


DOÑA ANA COUNTY
COOPERATIVE EXTENSION SERVICE

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Basic Soil Nutrition, Nutrient Cycling

What are the essential mineral nutrients?

Macronutrients - present in relatively high concentrations in plant tissues.

N, P, K, Ca, Mg, S, Si

Nitrogen is most commonly limiting to productivity of natural and managed soils. Phosphorus is next most limiting, and is most limiting in some tropical soils.

Micronutrients - present in very low concentrations in plant tissues.

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

All mineral nutrients together make up less than 4% of plant mass, yet plant growth is very sensitive to nutrient deficiency.

TABLE 5.1
Adequate tissue levels of elements that may be required by plants (Part 1)

Element	Chemical symbol	Concentration in dry matter (% or ppm)[a]	Relative number of atoms with respect to molybdenum
Obtained from water or carbon dioxide		[redacted]	
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

Not considered mineral nutrients

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 (% or ppm)[a]	Relative number of atoms with respect to molybdenum
Obtained from the soil		ppm	
Micronutrients			
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

Very low concentrations, but still essential because of specialized roles in metabolism

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.

List of Essential Plant Mineral Nutrients

MACRONUTRIENTS:

Element	Symbol	Form Taken Up	Conc. in Plant(%)
Nitrogen	N	NH_4^+, NO_3^-	2-5
Phosphorus	P	$H_2PO_4^-$, HPO_4^{2-}	0.2-0.4
Potassium	K	K^+	0.5-2.0
Calcium	Ca	Ca^{2+}	1.5-2.5
Magnesium	Mg	Mg^{2+}	0.3-0.5
Sulfur	S	SO_4^{2-}	0.1-0.3

MICRONUTRIENTS:

Element	Symbol	Form Taken Up	Conc. in Plant (ppm)
Boron	B	$H_2BO_3^-$	40
Manganese	Mn	Mn^{2+}	35
Copper	Cu	Cu^{2+}	7
Iron	Fe	Fe^{2+}	50
Zinc	Zn	Zn^{2+}	20
Molybdenum	Mo	MoO_4^-	0.5
Chlorine	Cl	Cl^-	100

There are four other micronutrients not listed in this table—sodium (Na), cobalt (Co), vanadium (V) and silicon (Si). Evidence to date suggests that these nutrients are essential in some plants species however they have not been proven essential in other species.

How to classify all of these macro and micro nutrients?

By biochemical function

TABLE 5.2
Classification of plant mineral nutrients according to biochemical function (Part 1)

Mineral nutrient	Functions
Group 1	**Nutrients that are part of carbon compounds**
N	Constituent of amino acids, amides, proteins, nucleic acids, nucleotides, coenzymes, hexoamines, etc.
S	Component of cysteine, cystine, methionine, and proteins. Constituent of lipoic acid, coenzyme A, thiamine pyrophosphate, glutathione, biotin, adenosine-5′-phosphosulfate, and 3-phosphoadenosine.
Group 2	**Nutrients that are important in energy storage or structural integrity**
P	Component of sugar phosphates, nucleic acids, nucleotides, coenzymes, phospholipids, phytic acid, etc. Has a key role in reactions that involve ATP.
Si	Deposited as amorphous silica in cell walls. Contributes to cell wall mechanical properties, including rigidity and elasticity.
B	Complexes with mannitol, mannan, polymannuronic acid, and other constituents of cell walls. Involved in cell elongation and nucleic acid metabolism.

Source: After Evans and Sorger 1966 and Mengel and Kirkby 1987.

TABLE 5.2
Classification of plant mineral nutrients according to biochemical function (Part 2)

Mineral nutrient	Functions
Group 3	**Nutrients that remain in ionic form**
K	Required as a cofactor for more than 40 enzymes. Principal cation in establishing cell turgor and maintaining cell electroneutrality.
Ca	Constituent of the middle lamella of cell walls. Required as a cofactor by some enzymes involved in the hydrolysis of ATP and phospholipids. Acts as a second messenger in metabolic regulation.
Mg	Required by many enzymes involved in phosphate transfer. Constituent of the chlorophyll molecule.
Cl	Required for the photosynthetic reactions involved in O_2 evolution.
Mn	Required for activity of some dehydrogenases, decarboxylases, kinases, oxidases, and peroxidases. Involved with other cation-activated enzymes and photosynthetic O_2 evolution.
Na	Involved with the regeneration of phosphoenolpyruvate in C_4 and CAM plants. Substitutes for potassium in some functions.

Source: After Evans and Sorger 1966 and Mengel and Kirkby 1987.

TABLE 5.2
Classification of plant mineral nutrients according to biochemical function (Part 3)

Mineral nutrient	Functions
Group 4	**Nutrients that are involved in redox reactions**
Fe	Constituent of cytochromes and nonheme iron proteins involved in photosynthesis, N_2 fixation, and respiration.
Zn	Constituent of alcohol dehydrogenase, glutamic dehydrogenase, carbonic anhydrase, etc.
Cu	Component of ascorbic acid oxidase, tyrosinase, monoamine oxidase, uricase, cytochrome oxidase, phenolase, laccase, and plastocyanin.
Ni	Constituent of urease. In N_2-fixing bacteria, constituent of hydrogenases.
Mo	Constituent of nitrogenase, nitrate reductase, and xanthine dehydrogenase.

Source: After Evans and Sorger 1966 and Mengel and Kirkby 1987.

1. **Oxidation refers to the loss of electrons, while reduction refers to the gain of electrons.**
2. **Each reaction by itself is called a "half-reaction", simply because there must be two half-reactions to form a whole reaction.**
3. **Thus in notating redox reactions, chemists typically write out the electrons explicitly:**

The term comes from the two concepts of reduction and oxidation. It can be explained in simple terms:
***Oxidation* is the *loss* of electrons or an *increase* in oxidation state by a molecule, atom, or ion.**
***Reduction* is the *gain* of electrons or a *decrease* in oxidation state by a molecule, atom, or ion.**

