MINERAL NUTRITION

How the plants obtain and use mineral nutrients

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Mineral Nutrition

How plants absorb and use mineral nutrients

1. Important of mineral nutrition
2. What are the essential and non essential mineral nutrients
3. Mineral nutrients in the soil- availability / adsorption
4. Roots and mineral nutrient gaining- root structure / depletion zones

Nutritional needs of plants

Plant cells contain more than 60 different kinds of elements like N, P, K, Ca, Mg, S, Fe, Cl, Mn, B, Zn, Cu, Mo etc

Essential elements:

- Required for normal growth and reproduction. Their absence inhibits plant growth and development/ life cycle.
- Have a definite biological / physiological role, have a direct or indirect action in plant metabolism
- **Part of an essential molecule *i.e.,* DNA, ATP, Protein Etc.** (macromolecule, metabolite)
- No other element may substitute / replace it and correct the deficiency

- Biochemical role and physiological function

- According to relative concentration in plants :

  17 elements can classified as
  - **9 macronutrients**
  - **8 micronutrients**

All essential mineral nutrients contribute less than 4% of plant mass, **yet** plant growth is very sensitive to mineral deficiency.

TABLE 5.1
Adequate tissue levels of elements that may be required by plants **(Part I)**

Element	Chemical symbol	Concentration in dry matter (%)[a]	Relative number of atoms with respect to molybdenum
Obtained from water or carbon dioxide → **Not considered mineral nutrients**			
Hydrogen	H	6	60,000,000
Carbon	C	45	40,000,000
Oxygen	O	45	30,000,000
Obtained from the soil			
Macronutrients			
Nitrogen	N	1.5	1,000,000
Potassium	K	1.0	250,000
Calcium	Ca	0.5	125,000
Magnesium	Mg	0.2	80,000
Phosphorus	P	0.2	60,000
Sulfur	S	0.1	30,000
Silicon	Si	0.1	30,000

Source: Epstein 1972, 1999.

[a] The values for the nonmineral elements (H, C, O) and the macronutrients are percentages. The values for micronutrients are expressed in parts per million.

Micronutrients are present in **very low concentrations**

TABLE 5.1
Adequate tissue levels of elements that may be required by plants **(Part 2)**

Element	Chemical symbol	Concentration in dry matter ppm)[a]	Relative number of atoms with respect to molybdenum
Micronutrients	**Very low concentrations, but still essential because of specialized roles in metabolism**		
Chlorine	Cl	100	3,000
Iron	Fe	100	2,000
Boron	B	20	2,000
Manganese	Mn	50	1,000
Sodium	Na	10	400
Zinc	Zn	20	300
Copper	Cu	6	100
Nickel	Ni	0.1	2
Molybdenum	Mo	0.1	1

Source: Epstein 1972, 1999.
[a] The values for the nonmineral elements (H, C, O) and the macronutrients are percentages. The values for micronutrients are expressed in parts per million.

The proportional weights of different inorganic element in plants are

Carbon, hydrogen, oxygen | Others

Macronutrients (3-5%)

Minerals found in **more than 1000 ppm** concentration

(present at > 10 mmol / kg dry wt.)

N, P, K, Ca, Mg, S

Micronutrients (0.5%)

Minerals found in **less than 100 ppm** concentration

(< 10 mmol / kg dry wt.)

Fe, Cl, Mn, B, Zn, Cu, Mo

Generalizations of Nutrition Requirement :

- plants require **different amounts** of **different element**
- different elements are absorbed in **different ionic forms** (ex. cation – anion)
- Plants can absorb/ accumulate an element although there is no specific requirement of such element
- Plants can accumulate an element although it is not considered to be an essential element
- Almost all elements have **several functions**

General functions of essential elements :

- Can be parts of structural molecules (ex. C, N)
- Can be parts of compounds, involved in metabolism (ex. Mg, P)
- Can be function as enzyme activators or sometimes as inhibitor
- Can help to maintain the osmotic balance (ex. K)
- Part of organic molecules (ex. N, S)
- Important in energy storage

  or structural integrity (P, Si, B)
- Involved in energy transfer reaction (Fe, Zn, Cu, Ni, Mo)

Mineral element deficiencies produce visible symptoms

- When any mineral is deficient, the growth of the plant is stunted and the plant also shows other deficiency symptoms.
- The combination of all observe symptoms can be traced to the roles that mineral plays in metabolism or physiology.

