GREENHOUSE OPERATION AND MANAGEMENT

Unit IV : Plant Growth

Lesson 1: Environmental Effects

Competency/Objective:

Describe environment necessary for optimal plant growth.

Study Questions

1. **What environmental factors affect plant growth?**
2. **What is the effect of light in the greenhouse?**
3. **How does light intensity affect plants?**
4. **How does light duration affect plant growth?**
5. **How does light quality affect plant growth?**
6. **How does temperature affect plant growth?**
7. **What gaseous elements within the greenhouse affect plant growth?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Master

   TM 4.1 Radiant Light Spectrum

3. Activity Sheets

   AS 4.1 Foot-Candle Demonstration
   AS 4.2 Effect of Light on Plants
   AS 4.3 Photoperiod in Plants
   AS 4.4 Greenhouse Air Pollutants

4. A current copy of Hummert's Helpful Hints

5. Carolina Biological Supply <http://www.carolina.com/general/company/Srv.asp>

6. NASCO catalogs <http://www.enasco.com/prod/Home>

TEACHING PROCEDURES

A. Introduction

This unit introduces students to basic concepts of plant growth: environmental effects, growing media and containers, irrigation, nutrients, and fertilizer. This lesson explains various environmental elements influencing plant growth. Students examine light intensity, duration, and quality, as well as temperature, air quality, and gaseous elements within the greenhouse.

B. Motivation

Students use the plants they have been tending since Unit I to illustrate the importance of light duration. Bring out the plants to initiate a conversation on the subject of light. Can the students recognize which plants have had too little light?

C. Assignment of Study Questions

In preparation for AS 4.6 in Lesson 3: Irrigation in this unit, take one plant from each student and organize them into three groups labeled D, E, and F. For at least 3 weeks, have students water plants in each group using a specific measuring cup. Use a measuring cup that is larger than needed for Group D plants so plants receive too much water. The measuring cup for Group E has the correct amount. Use a measuring cup that is smaller than necessary for Group F so that the plants receive very little water.

To prepare for AS 4.9 in Lesson 5: Fertilizer, split another batch of plants into groups G, H, and I. Have several forms of fertilizer available: slow release, water-soluble concentrate, and granular. Ask students to give plants in each group the following amounts of fertilizer: Group G - no fertilizer, Group H - too much, and Group I - the appropriate amount. As the plants grow, students should characterize how the plants in each group react to fertilizer during three stages of development: seedling/cutting, vegetative, and flowering. Be sure that students identify the type of fertilizer used on each pot.

At the end of Lesson 5, the class will complete a unit activity that relates to all of the activity sheets in Unit IV. Be sure that students keep each activity sheet in each lesson.

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. The instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement student responses and information with additional materials when needed.

1. What environmental factors affect plant growth?

Ask the students to name the three major environmental factors they have to monitor and control within a greenhouse. These are the basic factors directly related to successful plant growth. Be sure to mention that water is also important. It is discussed in Lesson 3 of this unit.

A. Light
B. Temperature
C. Air quality

2. What is the effect of light in the greenhouse?

Building on knowledge from Plant Processes (Unit III, Lesson 2), encourage students to discuss why light is important for plant growth. Why might artificial light be necessary? Ask students what characteristics of light are important for a greenhouse.

A. Light is necessary in order for photosynthesis to occur.
B. Different light sources are available for greenhouse crops.
    1. Solar
    2. Artificial (high-intensity discharge or fluorescent lamps)
        a. On a winter day
        b. On cloudy days
        c. To extend length of day
C. Light has various characteristics.
    1. Intensity (brightness)
    2. Duration (length of day)
    3. Quality (spectrum of color)

3. How does light intensity affect plants?

Based on their knowledge of photosynthesis, ask students to identify the benefits of adequate light intensity on greenhouse plants. Ask them to brainstorm what kind of crops might be low-, medium-, and high-intensity plants. To demonstrate the concept of foot-candles, have students perform AS 4.1 Because candles are lit, be sure to supervise carefully. Then to demonstrate the effect of light on plants, have students complete AS 4.2.

