Chapter 05
Mineral Nutrition

BIOL 5130/6130

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Chapter 05.01. Introduction - 01

- Minerals are nonorganic nutrients required for the growth of all organisms
- Minerals for the terestrial biosphere enter the biosphere mainly though the root system of plants accompanying the water taken up from the soil profile
- Mineral nutrients absorbed by the root system are tranported throughout the plant to provide the nutrient needs of all tissues.
- Mineral nutrition is the study of how plants acquire and use mineral nutrients.
- Fertilizers applied to agricultural crops is an important aspect of the food production chain.
- Nutrient cycling in an ecosystem is critical to understanding the funciton of ecosystems

Chapter 05.02. Essential Nutrients, Deficiencies, and Plant Disorders - 02

- An essential elements are intrinsic components of structure or metabolism of a plant whose absence causes severe abnormalities of growth, development or reproduction.

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			
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
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

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.

Chapter 05.02. Essential Nutrients, Deficiencies, and Plant Disorders - 03

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.

Chapter 05.02. Essential Nutrients, Deficiencies, and Plant Disorders - 04

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.

Chapter 05.02. Essential Nutrients, Deficiencies, and Plant Disorders - 05

TABLE 5.3
Composition of a modified Hoagland nutrient solution for growing plants (Part 1)

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}	m*M*	g L^{-1}	mL		μ*M*	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

Source: After Epstein 1972.

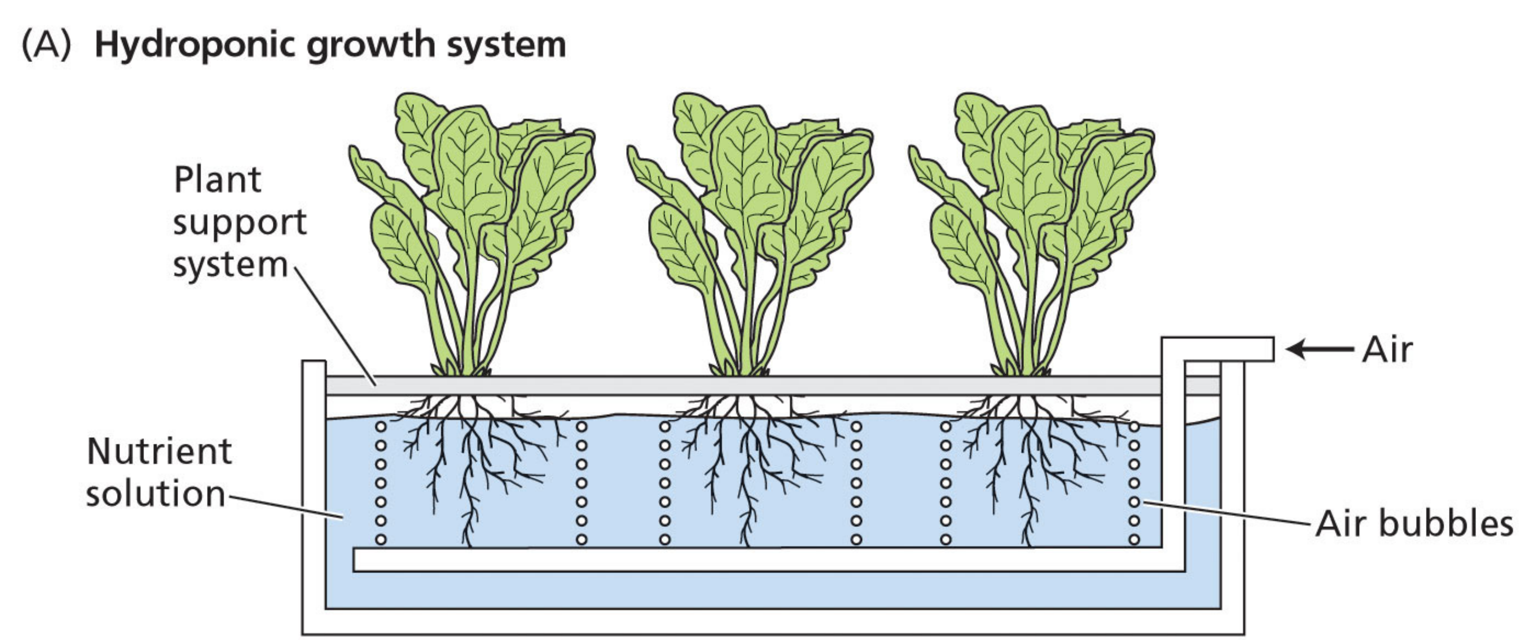
Note: The macronutrients are added separately from stock solutions to prevent precipitation during preparation of the nutrient solution. A combined stock solution is made up containing all micronutrients except iron. Iron is added as sodium ferric diethylenetriaminepentaacetate (NaFeDTPA, trade name 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.

Chapter 05.02. Essential Nutrients, Deficiencies, and Plant Disorders - 06

02.01. Special techniques are used in nutritional studies

- To study nutrient problems in plants hydroponic and aeroponic techniques have been developed because the soil medium complicates the plant studies.



