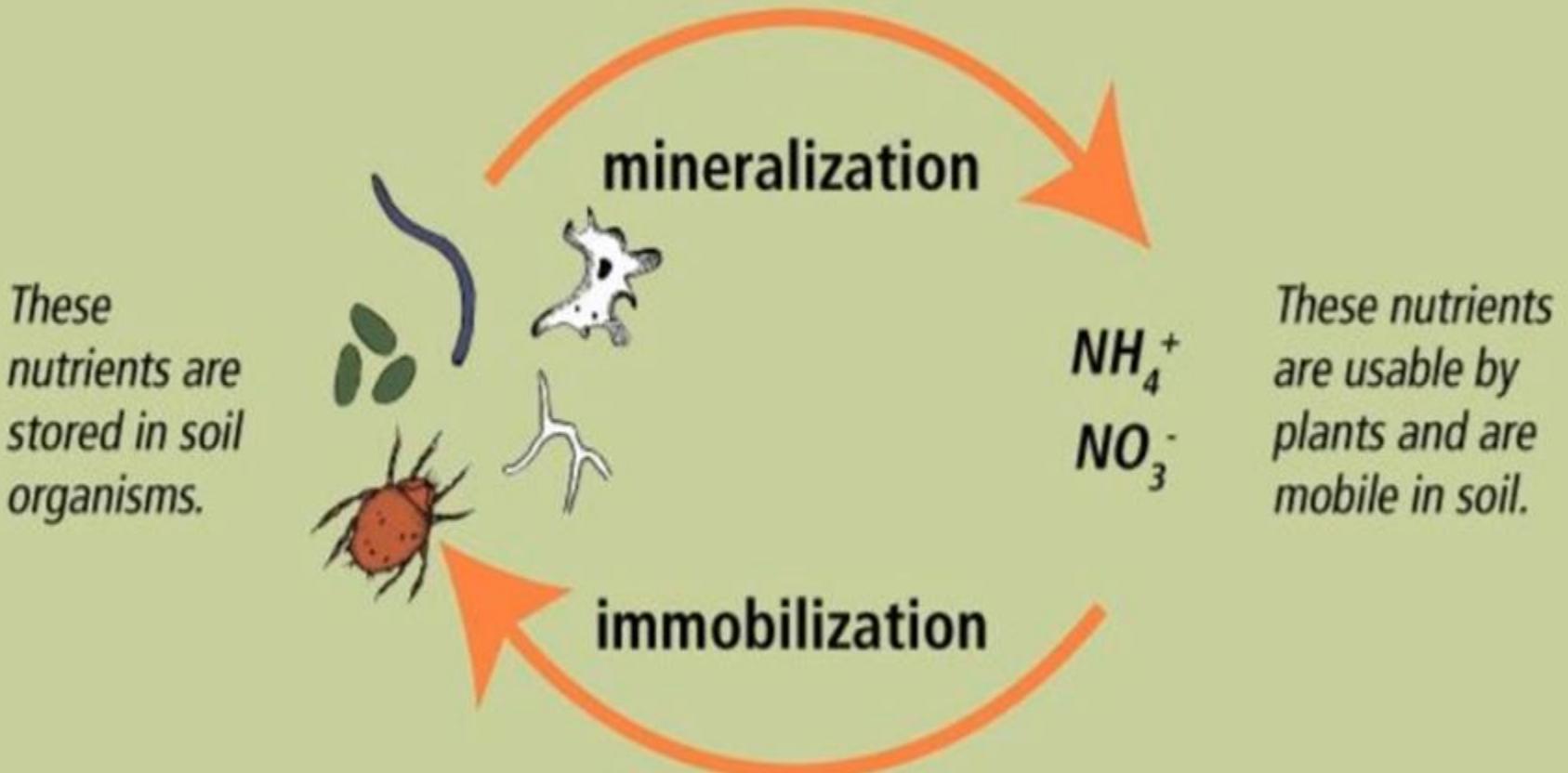
- The conversion of organically bound N in to inorganic mineral forms ( $\text{NH}_4^+$  and  $\text{NO}_3^-$ ) is termed mineralization.
- Mineralization and immobilization occur simultaneously in the soil.



# IMMOBILIZATION

- The opposite of mineralization is immobilization, the conversion of inorganic N ions ( $\text{NH}_4^+$  and  $\text{NO}_3^-$ ) into organic forms.
- Decay of plant residue does not always result in mineralization of N.
- When residue does not contain enough N to meet the needs of microbes decaying it, the microbes will utilize N in the residue and any additional mineral-N ( $\text{NH}_4^+$  and  $\text{NO}_3^-$ ) present in the soil.
- This process of transforming mineral-N to organic-N is called immobilization

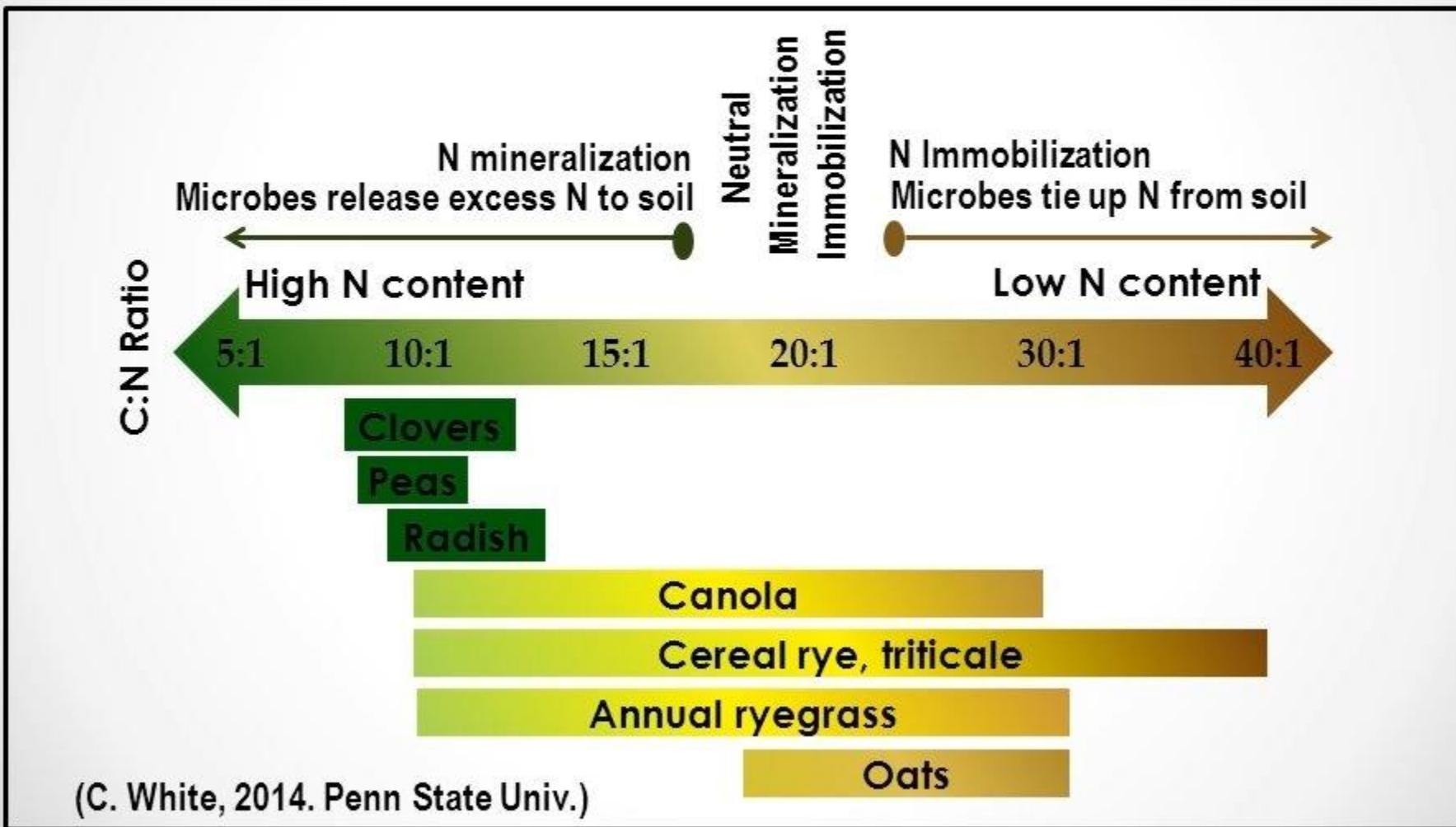
Organisms consume other organisms and excrete inorganic wastes.



Organisms retain nutrients as they grow.