A. Measurement of light intensity
    1. Light intensity measured in foot-candles (f.c.)
    2. One foot-candle: the amount of light striking a surface 1 foot from a standard wax candle
    3. Noon on a sunny day: 10,000 f.c.
B. Different plants - different light intensity requirements

1. Low-light intensity plants: 500-1,250 f.c. - e.g., for tropical foliage plants, impatiens, African violets, ferns
2. Medium-light intensity plants: 1,250-2,500 f.c.
3. High-light intensity plants: more than 2,500 f.c. - e.g., for lilies, roses, geraniums

C. Adequate light intensity
   1. Photosynthesis process
   2. Provides for healthy plant growth, such as
      a. Thicker stems
      b. Increased height
      c. Greater leaf area
      d. Shorter internodes
      e. More roots
      f. More flowers
      g. Larger flowers
      h. Increased pigment

D. Inadequate light intensity
   1. Reduces rate of photosynthesis
   2. Can stunt plant growth
      a. Long internodes, weak stems
      b. Delayed or no flowering
      c. Reduced pigment
      d. Less leaf area
   3. Too little exposure on one side of plant
      a. Plants bend in direction of light (phototropism).
      b. Plants develop stems curved in direction of light.
      c. Roots turn away from the light.

E. Excessive light intensity
   1. Goes beyond plant's need for photosynthesis
   2. High temperature - accelerating plant respiration process and deleting plant food supply
   3. Can stunt plant growth
      a. Reduce pigment
      b. Cause smaller leaves and flowers
      c. Burn leaves and flowers
      d. Bleach leaves

4. How does light duration affect plant growth?

The length of time a plant receives light affects it on many levels. Discuss how light variations occur both naturally and through human intervention. Split the class into small groups and have them complete AS 4.3.

A. Rate of growth is affected by the amount of light received.
   1. Photosynthesis only in presence of light
   2. Light duration
      a. Varies with latitude and season
      b. Can be increased with artificial lights

c. Can be decreased with dark cloths

B. Photoperiodism is the plant's response to light duration.
   1. Flower bud initiation
   2. Bulb formation
   3. Tuber formation
   4. Bract coloration
   5. Plantlet formation

C. Different plants have different photoperiod requirements.
   1. Short-day plants
      a. Need short days to flower
      b. Example: poinsettia
   2. Long-day plants
      a. Need long days to flower
      b. Example: asters
   3. Indeterminate plants (also called day-neutral plants)
      a. Flowering not affected by day length
      b. Example: African violet

5. How does light quality affect plant growth?

Demonstrate the light spectrum for the students by using the suggested activity in Section F. Ask students why the quality of light might be important when artificial light is used.

A. Light quality
   1. Wavelength (or color) of light
   2. Measured in nanometers (nm)
   3. Not all wavelengths used during photosynthesis

B. Wavelengths
   1. Ultraviolet (UV) light
      a. UV light has very short wavelength (less than 400 nm).
      b. UV light is invisible.
      c. High levels reduce photosynthesis and cause sunscald.
      d. Growth is stunted if plants are exposed to high levels of UV light.
      e. Some greenhouse coverings screen out different amounts of UV light.
   2. White or visible light (combination of violet, blue, green, yellow, orange, and red)
      a. Blue light
         i. Wavelength: 492 nm
         ii. Very high photosynthetic activity
         iii. Very evident phototropism
         iv. Plant's response: shorter, dark, hard tissues in plants
      b. Green light
         i. Wavelength: 535 nm
         ii. Very low photosynthetic activity
      c. Red light
         i. Wavelength: 647-760 nm
         ii. Very high photosynthetic activity

iii. Plant's response: soft growth, long internodes, seed germination, photoperiodic response in long-day plants

3. Far-red light
   a. Wavelength: 760-780 nm
   b. Plant's response
      i. Promotes flowering of short-day plants
      ii. Inhibits flowering of long-day plants
4. Infrared light
   a. Wavelength: 780+ nm
   b. Invisible
   c. Heat effect on plants
   d. Plant's response
      i. Causes photosynthesis process to stop
      ii. Overheating a cause of stomata closing

6. How does temperature affect plant growth?

Ask students to discuss why temperature is important to plant growth. Is the same temperature necessary for all segments of a single plant's growth?

