

Lesson C4–8

Determining Plant Nutrients and Fertility

Unit C. Basic Principles of Agricultural/Horticultural Science

Problem Area 4. Identifying Basic Principles of Plant Science

Lesson 8. Determining Plant Nutrients and Fertility

New Mexico Content Standard:

Pathway Strand: Plant Systems

Standard: I: Apply principles of anatomy and physiology to produce and manage plants in both a domesticated and natural environment.

Benchmark: I-A: Analyze and evaluate nutritional requirements and environmental conditions to develop and implement a fertilization plan.

Performance Standard: 1. Describe nutrient sources. 2. Determine plant nutrient requirements for optimum growth. 3. Identify function of plant nutrients in plants. 4. Determine the environmental factors that influence and optimize plant growth. 5. Apply nutrients to plants for economic growth. 6. Describe nutrient application methods and appropriate practices.

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

1. Identify the essential nutrients for plant growth.
2. Distinguish between micronutrients and macronutrients.
3. Discuss the nitrogen cycle and its affect on plant nutrition.
4. Define pH and discuss its role in plant nutrition.
5. Explain the use of fertilizers.

List of Resources. The following resources may be useful in teaching this lesson:

Recommended Resources. One of the following resources should be selected to accompany the lesson:

Lee, Jasper S. and Diana L. Turner. *AgriScience*, Third Edition. Danville, Illinois: Interstate Publishers, Inc., 2003. (Textbook and Activity Manual, Chapter 9).

Schroeder, Charles B., et al. *Introduction to Horticulture*, Third Edition. Danville, Illinois: Interstate Publishers, Inc., 200. (Textbook and Activity Manual, Chapter 8)

Other Resources. The following resources will be useful to students and teachers:

Biondo, Ronald J. and Jasper S. Lee. *Introduction to Plant and Soil Science and Technology*, Second Edition. Danville, Illinois: Interstate Publishers, Inc., 2003. (Textbook and Activity Manual, Chapters 5 and 7)

Plaster, Edward J. *Soil Science and Management*. Albany, New York: Delmar Publishers, 1997. (Textbook).

List of Equipment, Tools, Supplies, and Facilities

Writing surface
Overhead projector
Transparencies from attached masters
Copies of student lab sheets
Food Pyramid poster or transparency

Terms. The following terms are presented in this lesson (shown in bold italics):

Denitrification
Fertilizers
Fillers
Macronutrients
Micronutrients
Nitrification
Nitrobacter bacteria
Nitrogen cycle
Nitrosomas bacteria
Nutrients
pH
Stomata

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.

Use a food pyramid to discuss the importance of proper nutrients to people. Once students have talked about nutrients that are needed to keep themselves healthy, turn the discussion to plant nutrients and how plants acquire nutrients to grow properly.

Summary of Content and Teaching Strategies

Objective I: Identify the essential nutrients for plant growth.

Anticipated Problem: Which elements must be present for plants to grow?

- I. Just like people, plants require certain elements and minerals in order to grow. **Nutrients** are substances that are essential for growth and production. There are 16 nutrients that are required by growing plants.
 - A. Some of these nutrients are supplied to the plant from the air while others are found in the soil.
 1. Elements that are obtained from the air and water vapor by way of stomata include carbon, hydrogen and oxygen. **Stomata** are tiny pores on the underside of plant leaves that aid the plant in nutrient uptake and cooling processes.
 2. Nitrogen, phosphorus, potassium, calcium, sulfur, and magnesium are generally supplied by the soil in which the plant is growing. Plants absorb these nutrients using roots to pull in nutrients that have been dissolved in water.
 - B. Mnemonics (pronounced ni-mon-iks) is the art of improving the memory using a formula. A mnemonic formula has been developed to aid in recalling all sixteen elements.

C. B. HOPKiNS CaFé MightY good ClOsed MonDay Morning See You Zen.

Carbon (C), Boron (B), Hydrogen (H), Oxygen (O), Phosphorus (P), Potassium (K), Nitrogen (N), Sulfur (S), Calcium (Ca), Iron (Fe), Magnesium (Mg), Chlorine (Cl), Manganese (Mn), Molybdenum (Mo), Copper (Cu), Zinc (Zn).

