Fisiologia Vegetal
Nutrição vegetal

Primeira aula teórica de nutrição vegetal
2022-2023

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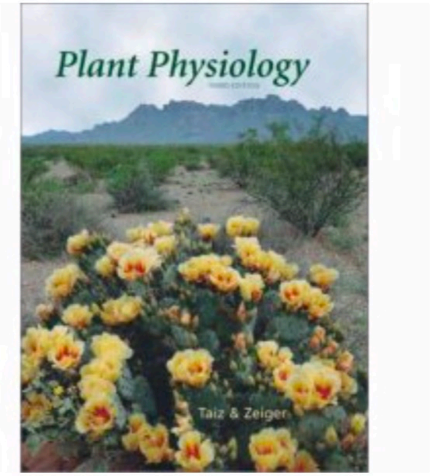
O objectivo deste bloco de aulas teóricas é dar aos alunos os fundamentos básicos da nutrição vegetal

Objectivos da aula:

1 – Definição de nutriente essencial
2 – Classificação dos nutrientes essenciais
3 – Hidroponia e soluções nutritivas
4 – A lei do mínimo
5 – Sintomas de deficiência de nutrientes

Nutrição Vegetal

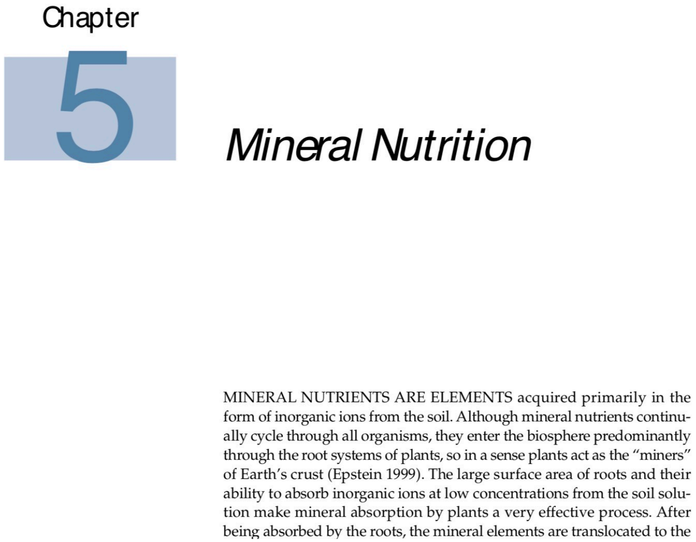
Leitura obrigatória



Plant Physiology, 3rd ed

by Lincoln Taiz and Eduardo Zeiger

Hardcover: 690 pages
Publisher: Sinauer Associates; 3 edition (Aug 30 2002)
Language: English
ISBN: 0878938230



Chapter
5

Mineral Nutrition

MINERAL NUTRIENTS ARE ELEMENTS acquired primarily in the form of inorganic ions from the soil. Although mineral nutrients continually cycle through all organisms, they enter the biosphere predominantly through the root systems of plants, so in a sense plants act as the "miners" of Earth's crust (Epstein 1999). The large surface area of roots and their ability to absorb inorganic ions at low concentrations from the soil solution make mineral absorption by plants a very effective process. After being absorbed by the roots, the mineral elements are translocated to the

Nutrição Vegetal

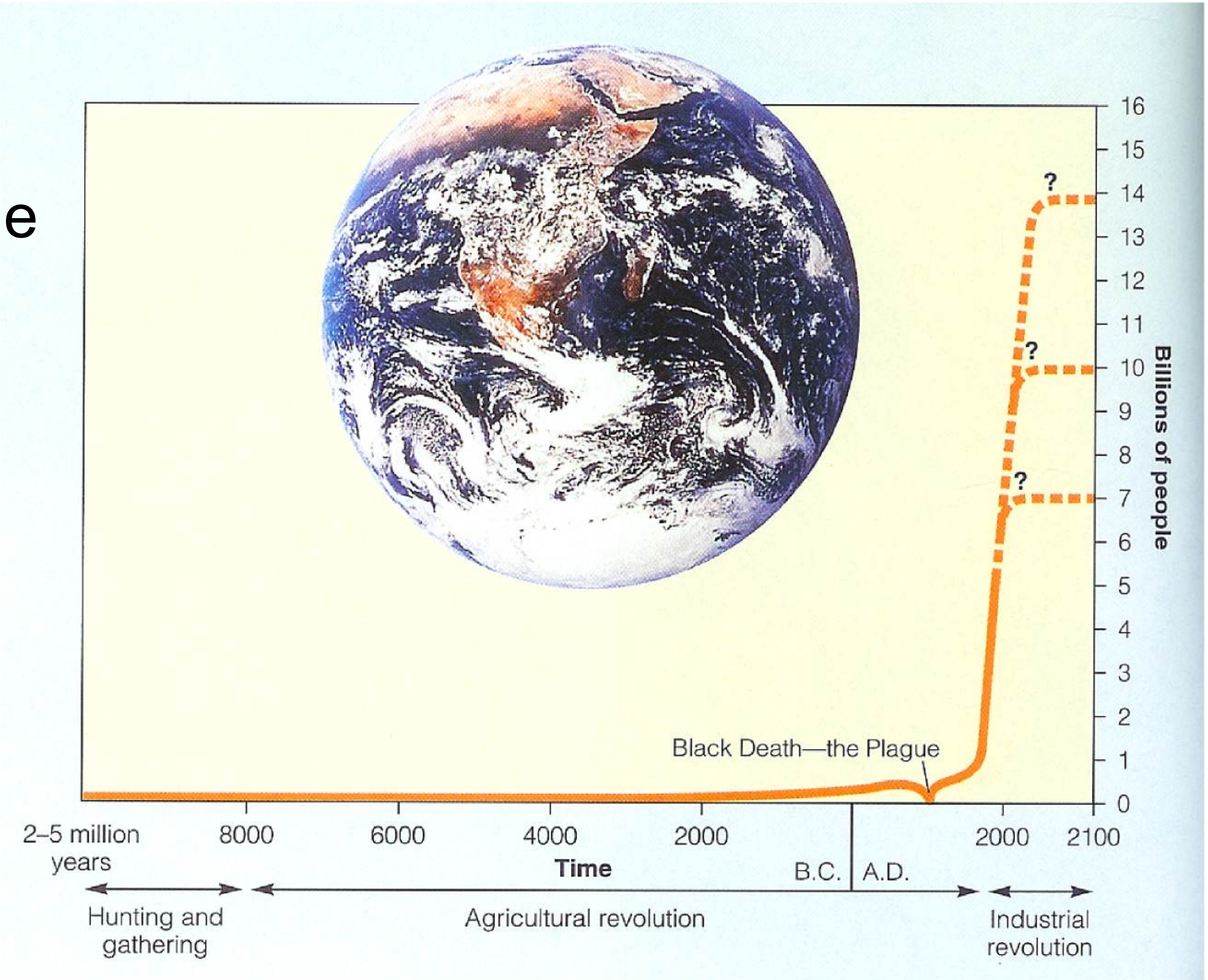
Mineral elements, those acquired primarily in the form of inorganic ions, continually cycle through all organisms and their environment. Mineral elements enter the biosphere predominantly through the root systems of plants, so in a sense plants act like the "miners" of Earth's crust (Epstein 1972, 1994).

Plant mineral nutrition is unique because green plants, the only multicellular autotrophic organisms, **can mine inorganic elements from the environment** without having to rely on high-energy compounds synthesized by other organisms.

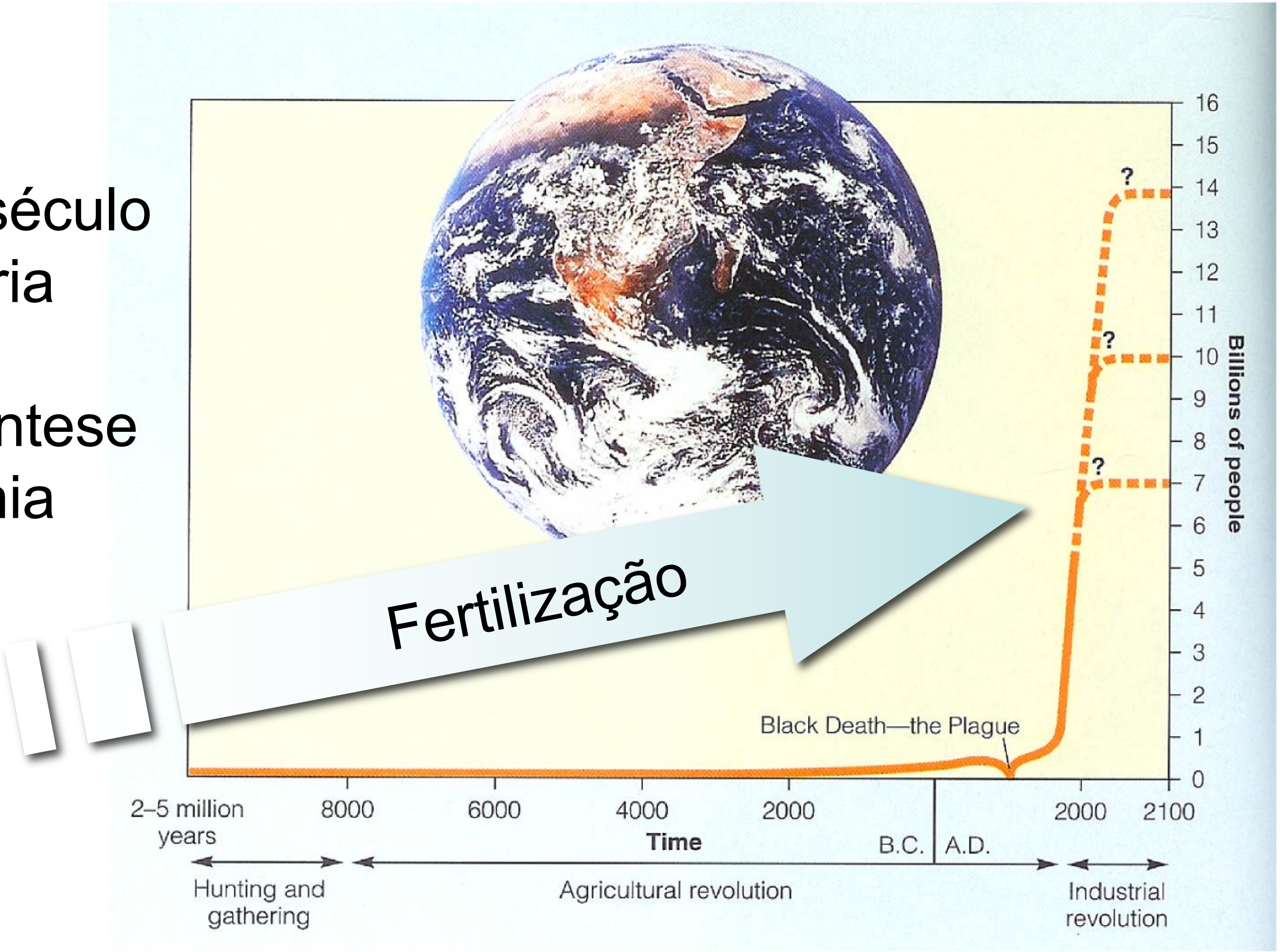
The study of how plants absorb and assimilate inorganic ions is called mineral nutrition; which is central to modern agriculture and environmental protection.