A. Temperature levels
   1. Minimum temperature level (below which growth does not occur)
   2. Maximum temperature level (above which growth does not occur)
   3. Optimum temperature level (at which growth is the greatest)

B. Seed germination
   1. Greatly affected by temperature
   2. Typically, optimum air temperature: 60-70^{o}F
   3. Can increase rate of germination with bottom heating

C. Photosynthesis
   1. Minimum temperature variable with plant species
   2. Maximum temperature: 95^{o}F
      a. Rate increases as temperature increases until it reaches 95^{o}F.
      b. At temperatures above 95^{o}F, rate drops quickly then stops (enzymes are deactivated).
   3. Optimum temperature in most plants: 50-75^{o}F

D. Other plant processes
   1. Respiration
      a. Higher temperatures increase respiration, depleting food needed to fuel cellular metabolism.
      b. Low temperatures (32-34^{o}F) slow respiration, keeping plants, cut flowers, fruits, and vegetables fresh for extended periods.
   2. Transpiration
      a. The rate of transpiration increases as leaf temperature rises.
      b. Leaf temperature can be affected by several factors, as listed below.
         i. Warm or cold air currents and drafts
         ii. Radiational cold (from sides of greenhouse on cold nights)
         iii. Condensation (moisture on leaves that is colder than the air)

E. Vegetative and flowering growth (varies with different plants)
   1. Lower than optimum temperature
      a. Delayed flowering
      b. Slowed growth
      c. Intensified color in leaves and flowers
   2. Higher than optimum temperature
      a. Earlier and smaller flowers
      b. Fewer leaves
      c. Reduced stem diameter
      d. Reduced flower color
      e. Inhibited or delayed flowering
      f. Shorter life

7. What gaseous elements within the greenhouse affect plant growth?

Air quality is an important issue in the growth cycle of greenhouse plants. Encourage students to discuss both positive and negative gases that may be present. Have students complete AS 4.4.

A. Gases that are essential for plant growth
   1. Oxygen
      a. Required for plant respiration
      b. Adequate amounts occurring naturally
   2. Carbon dioxide
      a. Required for photosynthesis
      b. Promotes plant growth and flowering
      c. Adequate amounts occurring naturally (produced by plant respiration and organic matter decay)
      d. CO_2 levels in the greenhouse environment
         i. Often limited (particularly when greenhouse fans are off)
         ii. Can be increased with use of a CO_2 generator (Refer to Unit II, Lesson 2.)
   3. Water vapors (humidity)
      a. Optimum relative humidity level is 45-85%.
      b. High levels (over 85%) promote fungal diseases.
      c. Low levels increase transpiration and stunt plant growth.
         i. Shorter plants
         ii. Fewer new shoots
         iii. Less leaf growth
         iv. Smaller flowers
         v. Stiff, upright stems
      d. There are two methods to increase relative humidity.
         i. Humidifiers
         ii. Water trays under benches

B. Air pollutants that can be detrimental to plant growth
   1. Natural gas
   2. Ethylene
   3. Fluoride

4. Ammonia
5. Chlorine
6. Nitrogen dioxide
7. Sulfur dioxide
8. Mercury
9. Herbicides
10. Wood preservatives (pentachlorophenol, creosote, and some paints)
11. Peroxyacetyl nitrate
12. Ozone

F. Other Activity and Strategy

To demonstrate light quality (see study question 5), use a prism or a clear, plastic disc that comes as a spacer for CD-Rewritable discs to refract sunlight onto a light surface. Reiterate that white light is not just white but a spectrum of color. Humans can discern violet, blue, green, yellow, orange, and red. These colors are important because each color of light has a specific effect on plants.