Mineral defficiensies disrupt metabolism and function

Inadequate supply

↓

Mineral nutritional disorders

↓

All related disorders are the results of essential elements in normal metabolims

↓

Characteristics defficiencies symptoms

Mobility of Mineral Elements in Phloem

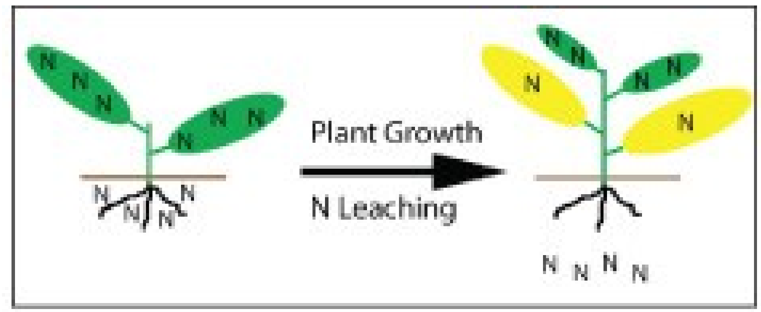
- **Mobile Nutrients** – Nutrient has moved to the younger parts of the plants. Deficiencies typically appear on older growth first.
- **Immobile nutrients** – When the soil is exhausted of mineral the younger zones suffer the symptoms because the minerals are held by the older leaves. Deficiencies typically appear on newer growth and shoot tips first. initially sequestered in younger leaves which are now the oldest ones.

Mobility and re-translocate

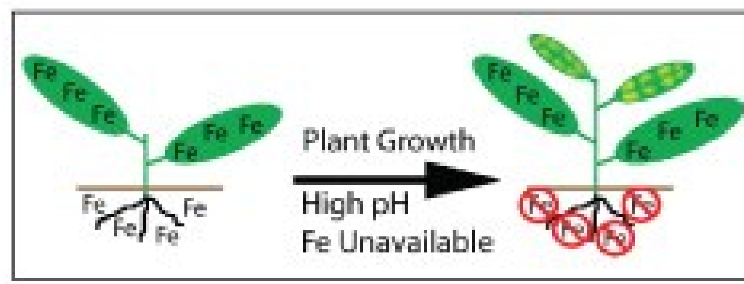
TABLE 5.4
Mineral elements classified on the basis of their mobility within a plant and their tendency to retranslocate during deficiencies

Mobile	Immobile
Nitrogen	Calcium
Potassium	Sulfur
Magnesium	Iron
Phosphorus	Boron
Chlorine	Copper
Sodium	
Zinc	
Molybdenum	

Note: Elements are listed in the order of their abundance in the plant.

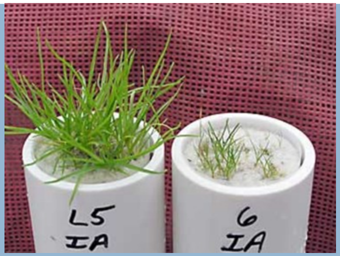


Nitrogen can be mobilized within a plant to support growth of new leaves.



Iron cannot be mobilized within a plant to support new growth. When iron becomes unavailable, new growth shows deficiency symptoms first.