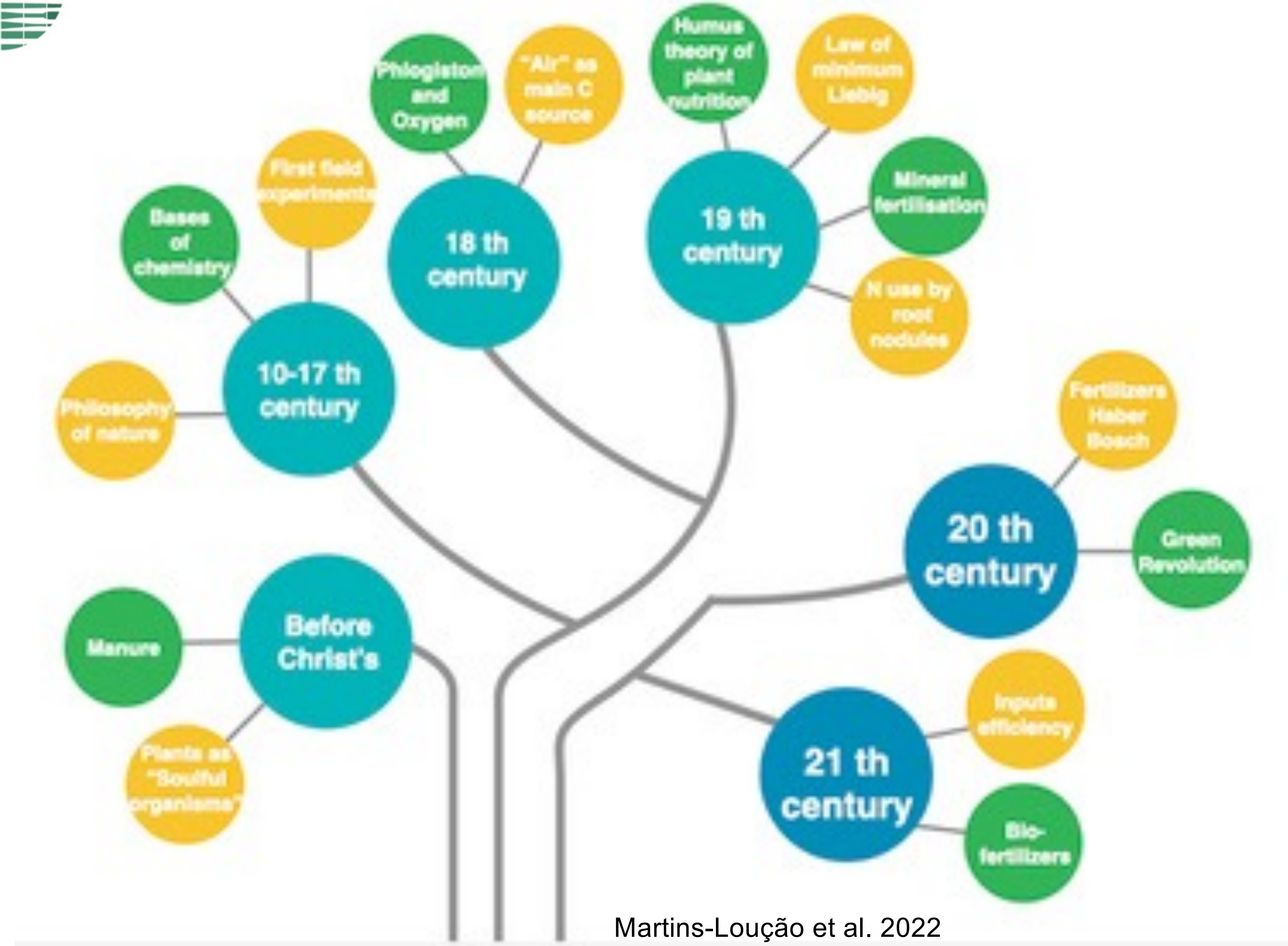
Na realidade, a vida dos quase 8 biliões de pessoas poderia ser melhor sem:

- ✓ Computadores
- ✓ 600 canais de televisão
- ✓ Reactores nucleares
- ✓ Vai-vem espaciais
- ✓ Redes sociais



Mas a explosão demográfica do século XX e XXI não seria possível sem a descoberta da síntese química da amónia





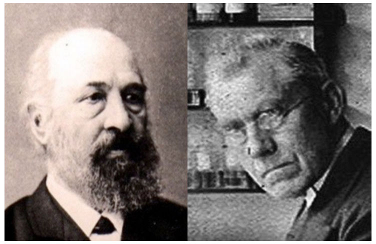
Martins-Loução et al. 2022

Roots absorb
humus and
transform it into
plant substance
(384-322 BC)

Rejection of the humus theory

" The conclusion should have been reached long ago that humus is not such an important substance as we have been led to believe, and that the current doctrine of humus is exceedingly full of contradictions."

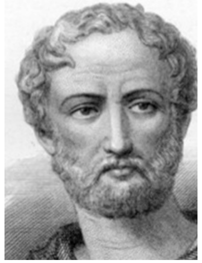
Carl Sprengel 1838



1888 – Hellriegel and Wilfarth

Organic matter Water Minerals (N) Biofertilizers

ks



Pliny (23-79 AC)
Growing a crop of
lupines improves next
crop

Justus von Leibig
(1844)

Carl Bosch and
Fritz Haber 1900

Regulators

Because of the complex nature of plant–soil–atmosphere relationships, studies in the area of mineral nutrition involve:

- atmospheric chemists
- soil scientists
- hydrologists
- microbiologists
- ecologists
- plant physiologists

What defines an "essential" element?

1. In its absence the plant **cannot complete a normal life cycle**
2. **Has a clear physiological role;** the element is **part of an essential molecule** (macromolecule, metabolite) inside the plant