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	

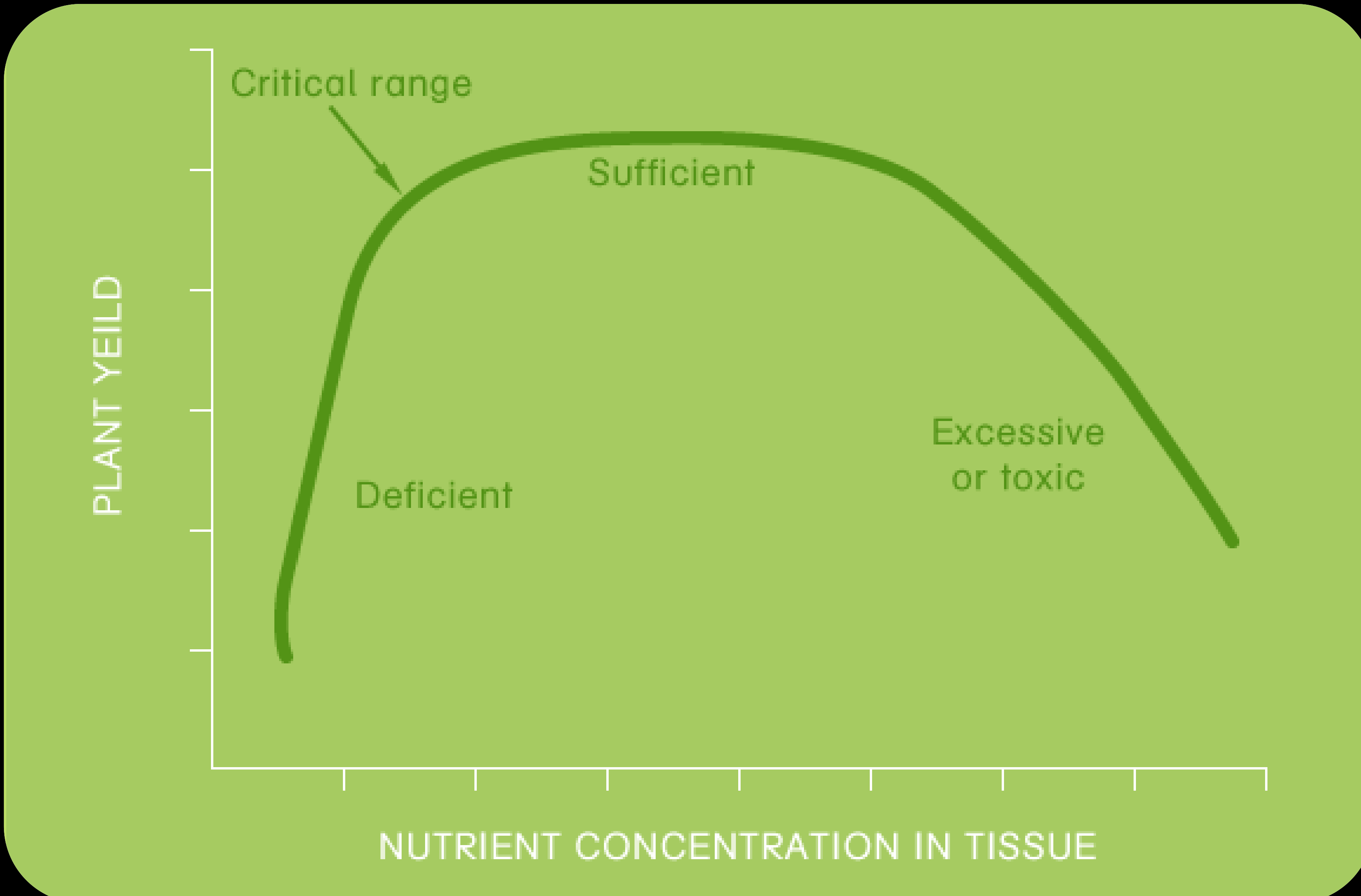
Note: Elements are listed in the order of their abundance in the plant.

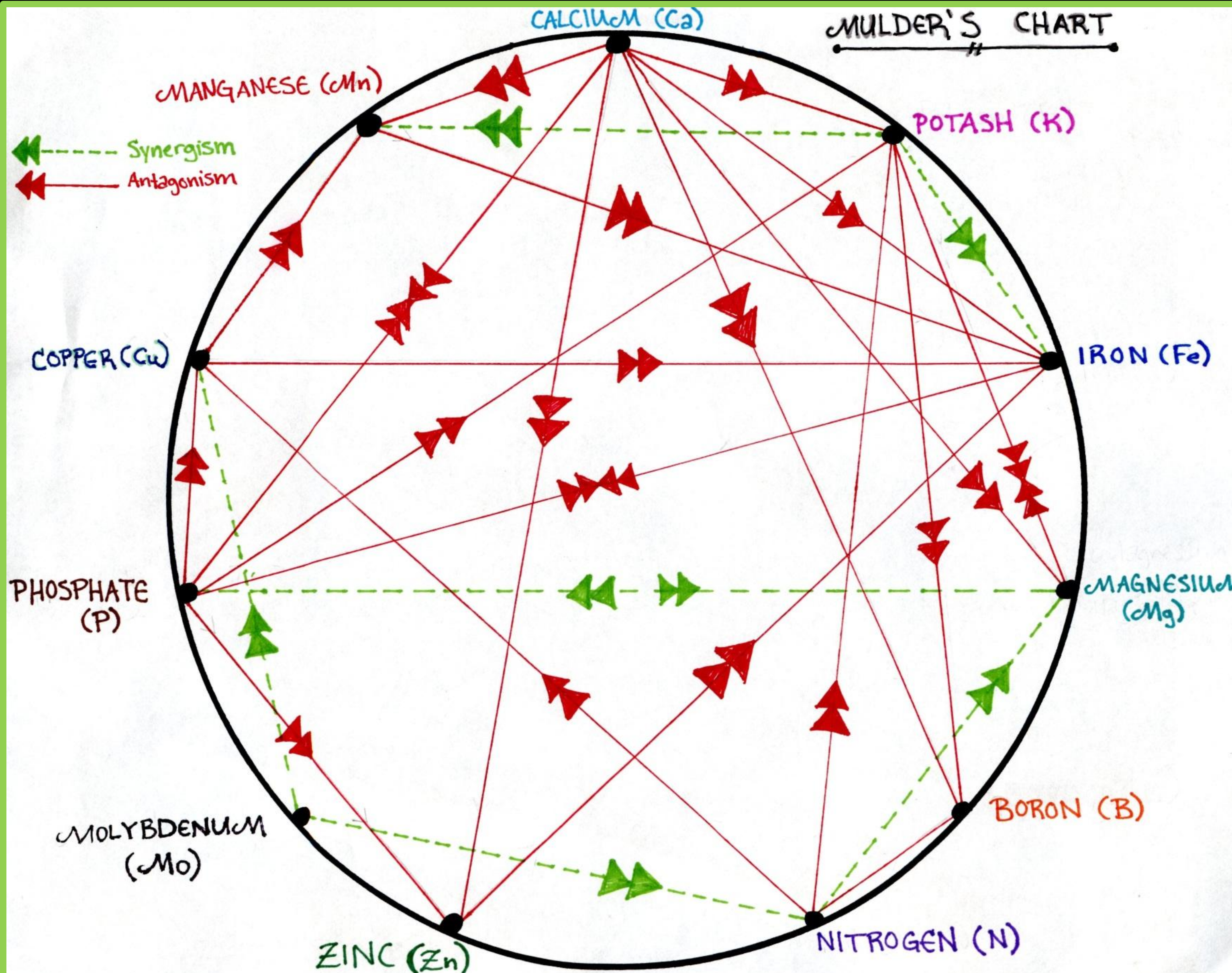
Element	Abbrev-iation	µmol/g dry wt	mg/kg (ppm)	%	Relative number of atoms
Molybdenum	Mo	0.001	0.1	---	1
Copper	Cu	0.10	6.0	---	100
Zinc	Zn	0.30	20.0	---	300
Manganese	Mn	1.0	50.0	---	1,000
Iron	Fe	2.0	100.0	---	2,000
Boron	B	2.0	20.0	---	2,000
Chlorine	Cl	3.0	100.0	---	3,000
Sulfur	S	30	---	0.1	30,000
Phosphorus	P	60	---	0.2	60,000
Magnesium	Mg	80	---	0.2	80,000
Calcium	Ca	125	---	0.5	125,000
Potassium	K	250	---	1.0	250,000
Nitrogen	N	1000	---	1.5	1,000,000