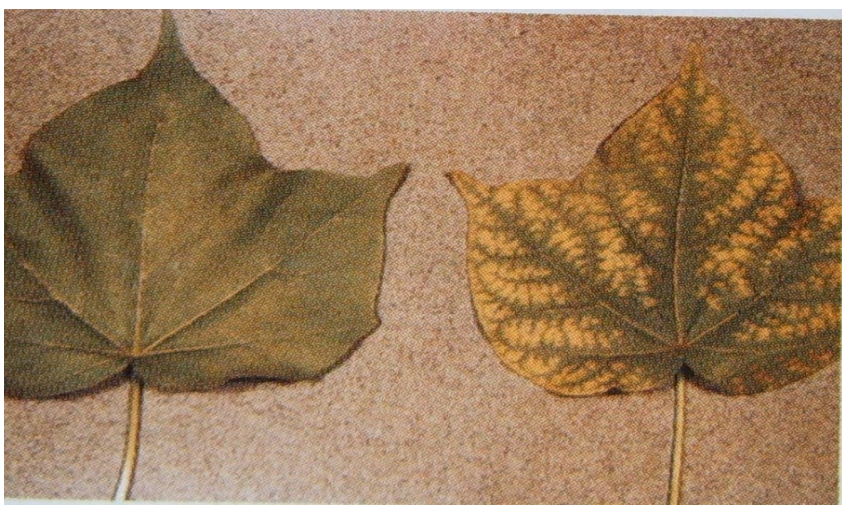
Some common deficiency symptoms

Stunted growth : N deficiency ~ stem P deficiency ~ root	
Chlorosis (Mg, N, and Fe deficiencies) : chlorophyll synthesis ↓ chlorophyll degradation ↑	
Necrosis : dead spots or zones on leaf (Mg, K or Mn deficiency)	
Color changes : ex. excessive anthocyanin production in stems ~ P deficiency	

N deficiency

P deficiency

K deficiency



Mg deficiency

Zn deficiency

The shortage in soil of any essential elements causes deficiency symptoms

- Essential because of their various metabolic functions
- Characteristic deficiency symptoms shown because of their specific roles
- Usual deficiency responses are
  - **Chlorosis:** yellowing; precursor to
  - **Necrosis:** tissue death
- Deficiency symptoms become visible when a supply of an essential metabolite becomes limiting in the environment
- Element concentrations are limiting for growth when they are below the **critical concentration**

Limiting nutrient levels negatively affect growth

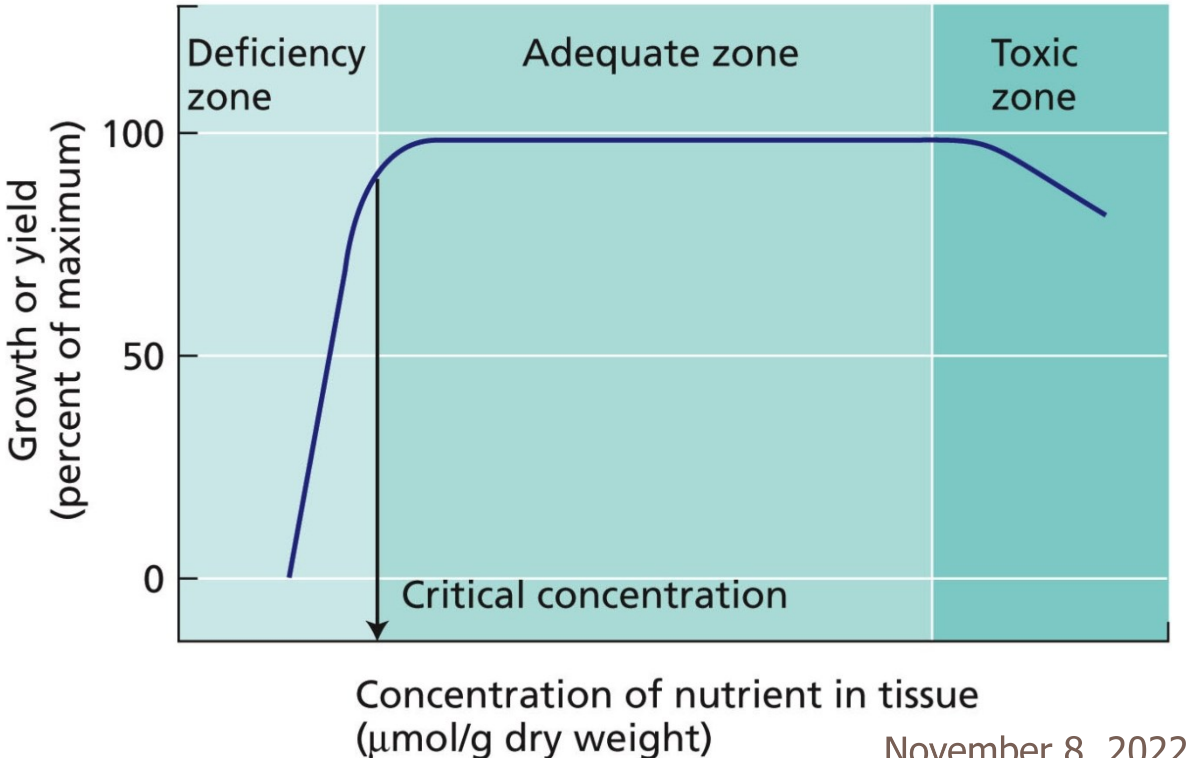
- Plant responses to limiting nutrients usually very visible **affects yield/growth**
- Chlorosis and/ or necrosis of leaves are typical symptoms
- Sometimes shows straightforward relationship, e.g., in chlorosis (lack of green color),
  - N: chlorophyll component
  - Mg: co-factor in chlorophyll synthesis