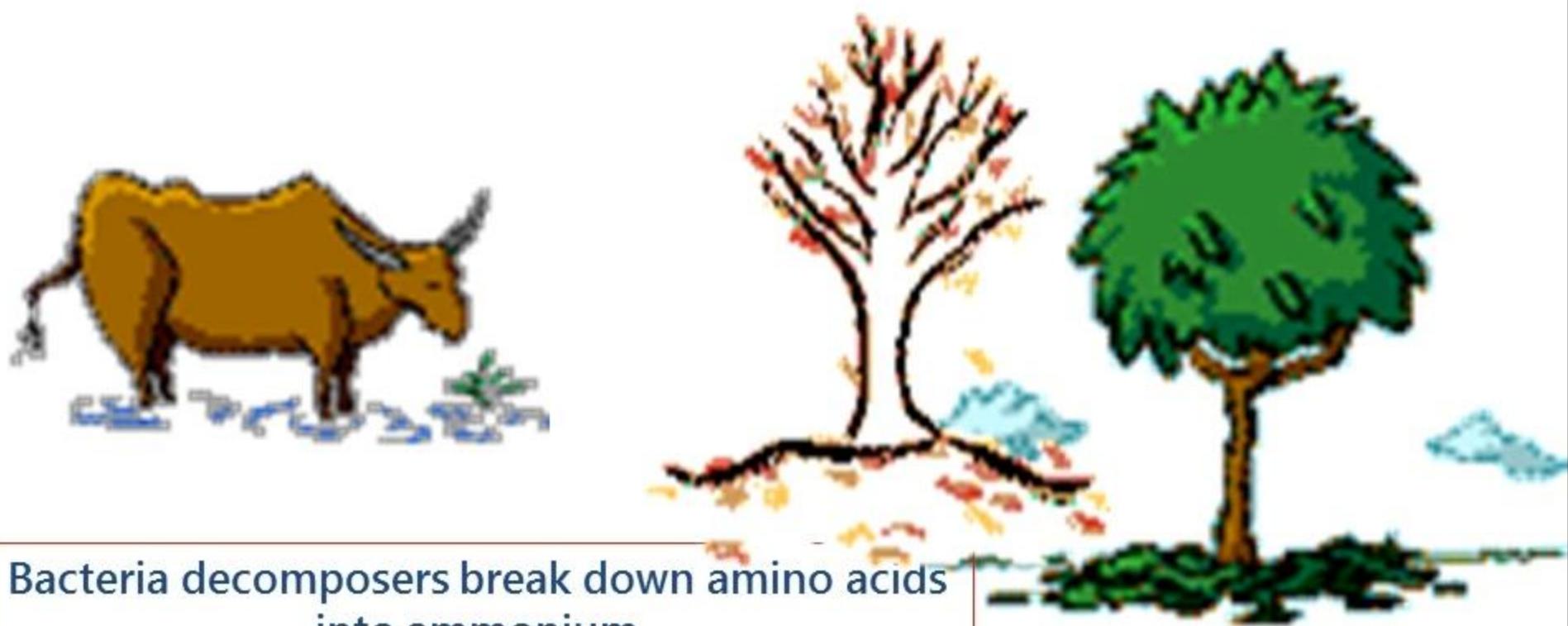
# *C:N Ratio and N Mineralization Rate*

## C:N Ratio of Cover Crops Residues and N Mineralization / Immobilization



# AMMONIFICATION

- When a plant or animal dies, the nitrogen will be in organic form and the microorganisms like bacteria or fungi convert the organic nitrogen into ammonia. This process is called ammonification.



- The ammonium is either taken up by the plants (only in a few types of plants) or is absorbed into the soil particles. Ammonium ( $\text{NH}_4$ ) in the soil is stored up to later be changed into inorganic nitrogen, the kind of nitrogen that most plants can use.

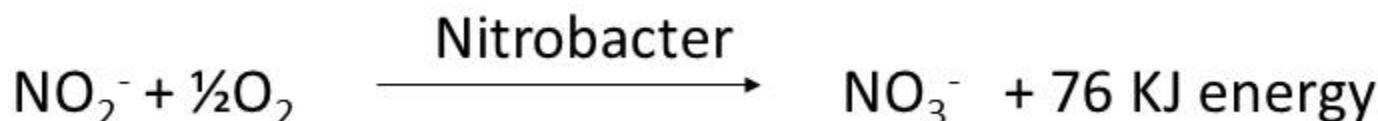
# NITRIFICATION

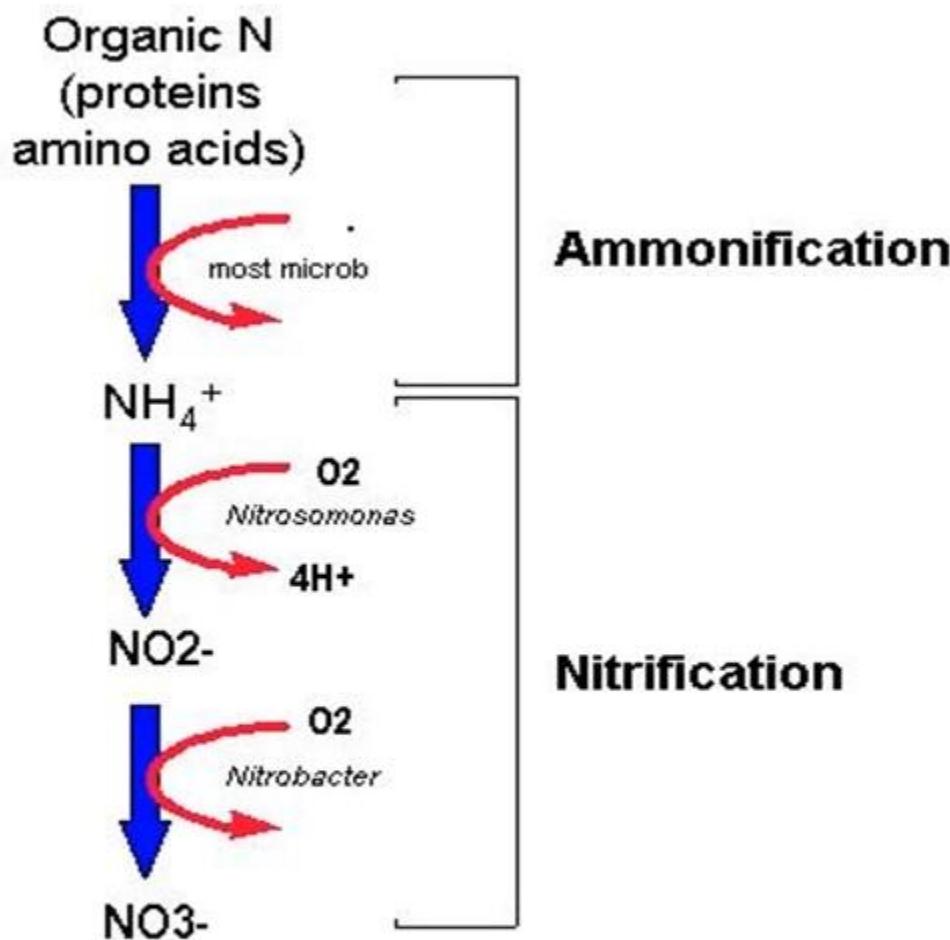
- Ammonium is converted to nitrite by nitrifying bacteria and there are many reactions taking place during the conversion (bacterial oxidation of  $\text{NH}_4^+$ ).

❖ Conversion of ammonium to nitrite



❖ Conversion of nitrite to nitrate





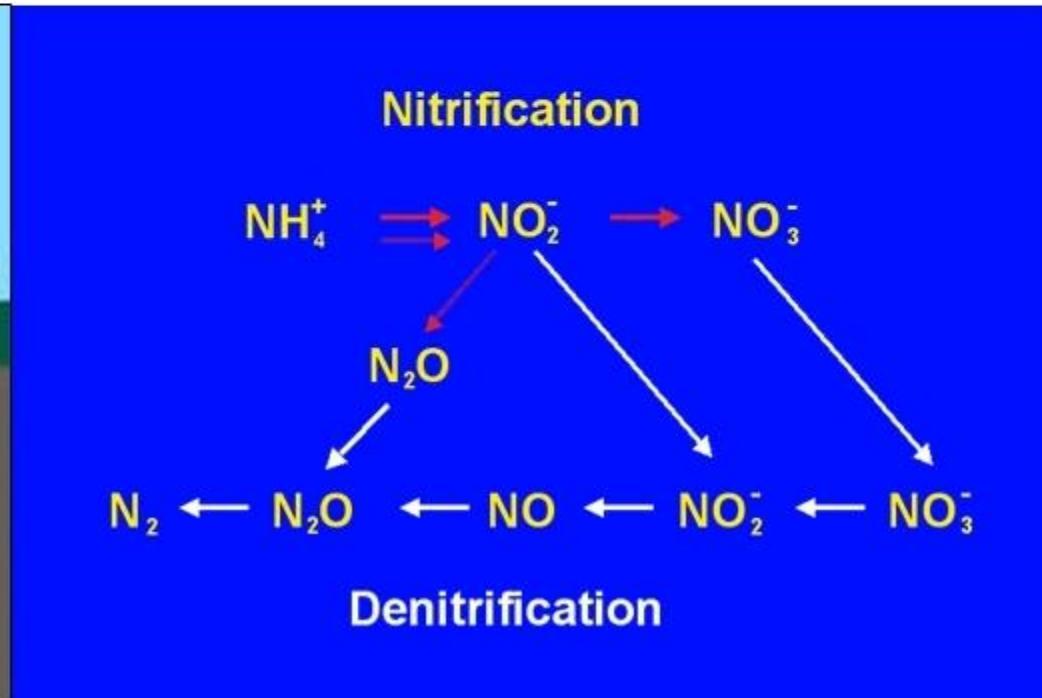
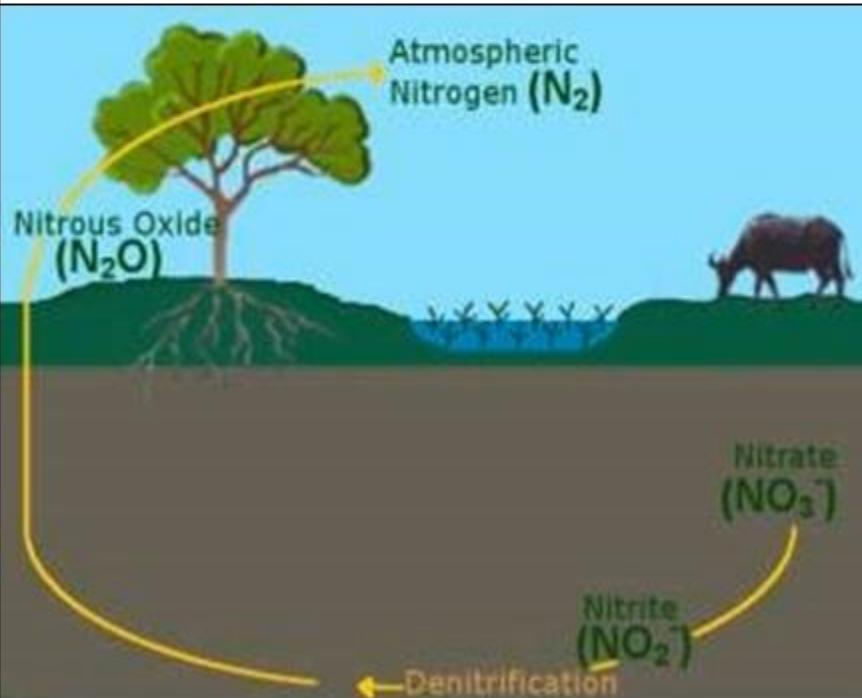
# THE NITRATE LEACHING PROBLEM

- Loss of  $\text{NO}_3^-$ -N causes an impoverishment of the ecosystem whether or not cultivated crops are grown, and leaching of  $\text{NO}_3^-$  causes several serious environmental problems.
- Nitrate lost by leaching is generally carried by drainage water to the ground water.
- It may reach domestic wells, and may also eventually flow underground to surface waters such as streams, lakes and estuaries.
- The  $\text{NO}_3^-$  may contaminate drinking water and it has potential to cause toxic effects

Methemoglobinemia (blue baby syndrome)

# DENITRIFICATION

- The biochemical reduction of nitrate or nitrite to gaseous nitrogen, either as molecular nitrogen or as an oxide of nitrogen.



