

Unit B: Seed Germination, Growth, and Development

Lesson 4: Determining Nutrient Functions and Utilization

Student Learning Objectives: Instruction in this lesson should result in students achieving the following objectives:

1. Discuss the 16 essential nutrients, their functions, and deficiency symptoms.
2. Identify the nonfertilizer nutrients and their functions.
3. Identify the primary macronutrients and their functions, and deficiency symptoms.
4. Identify the secondary micronutrients and their functions, and deficiency symptoms.
5. Identify the micronutrients and their functions, and deficiency symptoms.

Recommended Teaching Time: 3 hours

Recommended Resources: The following resources may be useful in teaching this lesson:

- A PowerPoint has also been developed with use of this lesson plan
- <http://agcrops.osu.edu/cropdoc/index.html>
- <http://gardening.about.com/od/gardenproblems/a/NutrientDeficie.htm>
- <http://water.me.vccs.edu/concepts/oxycycle.html>
- <http://library.thinkquest.org/11226/why.htm>

List of Equipment, Tools, Supplies, and Facilities:

Writing surface
Projector
Transparency Masters
Copies of student lab sheet
Plants or photos with nutrient deficiencies for lab

Terms: The following terms are presented in this lesson (shown in bold italics and on PowerPoint Slide 2):

- Denitrification
- Leach
- Macronutrient
- Micronutrient
- Nitrification
- Nitrogen cycle
- Nitrogen fixation
- Nutrient deficiency

- Nutrient excess
- Soluble salts
- Nutrients

Interest Approach: Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. A possible approach is included here.

Bring a variety of plants to class that show nutrient deficiencies. Ask the students what they notice about the plants. After they comment that the plants look sick, ask what might be the cause of the illness. Guide the discussion toward nutrient deficiencies and the objectives of this lesson. Poll the students as to who takes vitamins everyday. Follow up by asking why they take vitamins. What is the value of vitamins? Have a multivitamin bottle on hand and instruct a student to read off the minerals listed. Ask whether plants would benefit from vitamins and minerals?

Steer the discussion into the lesson and state the learning objectives.

Summary of Content and Teaching Strategies

Objective 1: Discuss the 16 essential nutrients, their functions, and deficiency symptoms.

(PowerPoint Slide 3)

I. Certain chemical elements, called *nutrients*, are essential for plant growth and development. Sixteen nutrients have been identified as being essential for plant growth.

(PowerPoint Slide 4)

A. A little phrase can be used to help memorize the 16 essential elements for plant growth. It is “C HOPKNS CaFe Managed By Mine CuZn, Mo and Claude” It represents the following: Carbon (**C**), Hydrogen (**H**opkns), Oxygen (**h**Opkns), Phosphorus (**ho**Pkns), Potassium (**hop**Kns), Nitrogen (**hopk**Ns), Sulfur (**hopkn**S), Calcium (**Ca**Fe), Iron (**Ca**Fe), Magnesium (**M**anaged), Boron (**B**y), Manganese (**M**ine), Copper (**Cu**Zn), Zinc (Cu**Zn**). Molybdenum (**Mo**), and Chlorine (**C**laude).

(PowerPoint Slide 5)

B. Plant growth, fueled by cellular respiration, takes place primarily at night when photosynthesis is shut down. With signals from hormones, enzymes are produced. Each enzyme has a specific job. The enzymes break down sugars and recombine them with nitrogen and other nutrients. Many complex products result including, starches, pectin, lignin, cellulose, lipids

or fats, proteins, pigments, hormones, vitamins, and alkaloids and tannins that protect plants from pests and diseases.

(PowerPoint Slide 6)

C. If a plant fails to receive the needed amount of nutrients, it will show signs of **nutrient deficiency**. Nutrient deficiencies most often result in an unhealthy plant appearance.