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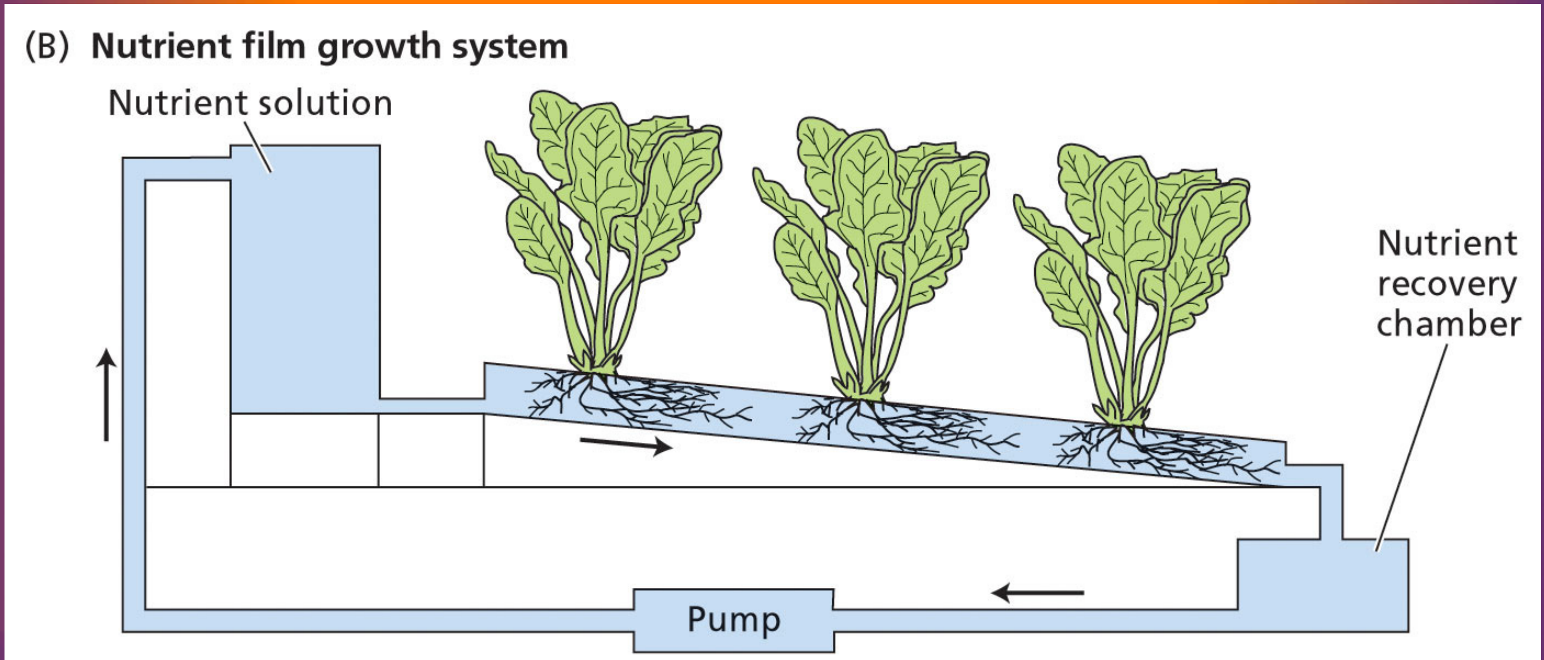
Chapter 05.02. Essential Nutrients, Deficiencies, and Plant Disorders - 07

02.01. Special techniques are used in nutritional studies



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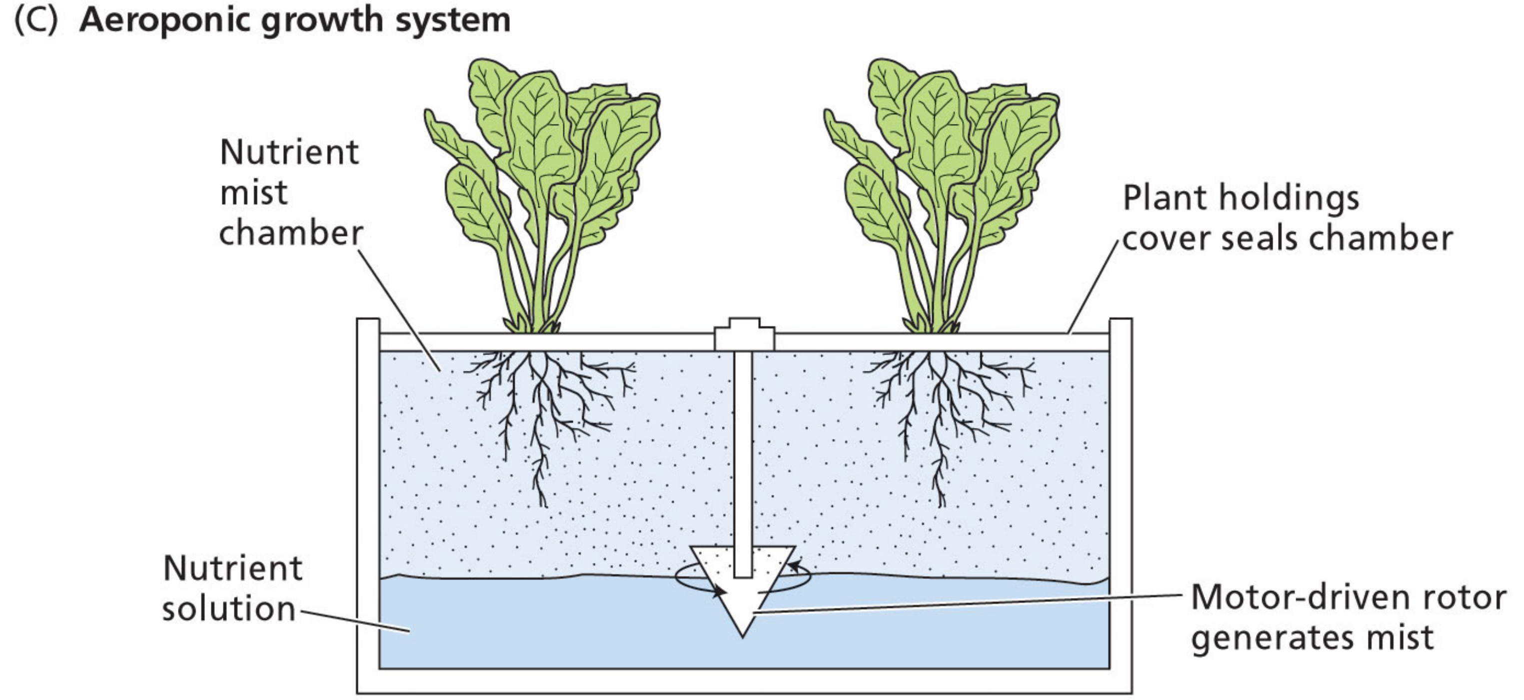
Chapter 05.02. Essential Nutrients, Deficiencies, and Plant Disorders - 08

02.01. Special techniques are used in nutritional studies



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Chapter 05.02. Essential Nutrients, Deficiencies, and Plant Disorders - 09

02.02. Nutrient solutions can sustain rapid plant growth

TABLE 5.3
Composition of a modified Hoagland nutrient solution for growing plants (Part 1)

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	
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					S	1,000	32
					Mg	1,000	24
Micronutrients							
KCl	74.55	25	1.864	2.0 (KCl through H_2MoO_4)	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.