Analysis of plant tissues reveals mineral deficiencies

Analysis of nutrient levels

Soil analysis:
Determination of minerals nutrient content in soil sample near the root zone

Plant tissue analysis



Minerals present in >1000 ppm concentration are macronutrients

	Role	Symptoms
P	**Part of nucleic acid, phospholipid, ATP**	**stunted, dark leaves, necrotic spots, anthocyanin in stem and leaves, thin weak stem**
K	**ion balance, and part of respiratory enzymes**	**marginal chlorosis, necrosis at tips and edges, curled/crinkled leaves, old leaves first, short weak stems, susceptible to diseases**
N	**Part of amino acids, nucleic acids**	**stunted, chlorosis of older leaves, abscission, thin stems with lignin or anthocyanin as "sink" for photosynthate**
S	**Part of cysteine, methionine, CoA, etc.**	**chlorosis of young leaves first**
Ca	**Part of enzyme cofactor, cyclosis, pectins**	**hooked leaves, necrosis of young meristems, severe stunting as meristems die**
Fe	**Present in cytochromes in resp., photosynth. and enzymes**	**chlorosis between veins on young leaves first**
Mg	**Part of chlorophyll**	**chlorosis between veins on older leaves first, early**

Minerals present in <100 ppm concentration are micronutrients (1)

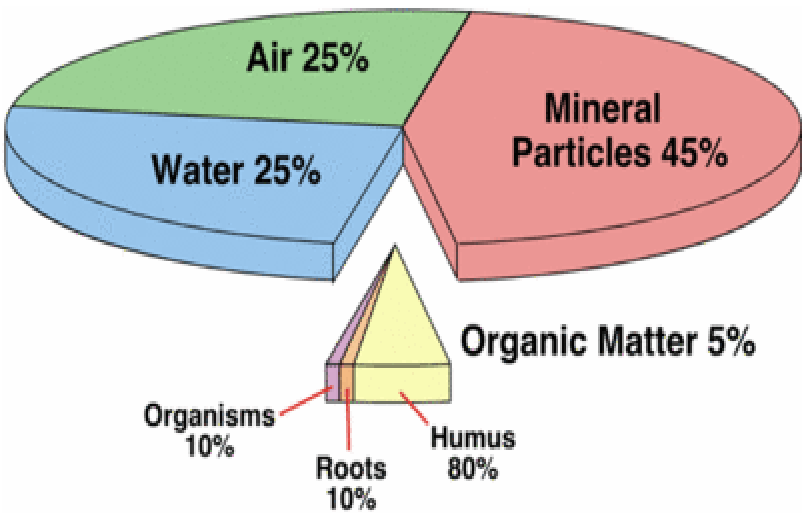
	µmol g^{-1}	Role	Symptoms
Co		Part of enzyme cofactor	controversial?
Mn	1	Part of some resp/photolysis enzyme cofactor	chlorosis and small necrotic spots throughout plant
Cu	0.1	Part of enzymes, plastocyanin, cytochrome oxidase	dark green leaves with necrotic spots at tips of young leaves, early abscission
Zn	0.3	Part of enzyme cofactor, chlorophyll synthesis, IAA synthesis	decrease internode length (rosette look), puckered leaf margins, chlorosis of older leaves with white necrotic spots
B	2	Required for pollen tube growth and orientation, nucleic acid synthesis, membrane synthesis	black necrosis at base of young leaves and buds, stiff/brittle stems, meristem death followed by excessive branching