Average Concentrations of Mineral Nutrients in Plant Shoot Dry Matter that are Sufficient for Adequate Growth

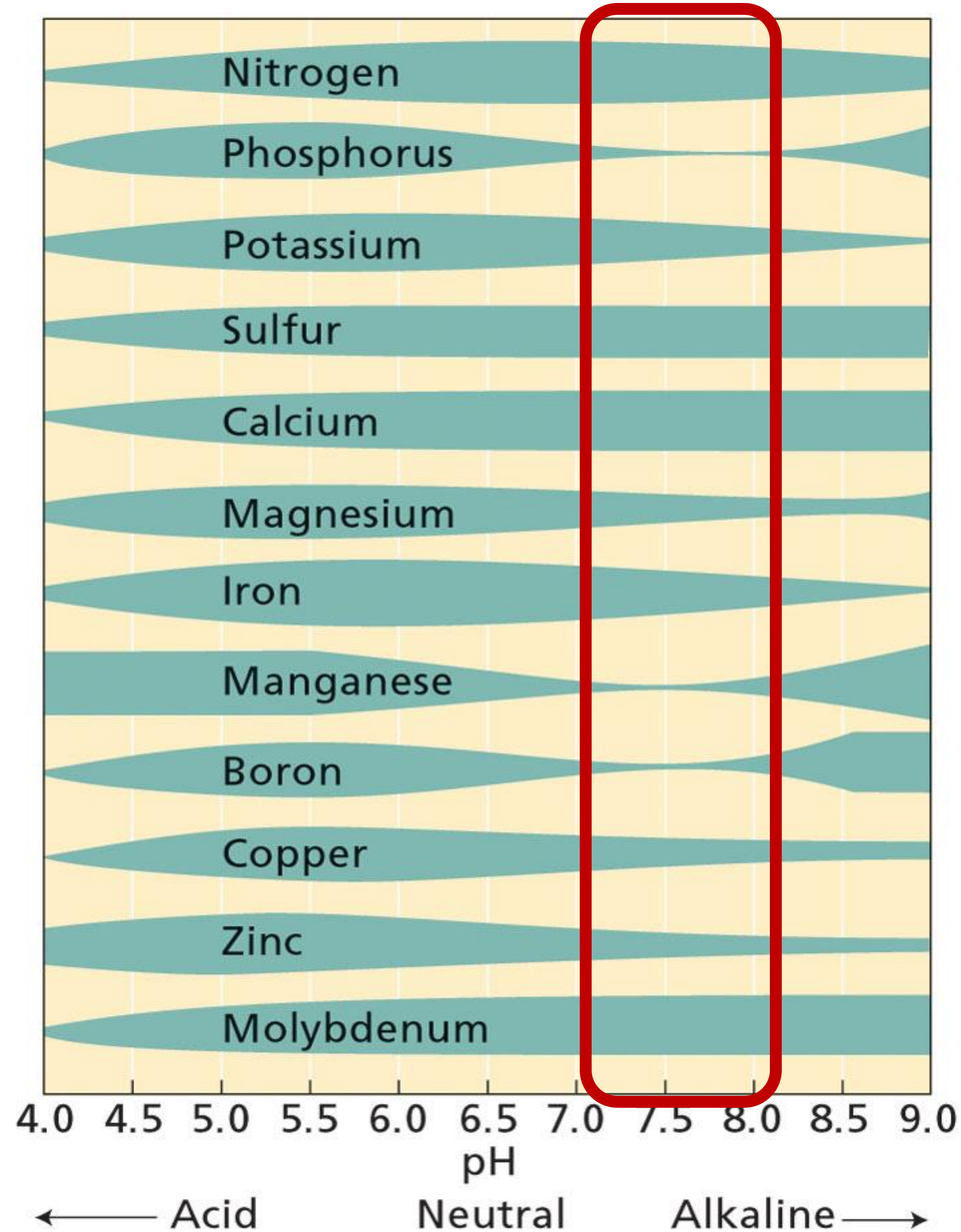
Balanced Nutrition is Key to Plant Growth