- This process is commonly carried out by facultative anaerobic bacteria (Pseudomonas, Bacillus, Micrococcus and Achromobacter).
- These organisms are heterotrophs, which obtain their energy and carbon from the oxidation of organic compounds.
- Other denitrifying bacteria are autotrophs (Thiobacillus denitrificans), which obtain their energy from the oxidation of sulfide.

# ATMOSPHERIC POLLUTION ASSOCIATED WITH DENITRIFICATION

- NO and  $\text{N}_2\text{O}$  contribute to formation of  $\text{HNO}_3$  (component of acid rain)
- NO contribute to the green house effect
- $\text{N}_2\text{O}$  help to destruction of ozone
- Eutrophication



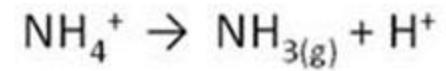
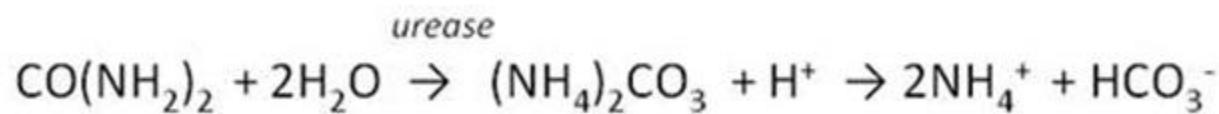
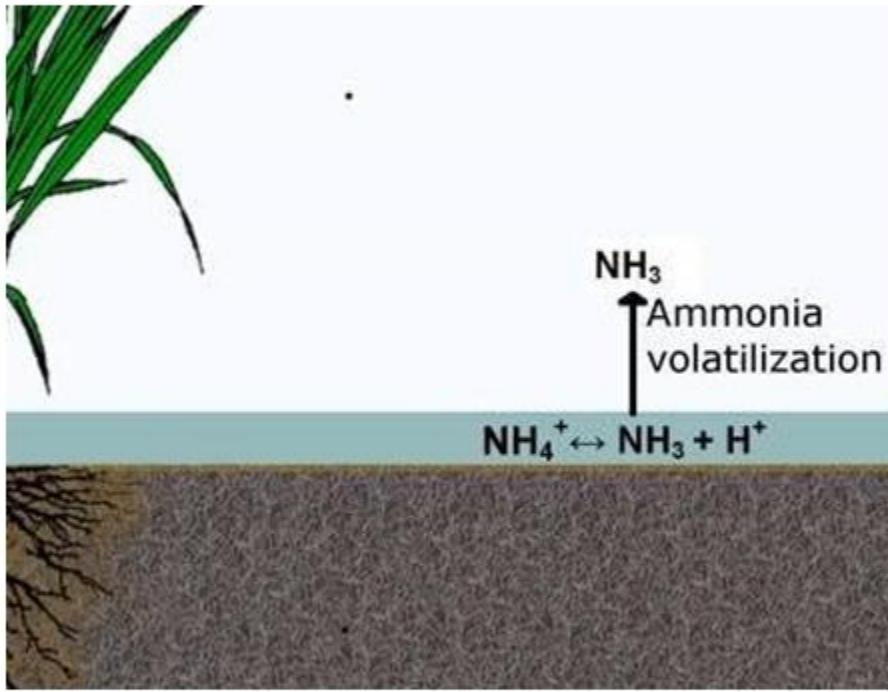
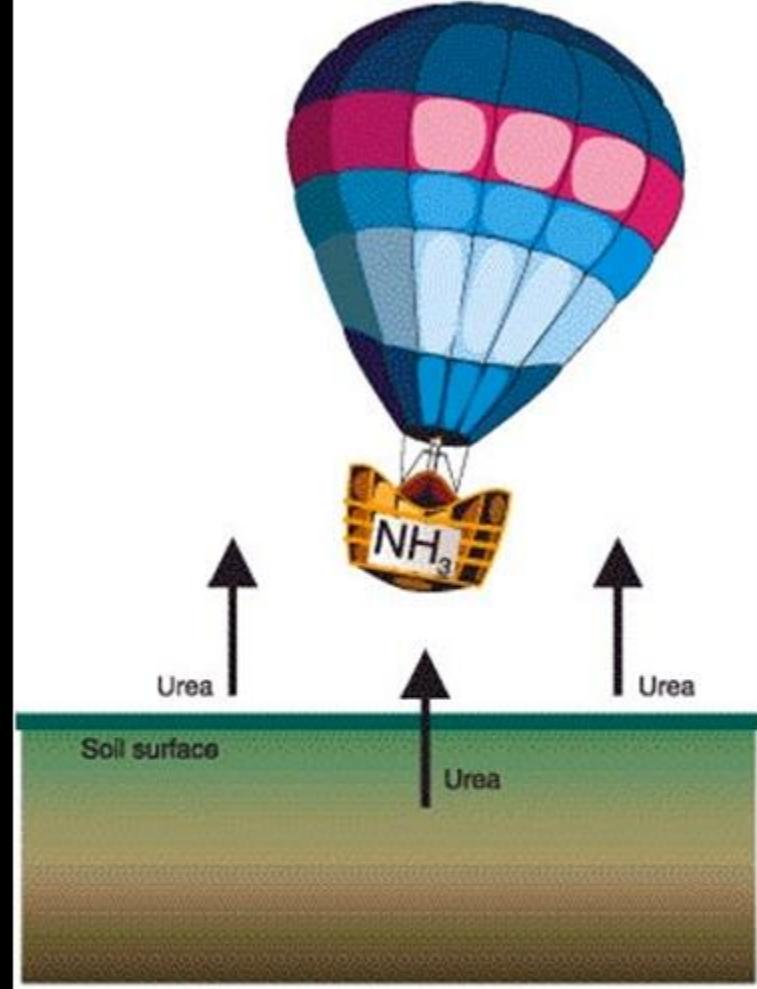
## CONDITIONS NECESSARY FOR SIGNIFICANT DENITRIFICATION

- $\text{NO}_3^-$  must be available
- Availability of readily decomposable organic compounds
- Soil air should contain less than 10%  $\text{O}_2$  ( $>0.2 \text{ mg/L}$  of dissolved  $\text{O}_2$ )
- Temperature should be  $2\text{-}50^{\circ}\text{C}$  (Optimum temperature  $25\text{-}35^{\circ}\text{C}$ )
- Very strong soil acidity ( $\text{pH}<5$ ) inhibits rapid denitrification.

# VOLATILIZATION

- Volatilization is the loss of nitrogen to the atmosphere as ammonia gas.
- Ammonia is released into the atmosphere and no longer available to the plant.
- Ammonia production and loss is typically associated with urea hydrolysis in soils.
- In urea hydrolysis, the pH of urea is increased drastically and the proportion of nitrogen in the ammonium form is shifted towards ammonia.
- Urea may originate from animal manure, urea fertilizers and, to a lesser degree, the decay of plant materials.

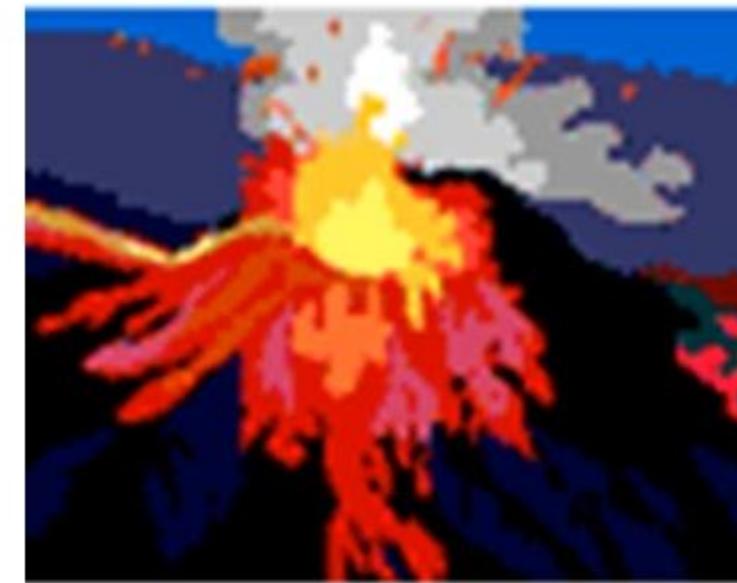
- Ammonia volatilization is most likely to take place when soils are moist and warm and the source of urea is on or near the soil surface.
- Ammonia volatilization will also take place on alkaline soils (pH greater than 8).
- Incorporation of manure and fertilizers in to the top few centimeters of soil can reduce  $\text{NH}_3$  losses by 25-75%.



## Other ways that nitrogen returns to the atmosphere...



Emissions from industrial combustion and gasoline engines create nitrous oxides gas ( $N_2O$ ).



Volcano eruptions emit nitrous oxides gas ( $N_2O$ ).

## AMMONIUM FIXATION

- $\text{NH}_4^+$  ions get trapped between layers of clay particles. This is called as ammonium fixation.
- $\text{NH}_4^+$  becomes unavailable to plants and they are released only slowly to higher plants and microbes.
- Ammonium fixation by clay minerals is generally greater in subsoil than in topsoil due to the higher clay content of subsoils.
- While ammonium fixation may be considered an advantage because it provides a means of conserving nitrogen, the rate of release of the fixed ammonium is often too slow to be of much practical value in fulfilling the needs of fast growing annual plants.

- $\text{NH}_4^+$  ions are attracted to the negatively charged surfaces of clay and humus.