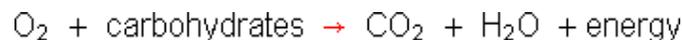
Symptoms vary with the nutrient that is in short supply. Common symptoms of deficiencies include discoloration of the leaves, death of leaf tissue, and stunted growth. Because of the complex interactions of nutrients in plant processes, deficiency symptoms for different nutrients are often very similar.

(PowerPoint Slide 7)

D. High levels of nutrients or **nutrient excess** can cause damage to plants. Chemical fertilizers dissolved in water are referred to as **soluble salts**. Nutrient excess involves the build up of soluble salts that have a burning effect on plant roots.

**** Have the students say the 16 nutrients aloud as a class. Repeat this a couple of times so they retain the information. Then have them repeat the phrase that will help them remember the nutrients. Use TM: B4-2 to illustrate the oxygen cycle, PowerPoint Slide 8 will also work. A brief description of the oxygen cycle is listed below. This can be used to help explain the oxygen cycle to the class.**

Just as water moves from the sky to the earth and back, oxygen is also cycled through the environment. Plants mark the beginning of the oxygen cycle. Plants are able to use the energy of sunlight to convert carbon dioxide and water into carbohydrates and oxygen in a process called photosynthesis as mentioned in the previous lesson.



This means that plants "breathe" in carbon dioxide and "breathe" out oxygen.

Animals form the other half of the oxygen cycle. We breathe in oxygen which we use to break carbohydrates down into energy in a process called respiration.



Carbon dioxide produced during respiration is breathed out by animals into the air.

So oxygen is created in plants and used up by animals, as is shown in the picture on TM: B4-2. But the oxygen cycle is not actually quite that simple.

Plants must break carbohydrates down into energy just as animals do. During the day, plants hold onto a bit of the oxygen which they produced in photosynthesis and use that oxygen to break down carbohydrates. But in order to maintain their metabolism and continue respiration at night, the plants must absorb oxygen from the air and give off carbon dioxide just as animals do. Even though plants produce approximately ten times as much oxygen during the day as they consume at night, the night-time consumption of oxygen by plants can create low oxygen conditions in some water habitats.

Objective 2: Identify the nonfertilizer nutrients and their functions.

(PowerPoint Slides 9 and 10)

- I. Three nutrients make up 89 percent of a plant's tissues. They are carbon, hydrogen, and oxygen.
 - A. These are considered to be nonfertilizer nutrients because they are not given to plants as a fertilizer. Plants obtain these nutrients from air and water. Carbon comes from carbon dioxide; hydrogen from air and water; and oxygen from the air, water, and carbon dioxide. These nutrients are the building blocks for carbohydrates, proteins, fats, nucleic acids, and the many other compounds in plants.

****Use TM: B4-1—Nonfertilizers, and TM: B4-3 —The Carbon Cycle as a guide to show students key points they should place in their notes. PowerPoint Slides 11 and 12 will also assist with these key points. Engage the students in discussion on nonfertilizer nutrients. Some information that might help explain the carbon cycle is described below:**

Plants, animals, and soil interact to make up the basic cycles of nature. In the carbon cycle, plants absorb carbon dioxide from the atmosphere and use it, combined with water they get from the soil, to make the substances they need for growth. The process of photosynthesis incorporates the carbon atoms from carbon dioxide into sugars. Animals, such as the rabbit pictured here, eat the plants and use the carbon to build their own tissues. Other animals, such as the fox, eat the rabbit and then use the carbon for their own needs. These animals return carbon dioxide into the air when they breathe, and when they die, since the carbon is returned to the soil during decomposition. The carbon atoms in soil may then be used in a new plant or small microorganisms. Ultimately, the same carbon atom can move through many organisms and even end in the same place where it began.

Objective 3: Identify the primary macronutrients and their functions, and deficiency symptoms.

(PowerPoint Slides 13 and 14)

II. **Macronutrients** are those elements used in great quantities by plants. There are six macronutrients. Those used in the largest amounts are called primary macronutrients. They are nitrogen (N), phosphorus (P), and potassium (K).