Excess May Lead to Problems

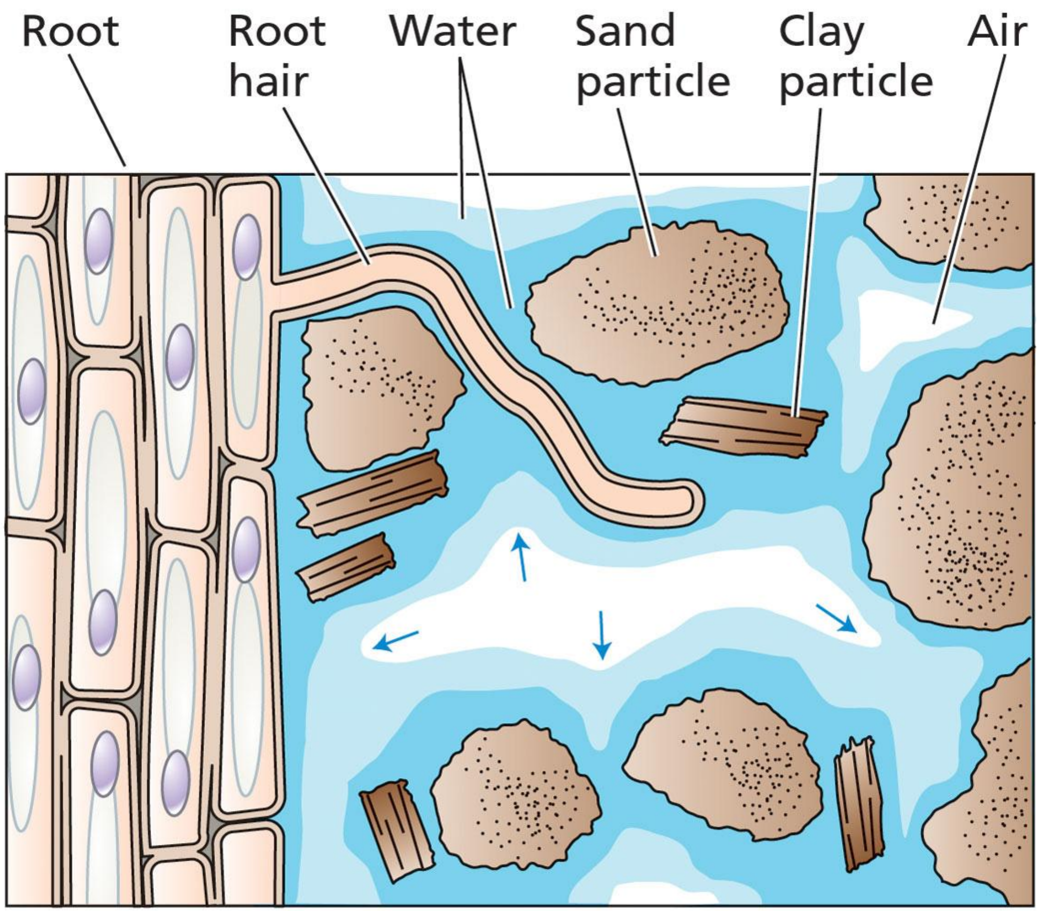

Critical range
Sufficient
Deficient
Excessive
or toxic
PLANT YEILD
NUTRIENT CONCENTRATION IN TISSUE


MULDER'S CHART
Synergism
Antagonism
CALCIUM (Ca)
POTASH (K)
IRON (Fe)
MAGNESIUM (Mg)
BORON (B)
NITROGEN (N)
ZINC (Zn)
MOLYBDENUM (Mo)
PHOSPHATE (P)
COPPER (Cu)
MANGANESE (Mn)

Soil pH influences availability of soil nutrients.



4. Roots and mineral nutrient acquisition

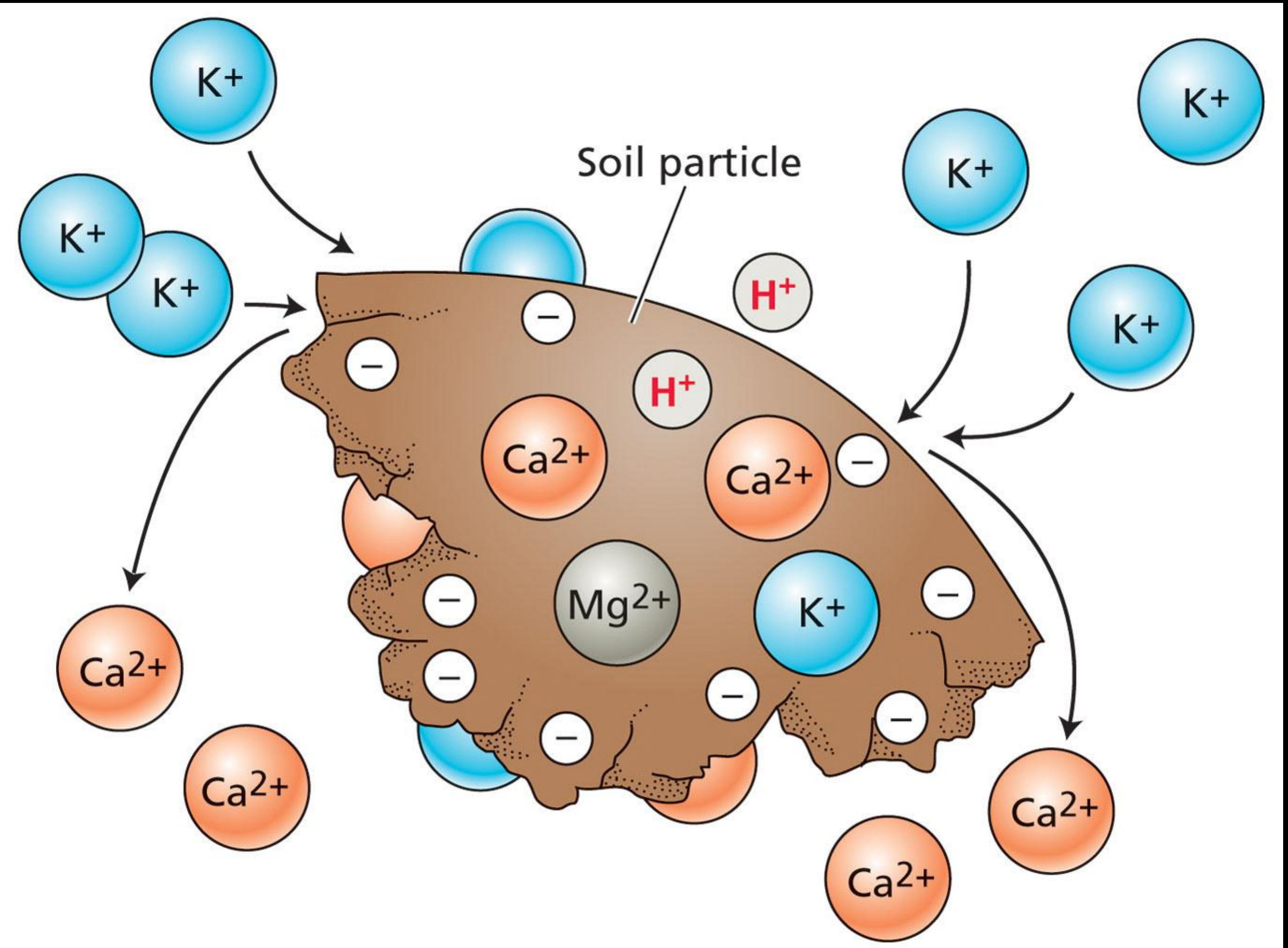


PLANT PHYSIOLOGY, Third Edition, Figure 4.2 © 2002 Sinauer Associates, Inc.

Fine roots and root hairs "mine" the soil for nutrients.
Mycorrhizal hyphae do this even better.

Soils particles are generally negatively charged and so bind positively charged nutrient ions (cations).