Minerals found in <u><100 ppm</u> concentration are <u>micronutrients (2)</u>

	μmol g^{-1}	Uses	Symptoms
Mo	**0.001**	**Part of nitrate reductase cofactor**	**enzyme converts nitrate into nitrite so symptoms are like N deficiency**
Si	**(30)**	**Required for cell wall rigidity in *Equisetum* and grasses**	**soft stems that lodge (fall over)**
Ni	**0.002**	**Part of urease cofactor**	**urea accumulates in leaf tips causing necrosis, unlikely in field**
Al		**Part of enzyme cofactor**	**difficult to have too little-toxicity more likely**
Cl	**3**	**Required for ion balance, photolysis, cell division**	**wilting leaf tips, bronze leaves, rare to be deficient in field**
Na	**0.4**	**Required for regeneration of PEP step C-4**	**chlorosis, necrosis, flowering failure in C-4 plants only**

SOIL

- Most of soils contain five basic components: **mineral particles**, **water**, **air**, **microbes** and **organic matter**. Organic matter can be further sub-divided into humus, and roots.
- **Humus** is the decomposing (by fungi and bacteria) organic matter of soil; biochemical substance that make upper layer of the soil become dark. Most plants grow **best in soil containing 10-20 % humus**



Type of Mineral Particle	Size Range
Sand	2.0 - 0.06 millimeters
Silt	0.06 - 0.002 millimeters
Clay	less than 0.002 millimeters

http://www.physicalgeography.net/fundamentals/10t.html

Components of soil

Humus

- Is the decomposing organic material in soil by fungi and bacteria
- Biochemical substance that make upper layer of the soil become dark
- Most plants grow best in soil containing 10-20 % humus

Air

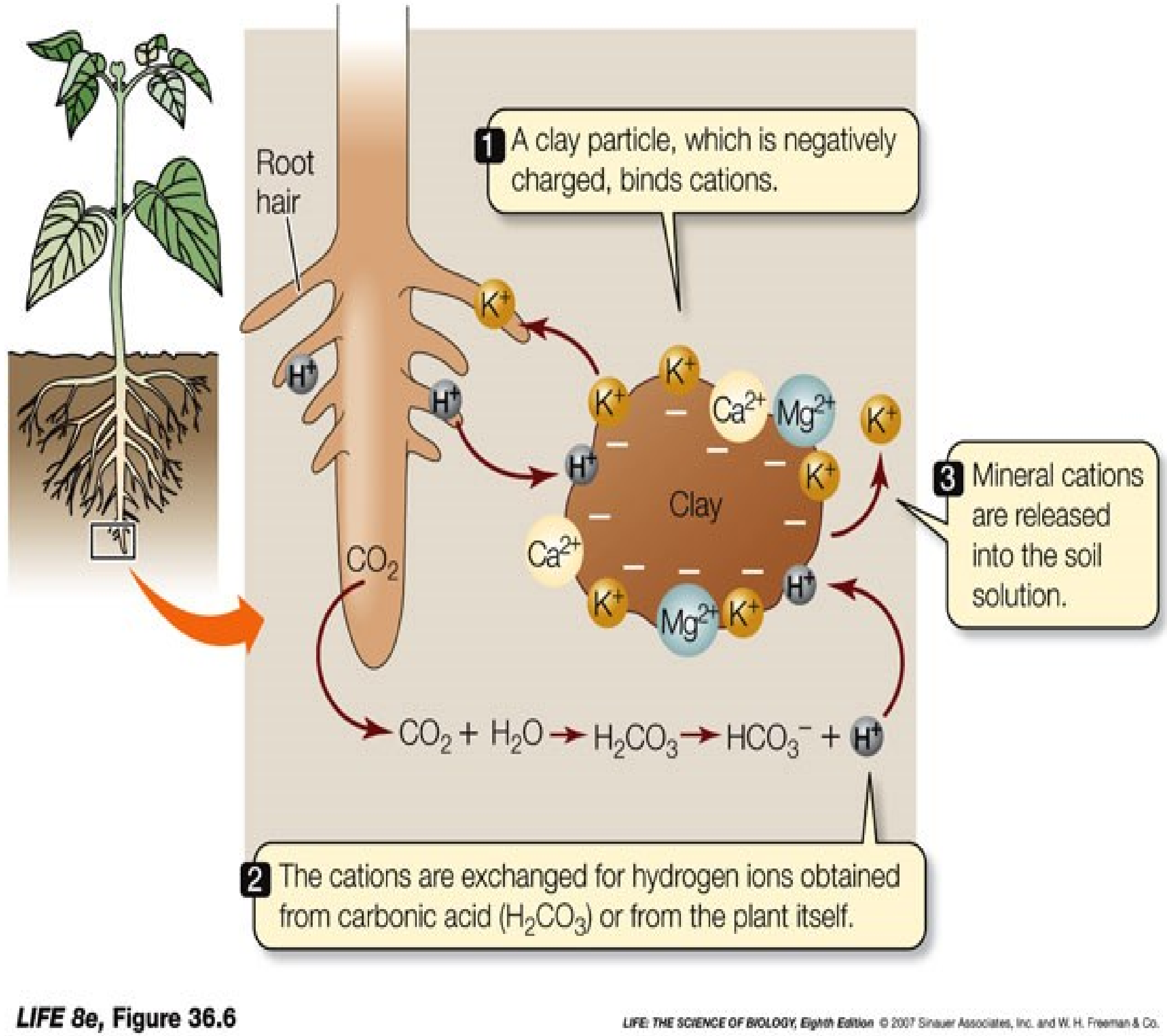
- About 23-30 % of the volume of most soils is air
- Critical role: provides oxygens for root
- Compare: clay soil and sandy soil