(PowerPoint Slide 15)

A. Nitrogen is one of the most abundant and mobile elements on Earth. It is found in the air and the soil. Nitrogen is a part of chlorophyll. Plants lacking in nitrogen take on a yellowish color and appear stunted. Organic matter in the soil is the source of most nitrogen obtained by plants. Nitrogen is absorbed in the form of nitrate (NO_3^-) regardless of whether nitrogen is applied as a fertilizer or is from organic matter. **Nitrification** is the process carried out by soil bacteria in which ammonium (NH_4^+) from organic matter or chemical fertilizers is converted to nitrate. The nitrate becomes part of the soil solution and is absorbed by crops. Nitrates **leach** or pass through soils readily and may erode primarily through water runoff.

(PowerPoint Slide 16)

Nitrate also converts to gaseous N_2 under wet soil conditions in a process known as **denitrification**. Nitrogen is therefore a nutrient that needs to be added to soils for optimal plant growth. Before plants can use nitrogen it must be removed from the atmosphere through nitrogen fixation or through the manufacture of chemical fertilizers. **Nitrogen fixation** is a natural process in which rhizobia bacteria in root nodules of legumes (alfalfa, clover, peas, beans, and vetch) convert nitrogen to a nitrate form. Legumes typically do not need nitrogen fertilizers because they make their own nitrogen supply. Nitrogen continually changes from usable nitrogen to atmospheric nitrogen. This flow of nitrogen is called the **nitrogen cycle**.

(PowerPoint Slide 17)

B. Phosphorus plays a crucial role in the reproduction of seed plants. It is an important element for DNA. It promotes rapid root growth. Unlike nitrogen, phosphorus is very immobile in soil. However, since a large portion of a plant's phosphorus is found in seeds and fruit, the soil must be replenished annually. Deficiency symptoms include a purple tinge to the leaves.

C. Potassium is necessary for the manufacture of starches and sugars. It assists in the plant disease and pest fighting mechanisms. It plays a role in the opening and closing of stomates. Symptoms of deficiency include a leaf tip burn and yellow or white streaks in the veins of the leaves.

****TM: B4-4—Primary Macronutrients and TM: B4-5—The Nitrogen Cycle can be used to illustrate main points. PowerPoint Slides 18 and 19 can also be**

used. The following information can be used to explain the nitrogen cycle in more depth:

The main component of the nitrogen cycle starts with the element nitrogen in the air. Two nitrogen oxides are found in the air as a result of interactions with oxygen. Nitrogen will only react with oxygen in the presence of high temperatures and pressures found near lightning bolts and in combustion reactions in power plants or internal combustion engines. Nitric oxide, NO, and nitrogen dioxide, NO₂, are formed under these conditions. Eventually nitrogen dioxide may react with water in rain to form nitric acid, HNO₃. The nitrates thus formed may be utilized by plants as a nutrient.

Nitrogen in the air becomes a part of biological matter mostly through the actions of bacteria and algae in a process known as nitrogen fixation. Legume plants such as clover, alfalfa, and soybeans form nodules on the roots where nitrogen fixing bacteria take nitrogen from the air and convert it into ammonia, NH₃. The ammonia is further converted by other bacteria first into nitrite ions, NO₂⁻, and then into nitrate ions, NO₃⁻. Plants utilize the nitrate ions as a nutrient or fertilizer for growth. Nitrogen is incorporated in many amino acids which are further reacted to make proteins.

Ammonia is also made through a synthetic process called the Haber Process. Nitrogen and hydrogen are reacted under great pressure and temperature in the presence of a catalyst to make ammonia. Ammonia may be directly applied to farm fields as fertilizer. Ammonia may be further processed with oxygen to make nitric acid. The reaction of ammonia and nitric acid produces ammonium nitrate which may then be used as a fertilizer. Animal wastes when decomposed also return to the earth as nitrates.

To complete the cycle other bacteria in the soil carry out a process known as denitrification which converts nitrates back to nitrogen gas. A side product of this reaction is the production of a gas known as nitrous oxide, N₂O.