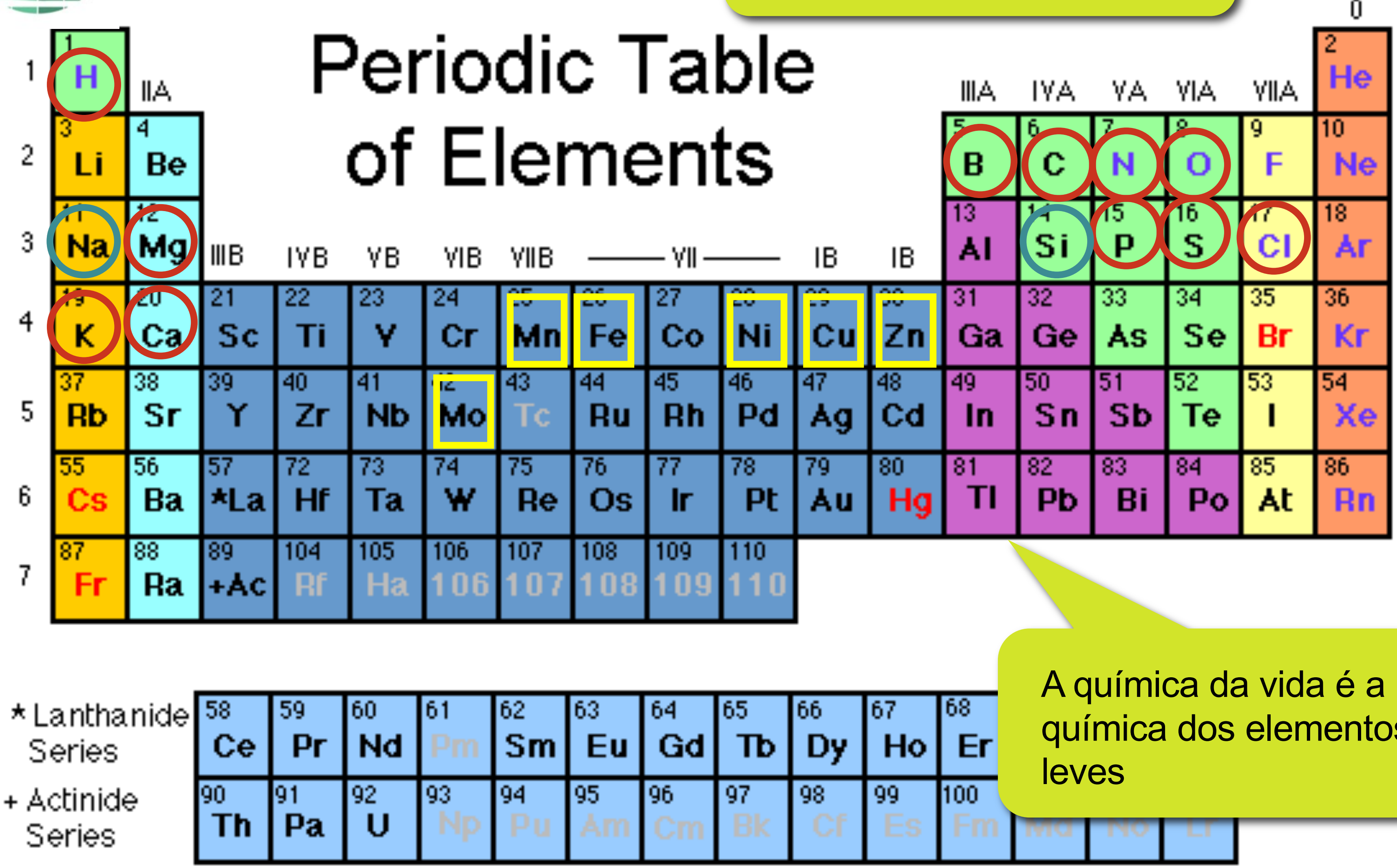
- Most elements fall into both categories above (e.g., structural vs. enzyme cofactor)
- These 17 elements are classified as
  - **9 macronutrients**

    (present at > 10 mmol / kg dry wt.)
  - **8 micronutrients**

    (< 10 mmol / kg dry wt.)

Arnon and Stout (1939)

A maior parte das plantas necessita destes elementos para viver:



Periodic Table of Elements

		IIA	IIIB	IVB	VB	VIB	VIIB	VII			IB	IB	IIIA	IVA	VA	VIA	VIIA	0
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 *La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 +Ac	104 Rf	105 Ha	106 106	107 107	108 108	109 109	110 110								

★ Lanthanide Series	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er			
+ Actinide Series	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	Md	No	Lr

A química da vida é a química dos elementos leves

I. Plant Nutrients - amount

Macro/Micronutrients

Hydroponics allowed us to see what was needed

According to their concentration in the plant tissue nutrients may be classified in two categories

- 1. Macronutrients (C, O, H, N, S, P, K, Ca, Mg)
  - Majority of the time used for the main organic compounds
- 2. Micronutrients (Cl, Fe, B, Mn, Zn, Cu, Mo, Ni)
  - Mostly cofactors for particular enzymes (Fe -> Cytochromes

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

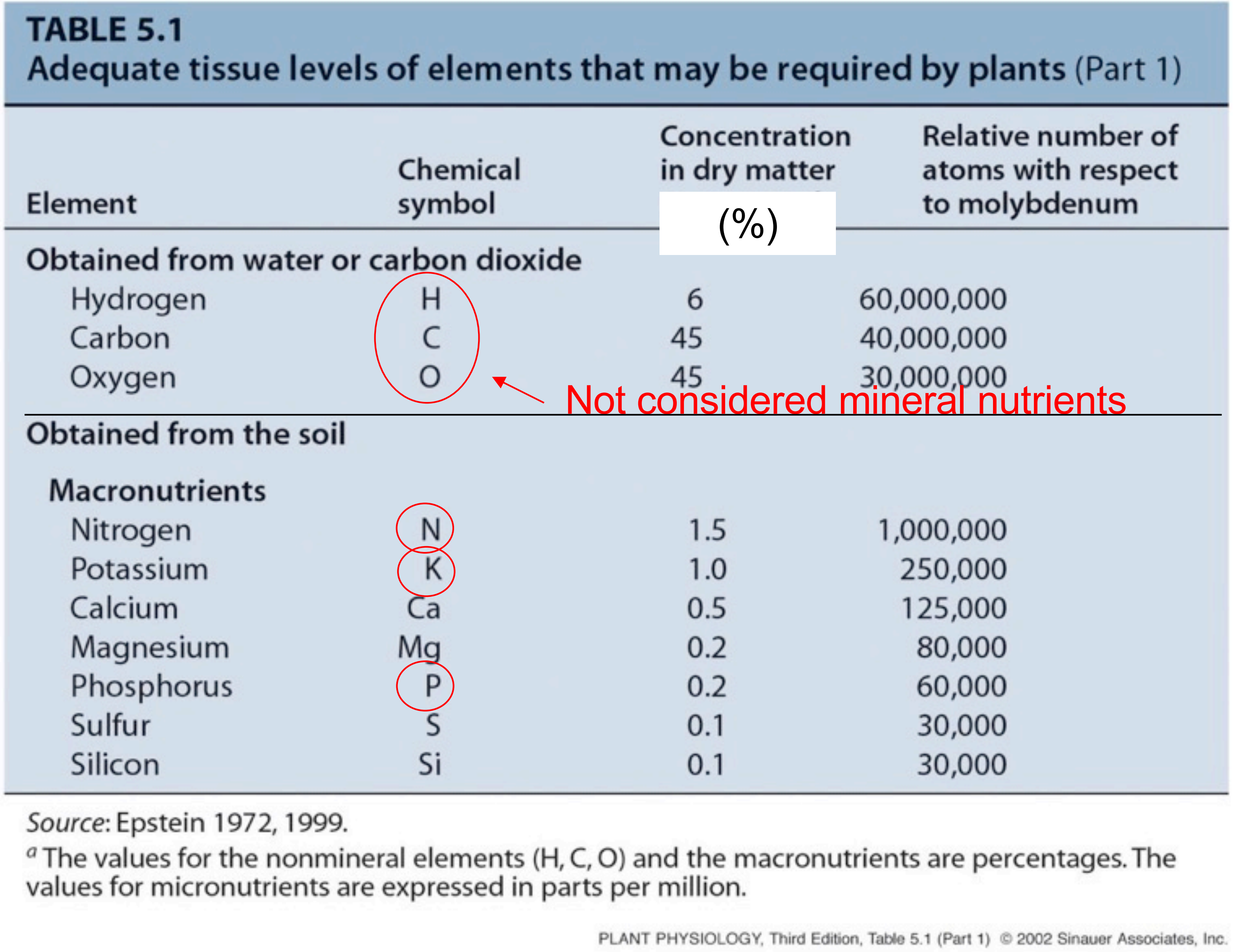


TABLE 5.1
Adequate tissue levels of elements that may be required by plants (Part 1)

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

PLANT PHYSIOLOGY, Third Edition, Table 5.1 (Part 1) © 2002 Sinauer Associates, Inc.