Held in exchangeable form



Available for plant uptake



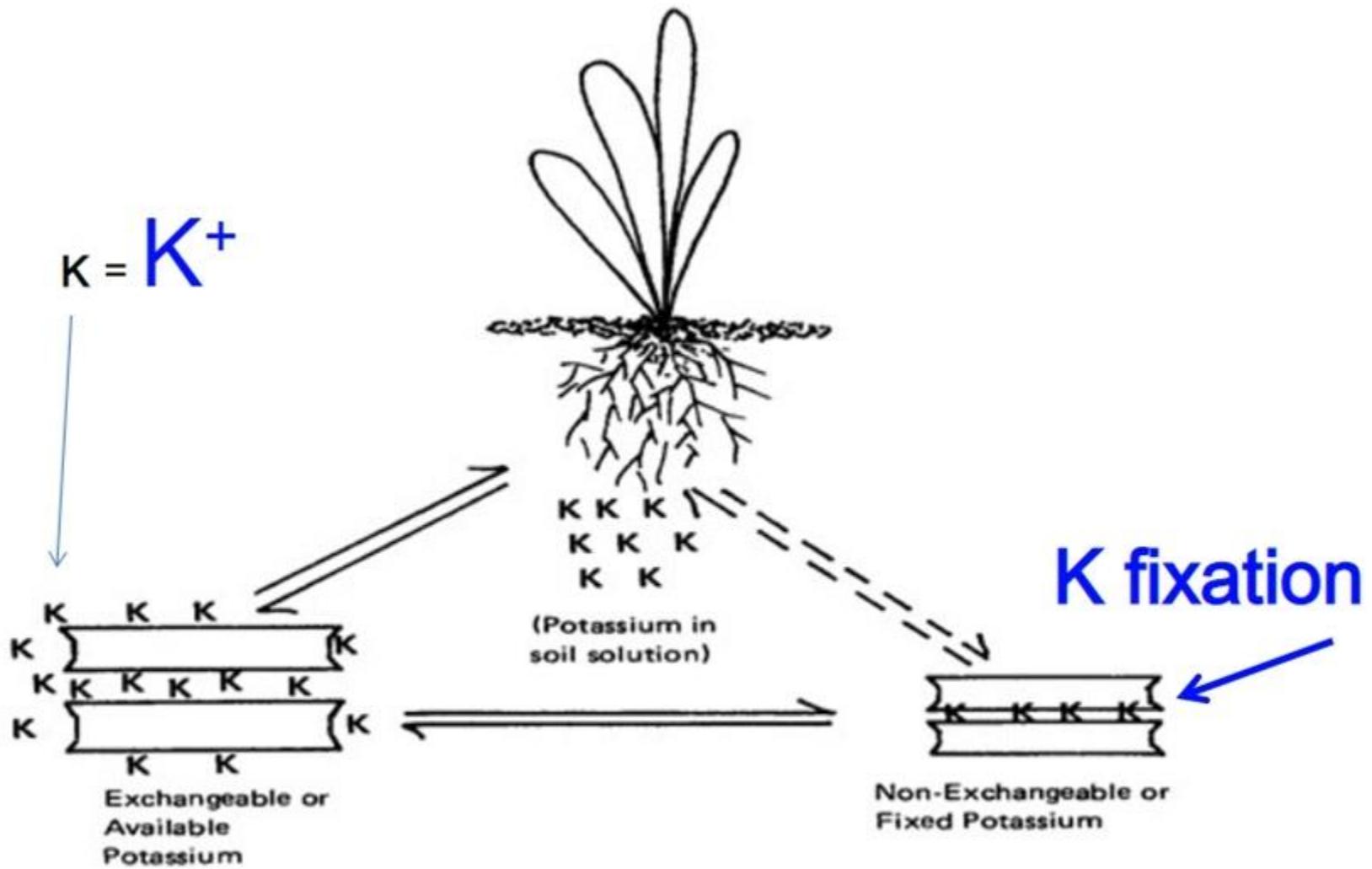
Partially protected from leaching

- Sometimes, it can become entrapped within cavities in the crystal structure of certain clays

Held in non-exchangeable form

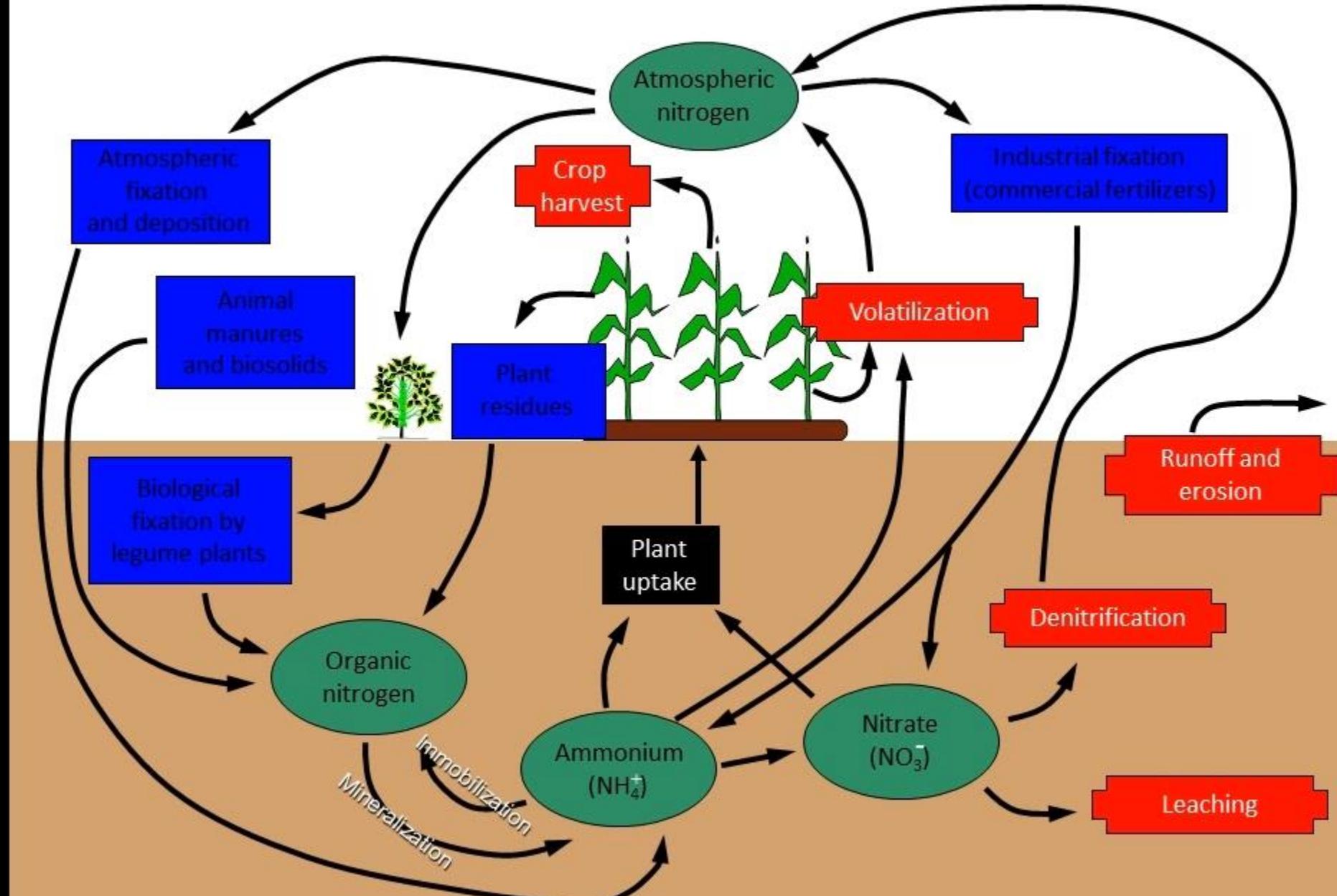
Slowly released to higher plants

protected from leaching



# THE NITROGEN CYCLE

Component      Input to soil      Loss from soil

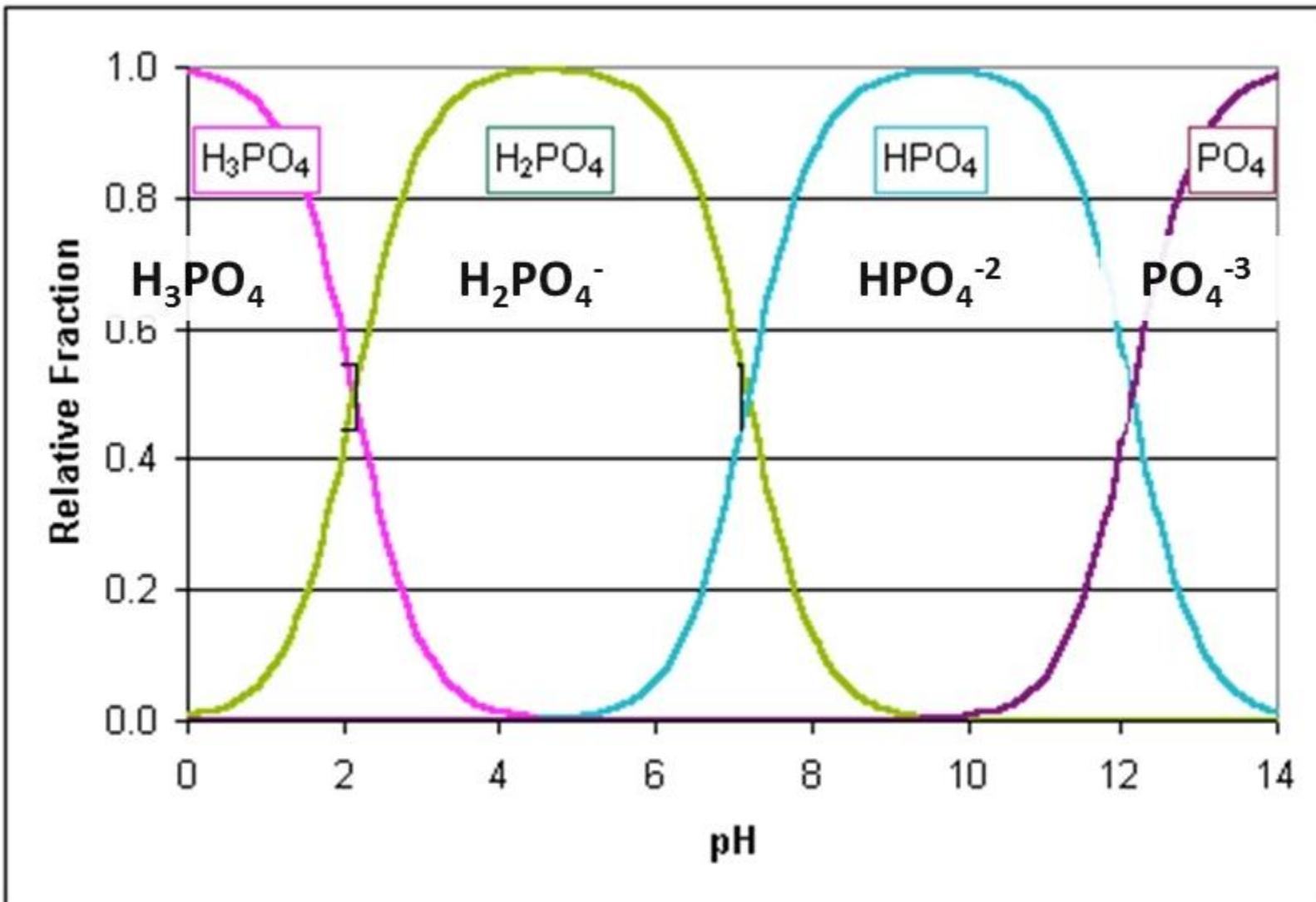


# PHOSPHORUS (P)

- In world Agriculture, management of P is second only to management of N in its importance for the production of healthy plants and profitable yields.
- The P problem
  - Low total soil P
  - Most P is insoluble and unavailable
  - P is quickly fixed