Living organism

- Organism mix and refine the soil.
- Organism add humus to the soil
- Respiration by these organism increase the amount of CO_2 in the soil
- Many organism affect the availability of nutrients in the soil

SOIL PARTICLES INFLUENCE THE AVAILABILITY OF NUTRIENTS

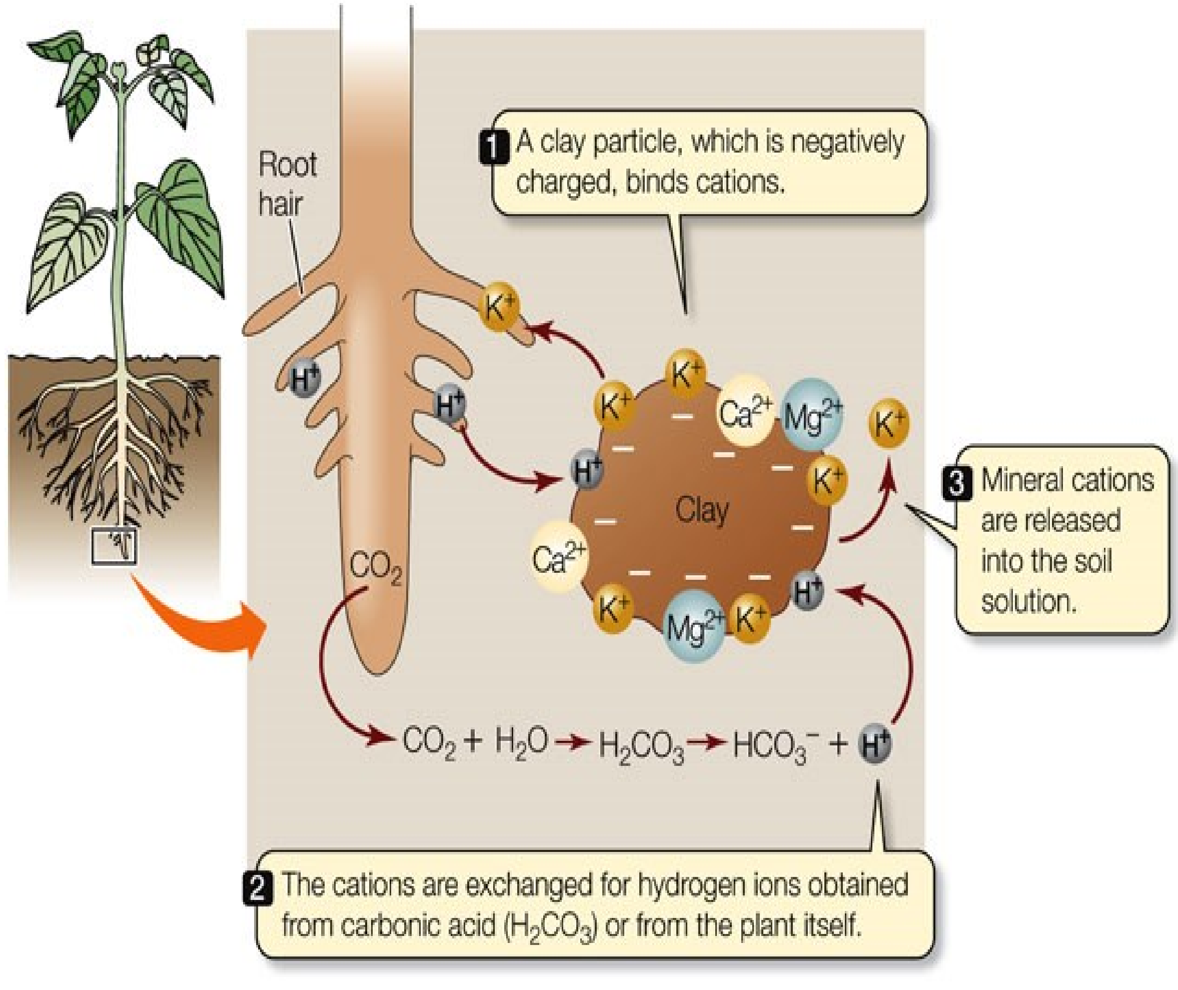
- Soil particles have (-) charge → allowing to bind cations (+) and prevents the cation from being washed from the soil by rainfall
- (-) ions stay in solution surrounding roots, creating a charge gradients that tends to pull (+) ions out off the root cells



http://bcs.whfreeman.com/thelifewire8e/content/cat_010/f36006.jpg

SOIL PARTICLES INFLUENCE THE AVAILABILITY OF NUTRIENTS

- Plants extract the cation by exchanging them for H+ : **<u>CATION EXCHANGE</u>**
- Cation exchange is enhanced by <u>roots respiratory:</u> production of CO2. Active transport is required to acquire and maintain positive ions in the root