Objective 4: Identify the secondary macronutrients and their functions, and deficiency symptoms.

(PowerPoint Slides 20 and 21)

III. Three macronutrients used to a lesser degree than nitrogen, phosphorus, and potassium are calcium (Ca), magnesium (Mg), and sulfur (S). Calcium, magnesium, and sulfur are said to be secondary macronutrients because moderate amounts are needed.

A. Calcium is needed for the formation of strong cell walls. It is instrumental in young, growing cells, especially in the root system. It also aids plants in using other nutrients. Calcium deficiencies appear as deformed, curled leaves.

(PowerPoint Slide 22)

- B. Magnesium is used in chlorophyll and is important to photosynthesis. It activates many plant enzymes. It is involved in the production of starches and fats and the movement of other nutrients throughout the plant. Deficiency symptoms include a yellowing of lower leaves and thin stems.
- C. Sulfur is needed for protein formation. It also stimulates root growth. Young leaves that have a light green color is a symptom of deficiency.

****Use TM: B4-6—Secondary Macronutrients as a guide for discussion. PowerPoint 23 can be used as a visual for the students. Have the students expand their notes based on the discussion. The discussion can also serve as a way to monitor students' mastery of the material.**

Objective 5: Identify the micronutrients and their functions, and deficiency symptoms.

(PowerPoint Slides 24 and 25)

- IV. Those nutrients that are needed in smaller amounts by the plants, but are still essential to plant growth are called *micronutrients*. The micronutrients are boron (B), copper (Cu), chlorine (Cl), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn).
 - A. The exact role of boron is unclear, but it appears to be essential for pollination and reproduction, cell division, and the transport of sugars. Young leaves look yellow and thick when the nutrient is lacking.

(PowerPoint Slide 26)

- B. Copper regulates several chemical processes including chlorophyll synthesis and respiration. A shortage results in the yellowing of leaves with the younger leaves affected first.
- C. Chlorine is involved in light reactions of photosynthesis. It aids root and shoot growth. Deficiency symptoms have not been recognized.
- D. Iron is important in chlorophyll formation and is a component of enzymes involved in photosynthesis, respiration, and nitrogen fixation. Young leaves yellow first. The veins remain green.

(PowerPoint Slide 27)

- E. Manganese is important in chlorophyll formation. It is part of enzymes involved in respiration and nitrogen metabolism. The symptom of deficiency is young leaves yellow first with the veins remaining green.
- F. Molybdenum is part of enzymes involved in nitrogen metabolism. It aids nitrogen fixation and protein synthesis. Deficiency symptoms appear as yellow older leaves and growth is stunted.

G. Zinc is important in chlorophyll, auxin, and starch formation, and it is part of the enzymes that are involved in respiration. Older leaves that yellow and stunted growth are deficiency symptoms.

****Students can be given the task of completing LS: B4-1—Essential Nutrient Functions and Deficiency Symptoms in class. If nearby fields are available take students to tour the fields to see plants exhibiting nutrient deficiencies. Use TM: B4-7—Micronutrients or PowerPoint Slide 28 to highlight concepts.**

Review/Summary: Restate the student learning objectives at the conclusion of the lesson. Review the material that has been covered in class discussions, laboratory activity, and other learning experiences. Call on students to explain the content associated with each objective. Use their responses as the basis for determining any areas that need re-teaching. Questions on PowerPoint Slide 29 can be used.

Also when students are finished with LS: B4-1, go over as a class. Review any information that class is having trouble with.

Application: Application can involve one or more of the following student activities using the attached lab sheets:

LS: *B4-1*—Essential Nutrient Functions and Deficiency Symptoms

TM: *B4-1*—Nonfertilizers

TM: *B4-2*—The Oxygen Cycle

TM: *B4-3*—The Carbon Cycle

TM: *B4-4*—Primary Macronutrients

TM: *B4-5*—The Nitrogen Cycle

TM: *B4-6*—Secondary Macronutrients

TM: *B4-7*—Micronutrients

Evaluation: Evaluation should focus on student achievement of the objectives for the lesson. Various techniques can be used, such as student performance on the application activities. A sample written test is attached.