Cation Exchange Capacity refers to a soil's ability to bind cations



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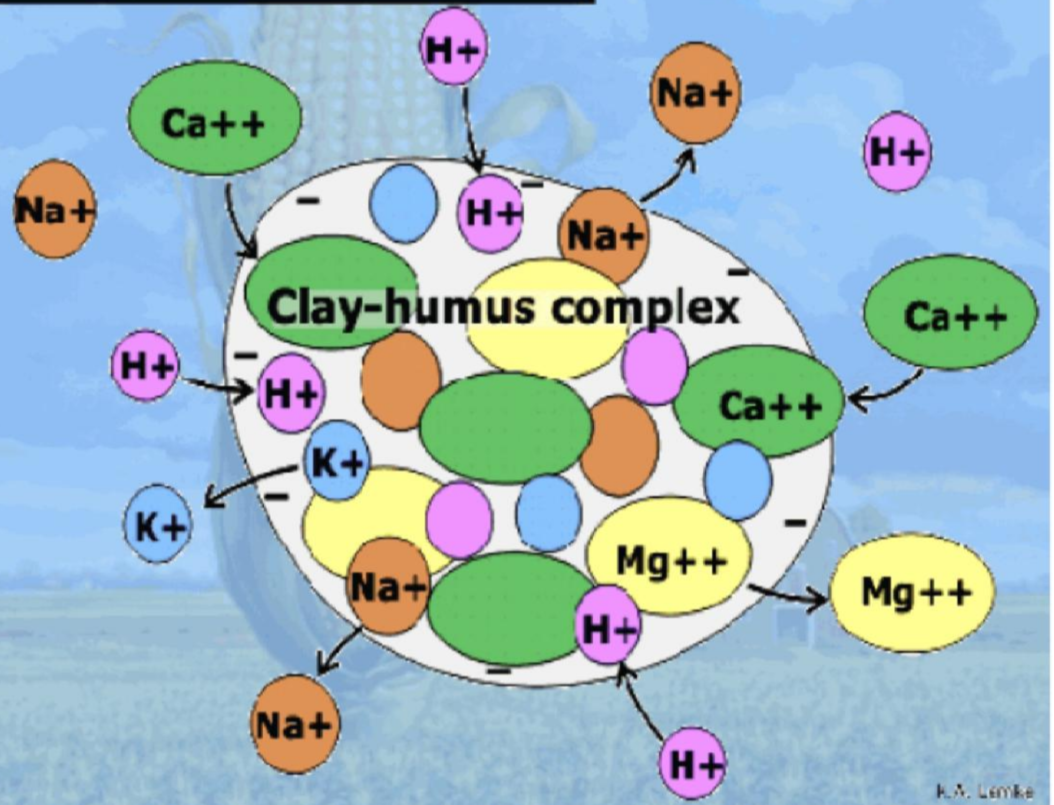
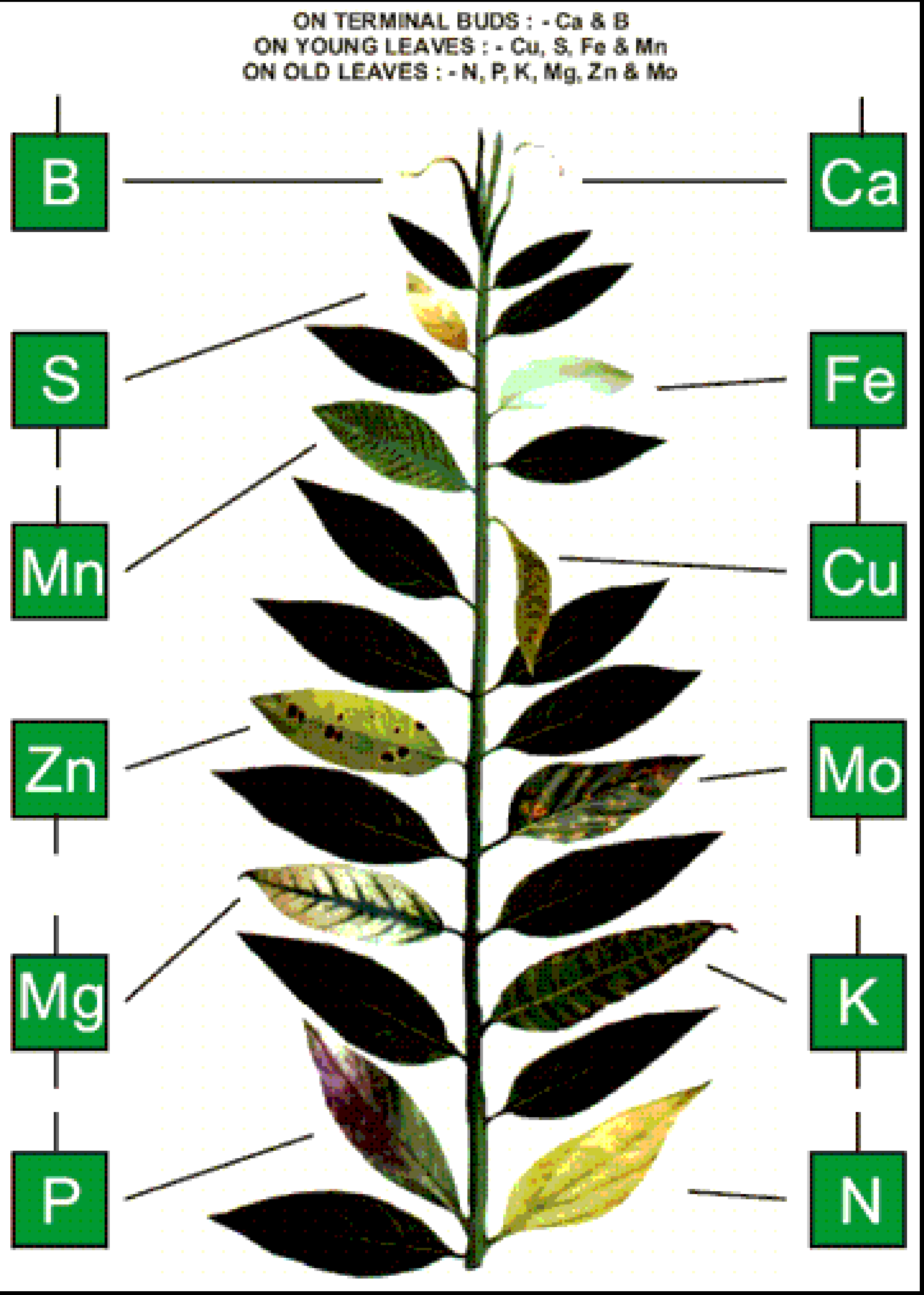
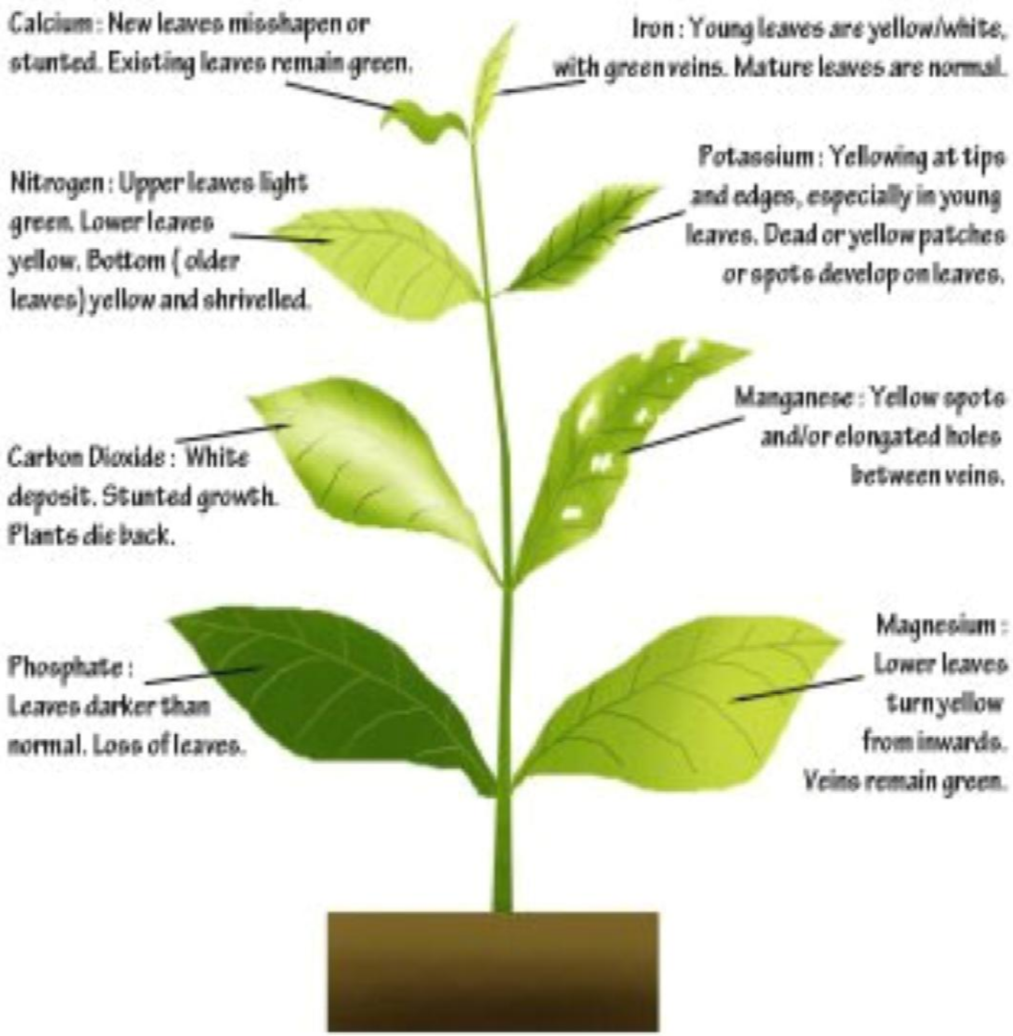
NH_4^+, NO_3^-, Cl^-, PO_4^{-2}, SO_4^{-2}