# PHOSPHORUS IN SOIL SOLUTION

- Concentration is very low (0.001 – 1 mg/L).
- Plants roots absorb P mainly as phosphate ions ( $\text{HPO}_4^{2-}$  and  $\text{H}_2\text{PO}_4^-$ ).
- P present in soil solution is determined by the solution pH.
- The dominates ion of strongly acid soil (pH 4.5-5) is  $\text{H}_2\text{PO}_4^-$  and  $\text{HPO}_4^{2-}$  dominates in alkaline soil



Various forms of phosphate ions in soil solution at different pH levels

## CHEMICAL FORMS OF P IN SOILS

- ❖ Both organic and inorganic forms P occur in soils, and both are important to plants as sources of P
  - ❖ The organic fraction generally constitutes 20-80% of the total P in surface soil horizons.
  - ❖ The deeper horizon may hold large amounts of inorganic P, especially in soils from arid and semiarid regions.
  - ❖ Generally exists three groups of compound
    - Organic P
    - Ca – bound inorganic P
    - Fe or Al- bound inorganic P
- } Inorganic

# ORGANIC P

- Most of the organic P compounds in soils are believed to have been synthesized by microbes.

## 1. Inositol phosphates or phosphates esters of sugar like compound

- ✓ Most abundant (10-50% of organic P)
- ✓ Quite stable in acid and alkaline conditions
- ✓ Interact with high molecular weight compound

## 2. Nucleic acid

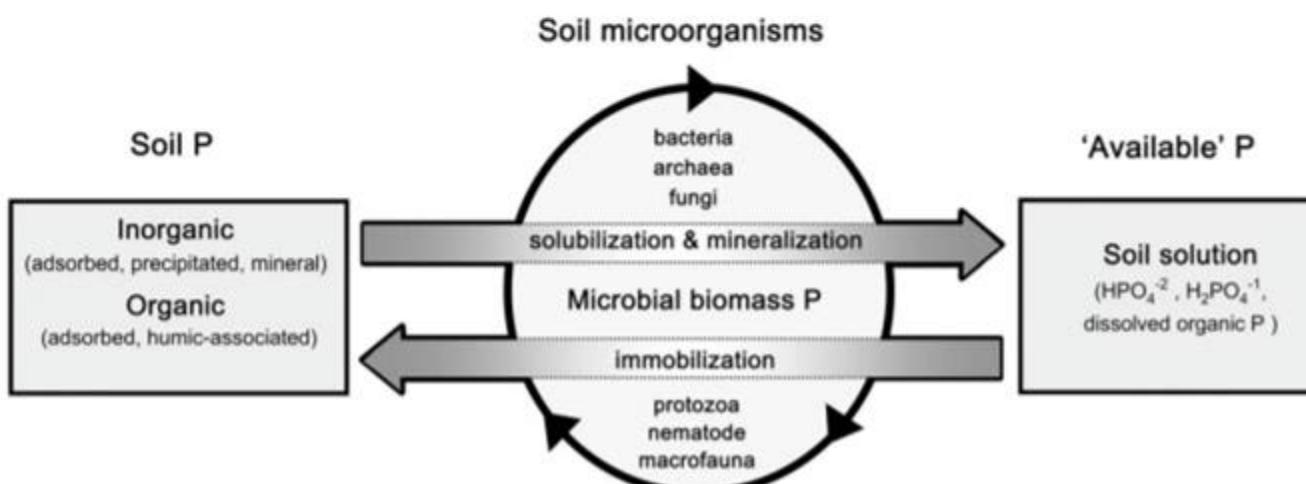
- ✓ Adsorbed by humic compounds and silicate clays

## 3. Phospholipids

- ✓ Phospholipids + Nucleic acid make 1 – 2% of the organic P in most soils

# MINERALIZATION AND IMMOBILIZATION OF ORGANIC P

- P held in organic form can be mineralized and immobilized by the same general process that release nitrogen from SOM
- Soluble P compounds are released when organic residues and humus decompose
- The resulting  $H_2PO_4^-$  ion is subject to uptake by plants or to fixation in to insoluble forms by reaction with Fe, Al, Mn, and Ca in soils



## INORGANIC P

- The concentration of inorganic P in the soil solution at any given time is very small.
- Most inorganic P compounds in soil fall in to two groups

- **Ca – bound inorganic P**
  - Ca-phosphate compounds become more soluble as soil pH decreases.
  - When pH goes up they are quite stable and very insoluble.
  - Ca-phosphate are the dominant forms of in neutral to alkaline soils.

Ex: Monocalcium phosphate  $\text{Ca}(\text{H}_2\text{PO}_4)_2 \cdot \text{H}_2\text{O}$

Dicalcium phosphate  $\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$

Tricalcium phosphate  $\text{Ca}_3(\text{PO}_4)_2$

Octacalcium phosphate  $\text{Ca}_8\text{H}_2(\text{PO}_4)_6 \cdot 5\text{H}_2\text{O}$

- Fe or Al- bound inorganic P
  - The Fe and Al hydroxy phosphate minerals have very low solubility in strongly acid soils.
  - When pH rise, become more soluble.
  - Quite stable in alkaline soils, but are prominent in acid soils.

Ex:      Strengite                   $\text{FePO}_4 \cdot 2\text{H}_2\text{O}$   
            Variscite                   $\text{AlPO}_4 \cdot 2\text{H}_2\text{O}$

# FACTORS CONTROLLING AVAILABILITY OF INORGANIC SOIL P

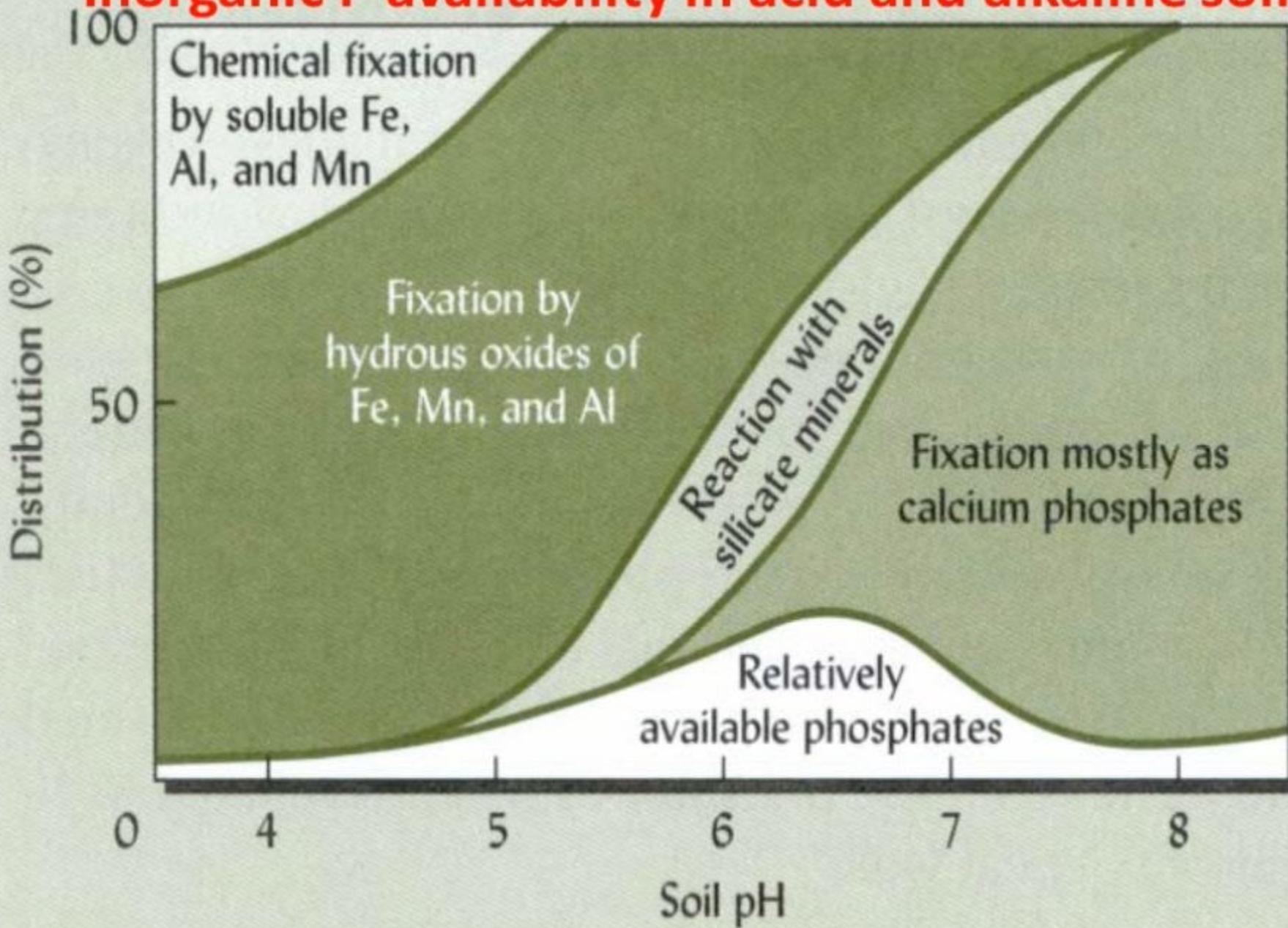
- Soil pH
- Soluble Fe, Al and Mn
- Presence of Fe, Al and Mn containing minerals
- Availability of Ca and Ca minerals
- Amount and decomposition of organic matter
- Activities of microorganisms



## FIXATION AND RETENTION

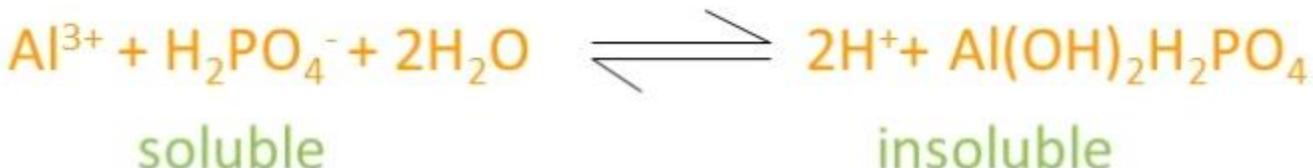
- Dissolved phosphate ions in mineral soils are subject to many types of reactions that tend to remove the ions from the soil solution and produce P containing compounds of very low solubility.
- These reactions are sometimes collectively referred to by the general terms P fixation and retention.