***LIFE 8e*, Figure 36.6**

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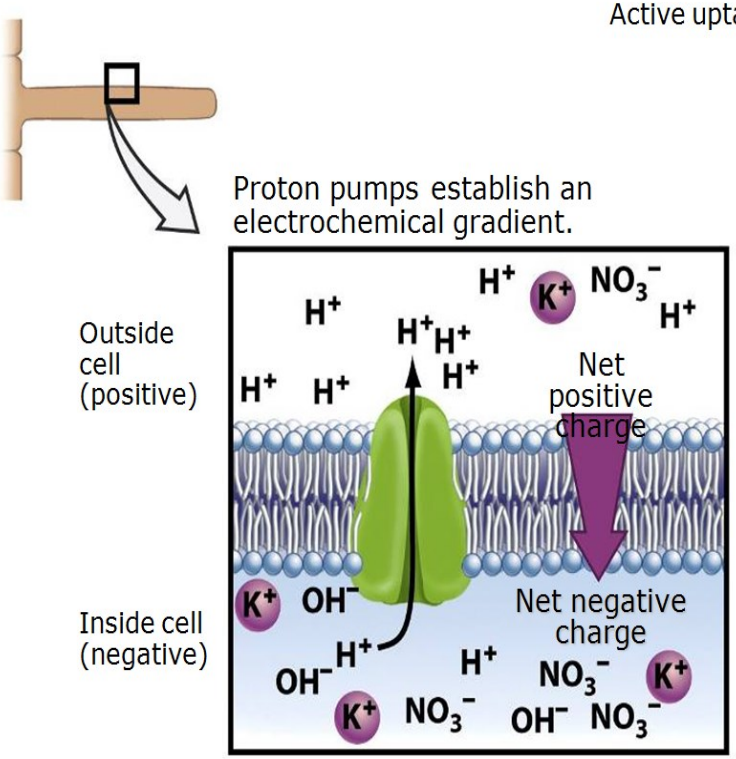
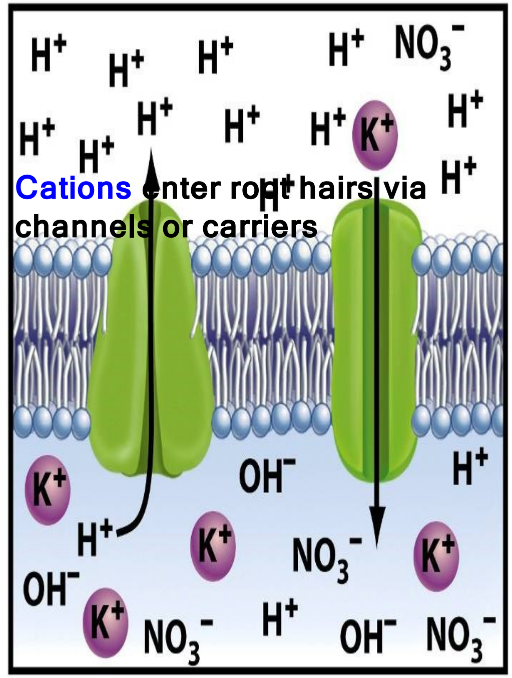
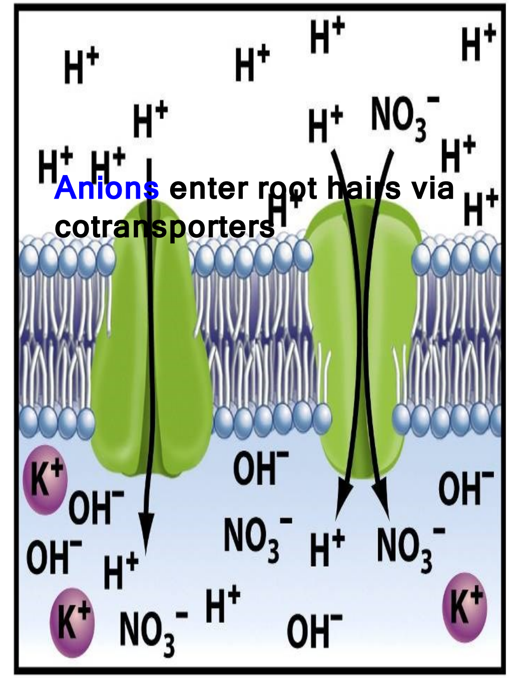
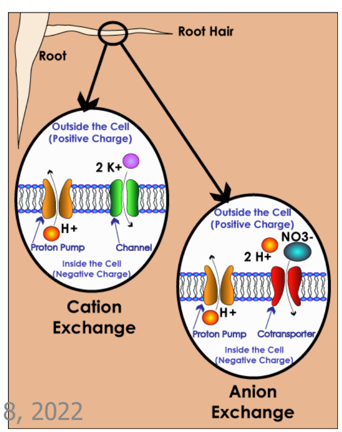
Cation exchange

Active uptake









http://housecraft.ca/author/jpriest/page/4/

Cation exchange is soil pH dependent :

- nutrient availability
- soil microbes : fungi – acidic; bacteria – alkaline
- root growth : slightly acidic soil (pH 5.5 & 6.5)

Acid soil ----- rocks release K+, Mg2+, Ca2+, Mn2+
↑ solubility of SO_4^{2-}, H_2PO_4-, HCO3-
So, availability to roots ↑

Soil pH ↓ due to : - decomposition of organic matter
- Rainfall

decomposition of org. Matter : $CO_2 + H_2O \rightarrow H^+ + HCO_3$-

(microbial decomposition) : $NH_3 + O_2 \rightarrow HNO_3$ (nitric acid)
H_2SO_4 (sulfuric acid)

H^+ displace K^+, Mg^{2+} ----- K^+, Mg^{2+} etc. Available --- pH ↓

THANK YOU