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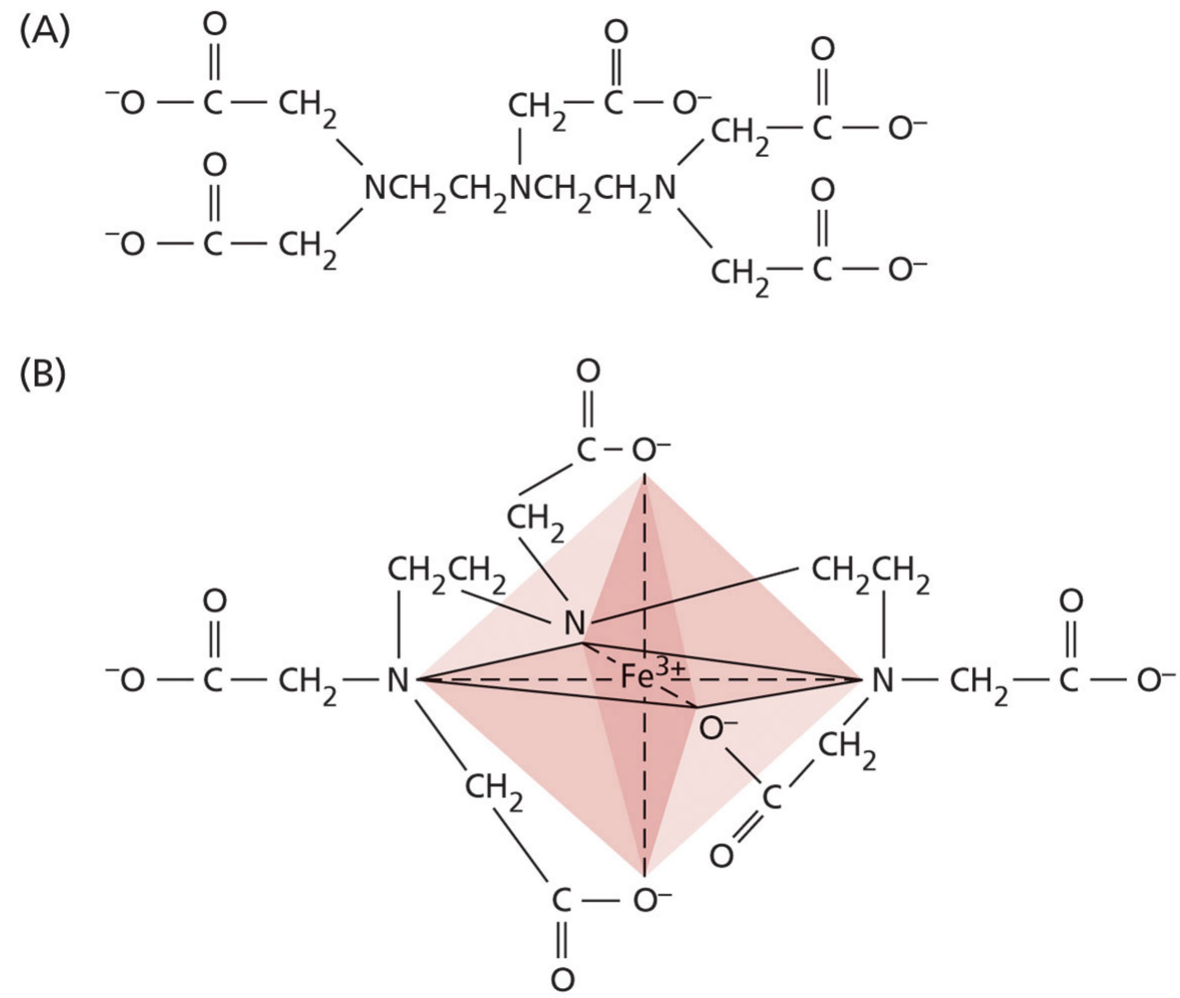
Chapter 05.02. Essential Nutrients, Deficiencies, and Plant Disorders - 10