## Inorganic P availability in acid and alkaline soils



## 1. Precipitation by Fe, Al and Mn ions

- Some soluble Fe, Al and Mn are usually found in strongly acid mineral soils.
  - Reaction with the  $\text{H}_2\text{PO}_4^-$  could immediately occur, resulting in the formation of insoluble hydroxy phosphates.



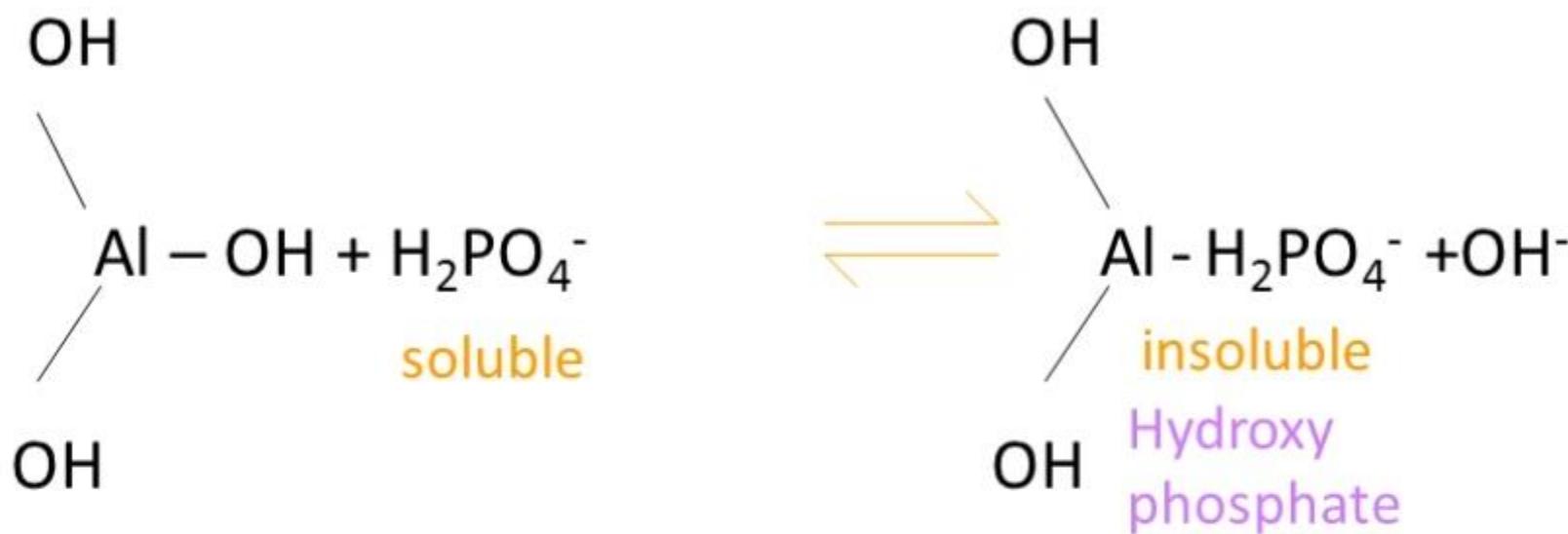
- In most strongly acid soils the concentration of the Fe and Al ions greatly exceeds that of the  $\text{H}_2\text{PO}_4^-$  ions.
- The reaction moves to right, forming the insoluble phosphates.
- This leaves only minute quantities of the  $\text{H}_2\text{PO}_4^-$  ion immediately available for plants.

## 2. Reaction with hydrous oxides

The  $\text{H}_2\text{PO}_4^-$  ions react not only with Fe, Al and Mn ions but even more extensively with insoluble hydrous oxides of these elements.

Ex: gibbsite  $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$

geothite  $\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$



- Fixation of P by this mechanism probably takes place over a relatively wide pH range.

### 3. Fixation by silicate clays

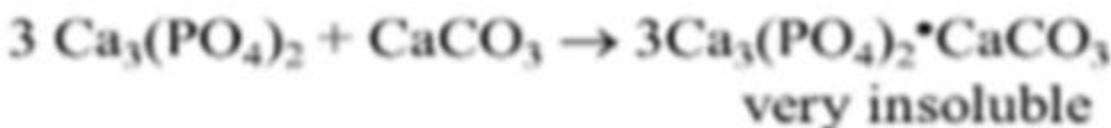
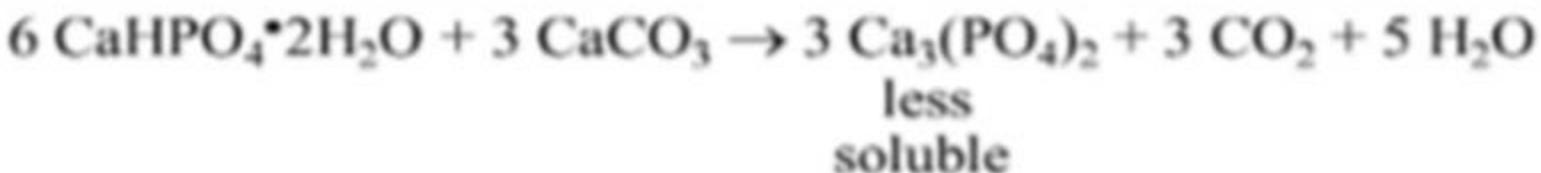
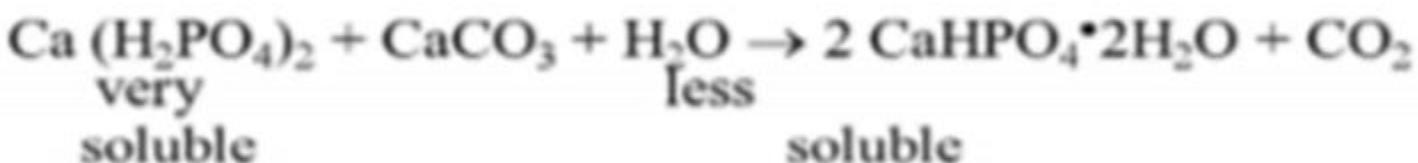
- Fixation of P under moderately acid conditions involves silicate minerals such as Kaolinite.
- Although, there is some doubt about the actual mechanisms involved, the overall effect is essentially the same as when P is fixed by similar Fe and Al compounds.



(in silicate crystal)

## Inorganic P availability in alkaline soils

- In alkaline soils soluble  $\text{H}_2\text{PO}_4^-$  quickly reacts with calcium to form a sequence of products of decreasing solubility