Micronutrients are present in very low concentrations

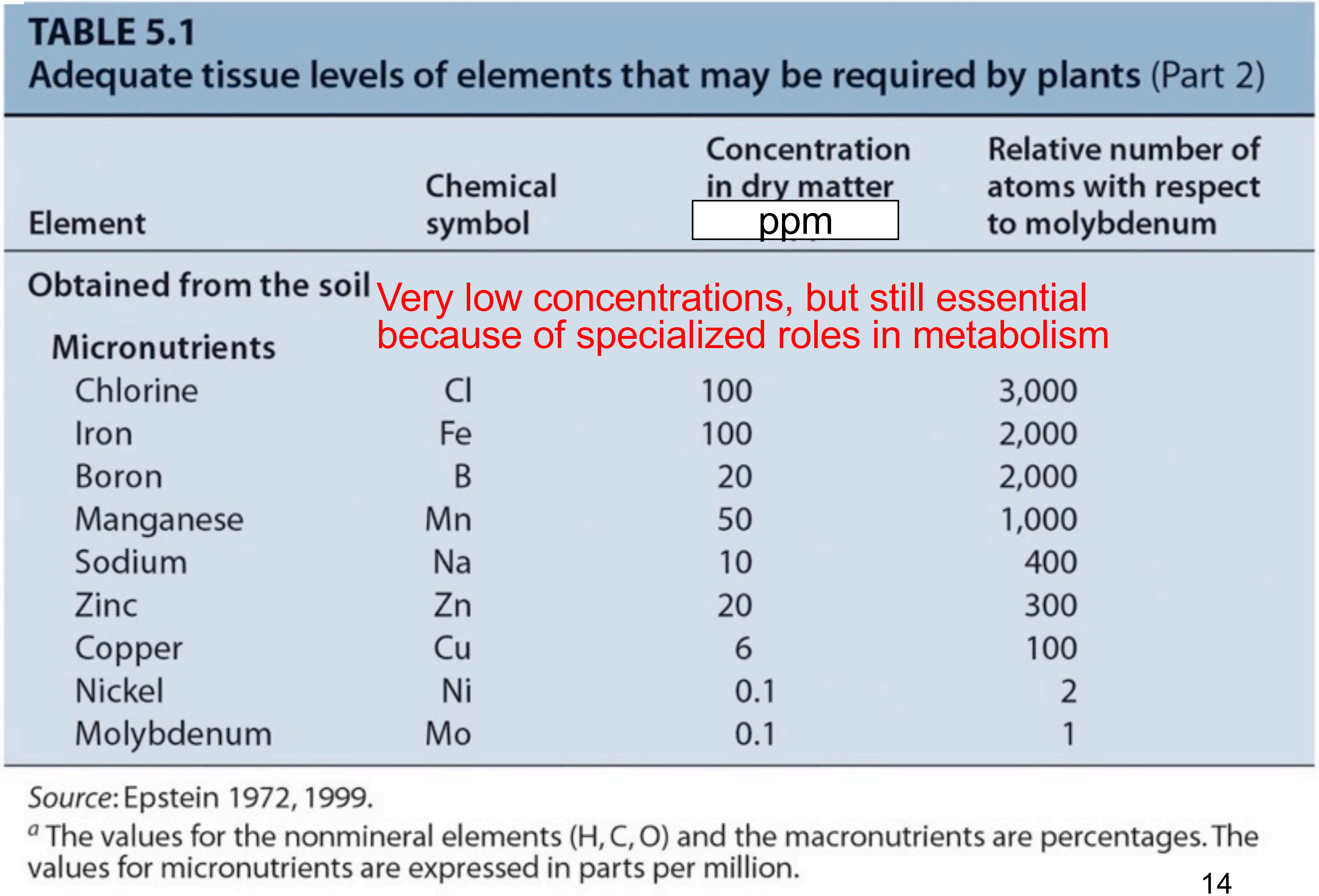


TABLE 5.1
Adequate tissue levels of elements that may be required by plants (Part 2)

Element	Chemical symbol	Concentration in dry matter ppm	Relative number of atoms with respect to molybdenum
Obtained from the soil			
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.

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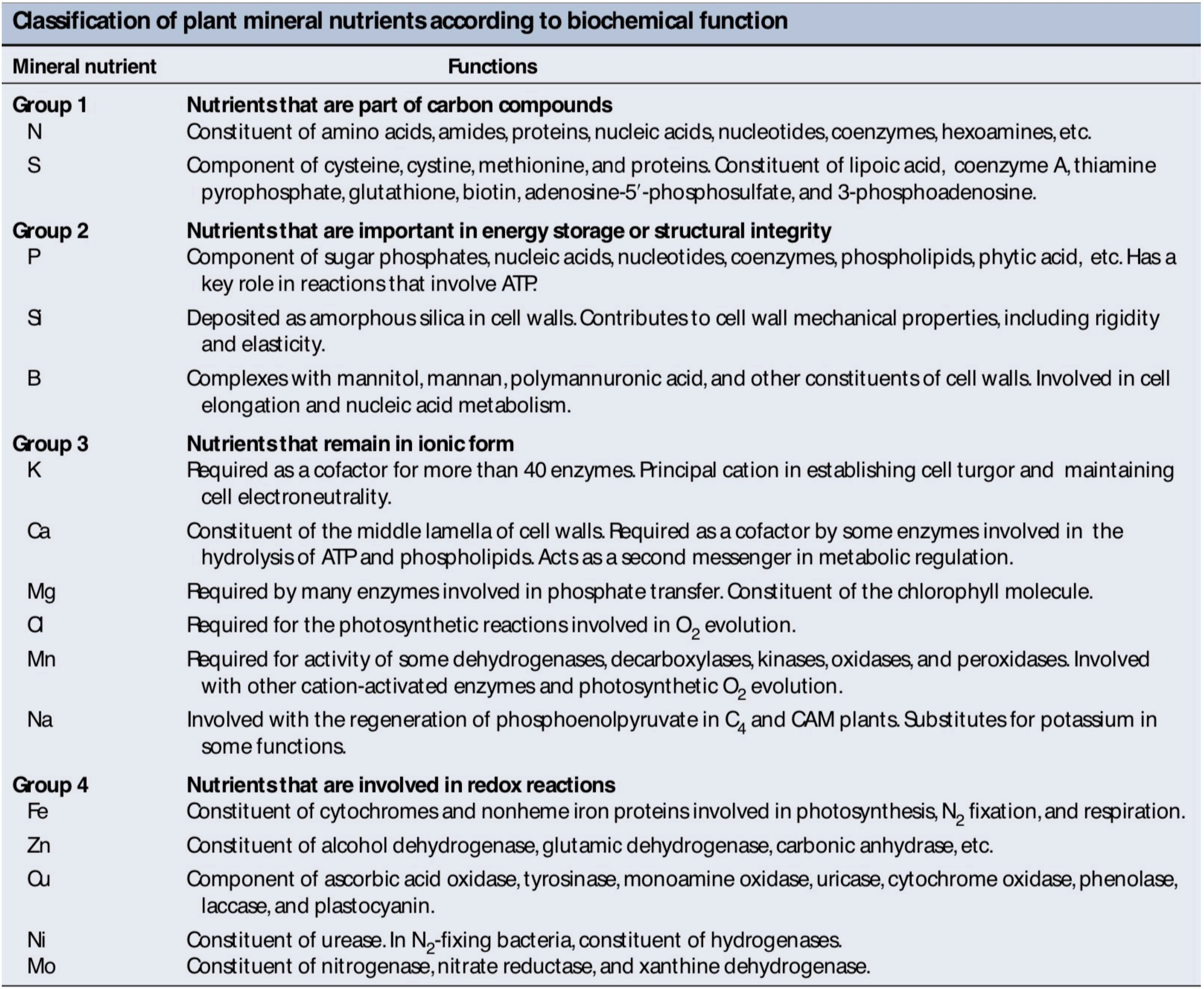
II. Plant Nutrients – function



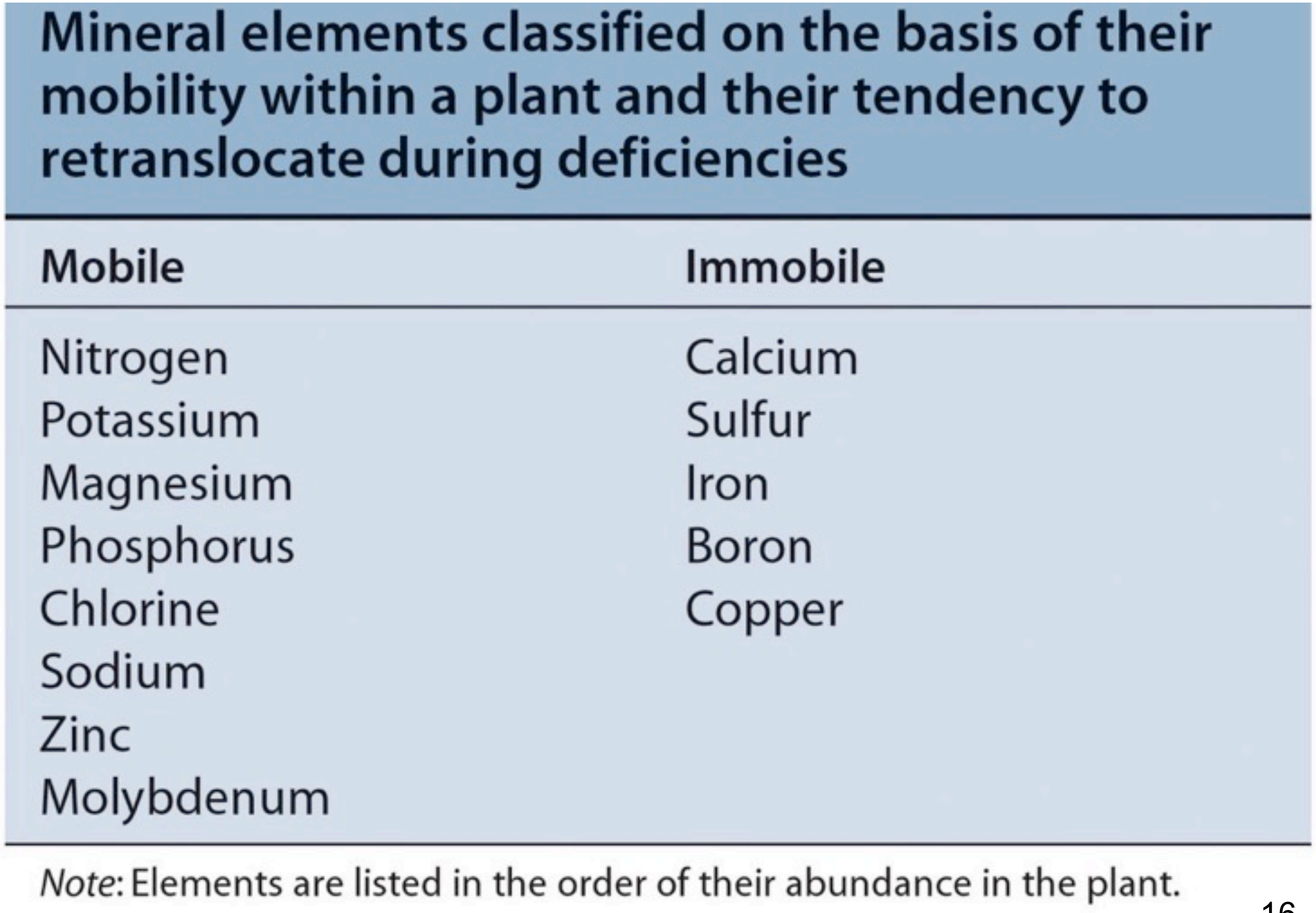
Classification of plant mineral nutrients according to biochemical function

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.
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.
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.