G. Conclusion

The primary environmental elements that affect plant growth are light, temperature, and air quality. (Water is also critical and is discussed in Lesson 3.) These elements must be monitored and possibly adjusted in all the plants, especially the ones the students are tending.

H. Answers to Activity Sheet

Instructor's discretion

I. Answers to Assessment

1. B
2. D
3. D
4. B
5. <u>Extreme heat</u> - any one of the following:
   A. Earlier and smaller flowers
   B. Fewer leaves
   C. Reduced stem diameter
   D. Reduced flower color
   E. Shorter life

   <u>Extreme cold</u> - any one of the following:
   A. Delayed flowering
   B. Slowed growth
   C. Intensified color in leaves and flowers
6. A. Blue light - shorter, dark, hard plant tissues
   B. Red light - long internodes, seed germination, and soft growth

7. Any two of the following: Not all plants have similar photoperiod requirements.
   A. Flower bud initiation
   B. Bulb formation
   C. Tuber formation
   D. Bract coloration
   E. Plantlet formation

UNIT IV: PLANT GROWTH

Name_____

Lesson 1: Environmental Effects

Date_____

ASSESSMENT

Multiple Choice: Circle the letter of the best answer.

1. Long internodes and weak stems are signs of what type of light intensity?

   A. Adequate light intensity
   B. Inadequate light intensity
   C. Excessive light intensity
   D. Random light intensity

2. In what condition can artificial light can be used to promote growth in a greenhouse?

   A. On a windy day
   B. On a summer day
   C. To promote one's business
   D. To extend length of day

3. What three factors in a greenhouse must be closely monitored to maintain healthy plant growth and production?

   A. Light, wavelengths, and temperature
   B. Air quality, temperature, and photoperiodism
   C. Inflorescence, light, and temperature
   D. Temperature, air quality, and light

4. What is the optimum level of relative humidity in a greenhouse?

   A. 20-60%
   B. 45-85%
   C. 50-75%
   D. 75-95%

Short Answer Questions: Write the answers in the space provided.

5. What is one consequence of extreme heat and one consequence of extreme cold on greenhouse plants?

   A. Extreme heat:

   B. Extreme cold:

6. Which two colors of visible light have the greatest effect on plant growth? Describe how plants respond to each light.

Color	Plant' s Response
A.	A.
B.	B.