A number of tools are available to help students in gaining mastery of this objective. Display TM:C4-8A and use it to illustrate the mineral elements required by plants. The recommended resources also have a good deal of information on this objective. Have students read the suggested chapters in the textbooks. Summarize the elements by having students develop their own mnemonic. Use class discussion and student comments to determine any content areas that need to be covered again.

Objective 2: Distinguish between micronutrients and macronutrients.

Anticipated Problem: How are plant nutrients classified?

- II. Plants nutrients are classified in two major categories.
 - A. Mineral or non-mineral nutrients.
 - 1. Four of the 16 essential nutrients are classified as non- mineral nutrients. Carbon, hydrogen, oxygen and nitrogen are all non-mineral nutrients.
 - 2. Mineral nutrients include: boron, phosphorus, potassium, sulfur, calcium, iron, magnesium, chlorine, manganese, molybdenum, copper, and zinc.
 - B. Micronutrients and macronutrients differ as follows:
 - 1. **Macronutrients** are elements that are needed in large quantities by plants. Nitrogen, phosphorus and potassium are the three primary macronutrients. These nutrients are usually the main components of fertilizers. Calcium, magnesium, and sulfur are secondary macronutrients.
 - 2. Nutrients that are needed by plants in small quantities are called **micronutrients**. The remaining 10 nutrients are classified as micronutrients.

Use TM:C4–8B to help students in reinforcing an understanding of macronutrients and micronutrients. Assign students to read the suggested chapters in the recommended resources. Follow the reading up with classroom discussion. Use student responses to questions to determine if any concepts need further emphasis. Use LS:C4–8A to help students in determining macronutrient levels in plant tissue.

Objective 3: Discuss the nitrogen cycle and its affect on plant nutrition.

Anticipated Problem: What influence does the nitrogen cycle have on plant nutrition?

- III. Nitrogen is a major requirement for plants to grow rapidly and maintain a healthy green color. Although the atmosphere is 78 % nitrogen gas, it is the most common nutrient deficiency seen in plants. Plants cannot utilize nitrogen in the gas form; it must first be converted to the nitrate or ammonium forms.
 - A. The **nitrogen cycle** is the process that converts nitrogen gas to forms that are usable to plants.
 - 1. A symbiotic relationship that exists between bacteria and legume plants is utilized to convert nitrogen gas (N₂) to ammonium ions (NH₄⁺). When the bacteria decompose plant material, nitrogen is formed. This nitrogen becomes available to plants in the form of ammonium ions when the bacteria die.
 - 2. Plants can utilize this form of nitrogen; however, most of the ammonium ions are converted to nitrite ions by **Nitrosomas bacteria**. The nitrite ions then undergo another reaction with **Nitrobacter bacteria** to convert the nitrite to nitrate. This process is called **nitrification**.
 - 3. To complete the nitrogen cycle, a process called denitrification occurs. This process involves the loss of nitrogen from the soil. Nitrogen can be removed from the soil by

the uptake of nitrogen by the plant, losses due to leaching, or by denitrification. **Denitrification** occurs in soils that have no oxygen because of saturation from water. When soils are saturated with water, bacteria will convert the nitrate to nitrogen gas, which is then lost to the atmosphere.

- B. Nitrogen can also be added to the soil by lightning or the application of commercial fertilizers.

A number of techniques are available to help students in understanding this objective. Use TM:C4–8C to reinforce the general concept of the nitrogen cycle. Reinforce the nitrogen cycle through assigned readings in the recommended resources. Have students sketch the nitrogen cycle. Discuss the sketches and use student comments as a basis for determining if any portion of the content needs to be retaught.

Objective 4: Define pH and discuss its role in plant nutrition.

Anticipated Problem: What does pH have to do with plant nutrition?

- IV. The measure of alkalinity or acidity of a substance is known as **pH**. The pH scale runs from 0 to 14, with 0 being extremely acidic, 7 as neutral, and 14 as extremely basic.
 - A. Changes in pH can be made by adding sulfur or gypsum to lower pH (make more acidic) and by adding limestone to increase pH (make more basic). Generally plants grow best within the pH range of 5.5 to 8.0.
 - B. The pH value of soil is important to agriculturists because certain nutrients become unavailable to plants if the pH value is too high or too low. The amount of nitrogen, phosphorus, and potassium that are available is dependent upon soil pH.