III. Plant Nutrients - mobility

But nutrients can also be classified according to their mobility in the plant



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.

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Hydroponic culture techniques come in different flavors

- **Main disadvantage** of simple solution culture → as plant grows, it selectively depletes certain minerals
  - When one becomes limiting, growth will slow significantly
  - Can grow in vermiculite/perlite (inert, non-nutritive) and refertilize daily
- Commercially, it is often cheaper and easier to continuously bathe roots in a nutrient solution (**nutrient film technique**)
  - Aerates
  - Standard nutrient level maintained
  - Continuous process monitoring
- To define “essential”, researchers need inert materials contributing low levels of nutrients (NO METAL PARTS!)

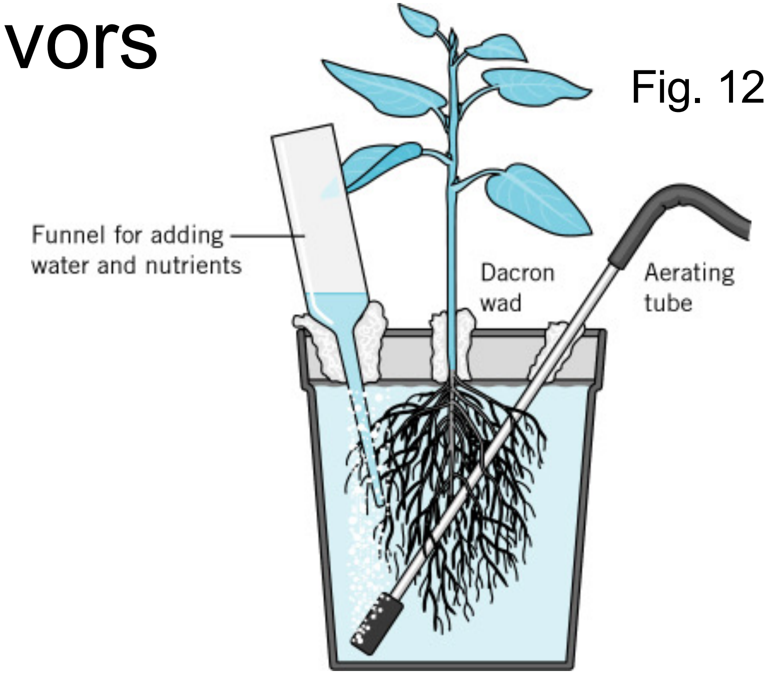


Fig. 12.1

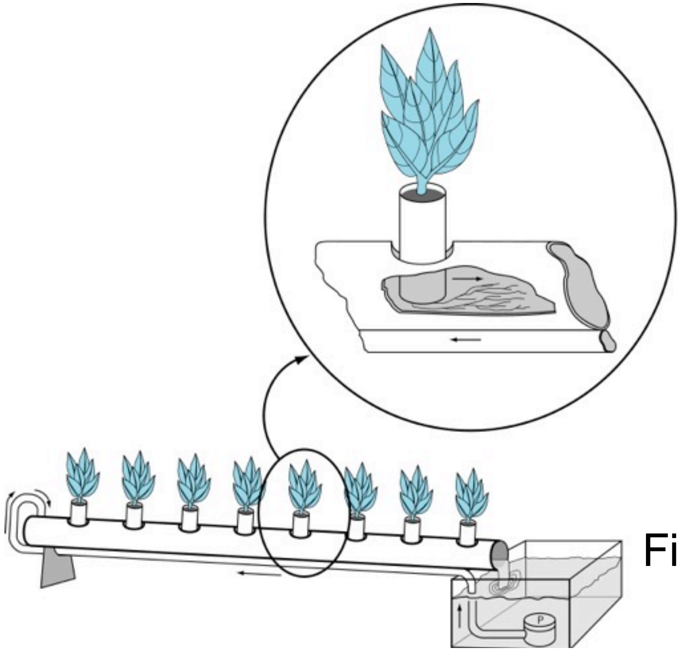
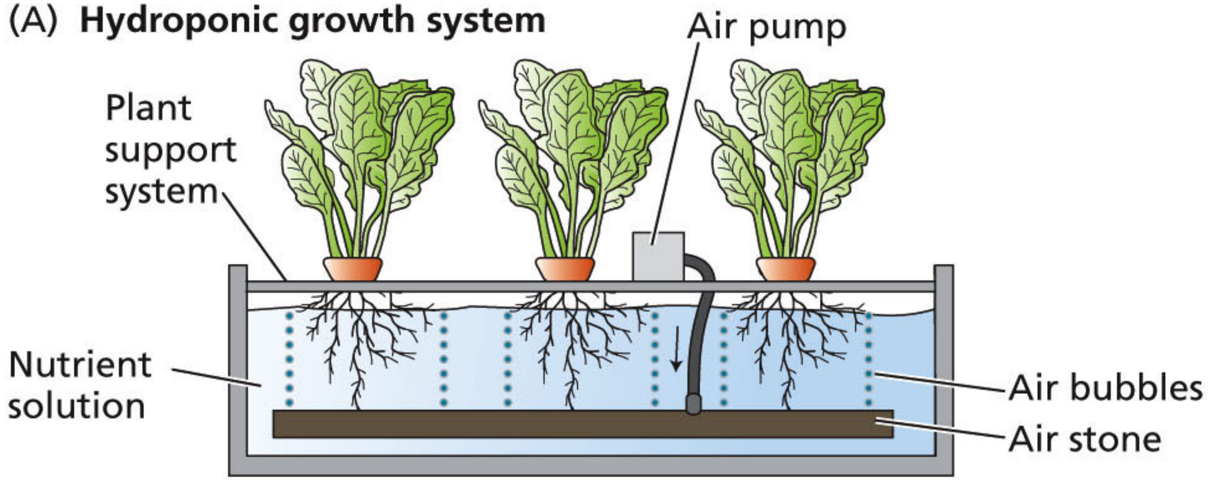
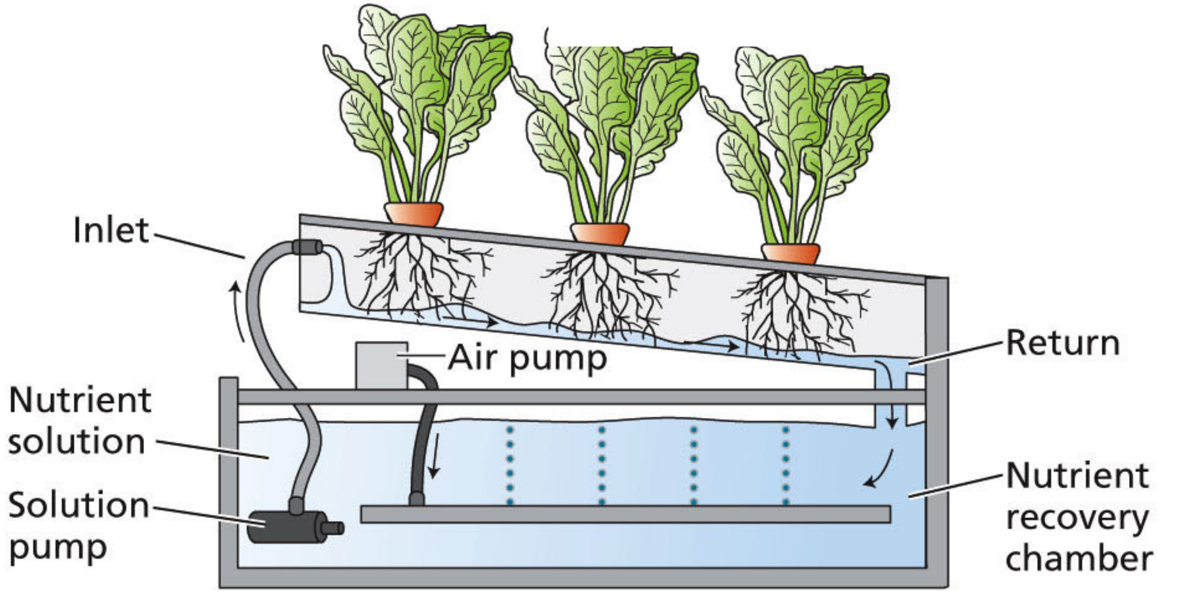


Fig. 12.2

(A) **Hydroponic growth system**



(B) **Nutrient film growth system**



PLANT PHYSIOLOGY, Fourth Edition, **Figure 5.1 (Part 1)** © 2006 Sinauer Associates, Inc.