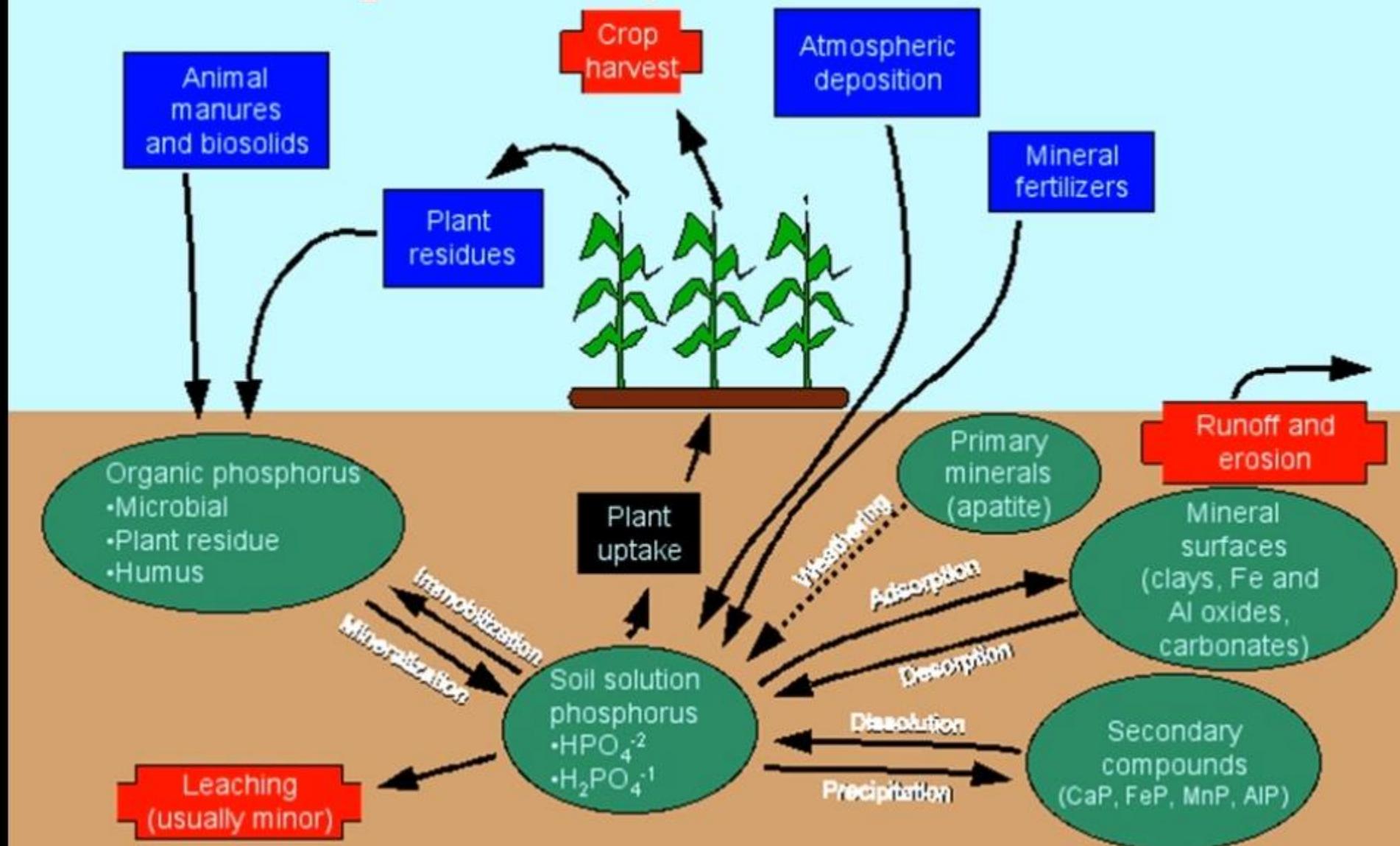


Component

Input to soil

Loss from soil

# The Phosphorus Cycle



# POTASSIUM (K)

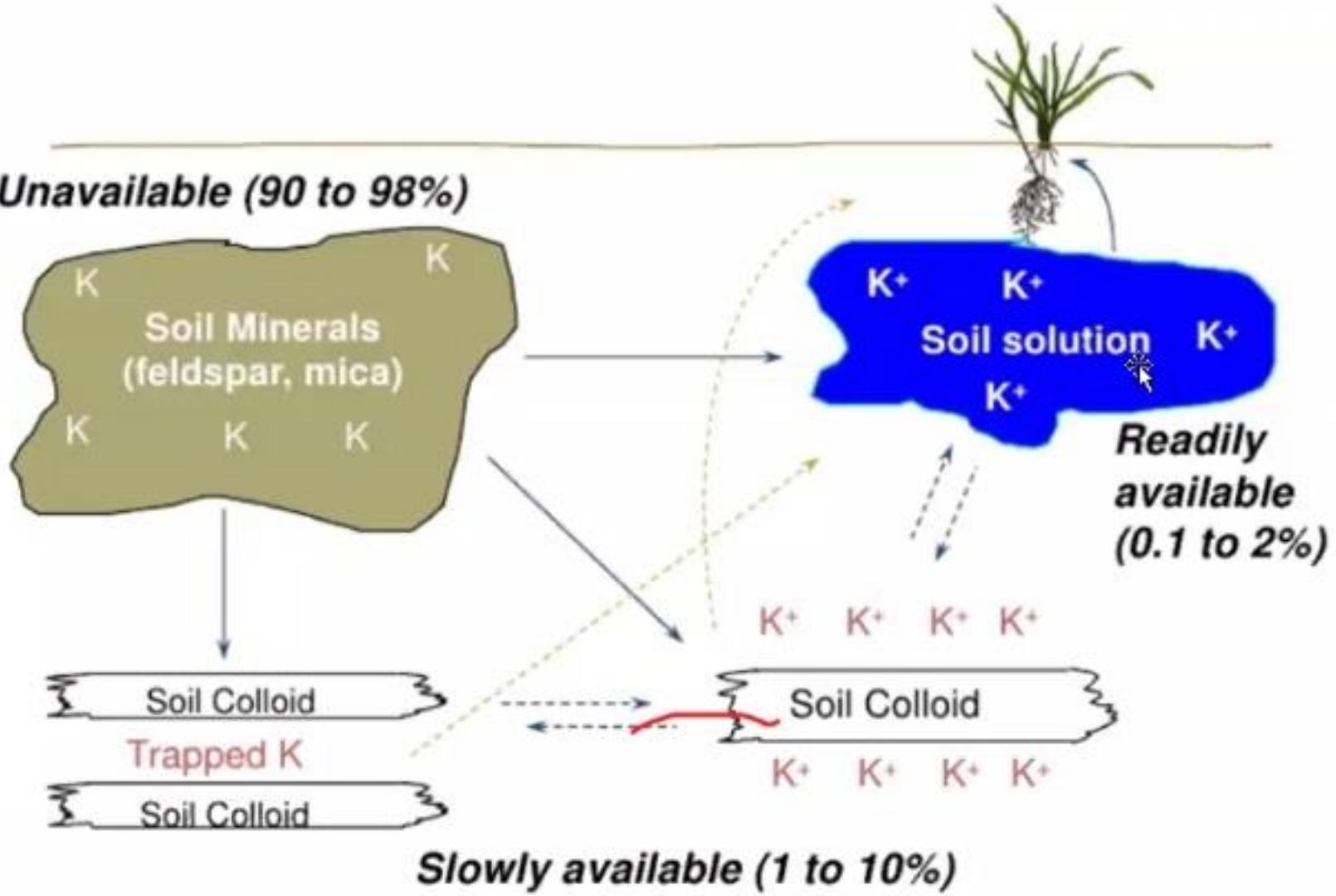
- Of the elements essential for plants, K and Ca are the abundant in the earth's crust (K - 2.6% and Ca – 3.6%).
- K is not complexed or bound up in to organic matter to any degree, compared to N; essentially all of it associated with mineral fraction.
- K is present in the soil solution only as a positively charged cation,  $K^+$ .

- Soil K is mostly mineral, and the daily K needs of plants are little affected by organic associated K except for exchangeable K adsorbed on organic matter.
- Weathering of K minerals is the major process for converting unavailable K in to forms that plant can use.

## 1. Relatively unavailable form

- 90-98% of all soil K in mineral soil in relatively unavailable forms.
- The compounds containing most this form of K are the feldspar and micas.
- Those minerals are quite resistant to weathering and supply relatively small quantities of K during a given growing season.

### **Unavailable (90 to 98%)**



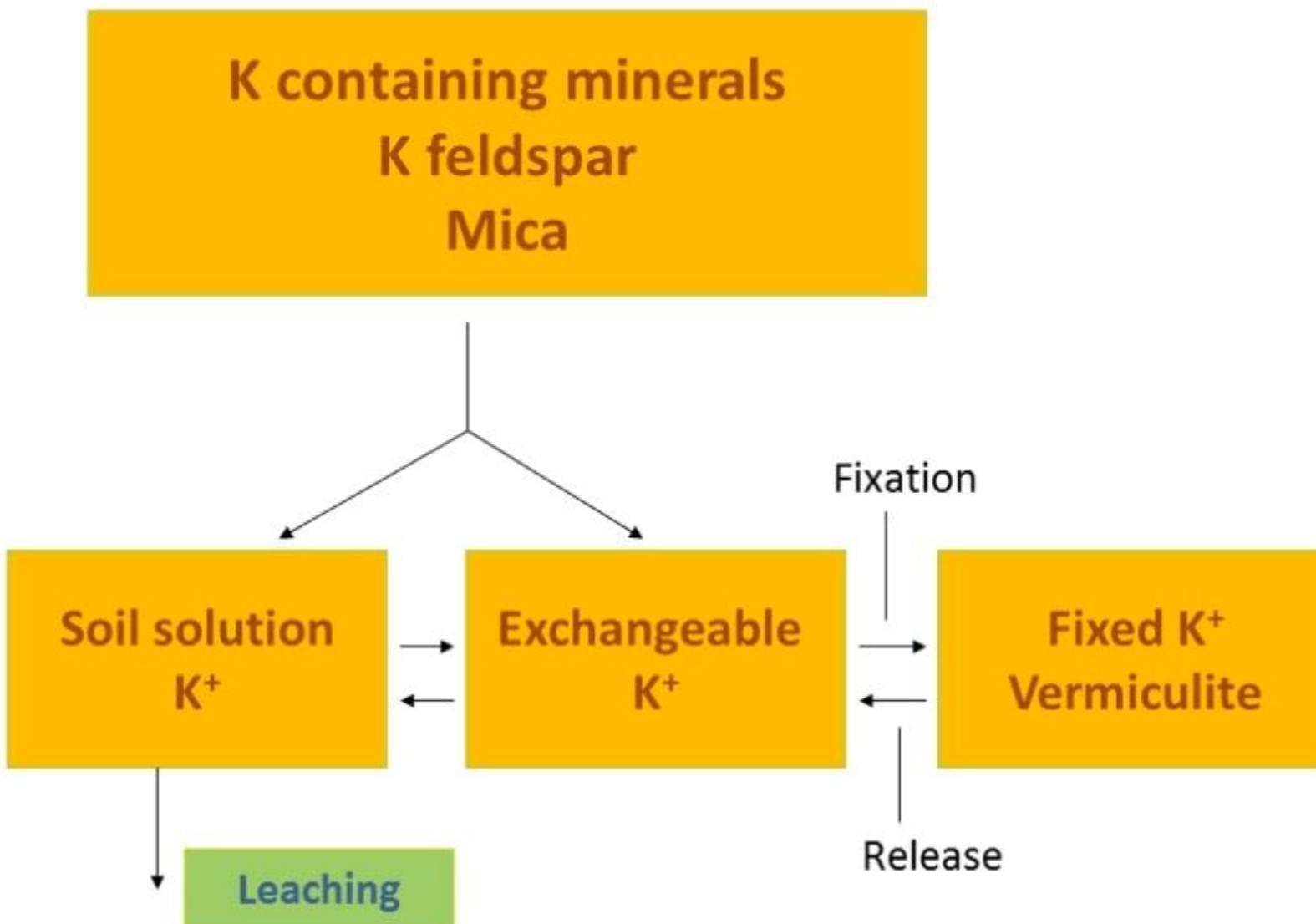
## 2. Readily available forms

- Only 1-2% of the total soil K readily available.
- Available K exist in soils in two forms
  1. In the soil solution
  2. As exchangeable K adsorbed in the soil colloidal surface
- Although most of this available K is in exchangeable form (approximately 90%), soil solution K is most readily absorbed by higher plants.
- K in soil solution is subject to considerable leaching losses.