02.02. Nutrient solutions can sustain rapid plant growth



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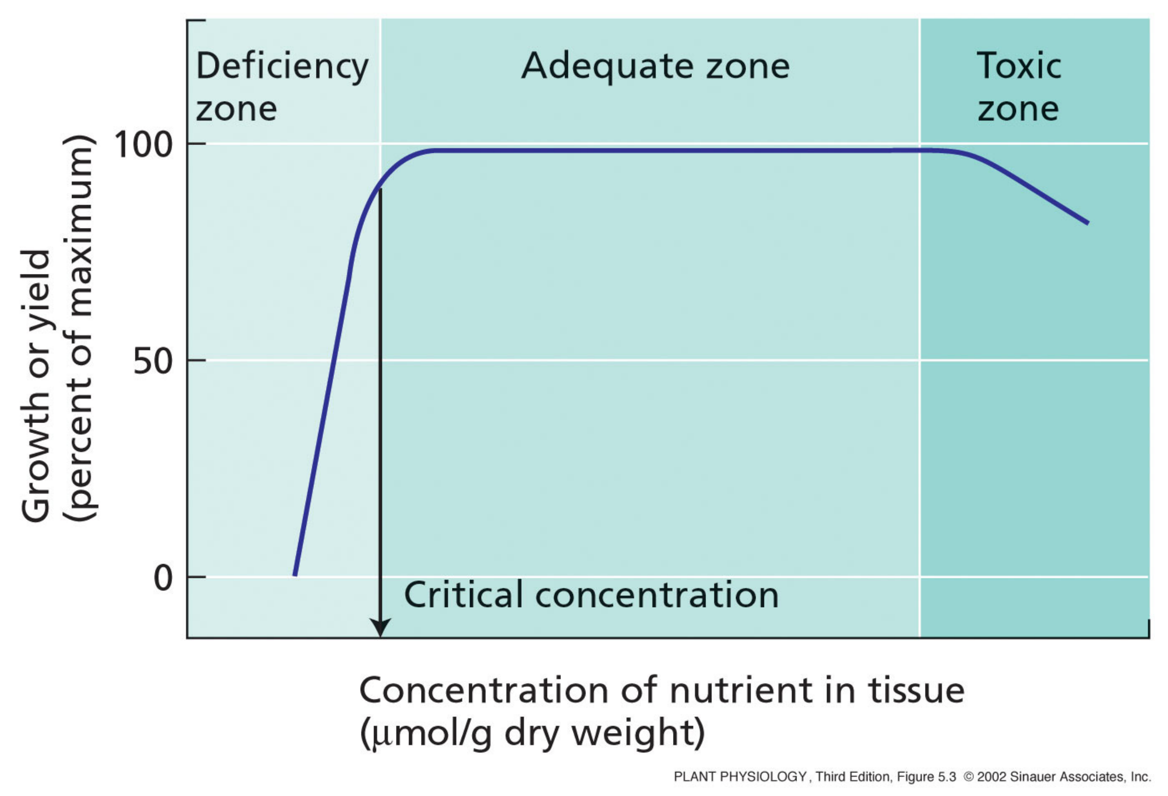
Chapter 05.02. Essential Nutrients, Deficiencies, and Plant Disorders - 11

02.03. Mineral deficiencies disrupt plant metabolism and function

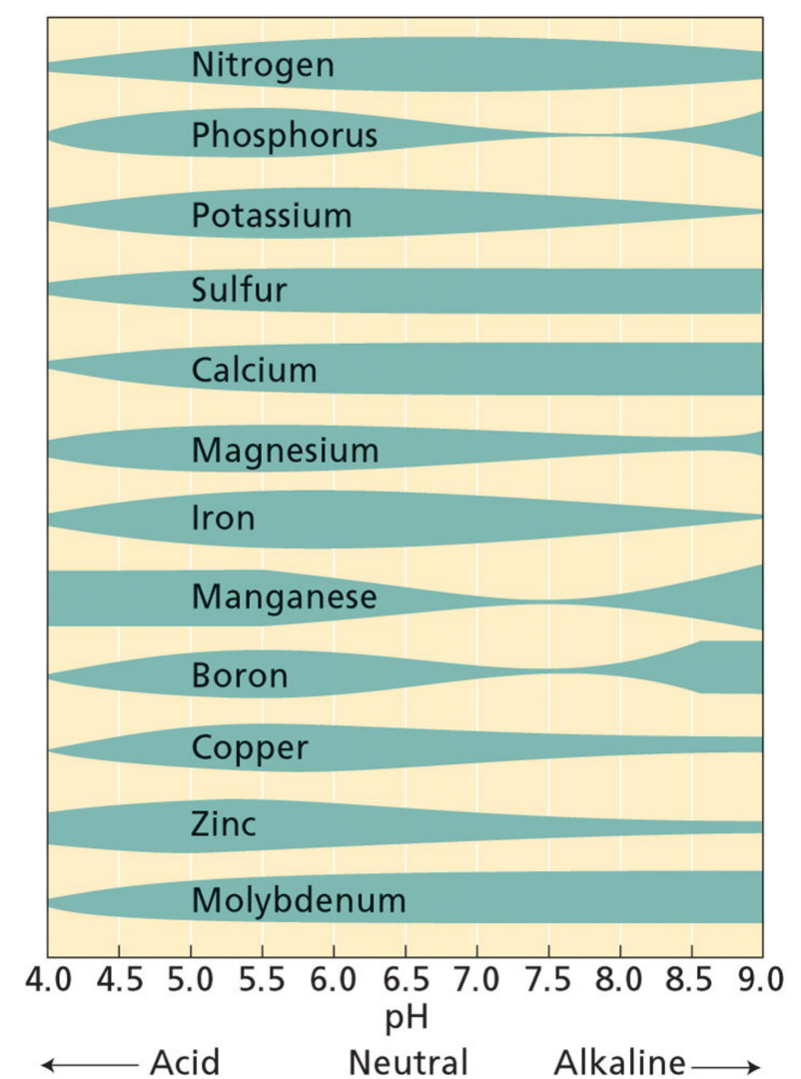
- Typical symptoms for mineral deficiencies are given on pg 79-82 of your text.

02.04. Analysis of plant tissues reveals mineral deficiencies



Chapter 05.03. Treating Nutritional Deficiencies - 12

- 03.01. Crop yields can be improved by addition of fertilizers
  - Availability of all nutrients at the
    - adequate level is a necessity fo
    - sustaining optimal crop yields.
  - Most fertilizers are characterized
    - by a 3 number tag that reflects t
    - mole % of nitrogen, the mole %
    - phosphate, and the mole % of
    - potassium.
  - Soil pH can play a critical role in
    - the availability of nutrients.
  - Soil pH can be adjusted by the
    - addition of lime to low pH soils o
    sulfur to high pH solis.