28-06-2017 Wed 13:39:45
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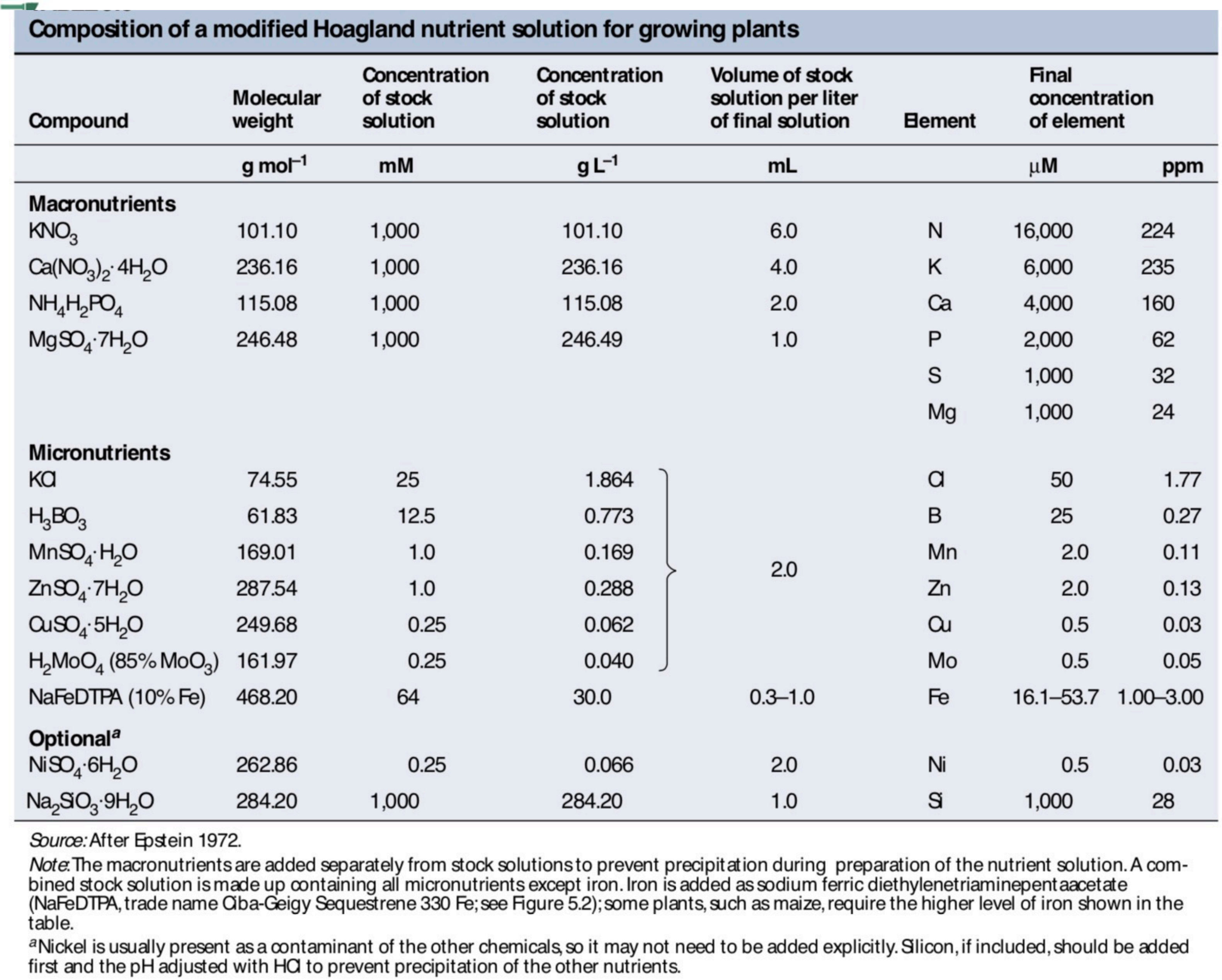
https://www.youtube.com/watch?v=F_WuJ9P1u-k

Hydroponics



Composition of a modified Hoagland nutrient solution for growing plants

Compound	Molecular weight	Concentration of stock solution	Concentration of stock solution	Volume of stock solution per liter of final solution	Element	Final concentration of element	
	g mol^{-1}	mM	g L^{-1}	mL		μM	ppm
Macronutrients							
KNO_3	101.10	1,000	101.10	6.0	N	16,000	224
$Ca(NO_3)_2 \cdot 4H_2O$	236.16	1,000	236.16	4.0	K	6,000	235
$NH_4H_2PO_4$	115.08	1,000	115.08	2.0	Ca	4,000	160
$MgSO_4 \cdot 7H_2O$	246.48	1,000	246.49	1.0	P	2,000	62
					S	1,000	32
					Mg	1,000	24
Micronutrients							
KCl	74.55	25	1.864	2.0	Cl	50	1.77
H_3BO_3	61.83	12.5	0.773		B	25	0.27
$MnSO_4 \cdot H_2O$	169.01	1.0	0.169		Mn	2.0	0.11
$ZnSO_4 \cdot 7H_2O$	287.54	1.0	0.288		Zn	2.0	0.13
$CuSO_4 \cdot 5H_2O$	249.68	0.25	0.062		Cu	0.5	0.03
H_2MoO_4 (85% MoO_3)	161.97	0.25	0.040		Mo	0.5	0.05
NaFeDTPA (10% Fe)	468.20	64	30.0	0.3–1.0	Fe	16.1–53.7	1.00–3.00
Optional[a]							
$NiSO_4 \cdot 6H_2O$	262.86	0.25	0.066	2.0	Ni	0.5	0.03
$Na_2SiO_3 \cdot 9H_2O$	284.20	1,000	284.20	1.0	Si	1,000	28

Source: After Epstein 1972.

Note: The macronutrients are added separately from stock solutions to prevent precipitation during preparation of the nutrient solution. A combined stock solution is made up containing all micronutrients except iron. Iron is added as sodium ferric diethylenetriaminepentaacetate (NaFeDTPA, trade name Ciba-Geigy Sequestrene 330 Fe; see Figure 5.2); some plants, such as maize, require the higher level of iron shown in the table.

[a] Nickel is usually present as a contaminant of the other chemicals, so it may not need to be added explicitly. Silicon, if included, should be added first and the pH adjusted with HCl to prevent precipitation of the other nutrients.

Hydroponics

At

https://www.2lua.vn/agritec/hydroponics-calculator.html?hl=en

You can see the basics of an hydroponic calculator that Combines plants needs with the available chemicals in order to rich a certain production.

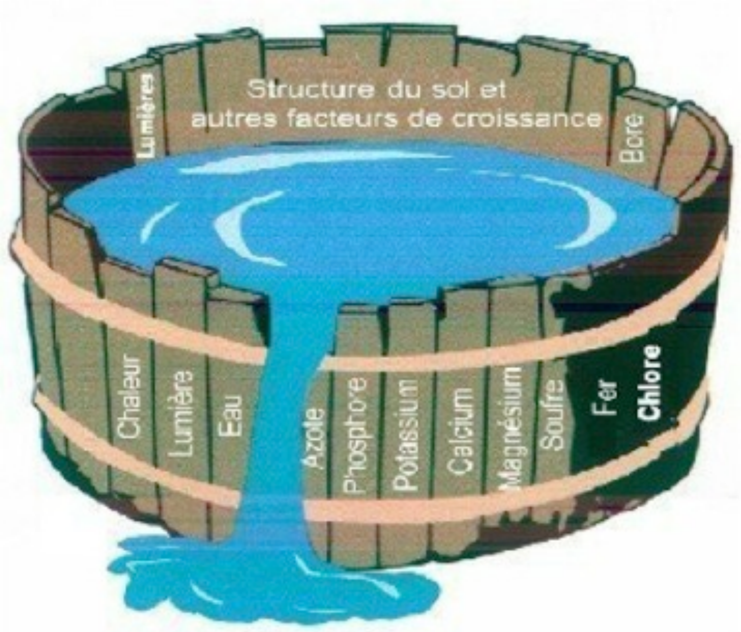
Try!

Justus von Leibig (1844)

✓Estabelece através da **experimentação** o carácter **puramente mineral** da nutrição vegetal.