Answers to Sample Test:

Part One: Matching

1 = e, 2 = g, 3 = h, 4 = c, 5 = a, 6 = j, 7 = i, 8 = b, 9 = f, 10 = d

Part Two: Completion

1. 89
2. nonfertilizer
3. Sixteen

4. burning
5. primary
6. calcium (Ca), magnesium (Mg), and sulfur (S)
7. nitrate (NO₃⁻)
8. Phosphorus
9. Potassium
10. photosynthesis

Part Three: Short Answer

1. Discoloration of the leaves, death of leaf tissue, and stunted growth.
2. "C HOPKNS CaFe Managed By Mine CuZn, Mo and Claude" It represents the following:

Carbon (**C**), Hydrogen (**H**opkns), Oxygen (h**O**pkns), Phosphorus (ho**P**kns), Potassium (hop**K**ns), Nitrogen (hopk**N**s), Sulfur (hopkn**S**), Calcium (**Ca**Fe), Iron (Ca**Fe**), Magnesium (**M**anaged), Boron (**B**y), Manganese (**M**ine), Copper (**Cu**Zn), Zinc (Cu**Zn**). Molybdenum (**Mo**), and Chlorine (**C**laude).

3. Carbon, Hydrogen, Oxygen; Nitrogen, Phosphorus, Potassium; Calcium, Magnesium, Sulfur; Boron, Iron, Chlorine, Manganese, Molybdenum, Copper.
4. Carbohydrates, proteins, fats, nucleic acids, and the many other compounds in plants.
5. Starches, pectin, lignin, cellulose, lipids or fats, proteins, pigments, hormones, vitamins, alkaloids, and tannins that protect plants from pests and diseases.

Sample Test

Name _____

Test

Unit B Lesson 4: Determining Nutrient Functions and Utilization

Part One: Matching

Instructions. Match the term with the correct response. Write the letter of the term by the definition.

- | | |
|--------------------|------------------------|
| a. Denitrification | f. Nitrate |
| b. Nutrient excess | g. Nitrification |
| c. Nutrients | h. Nitrogen fixation |
| d. Macronutrient | i. Nutrient deficiency |
| e. Micronutrient | j. Soluble salts |

- _____ 1. Those nutrients that are needed in smaller amounts by the plants, but are still essential to plant growth.
- _____ 2. The process carried out by soil bacteria in which ammonium (NH_4^+) from organic matter or a chemical fertilizer is converted to nitrate.
- _____ 3. A natural process in which rhizobia bacteria in root nodules of legumes convert nitrogen to a nitrate form.
- _____ 4. Chemical elements essential for plant growth and development.
- _____ 5. Process in which nitrate converts to gaseous N_2 under wet soil conditions.
- _____ 6. Chemical fertilizers dissolved in water.
- _____ 7. Signs that a plant fails to receive the needed amount of nutrients.
- _____ 8. High levels of nutrients that can cause damage to plants.
- _____ 9. Nitrogen is absorbed by plants in this form.
- _____ 10. Those elements used in great quantities by plants.

Part Two: Completion

Instructions. Provide the word or words to complete the following statements.

1. Three nutrients make up _____ percent of a plant's tissues.
2. Carbon, hydrogen, and oxygen are considered to be _____ nutrients.
3. _____ nutrients have been identified as being essential for plant growth.
4. Nutrient excess involves the buildup of soluble salts that have a _____ effect on plant roots.

4. Carbon, hydrogen, and oxygen are the building blocks for compounds?

5. Identify many complex products made when enzymes break down sugars and recombine them with nitrogen and other nutrients.