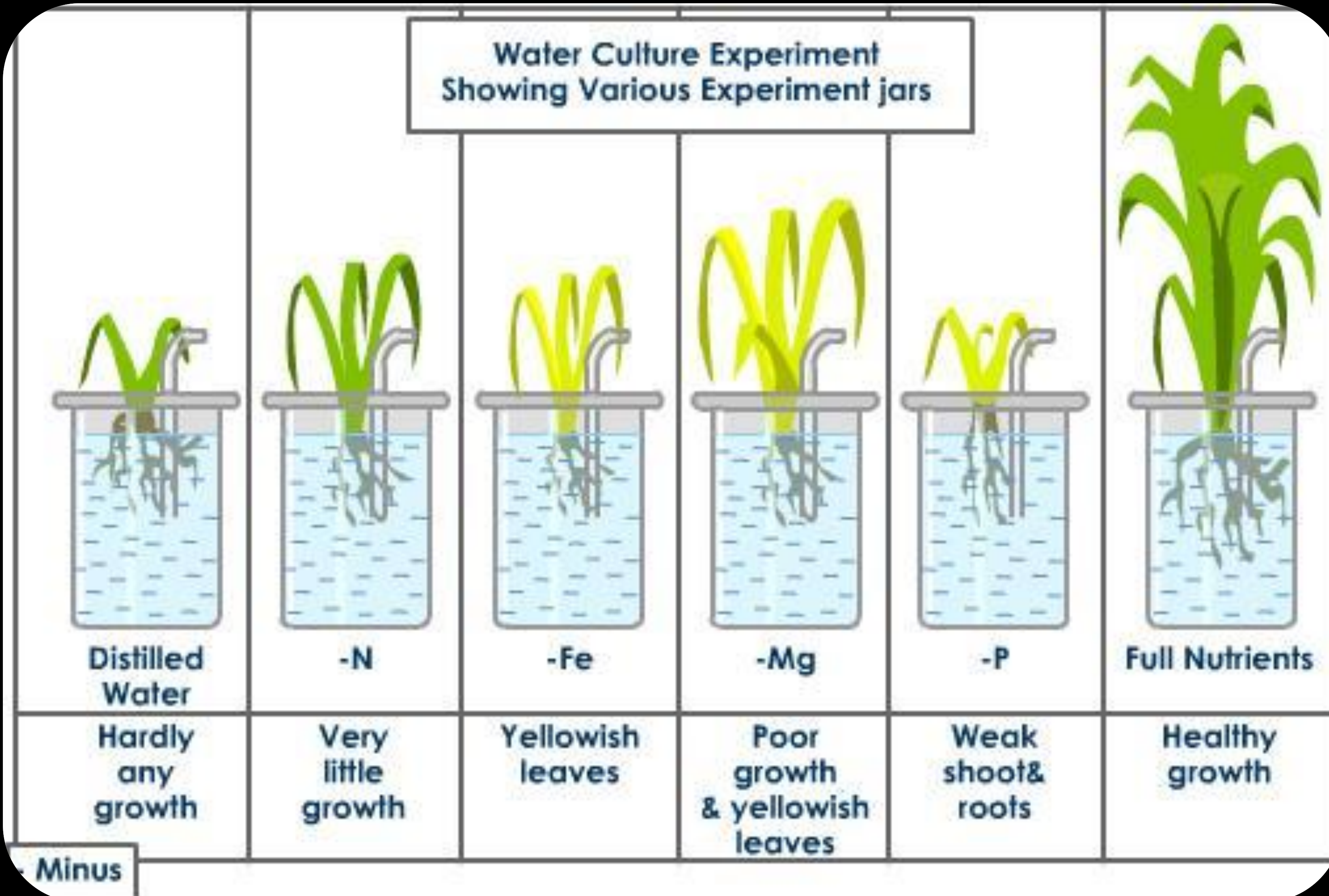
III. CEC Continued




ON TERMINAL BUDS : - Ca & B
ON YOUNG LEAVES : - Cu, S, Fe & Mn
ON OLD LEAVES : - N, P, K, Mg, Zn & Mo
B
Ca
S
Fe
Mn
Cu
Zn
Mo
Mg
K
P
N