  ✓Análise da composição química das cinzas

  ✓Hidroponia

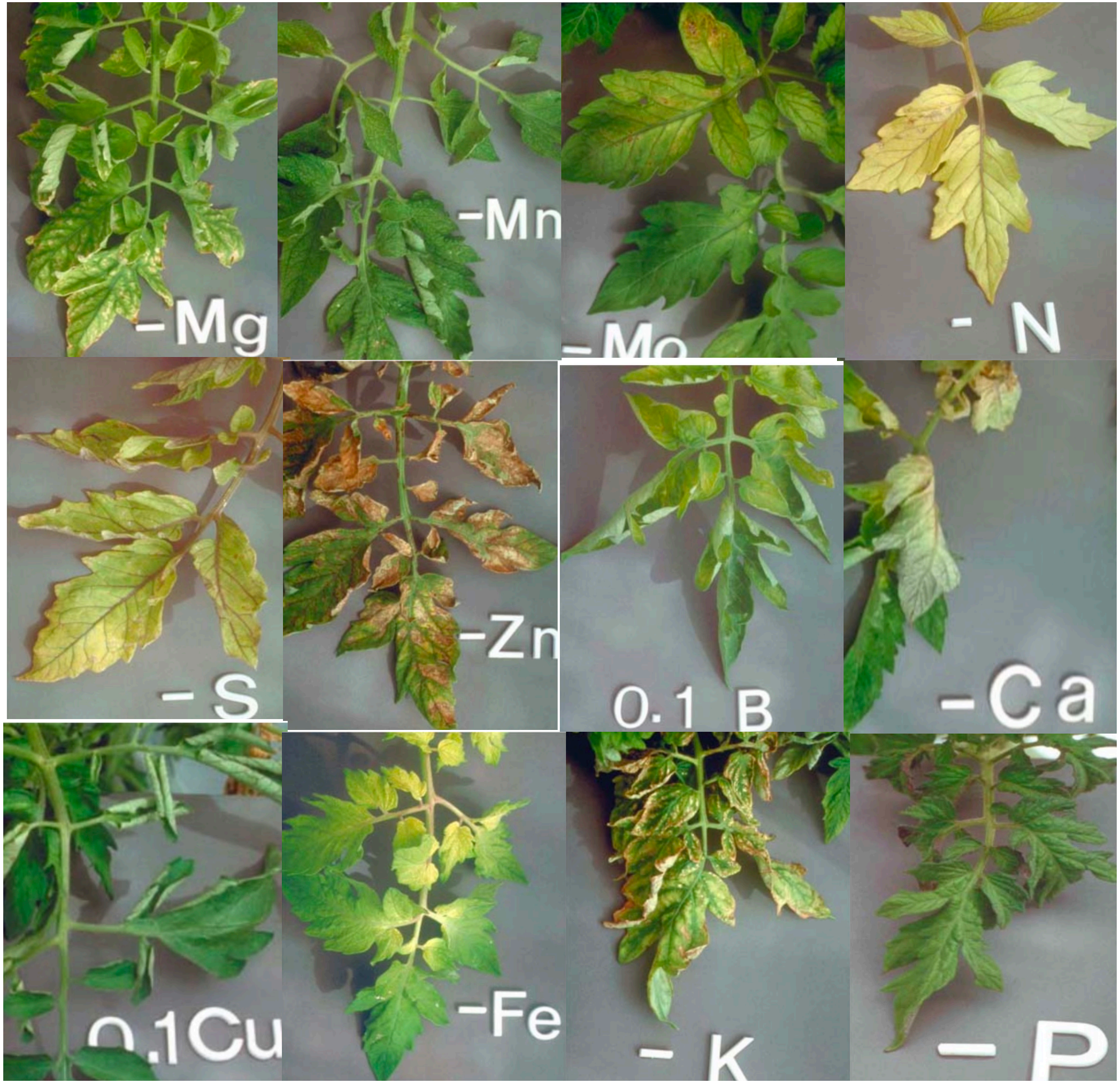


Lei do mínimo

Hidroponia

Plant nutrient deficiency symptoms:

- Are the expression of metabolic disorders resulting from insufficient supply of an essential nutrient.
- These are related to the roles played by essential elements in normal plant metabolism and functions (see slide 16).
- Consider to which extent an element can be recycled from older to younger leaves (see slide 15).


-Mg
-Mn
-Mo
- N
-S
-Zn
0.1 B
-Ca
0.1Cu
-Fe
- K
- P

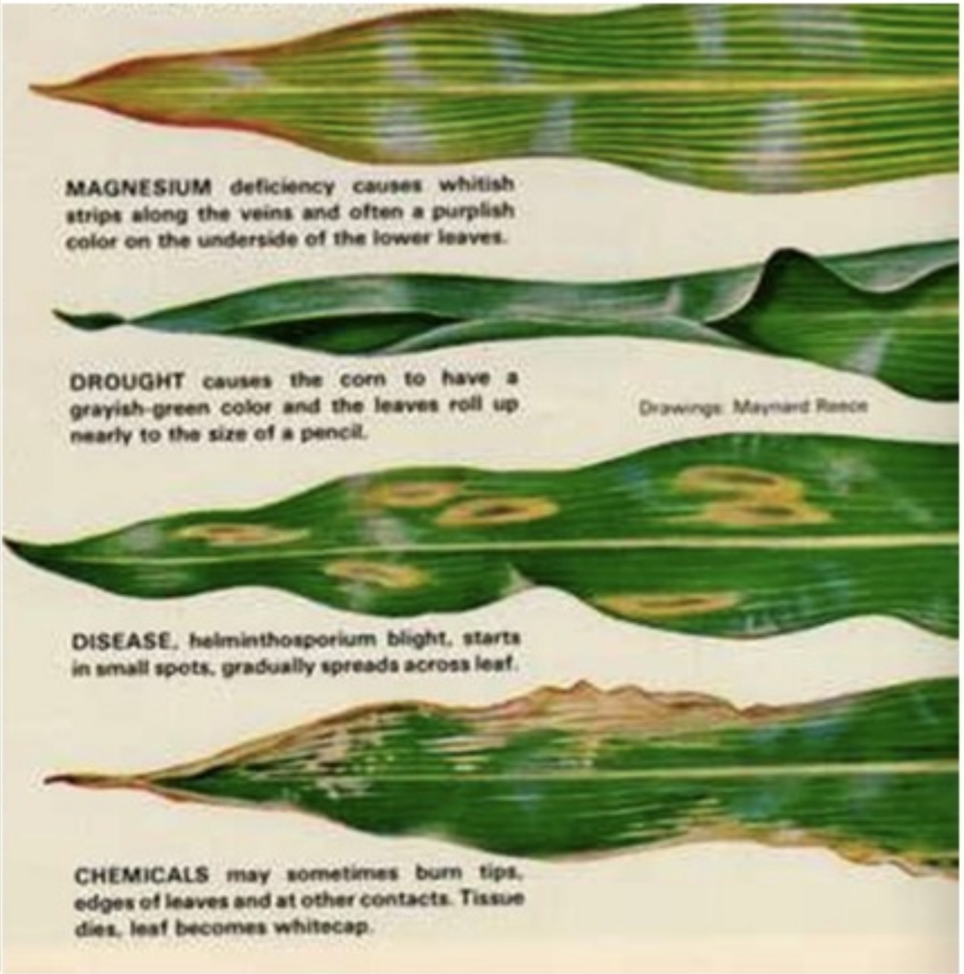
Nutritional Deficiencies in Corn
NUTRIENT DEFICIENCY SYMPTOMS IN CORN

HEALTHY leaves shine with a rich dark green color when adequately fed

PHOSPHATE shortage marks leaves with reddish-purple, particularly on young plants.

POTASH deficiency appears as a firing or drying along the tips and edges of lowest leaves.

NITROGEN hunger sign is yellowing that starts at tip and moves along middle of leaf.



MAGNESIUM deficiency causes whitish strips along the veins and often a purplish color on the underside of the lower leaves.

DROUGHT causes the corn to have a grayish-green color and the leaves roll up nearly to the size of a pencil.

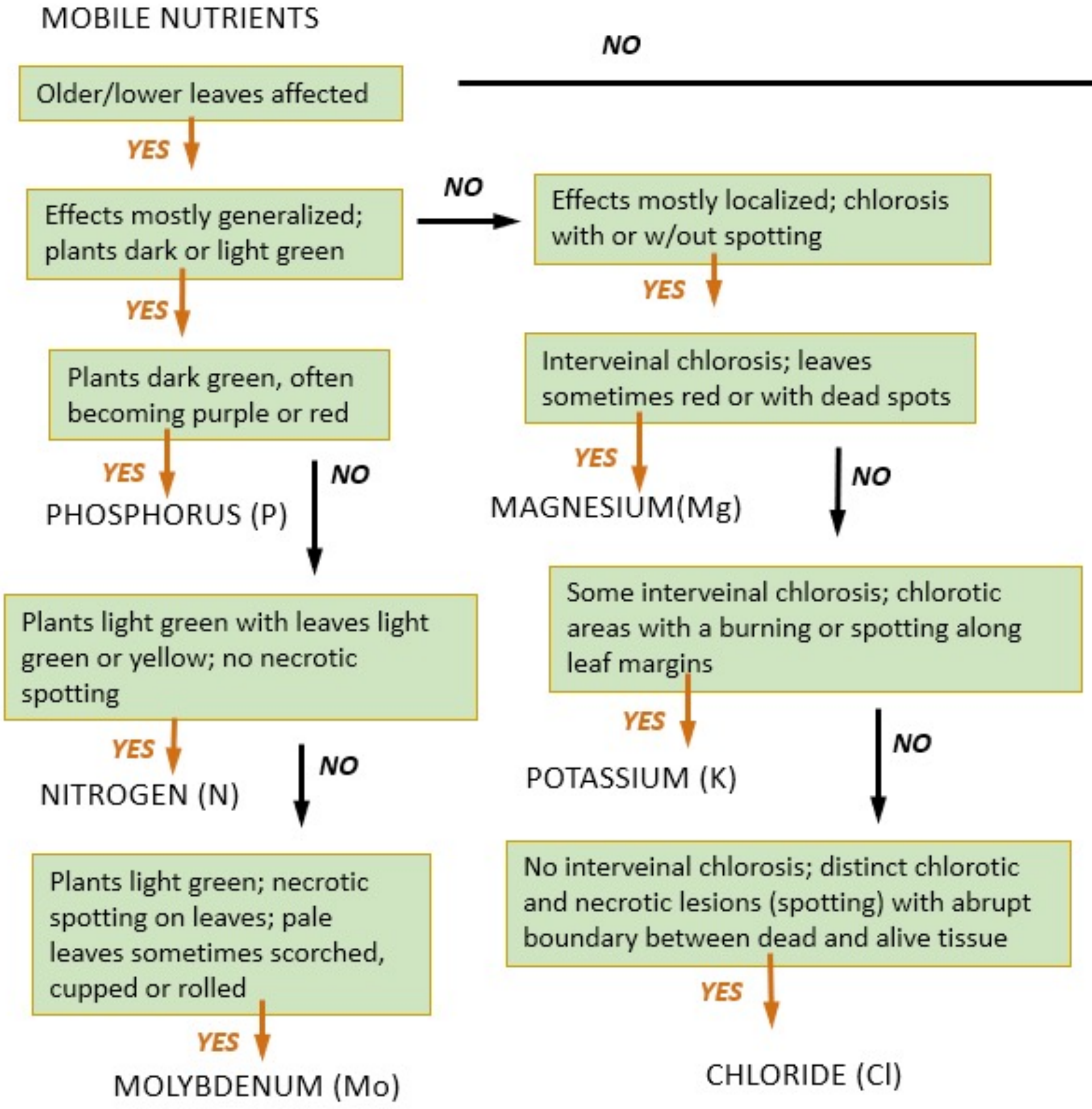
Drawings: Maynard Reece

DISEASE, helminthosporium blight, starts in small spots, gradually spreads across leaf.