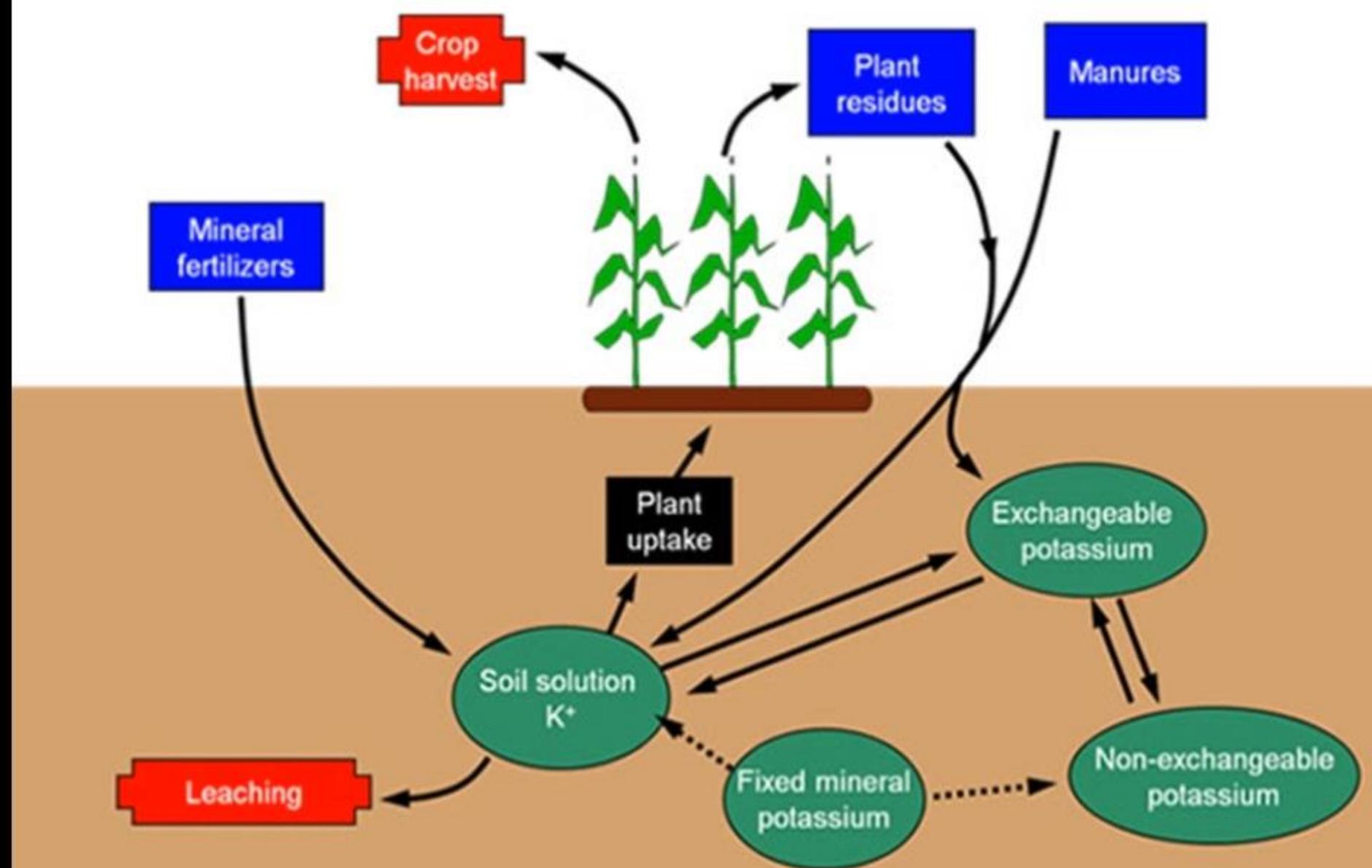
### 3. Slowly available forms

- In the presence of vermiculite, smectite and other 2:1 type minerals, the K<sup>+</sup> ions ( $\text{NH}_4^+$ ) in the soil solution (or added as fertilizers) not only become adsorbed but also may become definitely 'fixed' by soil colloids.
- These ion can't be replaced by ordinary exchange methods and consequently are referred to as 'non exchangeable' ions.
- The fixed K is continually release to the exchangeable form in amounts large enough to be of great practical importance.

# FORMS AND AVAILABILITY OF K IN SOILS



# The Potassium Cycle



## AVAILABILITY OF POTASSIUM IN SOILS

- In contrast to P, K is found in comparatively high levels in most mineral soils, except those containing mostly of quartz sand.
- In fact, the total quantity of K is generally greater than that of any other major nutrient element.
- However, the quantity of K held in an easily exchangeable form at any one time is very small.
- Most of the K is held rigidly as part of the primary minerals or is fixed in forms that are at best only moderately available to plants.

## LEACHING LOSSES OF K

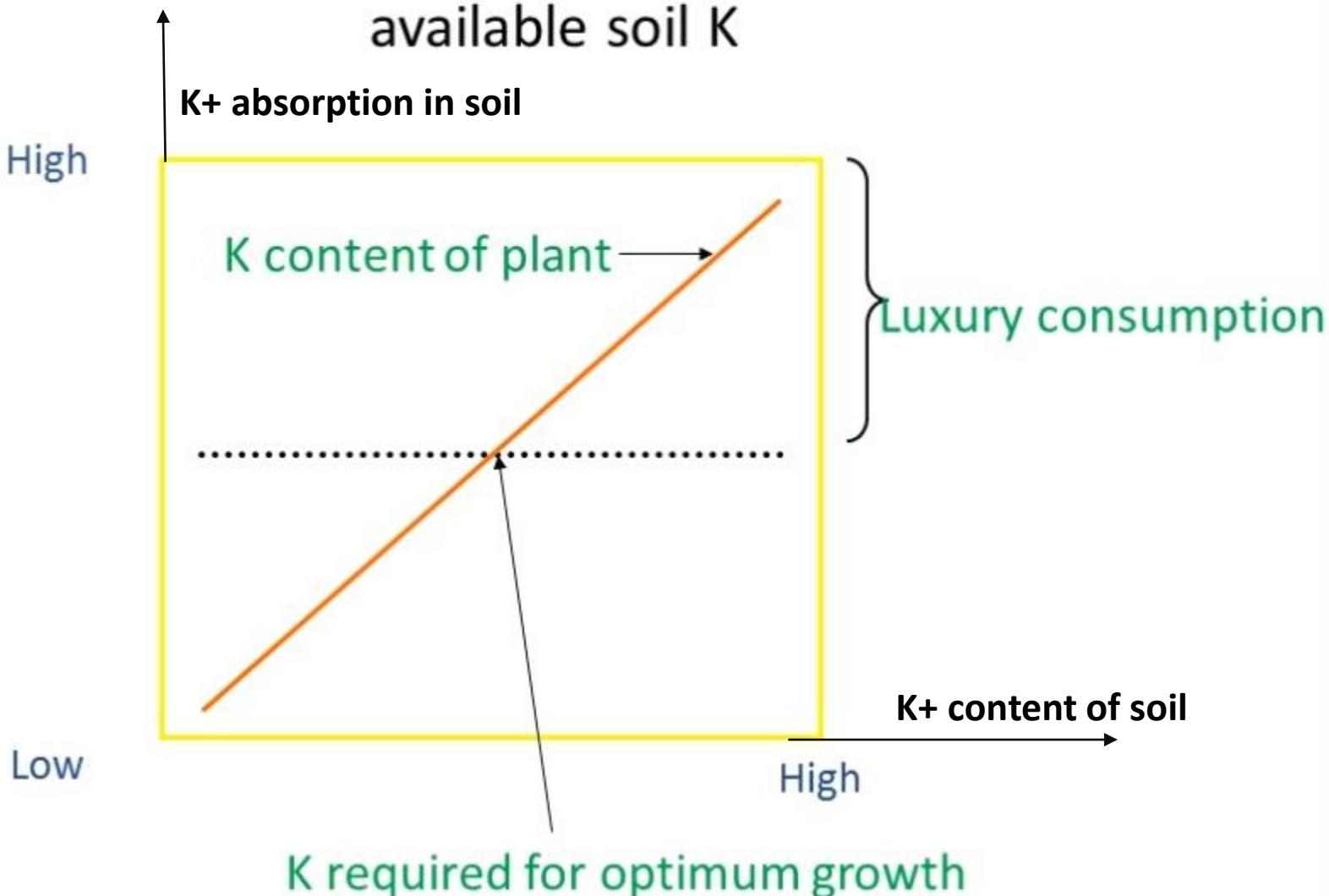
- K is much more readily lost by leaching compared to P.
- Drainage waters from soils receiving liberal fertilizer applications usually contain high quantities of K.
- Liming an acid soil to raise its pH can reduce the leaching losses of K due to the complementary ion effect in cation exchange.
- In a limed soil, where higher levels of exchangeable  $\text{Ca}^{2+}$  and  $\text{Mg}^{2+}$  are present, monovalent  $\text{K}^+$  ions are better able to replace them on the exchange complex.

## PLANT UPTAKE AND REMOVAL OF K

- Plants take up very large amounts of K, often five to ten times as much as for P and about the same amount as for N.
- If most or all of the above plant parts are removed in harvest, the drain on the soil supply of K can be very large.
- This situation is made even more critical by the tendency of the plants to take up soluble K far in excess of their needs if sufficiently large quantities are present.
- This tendency is termed luxury consumption, because the excess K adsorbed does not increase crop yields to any extent.

# LUXURY CONSUMPTION

Relationship between the K content of plants and the available soil K



## CALCIUM (CA) AND MAGNESIUM (MG)

- Both them are released from minerals by weathering and occur as exchangeable ion.
- They are highly available in soil solution than K.
- Plant needs relatively low amount of Ca and Mg compared with K.
- Also Ca deficiencies in plants are rare, and Mg deficiencies occur only occasionally.

# SULFUR (S)

- Sulfur exists in several minerals forms in soils, with sulfide and sulfate minerals.
- The sulfate minerals are most easily solubilized and the sulfate ion is easily assimilated by plants.
- Sulfur is important constituent of the precipitation.
- So, in many location more S is added to soils than plants need.

# MICRONUTRIENTS

- Micronutrients are required in very small amounts and function largely in plant-enzyme systems.
- The factors that determine the amounts of micronutrients available to plants are closely related to soil conditions and plant species.

## **BORON (B)**

- Helps in the use of nutrients and regulates other nutrients.
- Aids production of sugar and carbohydrates.
- Essential for seed and fruit development.
- Sources of boron are organic matter and borax

## COPPER (Cu)

- Important for reproductive growth.
- Aids in root metabolism and helps in the utilization of proteins.

## CHLORIDE (Cl)

- Aids plant metabolism.
- Chloride is found in the soil.

## IRON (Fe)

- Essential for formation of chlorophyll.
- Sources of iron are the soil, iron sulfate, iron chelate.

## MANGANESE (Mn)

- Functions with enzyme systems involved in breakdown of carbohydrates, and nitrogen metabolism.
- Soil is a source of manganese.

## MOLYBDENUM (MO)

- Helps in the use of nitrogen
- Soil is a source of molybdenum.

## ZINC (Zn)

- Essential for the transformation of carbohydrates.
- Regulates consumption of sugars.
- Part of the enzyme systems which regulate plant growth.
- Sources of zinc are soil, zinc oxide, zinc sulfate, zinc chelate.

**Thank You!**