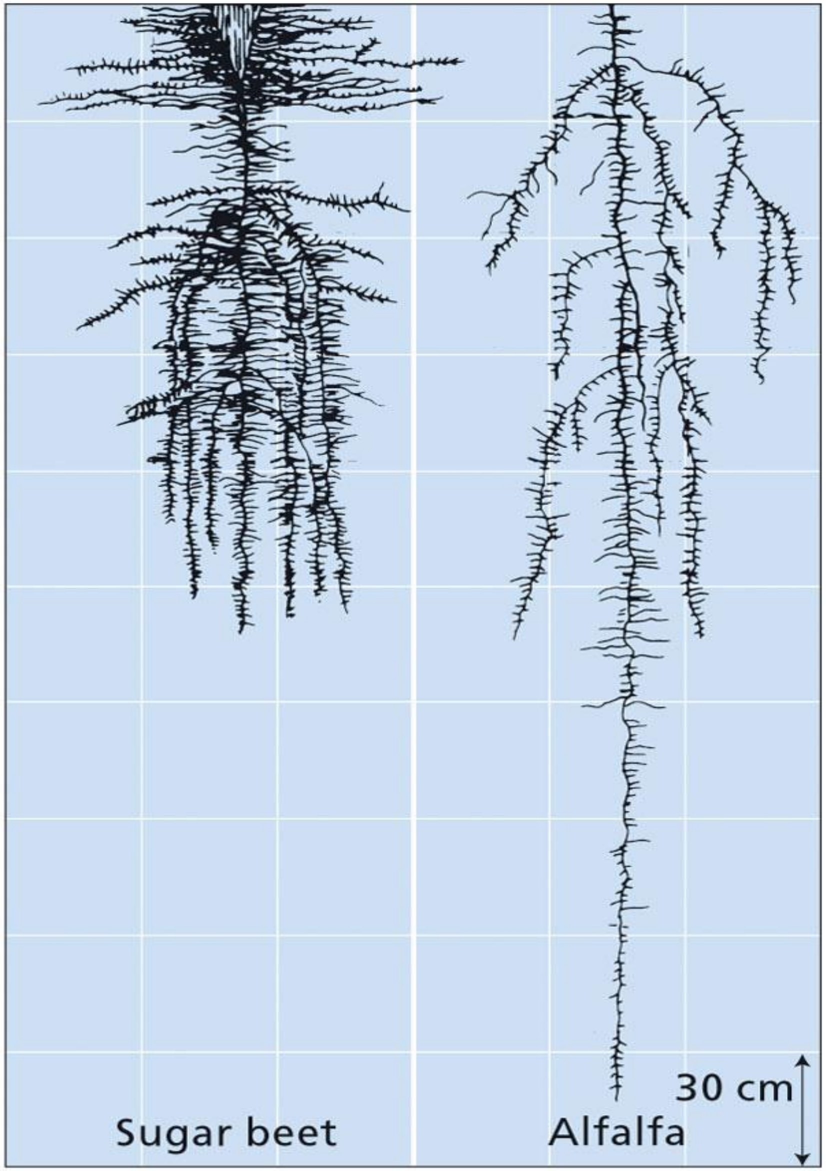
Signs Of Nutrient Deficiency


Water Culture Experiment
Showing Various Experiment jars
Distilled Water
-N
-Fe
-Mg
-P
Full Nutrients
Hardly any growth
Very little growth
Yellowish leaves
Poor growth & yellowish leaves
Weak shoot& roots
Healthy growth
- Minus

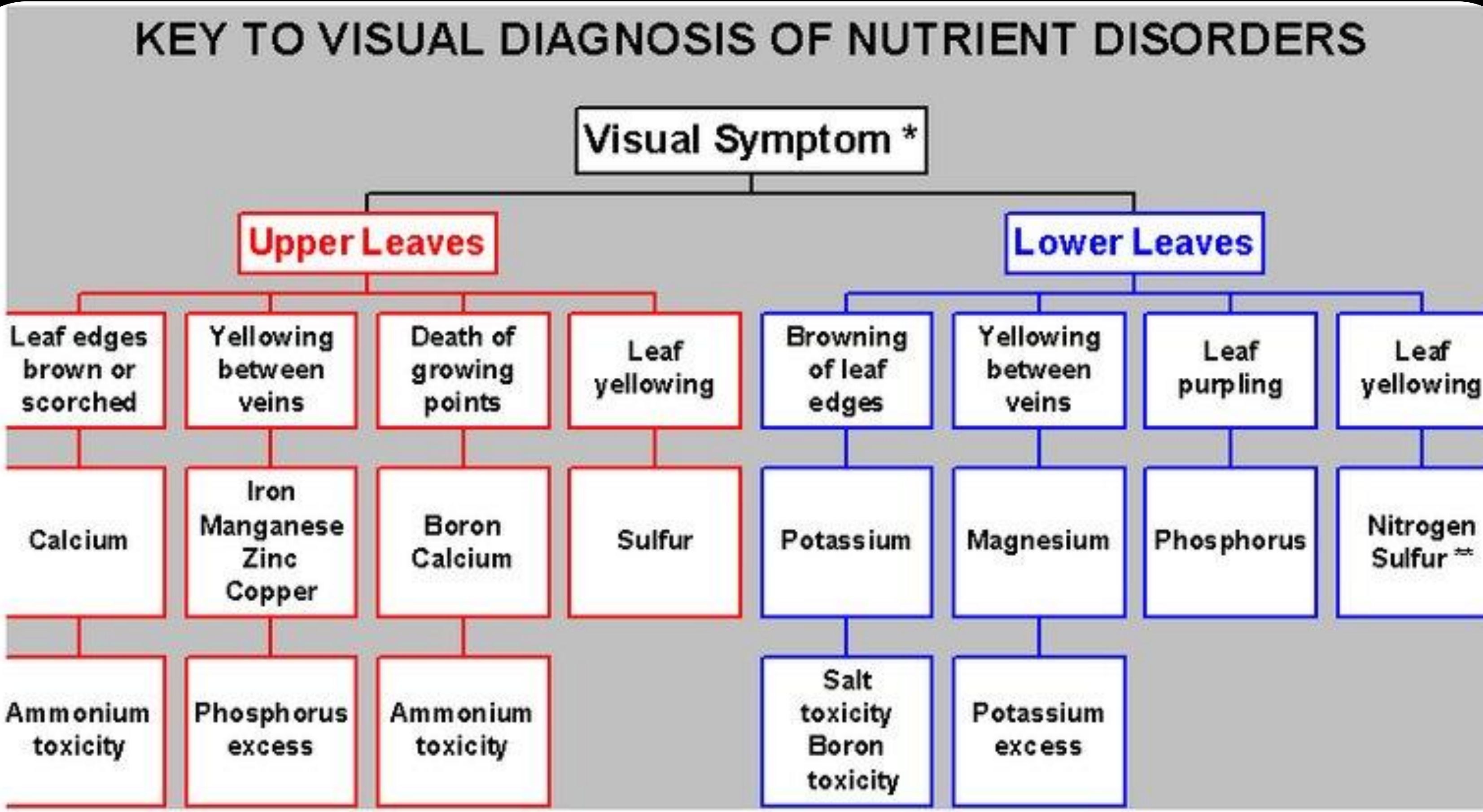
PHOSPHORUS	
DEFICIENCY SYMPTOMS	Reduced growth. Production of dark green foliage. Reduced tillering in cereals. Reddening or yellowing of leaf margins and necrosis of older leaves. Reduced fruit quality and storage potential.
MADE WORSE BY	Low organic matter. Acidic soils or very alkaline soils. Cold wet conditions High calcium levels.
ROLE IN PLANT NUTRITION	Energy transfer. Formation of nucleic acids. Protein synthesis. Cell membrane component.