CHEMICALS may sometimes burn tips, edges of leaves and at other contacts. Tissue dies, leaf becomes whitecap.

Visual tissue assessment

In Nutrient Management Module 9
http://landresources.montana.edu/nm



MOBILE NUTRIENTS

Older/lower leaves affected

YES: Effects mostly generalized; plants dark or light green

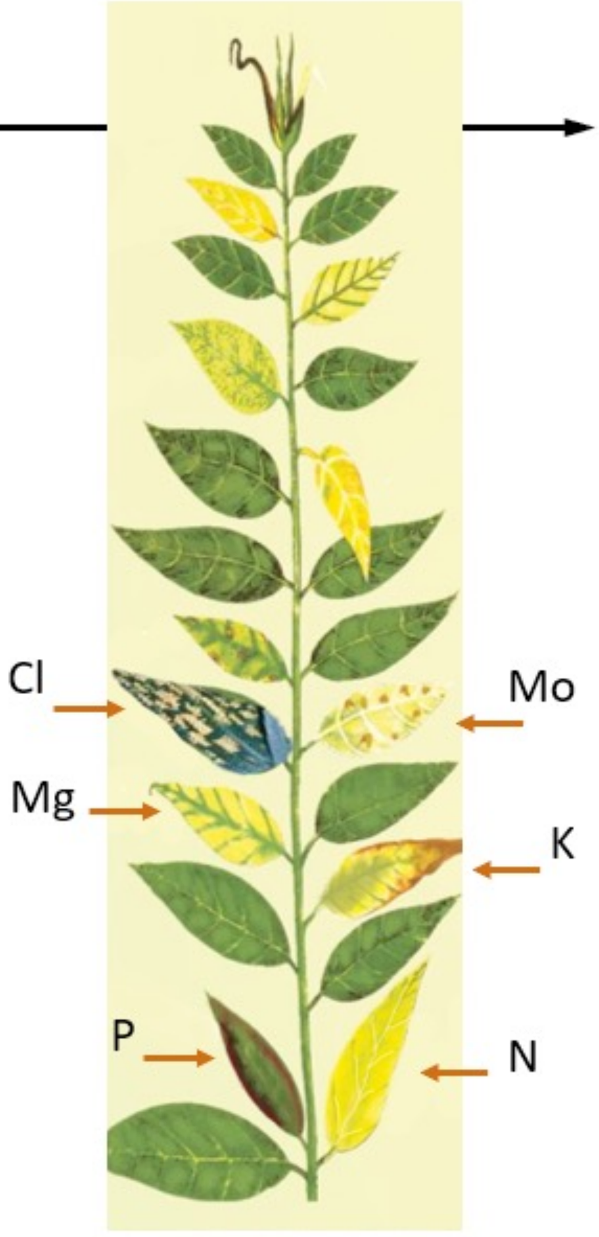
NO: Effects mostly localized; chlorosis with or w/out spotting

Effects mostly generalized; plants dark or light green

- YES: Plants dark green, often becoming purple or red
  - YES: PHOSPHORUS (P)
  - NO: Plants light green with leaves light green or yellow; no necrotic spotting
    - YES: NITROGEN (N)
    - NO: Plants light green; necrotic spotting on leaves; pale leaves sometimes scorched, cupped or rolled
      - YES: MOLYBDENUM (Mo)

Effects mostly localized; chlorosis with or w/out spotting

- YES: Interveinal chlorosis; leaves sometimes red or with dead spots
  - YES: MAGNESIUM(Mg)
  - NO: Some interveinal chlorosis; chlorotic areas with a burning or spotting along leaf margins
    - YES: POTASSIUM (K)
    - NO: No interveinal chlorosis; distinct chlorotic and necrotic lesions (spotting) with abrupt boundary between dead and alive tissue
      - YES: CHLORIDE (Cl)

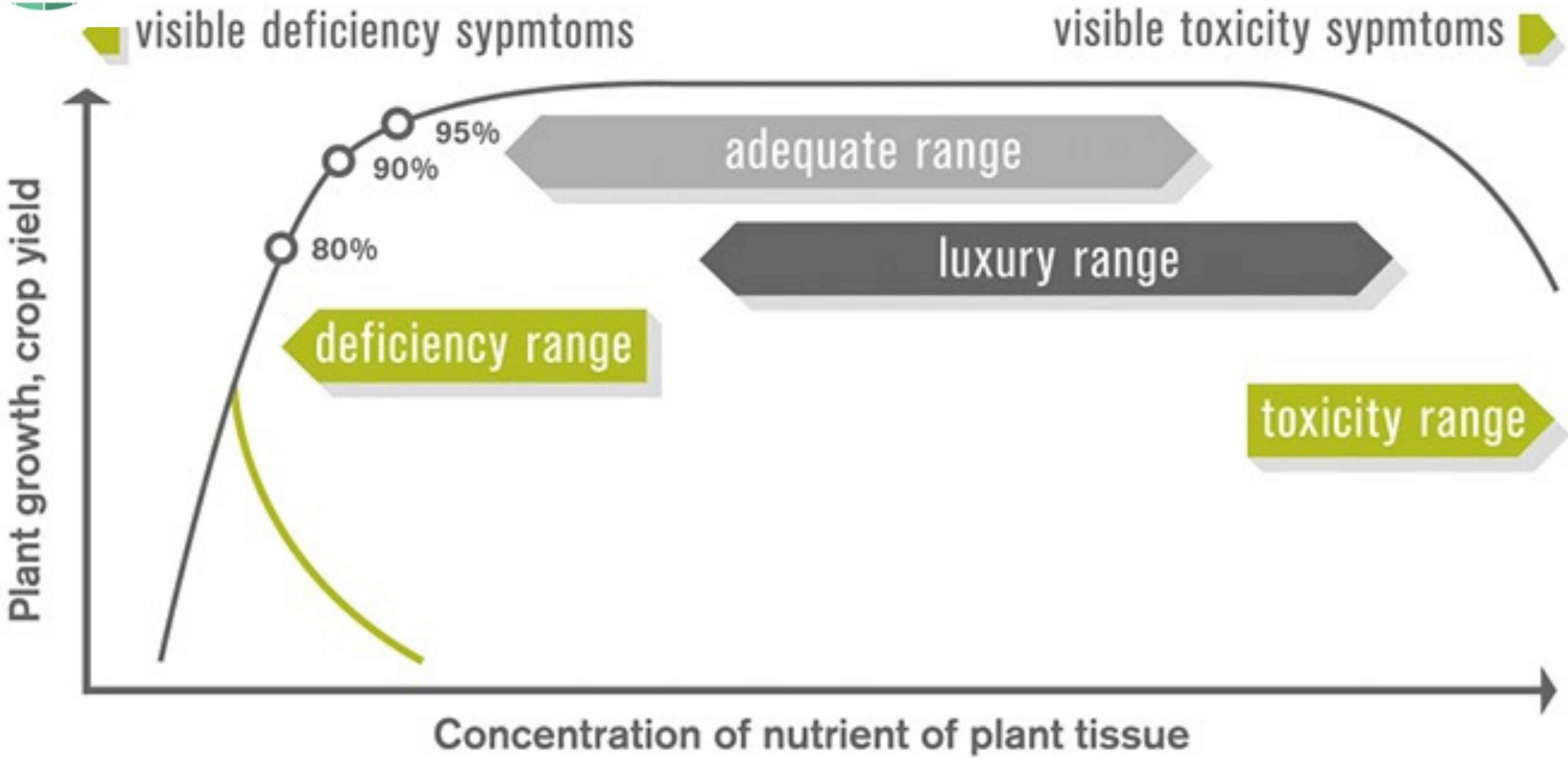


Leaf image source unknown

PLANT NUTRITIONAL DEFICIENCIES SYMPTOMS CHART

Symptoms	Ca	S	Fe	Mn	Zn	B	Cu	N	P	K	Mg	Mo
Chlorosis throughout leaves		Y/O citrus						O Starts @ tips		O starts @ edge		O
Interveinal chlorosis leaves			Y	Y	Y/O legumes						O	
Chlorosis in tiny spots - dicot				Y								
Grey-green spots-monocot				Y								
Bleached/blanched leaves			Y	Y			Y	O				O
Dark green/purple leaf/stem									O			
Bronzed leaves possible					Y						O	
Marginal/tip leaf chlorosis burn								O starts @ tips		O starts @ edge		O starts @ edge
Necrotic spots on leaves										O		
Growing tips die	Y					Y	Y					
Drooping leaves/wilting											O	
Leaf drop							Y	O				O
Strap-like leaves					Y							
Rosetting of leaves					Y	Y	Y					
Distorted leaves	Y					Y	Y			O		O
Reduced flowering/fruiting	*							*	*	*		*
Weak/brittle/thin stems		*							*	*		
Stunted growth						*	*	*	*	*		*
Abnormal root growth	*				*				*			

Key: Calcium(Ca); Sulfur(S); Iron(Fe); Manganese(Mn); Zinc (Zn); Boron(B); Copper(Cu); Nitrogen(N); Phosphorus (P); Potassium(K); Magnesium(Mg); Molybdenum(Mo) **Y = Younger** **O = Older** *** = present** **Chlorosis = Yellow**



- Plant tissue analysis is routinely used by farmers for N, P and K;
- Can be done for different plant tissues and organs (leaves of different ages and positions, stems, roots, fruits, etc.)
- More accurate than visual symptoms analysis; can be used to correct deficiencies