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Chapter 05.03. Treating Nutritional Deficiencies - 13

03.02. Some mineral nutrients can be absorbed by leaves

- Foliar application of fertilizers has been demonstrated effective.
- Coating leaves with nutrients, particularly nitrogen can get nitrogen to the leave where it is needed more rapidly
- The vagaries of plant water relations that affect nutrient flow can be largely avoided by foliar application.

Chapter 04.04. Soil, Roots, and Microbes - 14

04.01a. Negatively charged soil particles affect the adsorption of mineral nutrients

- Soil particles can be orgnaic or inorganic
- Inorganic soil partilces are characterized by size
  - Gravel is larger than 2 mm
  - coarse sand is 0.2 - 2 mm
  - fine sand is 0.02 – 0.2 mm
  - silt is 0.002 – 0.02 mm
  - Clay is < 0.002 mm
- Additionally there are different types of clays

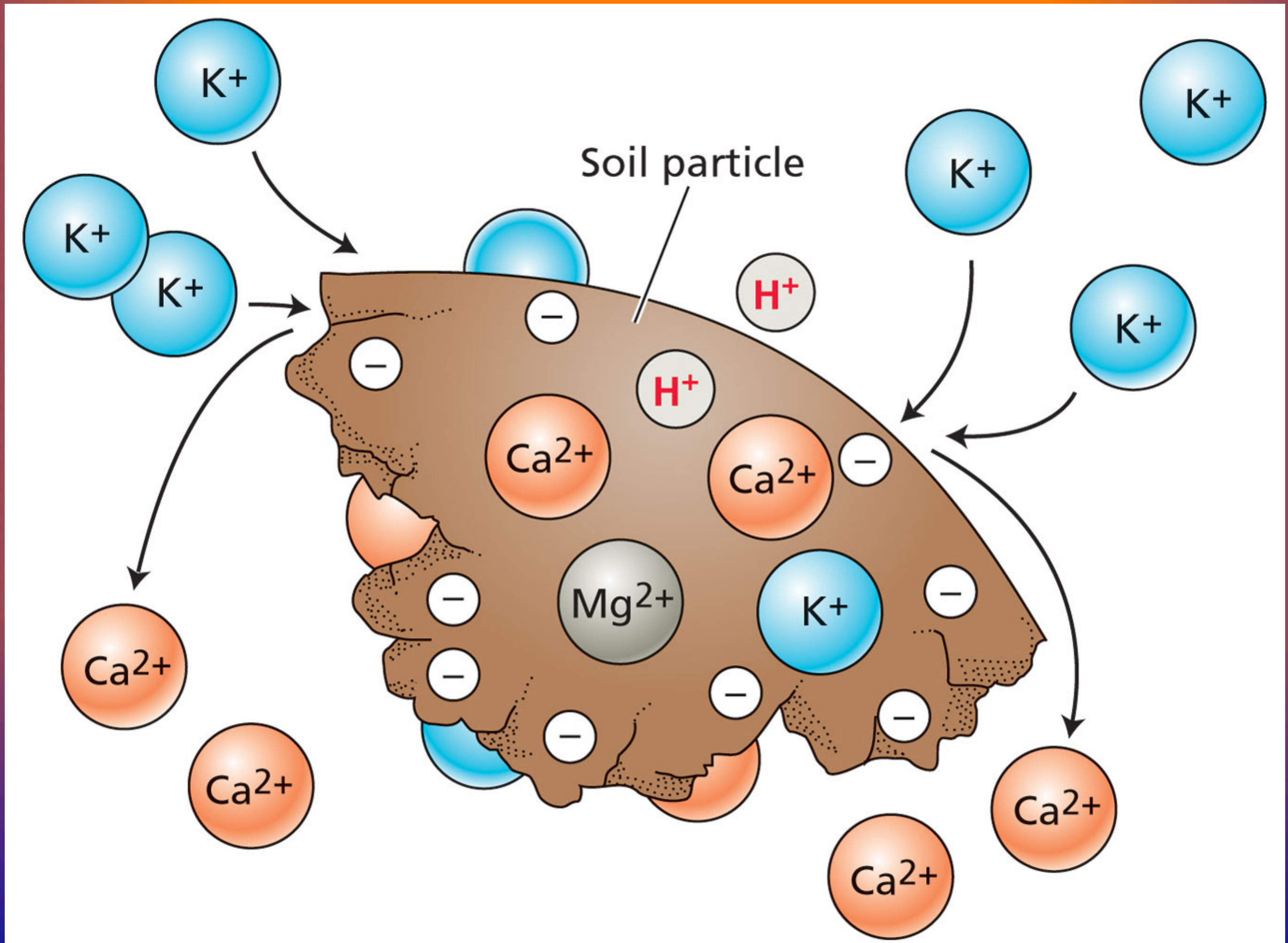
TABLE 5.5
Comparison of properties of three major types of silicate clays found in the soil

	Type of clay		
Property	**Montmorillonite**	**Illite**	**Kaolinite**
Size (μm)	0.01–1.0	0.1–2.0	0.1–5.0
Shape	Irregular flakes	Irregular flakes	Hexagonal crystals
Cohesion	High	Medium	Low
Water-swelling capacity	High	Medium	Low
Cation exchange capacity (milliequivalents 100 g^{-1})	80–100	15–40	3–15

Source: After Brady 1974.