Display TM:C4–8D to reinforce the concept of the pH scale. Follow this up with TM:C4–9E to reinforce the relationship of pH to availability of plant nutrients in soil. Use LS:C4–8B to help students in determining the nutrient levels in soil samples. The recommended resources will also be helpful. Have the class read the suggested chapters. Follow this with class discussion.

Objective 5: Explain the use of fertilizers

Anticipated Problem: How can fertilizers improve plant growth?

- VI. **Fertilizers** are materials that are added to growing media to provide the plant with the necessary nutrients. Adding fertilizer to plants can increase their productivity.
 - A. Fertilizers can be grouped into two major categories.
 1. Complete fertilizers contain all three macronutrients, such as 12-12-12.
 2. Incomplete fertilizers lack at least one macronutrient, such as 18-46-0.
 - B. Fertilizer labels contain information indicating the percentage of each macronutrients included in the formulation. A fertilizer analysis contains three numbers, for example 12-4-8.

1. The first number in the fertilizer analysis is the percentage of pure nitrogen in the formulation. If the numbers above appeared on a 100 pound bag of fertilizer, there would be 12 pounds of pure nitrogen contained in that bag.
 2. The second number shows the percentage of pure phosphorus in the bag. Given the sample above, this formulation contains 4 pounds of pure phosphorus.
 3. The final number indicated the amount of pure potassium in the formulation. Eight pounds of pure potassium are included in the bag from the example above.
 4. When the numbers from the analysis do not add up to 100 %, the remaining weight is comprised of filler, made up of the remaining essential plant nutrients. **Fillers** are used to ensure a more even application of the fertilizer. The amount of filler in the above example can be figured as follows: $100 - (12 + 4 + 8) = 76$. This means that 76 % of this fertilizer formulation is filler.
- C. Before selecting which fertilizer to apply, the producer must first determine the nutrients that are not already available to the plant. Producers can determine nutrient deficiencies by three different ways.
1. Deficiency symptoms occur in plants that are not receiving all the necessary nutrients. Pale leaves can be a sign of a nitrogen deficiency while a phosphorus deficiency can cause stunted growth and reddish-purplish regions on leaves. A well-trained crop scout can generally recognize these symptoms by visual observation.
 2. Soil testing will also reveal which nutrients are present or lacking. The grower can do the soil testing or it can be sent into a laboratory for more precise results.
 3. Tissue testing can indicate which nutrients are available to the plant. In some cases nutrients will be found in the soil but are not available to the plant.

A variety of tools are available to help students in fully understanding this objective. Use TM:C4–8F to reinforce N-P-K percentages in fertilizers. Depending on the time of year, have students check local store displays to determine what N-P-K percentages are most commonly sold. Assigning a problem similar to Question #4 in the short answer portion of the attached sample test may also prove helpful. The recommended resources also have a good deal of information on this topic. Follow reading of the text materials with classroom discussion.

Review/Summary. Focus the review and summary of the lesson around the student learning objectives. Call on students to explain the content associated with each objective. Questions at the end of each chapter in the recommended textbooks may also be used in the review/summary.

Application. Application can involve the following student activity using the attached lab sheets.

Plant Tissue Testing—LS: C4–8A

Soil Testing—LS: C4–8B

Evaluation. Evaluation should focus on student achievement of the lesson objectives. Various techniques can be used, such as student performance on the application activities. The self-check section at the end of each chapter in the suggested references will be helpful. A sample written test is attached.

Answers to Sample Test:

Part One: Completion

1 = nutrients; 2 = macronutrients, micronutrients; 3 = three, nitrogen, phosphorus, potassium; 4 = nitrogen cycle; 5 = nitrosomas; 6 = nitrobacter; 7 = 5.5, 8.0; 8 = fertilizers.