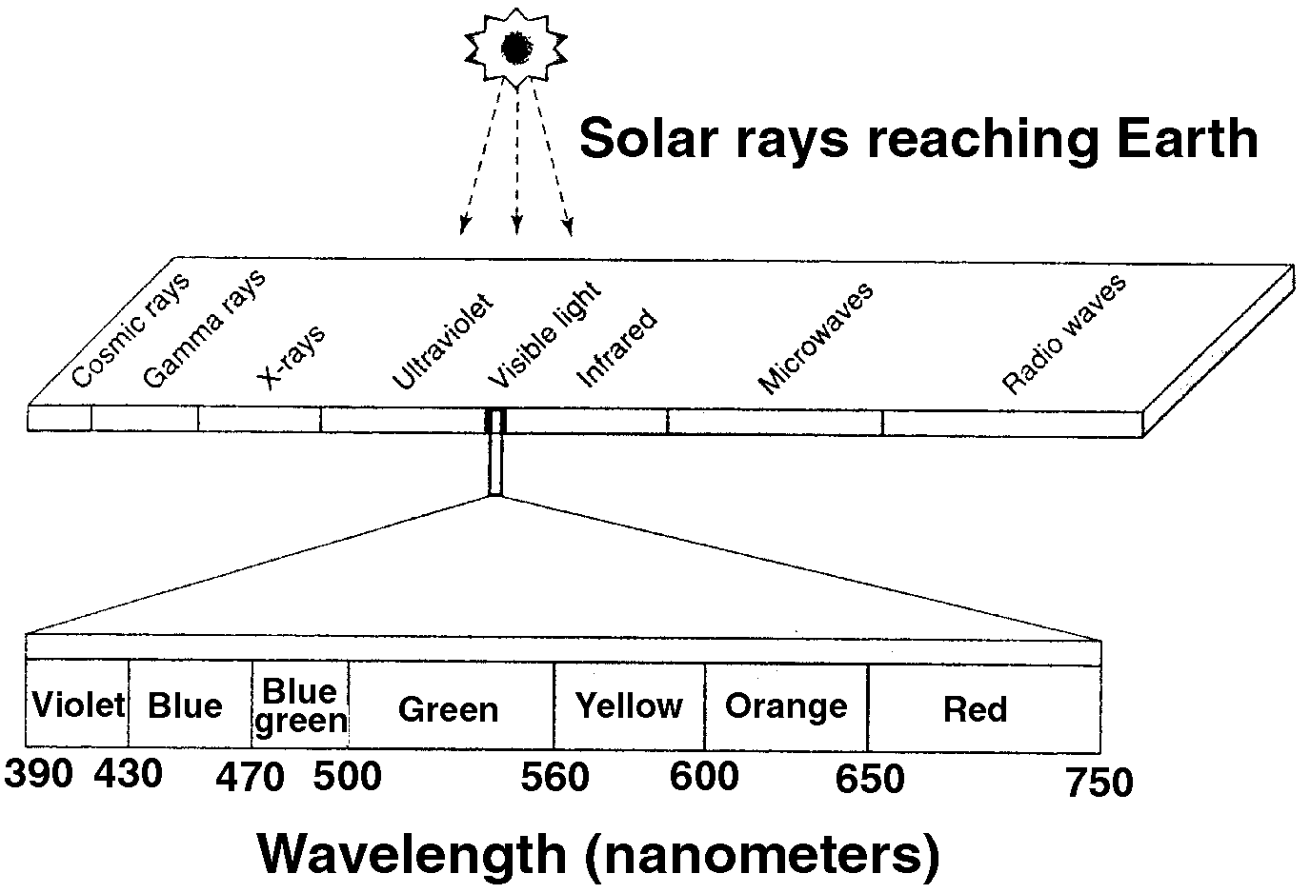
7. What are two events that occur during photoperiodism? Do all plants have the same light duration requirements? Why or why not?

   A

   B.

TM 4.1

Radiant Light Spectrum



Adapted from Acquaah, George. *Horticulture: Principles and Practices.* Upper Saddle River, NJ: Prentice Hall, 1999.

UNIT IV: PLANT GROWTH

AS 4.1

Lesson 1: Environmental Effects

Name_____

Foot-Candle Demonstration

Objective: Demonstrate how a foot-candle measures light.

Directions: Follow the procedures listed below and answer the questions.

Materials:

16 standard-size candles
Ruler
Sturdy piece of light-colored cardboard
Matches

Procedures:

1. Set one candle on a flat surface.
2. Measure a distance of 1 foot. Place the cardboard parallel to the candle.
3. Light the candle and turn off the overhead light.
4. The light hitting the board represents 1 foot-candle of intensity.
5. Add a second candle.
6. Observe the intensity of the light. Record your findings.
7. Double the number of candles to four.
8. Observe the intensity of the light. Record your findings.
9. Double the number of candles to 16.
10. Observe the intensity of the light. Record your findings.

1. How did the intensity of light change when the second candle was lit?

2. How did the intensity of light change when four candles were lit?

3. How did the intensity of light change when 16 candles were lit?

UNIT IV: PLANT GROWTH

AS 4.2

Lesson 1: Environmental Effects

Name_____

Effects of Light on Plants

Objective: Identify the effects of light in greenhouse plants.