Chapter 04.04. Soil, Roots, and Microbes - 15

04.01b. Negatively charged soil particles affect the adsorption of mineral nutrients



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Chapter 04.04. Soil, Roots, and Microbes - 16

04.02. Soil pH affects nutrient availability, soil microbes, and root growth

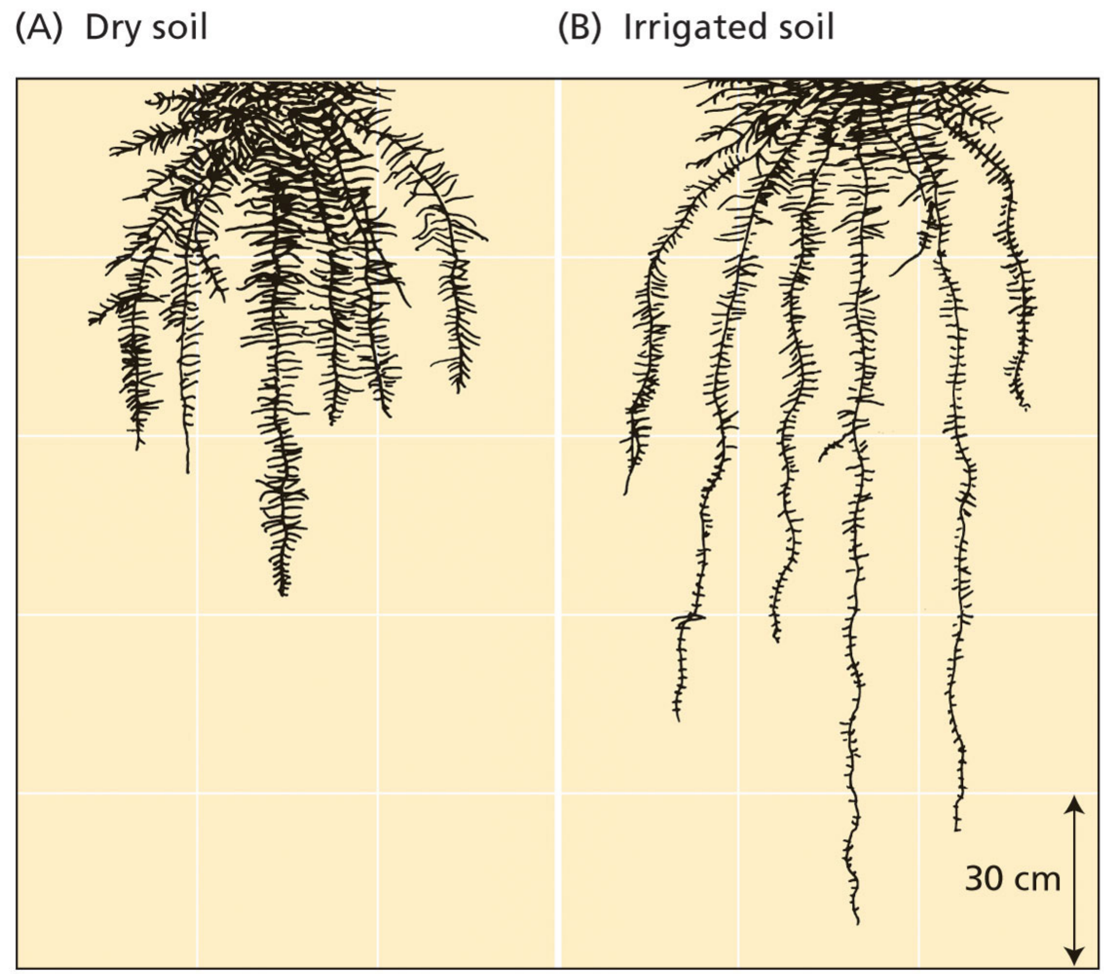
- Soil pH affects nutrient availability (see table 5.4)
- Organic matter content and rainfall tend to affect soil pH
- Older weatered soils have lower pH's
- Typical of tropical soils

04.03. Excess minerals in the soil limit plant growth

- Mineral salt accumulation, particular sodium ion accumulation leads to soil salinization
- In arid regions, salt accumulation can be significant
- Leaching through the root zone
- Halophytes survive or thrive in saline soil conditions
- Glycophytes tend to be more salt sensitivie

Chapter 04.04. Soil, Roots, and Microbes - 17

04.04. Plants develop extensive root systems



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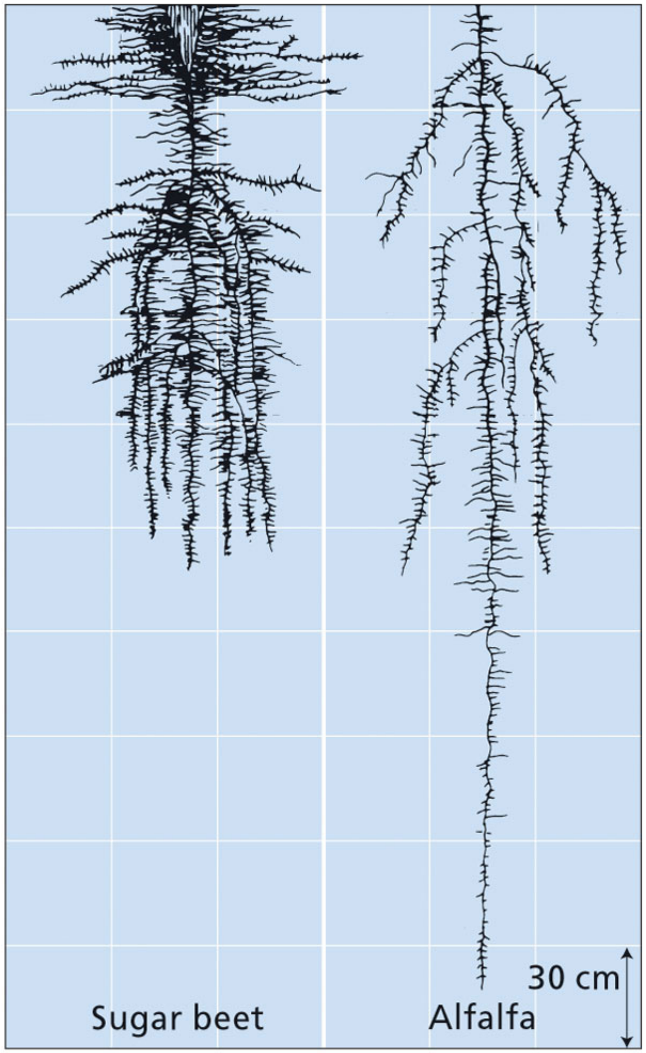