IRON	
DEFICIENCY SYMPTOMS	Yellowing (Chlorosis) of youngest leaves
MADE WORSE BY	High pH soils. Calcareous soils. High levels of copper. Poorly drained crops
ROLE IN PLANT NUTRITION	Necessary for the formation of chlorophyll. Necessary for photosynthesis. Necessary for the formation of proteins

ZINC	
DEFICIENCY SYMPTOMS	Stunted plants. Pale stripes to the leaf mid rib (maize). Formation of rosettes (fruit trees)Formation of small leaves. Chlorosis of young leaves
MADE WORSE BY	Organic soils. High pH soils. Soils rich in phosphorus application. Cold wet conditions
ROLE IN PLANT NUTRITION	Necessary for the correct functioning of many enzyme systems. Necessary for the synthesis of nucleic acids. Necessary for auxcin (plant hormone) metabolism



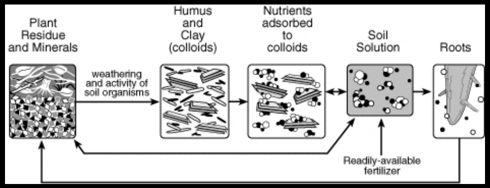
PLANT PHYSIOLOGY, Third Edition, Figure 5.7


KEY TO VISUAL DIAGNOSIS OF NUTRIENT DISORDERS
Visual Symptom *
Upper Leaves
Lower Leaves
Leaf edges brown or scorched
Calcium
Ammonium toxicity
Yellowing between veins
Iron Manganese Zinc Copper
Phosphorus excess
Death of growing points
Boron Calcium
Ammonium toxicity
Leaf yellowing
Sulfur
Browning of leaf edges
Potassium
Salt toxicity Boron toxicity
Yellowing between veins
Magnesium
Potassium excess
Leaf purpling
Phosphorus
Leaf yellowing
Nitrogen Sulfur **

Leibig’s Law

Typical Sewage Treatment Plant

Bio-Solids
Class: A or B



Bio-Solids, Class (A) vs. Class (B)

Class A Bio-solids

1. Class A biosolids contain minute levels of pathogens.
2. To achieve Class A certification, biosolids must undergo heating, composting, digestion or increased pH that reduces pathogens to below detectable levels.
3. Some treatment processes change the composition of the biosolids to a pellet or granular substance, which can be used as a commercial fertilizer.
4. Once these goals are achieved, Class A biosolids can be land applied without any pathogen-related restrictions at the site.
5. Class A biosolids can be bagged and marketed to the public for application to lawns and gardens.

The biosolids rule spells out specific treatment processes and treatment conditions that must be met for both A or B classifications.

Bio-Solids, Class (**A**) vs. Class (B)

Class B Bio-solids

1. Class B biosolids have less stringent standards for treatment and contain small but compliant amounts of bacteria.
2. Class B requirements ensure that pathogens in biosolids have been reduced to levels that protect public health and the environment and include certain restrictions for crop harvesting, grazing animals and public contact for all forms of Class B biosolids.
3. As is true of their Class A counterpart, Class B biosolids are treated in a wastewater treatment facility and undergo heating, composting, digestion or increased pH processes before leaving the plant.
4. This semi-solid material can receive further treatment when exposed to the natural environment as a fertilizer, where heat, wind and soil microbes naturally stabilize the biosolids.

The biosolids rule spells out specific treatment processes and treatment conditions that must be met for both A or B classifications.

Control C, Anhydrous Ammonia 50#/acre A, Biosolids 50#/acre, Biosolids 100#/acre

Some folks balk at the idea of biosolids. I used to, so I understand this reaction quite well. No doubt, there is a serious ick factor associated with poop. From childhood we are taught waste is dirty and a cause of disease (remember this is why we have wastewater treatment systems). But then I actually saw, touched, and smelled biosolids composts (pretty innocuous), and I started to think about the sustainability factor. It became clear to me biosolids aren't icky, but actually a wonderful, renewable, natural resource worthy of reverence. Biosolids are full of nutrients derived from our food, which are nutrients that originated from farm soils. To close the nutrient loop, we need to return these nutrients to the soil, otherwise we need to mine or manufacture more fertilizer. The decision here is easy since one choice is sustainable and the other is not. The other important question to ask is: if we don't use biosolids as a soil conditioner and fertilizer replacement, what do we do with them?


Night Hawks Dream
Halloween Halo
Chance Encounter

Grateful Red

Edgefield Glow

Amarillo Frills

Blue Crusader

Dangerous Liaison

June Krausse

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Mulder's Chart