Part Two: Short Answer

1. Carbon, hydrogen, oxygen, and nitrogen
2. Nitrogen, phosphorus and potassium
3. C. B. HOPKiNS CaFé Mighty good Closed Monday Morning See You Zen
Carbon, boron, hydrogen, oxygen, phosphorus, potassium, nitrogen, sulfur, calcium, iron, magnesium, chlorine, manganese, molybdenum, copper, zinc.
4. N = 12.8 lbs; P = 3.2 lbs; K = 6.4 lbs; filler = 77.6 lbs.

Test

Lesson C4–8: Determining Plant Nutrients and Fertility

Part One: Completion

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

1. There are 16 plant _____ that are necessary for normal growth and production.
2. Nutrients needed by plants in large quantities are called _____ while _____ are only needed in small quantities.
3. There are _____ primary macronutrients which are: _____, _____, and _____.
4. The _____ _____ is the process by which atmospheric nitrogen is converted to a form that is usable by plants.
5. Ammonium ions are converted to nitrite by _____ bacteria.
6. Nitrite is then converted to nitrate by _____ bacteria.
7. Plants grow best at a pH between _____ and _____.
8. When plants or soil are lacking in one or more nutrients, _____ can be added to increase available nutrients.

Part Two: Short Answer

Instructions. Provide information to answer the following questions.

1. List the four non-mineral nutrients.
2. List the three primary macronutrients.
3. Write the mnemonic for naming plant nutrients and list all 16 of them.
4. Determine the amount (lbs) of each macronutrient in a fertilizer bag that weighs 80 pounds and has an analysis of 16-4-8. Indicate how many pounds of filler are in this bag.

Mineral Elements Required by Plants

Element and symbol	Forms absorbed	Concentration in whole plant	Some functions
Macronutrients*		(% dry weight)	
Nitrogen (N)	NO_3^- or NH_4^+	1–3	Amino acids, proteins, nucleotides, nucleic acids, chlorophyll, and coenzymes
Phosphorus (P)	H_2PO_4^- or HPO_4^{2-}	0.05–1.0	Formation of “high-energy” phosphate compounds (ATP and ADP); nucleic acids; phosphorylation of sugars; several essential coenzymes; phospholipids
Potassium (K)	K^+	0.1–3.5	Enzymes, amino acids, and protein synthesis; opening and closing of stomata
Calcium (Ca)	Ca^{2+}	0.1–3.5	Calcium of cell walls; enzyme cofactor; cell permeability
Magnesium (Mg)	Mg^{2+}	0.05–0.7	Part of the chlorophyll molecule; activator of many enzymes
Sulfur (S)	SO_4^{2-}	0.05–1.5	Some amino acids and proteins; coenzyme A
Micronutrients		(ppm)	
Iron (Fe)	Fe^{2+} , Fe^{3+}	10–1500	Chlorophyll synthesis, cytochromes, and ferredoxin
Copper (Cu)	Cu^{2+}	2–75	Activator of some enzymes
Manganese (Mn)	Mn^{2+}	5–1500	Activator of some enzymes
Zinc (Zn)	Zn^{2+}	3–150	Activator of many enzymes
Molybdenum (Mo)	MoO_4^{2-}	0.1–5.0	Nitrogen metabolism
Boron (B)	BO_3^{3-} or $\text{B}_4\text{O}_7^{2-}$ (borate or tetraborate)	2–75	Influences Ca^{2+} utilization; functions unknown
Chlorine (Cl)	Cl^-	100–10,000	Osmosis and ionic balance; probably essential in photosynthesis in the reactions in which oxygen is produced
Elements Essential to Some Plants or Organisms			
Cobalt (Co)	Co^{2+}	Trace	Required by nitrogen-fixing microorganisms

*Carbon, hydrogen, and oxygen are essential to all cells in a plant. However, these elements are not described in this table.