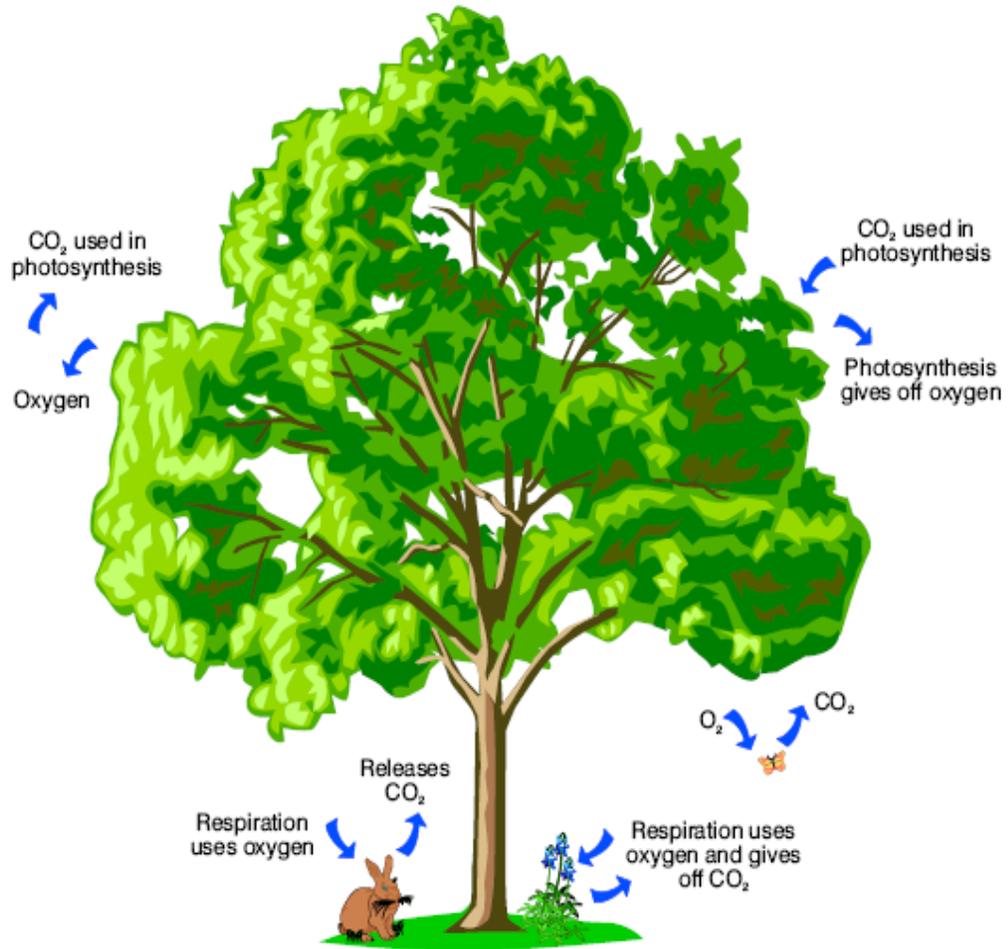
TM: B4-1

NONFERTILIZERS

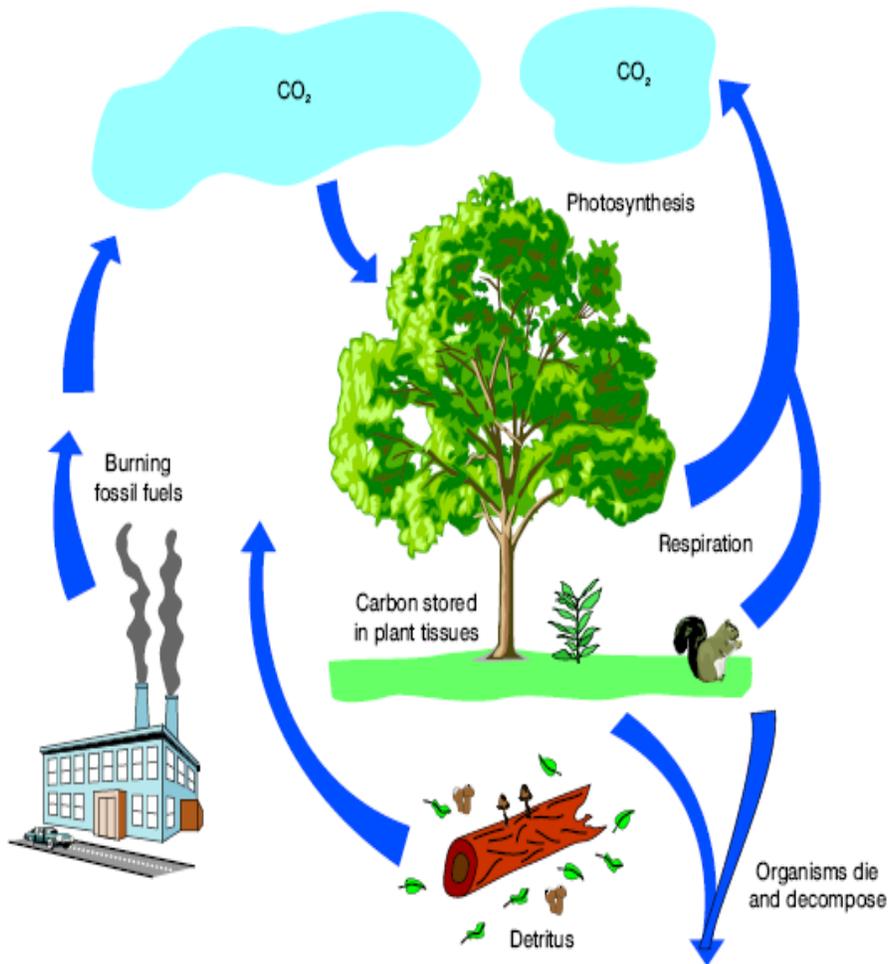
Nutrient	Influence/Function
Carbon	Building block for carbohydrates, proteins, fats, nucleic acids
Hydrogen	Building block for carbohydrates, proteins, fats, nucleic acids
Oxygen	Building block for carbohydrates, proteins, fats, nucleic acids