Directions: Use the plants that were sown in Unit I, Lesson 1. These plants were assigned to three groups: Group A, Group B, and Group C. Your own plant belongs to one of these three groups. Since the seeds were planted at the beginning of Unit I, the three groups of plants have been exposed to various amounts of light as follows:

- Group A plants received 4 hours of light per day and then were put in a closet or under a cardboard box.
- Group B plants received natural light during normal daylight hours. (Plant was left on a window sill.)
- Group C plants received 17 hours of light per day with additional artificial light (identify type of artificial light).

Observe the groups of plant closely and answer the following questions. Some questions may require further research using various resource materials.

1. What type of plant did you grow?

2. What is the recommended amount of light for that plant?

3. Describe plants in Group A, Group B, and Group C in detail. Be sure to focus on the influence of light.

   Group A

   Group B

   Group C

4. What group is your plant in? How does it look? How much light do you think it received: too much, too little, or the proper amount of light? Why? Be specific.

5. What other factors could affect your plant's growth?

UNIT IV: PLANT GROWTH

AS 4.3

Lesson 1: Environmental Effects

Name_____

Photoperiod in Plants

Objective: Describe photoperiodism and its relation to plants.

Directions: Work in small groups of three or four students. Use the Internet, books, magazines, and science and horticulture textbooks to answer the following questions. When answering the questions listed below, do not use examples given in the text. Relate your findings to the class in a poster, collage, oral presentation, or any other format that answers the questions.

1. List three to five long-day plants.

2. List three to five short-day plants.

3. List three to five plants day-neutral plants.

UNIT IV : PLANT GROWTH

AS 4.4

Lesson 1: Environmental Effects

Name_____

Greenhouse Air Pollutants

Objective: Investigate the origin of air pollutants that could occur in greenhouses and point out ways to correct the problem.

Directions: Work in small groups of three or four students. Answer the following questions for three of the pollutants listed in Unit IV, Table 4.2, of the Student Reference. Use the Internet, books, magazines, science and horticulture textbooks to answer the following questions. Relate your findings to the class in a PowerPoint presentation, poster, oral presentation, or any other format that shares information with the class.

Pollutant #1_____

Pollutant # 2_____

Pollutant #3 _____

1. How could these pollutants enter a greenhouse? Are they naturally occurring substances? Are they a by-product of the greenhouse structure?

2. Do these pollutants affect all organic matter in a greenhouse? What signs do susceptible plants display? Do the pollutants have an effect on humans?

3. How would greenhouse professionals manage the presence of these air pollutants? Give at least two examples.

   A.

   B.

GREENHOUSE OPERATION AND MANAGEMENT

Unit IV: Plant Growth

Lesson 2: Growing Media and Containers

Competency/Objective:

Distinguish components of growing media, their uses, and basic types and sizes of containers.

Study Questions

1. **What is the importance of growing media?**
2. **How is field soil pasteurized?**
3. **Why is soilless media preferred for growing greenhouse crops?**
4. **What are the ingredients in soilless mixes and soil amendments?**
5. **What are some considerations in selecting growing containers?**
6. **What are the basic types of containers?**
7. **What are the most common materials for growing containers?**

References/Supplies/Materials

1. G*reenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 4.2 Composition of Soil-Based Growing Medium
   TM 4.3 Soil Texture Triangle
   TM 4.4 pH Scale
   TM 4.5 Peat Containers
   TM 4.6 Identifying Cell Packs
   TM 4.7 Container Shapes

3. Activity Sheets

   AS 4.5 Growing Media and Containers
   AS 4.6 Materials Update
   AS 4.7 Container Shopping

4. *Soil Science*. University of Missouri-Columbia: Instructional Materials Laboratory, 1995 (catalog numbers 10-5050-I, 10-5050-S).

5. *How Water Moves Through Soil* (Video). Available from University of Missouri-Columbia: Instructional Materials Laboratory (catalog number 10-5600-V).

TEACHING PROCEDURES

A. Review

The previous lesson described elements required to promote successful plant growth. This lesson continues with a discussion of what the plant is grown in, both the media inside and the container.