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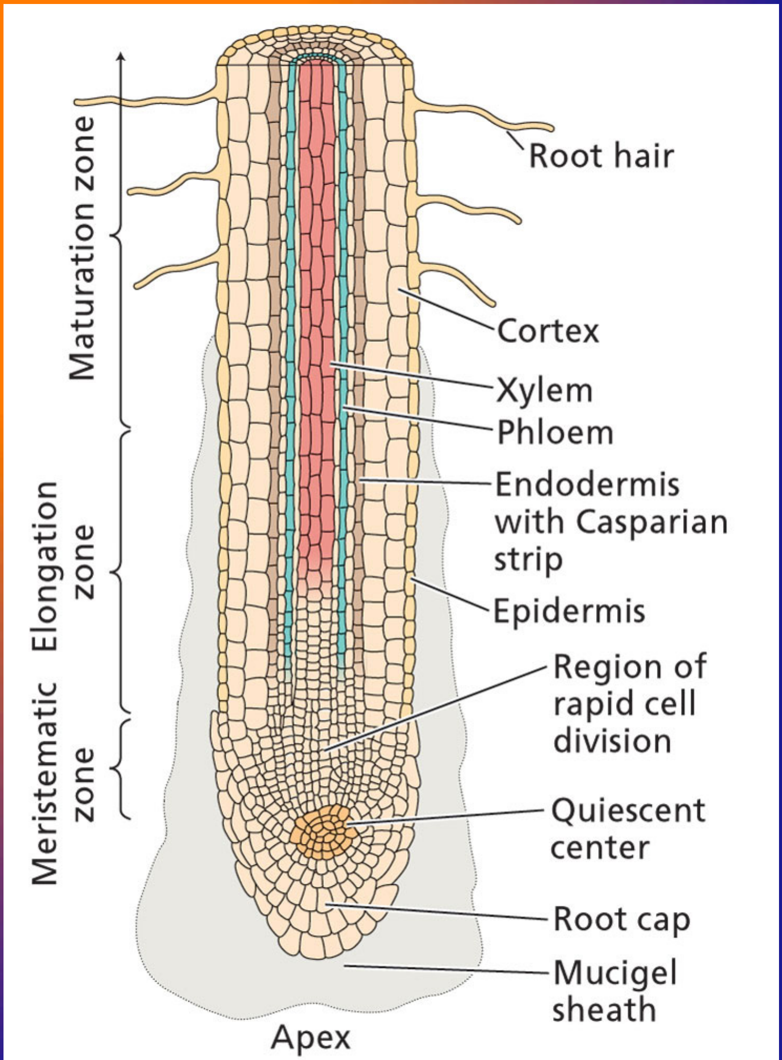
Chapter 04.04. Soil, Roots, and Microbes - 18

04.05. Root systems differ in form but are based on common structures

- Cell division takes place in the root meristem, and takes place 2 dimentions to give dimension to the root.
- The Casperian strip separates the cortex from the steele.
- Xylem and Phloem are separated inside the steele.



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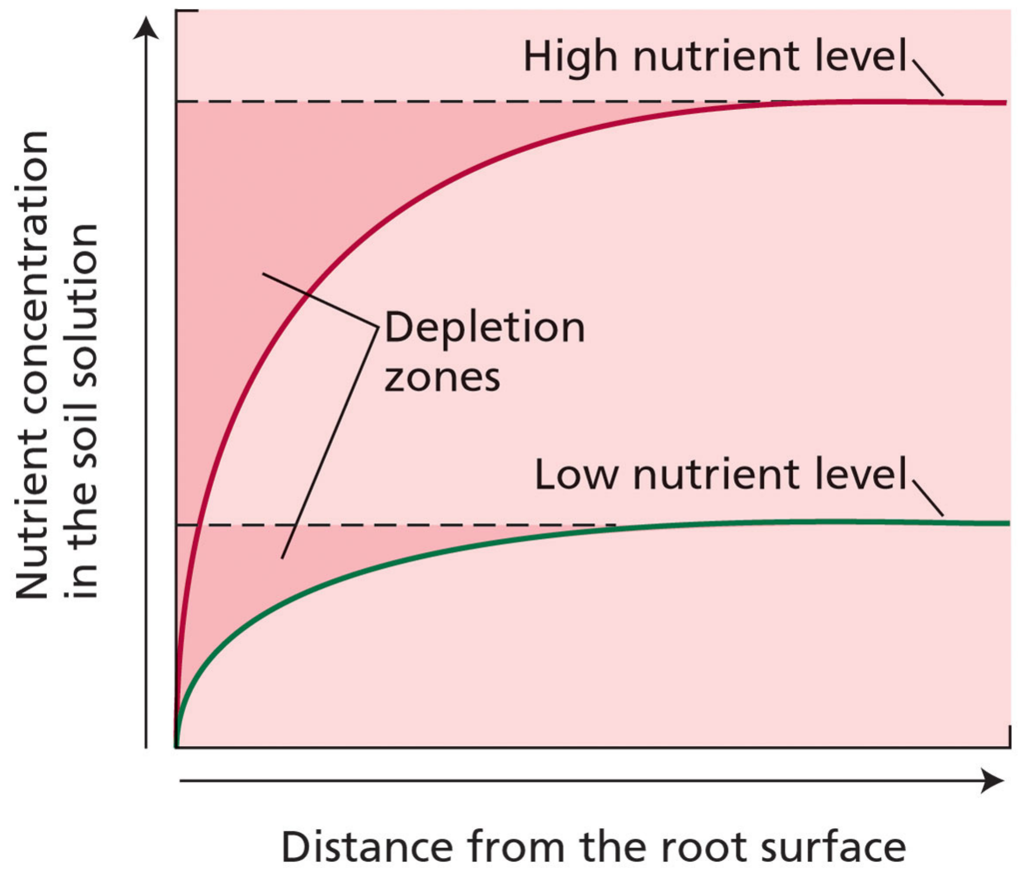
Chapter 04.04. Soil, Roots, and Microbes - 19

04.06. Different areas of the root absorb different mineral ions

- Depending on the crop different ions are taken up by different parts of the root, but this differs for different crops.
- In the rhizosphere, minerals must move to the root surface by diffusion.
- The soil volume immediately adjacent to the root becomes depleted of nutrients and is rererred to as the depletion zone.