Macronutrients

Primary

1. Nitrogen
2. Phosphorus
3. Potassium

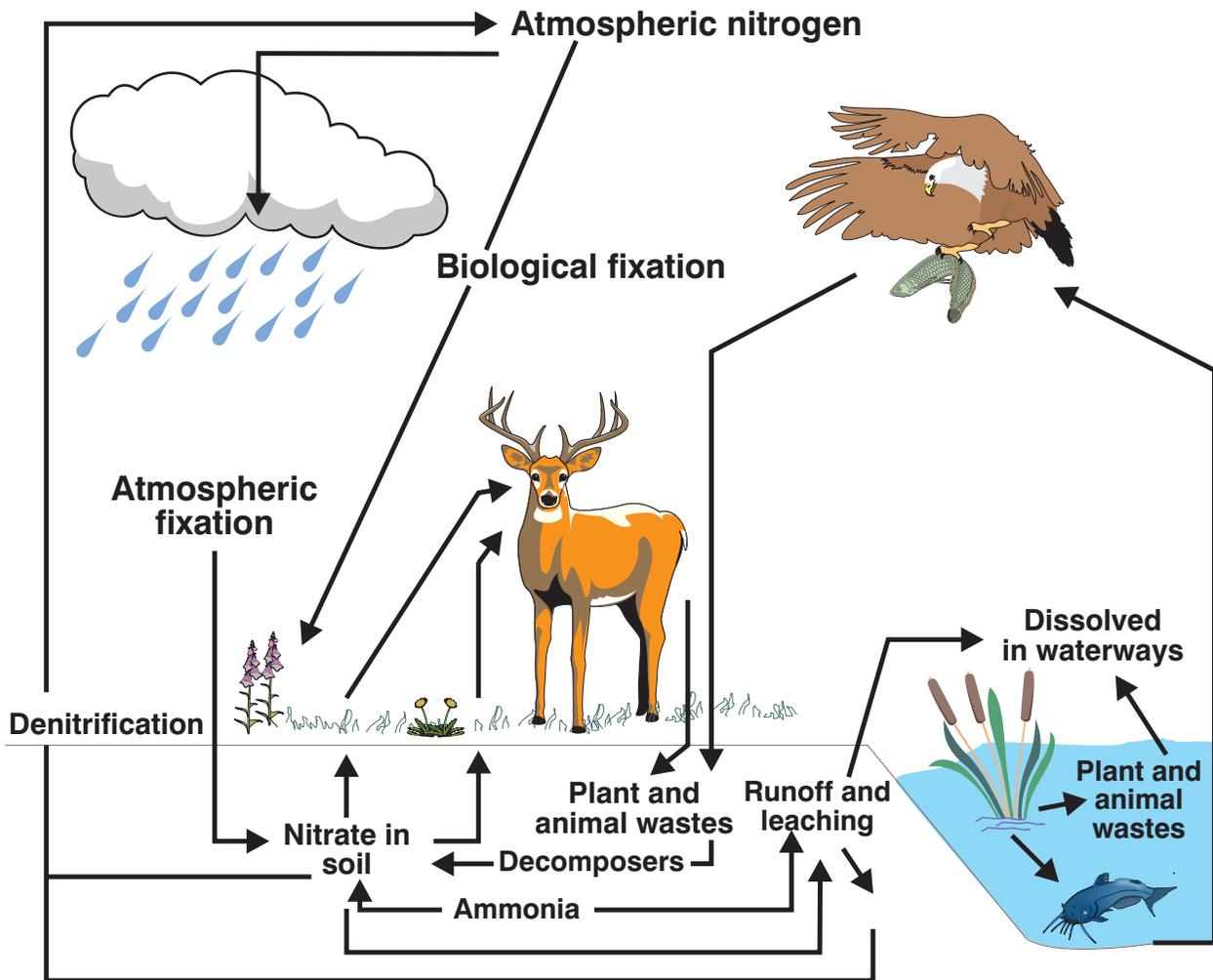
Secondary

1. Calcium
2. Manganese
3. Sulfur

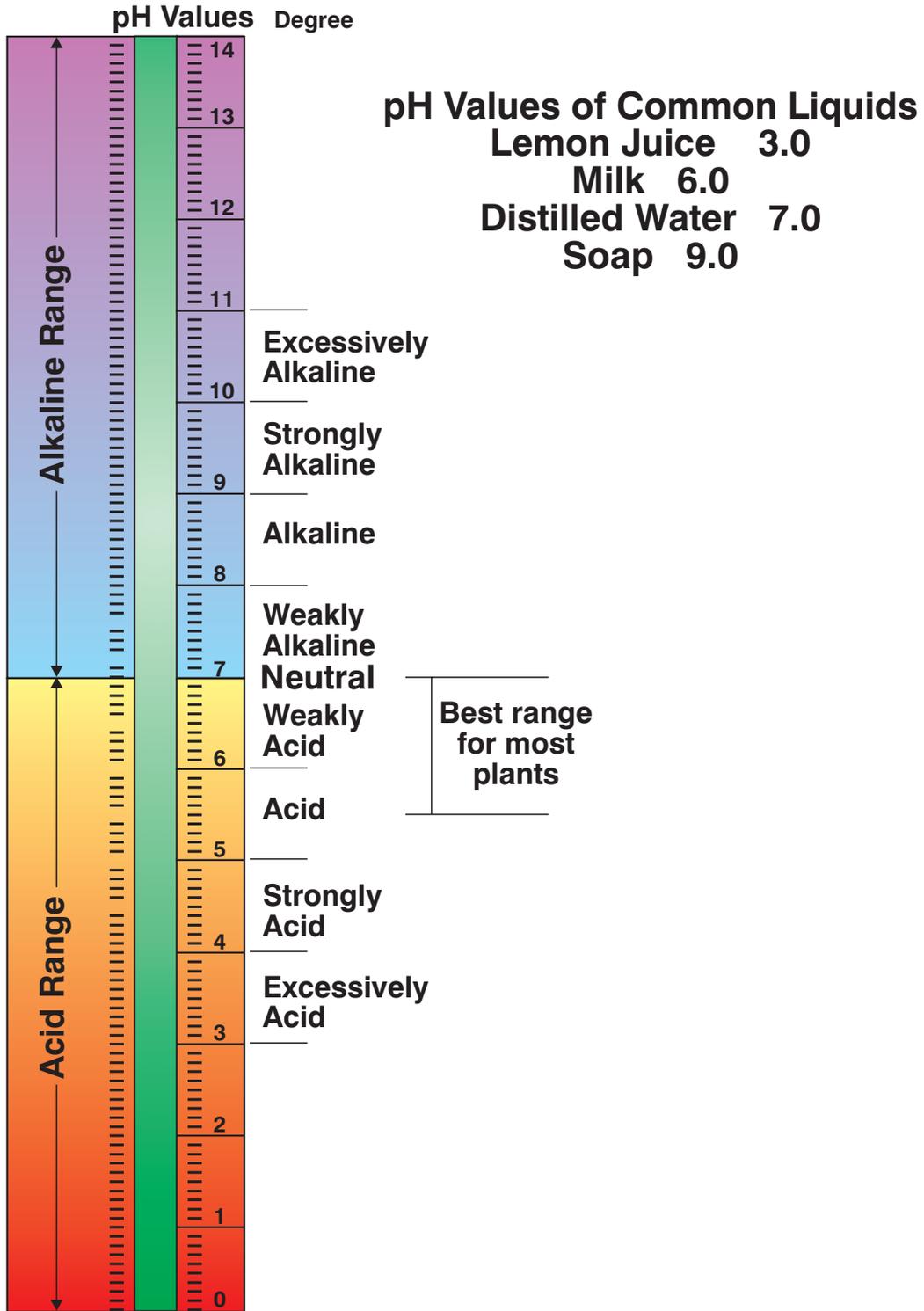
Micronutrients

- | | |
|---------------|--------------|
| 1. Carbon | 6. Copper |
| 2. Boron | 7. Iron |
| 3. Chlorine | 8. Oxygen |
| 4. Hydrogen | 9. Magnesium |
| 5. Molybdenum | 10. Zinc |