TM: B4-2

THE OXYGEN CYCLE



THE CARBON CYCLE

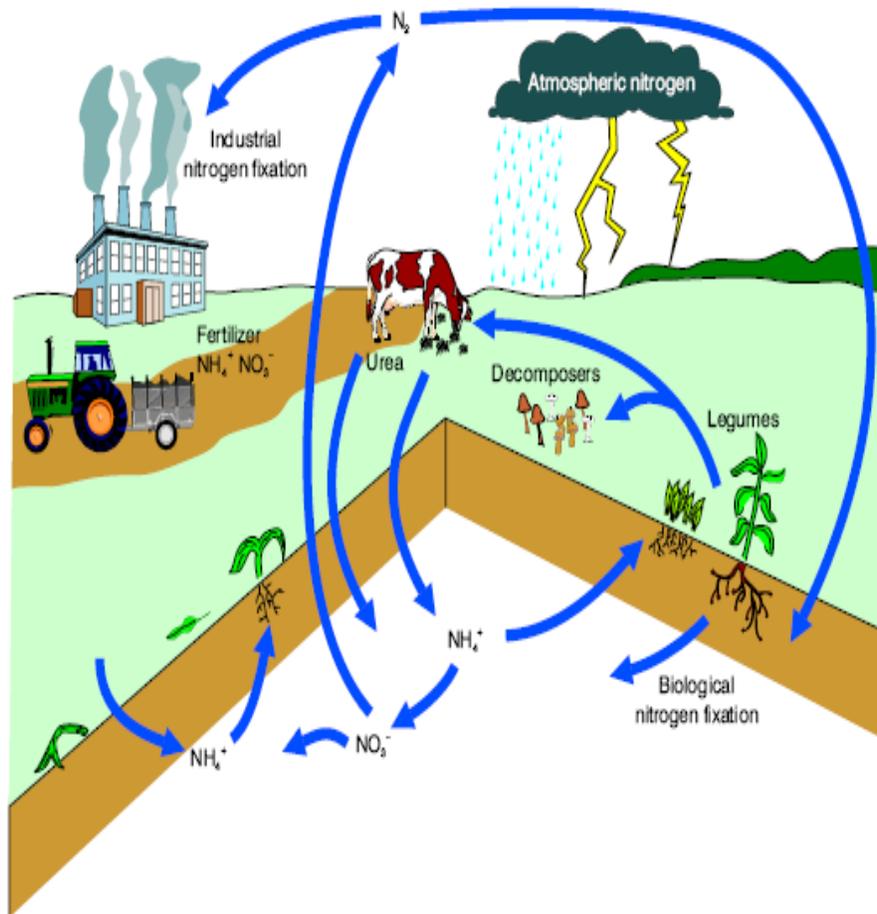


PRIMARY MACRONUTRIENTS

Nutrient	Influence/Function	Deficiency Symptom
Nitrogen	Produces stem and leaf growth; gives plants dark green color; synthesis of amino acids and proteins	Entire plant lighter green, lower leaves yellowing; slow or dwarfed growth
Phosphorus	Stimulates root development and growth; aids in cell division; encourages flower bud formation; improves winter hardiness; helps plants to a vigorous and rapid start	Purplish coloration to leaves and stems; stunted growth
Potassium	Increases plant vigor and disease resistance; aids in the transport of foods through the phloem; has key role in opening and closing stomata; thickens cell walls	Yellowing or death of tissues at tips and outer edges of older leaves

TM: B4-5

THE NITROGEN CYCLE



SECONDARY MACRONUTRIENTS

Nutrient	Influence/Function	Deficiency Symptom
Calcium	Maintains strength of cell walls; promotes early root growth	Short, much branched roots; young leaves at growing points die back
Magnesium	Essential for chlorophyll and photosynthesis; activator for many plant enzymes; aids nutrient uptake	Loss of green leaf color starting with bottom leaves
Sulfur	Stimulates root growth; needed for protein formation; gives green color	Young leaves light green with veins being lighter

MICRONUTRIENTS

Nutrient	Influence/Function	Deficiency Symptom
Boron	Essential for pollination and reproduction; cell division; transport of sugars	Young leaves yellow and thick
Copper	Regulates several chemical processes; chlorophyll synthesis and respiration	Yellowing of leaves,, younger leaves affected first
Chlorine	Involved in light reactions of photosynthesis; aids root and shoot growth	Symptoms have not been recognized
Iron	Important in chlorophyll formation; component of enzymes involved in photosynthesis, respiration and nitrogen fixation	Young leaves yellow first; veins remain green
Manganese	Important in chlorophyll formation; part of enzymes involved in respiration and nitrogen metabolism	Young leaves yellow first; veins remain green
Molybdenum	Part of enzymes involved in nitrogen metabolism; aids nitrogen fixation and protein synthesis	Older leaves yellow; stunted growth
Zinc	Important in chlorophyll, auxin, and starch formation; part of enzymes involved in respiration; needed for auxin and starch formation	Older leaves yellow; stunted growth

Lab Sheet

Essential Nutrient Functions and Deficiency Symptoms

Instructions: Complete the table.

Nutrient	Influence/Function	Deficiency Symptom
Carbon		
Hydrogen	Building block for carbohydrates, proteins, fats, nucleic acids	
Oxygen	Building block for carbohydrates, proteins, fats, nucleic acids	
Nitrogen		
Phosphorus		
Potassium	Increases plant vigor and disease resistance; aids in the transport of foods through the phloem; has key role in opening and closing stomata; thickens cell walls	

Calcium		
Magnesium		Loss of green leaf color starting with bottom leaves
Sulfur		Young leaves light green with veins being lighter
Boron		
Copper		Yellowing of leaves,, younger leaves affected first
Chlorine		Symptoms have not been recognized
Iron		
Manganese		
Molybdenum	Part of enzymes involved in nitrogen metabolism; aids nitrogen fixation and protein synthesis	
Zinc		