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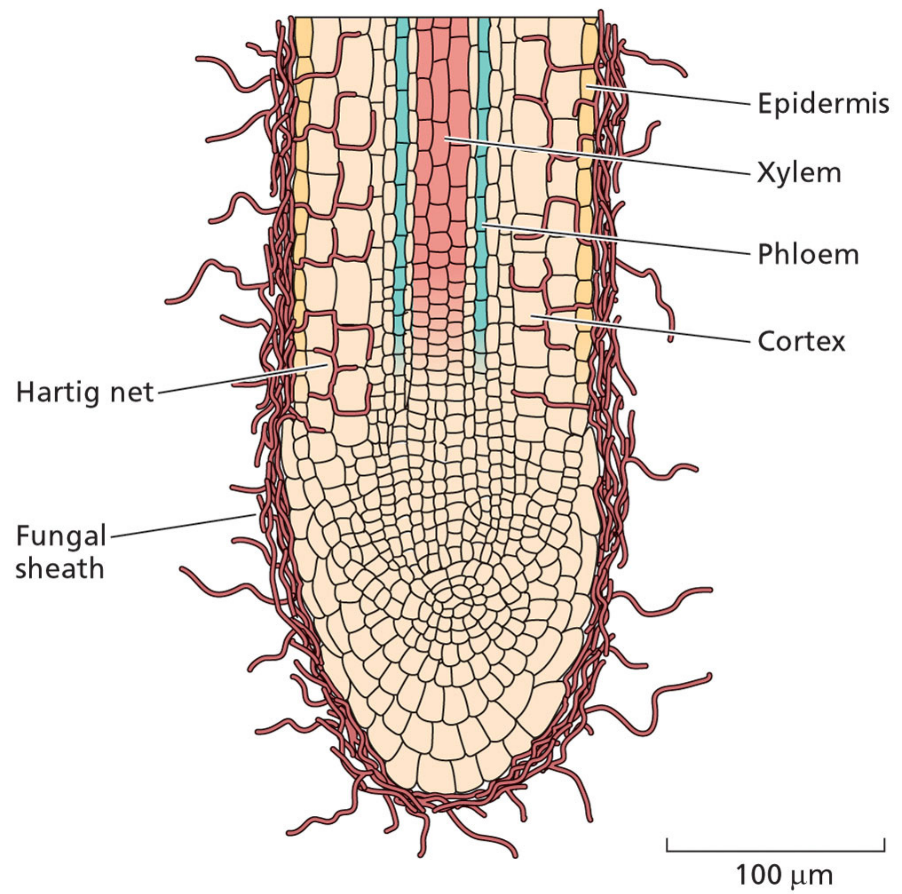
Chapter 04.04. Soil, Roots, and Microbes - 20

04.07. Mycorrhizal fungi facilitate nutrient uptake by roots

04.08. Nutrients move from the mycorrhizal fungi to the root cells



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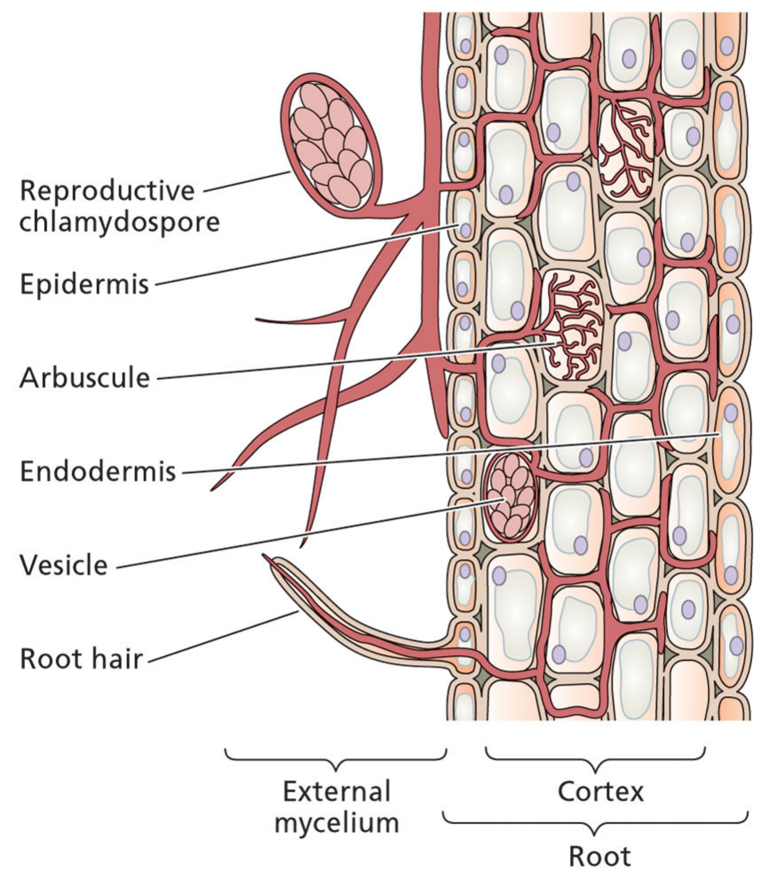

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END
Chapter 05
Mineral Nutrition

Supplemental topics and study questions
Can be found at:

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