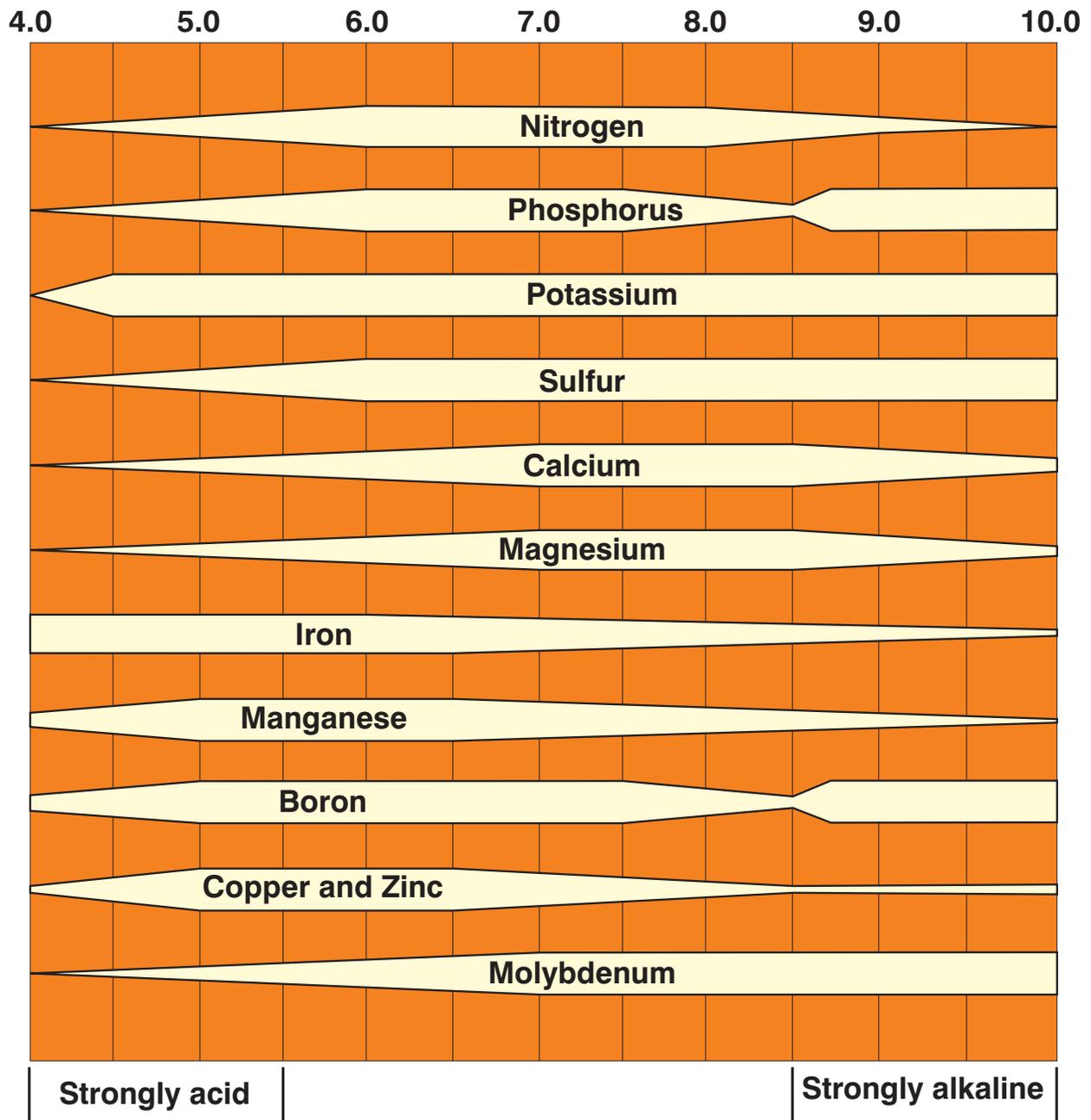
The Nitrogen Cycle



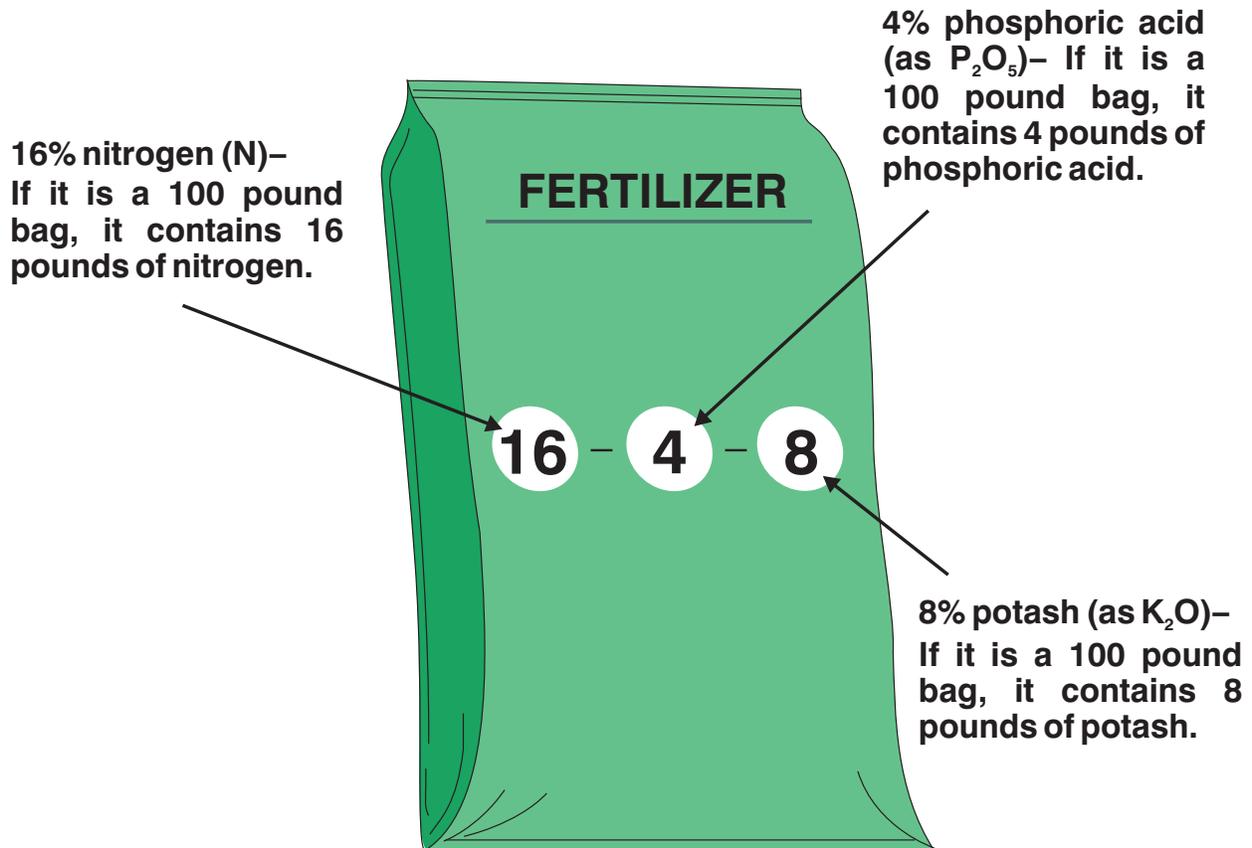
pH Scale



Relationship of pH to Availability of Plant Nutrients in the Soil



Fertilizer Guaranteed Analysis



- Guaranteed percentages by weight
- This bag has 16% nitrogen, 4% phosphorus, and 8% potassium
- Balance of weight is filler
- May be formulated to include herbicides or insecticides

Lab Sheet

Plant Tissue Testing

Purpose:

The purpose of this activity is to allow the students to determine the level of nitrogen, phosphorus, and potassium in the tissues of a selected plant.

Materials:

Plant tissue samples from various plants
Plant tissue testing kit (LaMotte Plant Tissue Test Kit)
Paper towels
Scalpel

Procedures:

1. Obtain leaf samples from several plants. It is best to use the youngest leaves that are fully-grown.
2. When extracting the plant sap, take cuttings from the petiole or midrib of the leaf.
3. Using only freshly cut samples, follow the instructions in the testing kit.

Lab Sheet

Soil Testing

Purpose:

The purpose of this activity is to allow students to determine the availability of soil nutrients found in various soil samples.

Materials:

Soil Test Kit
Soil samples
Soil tube or auger
Paper towels

Procedures

1. Using a soil tube or auger collect several samples of soil from random areas. Samples should be taken at a depth of 2 to 3 inches for garden crops and 7 inches for field crops.
2. Prepare a composite sample by mixing 5 subsamples.
3. Label the samples and allow them to dry at room temperature. Make sure all large clumps of soil have been broken into smaller pieces.
4. Conduct the soil test by following the instructions included in the soil testing kit.