B. Motivation

To identify the ingredients of an ideal growing media, use the previously planted seeds to start a discussion of the differences in soil, amended soil, and soilless media. Point out container shapes, sizes, and material.

C. Assignment of Study Questions

Students should continue to water their plants.

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. Instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. What is the importance of growing media?

Ask the students to brainstorm about the functions and qualities of growing media. Why is the selection of the growing media a vital aspect of plant growth?

A. Material in which the roots of plants grow
B. Functions
    1. Support the plant upright
    2. Hold mineral nutrients
    3. Hold water
    4. Allow for exchange of gases (oxygen, CO_2, nitrogen)

C. Important considerations
   1. Water-holding capacity
   2. Drainage
   3. Porosity - pore space between solid particles
      a. The total amount of pore space determines how well the growing medium can retain air and water.
      b. The levels of available oxygen are a function of porosity.
         i. Inadequate pore space means that a shortage of oxygen develops when too much water is supplied.
         ii. The size and distribution of individual pores determine the rate of gas exchange and drainage. These two factors influence the effectiveness of the growing medium.
         iii. The ideal medium has a mixture of large and small pore spaces.
   4. Effect of temperature on growing medium
      a. Affects activity of microorganisms
      b. Affects absorption rate of water and fertilizer
      c. Above 32^{o}F to slightly over 110^{o}F - microorganisms converting organic nitrogen fertilizers in soil to forms that can be readily absorbed
   5. Desirable features
      a. Loose and well aerated
      b. Suitable pH level and cation exchange capacity
      c. Good drainage, holding enough water for plant growth
      d. Free of unwanted seeds, weeds, insects, and pathogens

D. Physical characteristics of ideal field (mineral) soil (TM 4.2)
   1. Composition
      a. 50% solids
         i. 5% organic matter (decayed plant and animal residue)
         ii. 45% mineral matter
            (a) Sand - largest particle
            (b) Silt - formed by water breaking down minerals; smaller than sand
            (c) Clay - smallest particle; fills the gaps between the other particles
      b. 25% water
      c. 25% air (pore spaces - consist of oxygen, carbon, and hydrogen)
   2. Texture - size; distribution; proportion of sand, silt, and clay particles (TM 4.3)
      a. Water retention and air porosity are related to the soil's texture.
      b. Soil containing mostly sand (large particles) is composed of large pores.
      c. Soil with a majority of small, finely textured particles (clay) has small pores that resist the flow of water and therefore increase the soil's water-holding capacity.
      d. Equal amounts of all three particles in soil are called "loam."
      e. Pure loam is not found in the field.
      f. The combination of particles determines whether the soil texture is fine, medium, or coarse.
   3. Structure - arrangement of solid particles
      a. Affects water-holding capacity, porosity, soil's ability to transmit water into the plant (permeability), and the rate of water absorption into the roots (infiltration)
      b. Rearranging soil structure to achieve ideal composition for crop

E. Chemical characteristics
   1. pH - measurement of the level of alkalinity/acidity (TM 4.4)
      a. Ranges from 0 to 14
         i. 7 - neutral
         ii. Above 7 - alkaline (base)
         iii. Below 7 - acidic
      b. Determines whether the soil can receive nutrients (See Unit IV, Lesson 4.)
      c. pH range for most greenhouse crops from 5.5 to 6.5
   2. Cation exchange capacity - measurement of the capacity to hold nutrients
      a. Fertile soil attracts and retains essential nutrients, promoting plant growth.
      b. A cation is a positively charged ion in a solution.
      c. The soil's clay, silt, and organic particles have negative charges that attract and hold cations.
      d. A clay particle in soil has a large surface area, making the cation's absorption more efficient.

2. How is field soil pasteurized?

Have students look at the plants that were sown in field soil and soilless media. What differences do they see in the containers? Have them complete AS 4.5. If possible, demonstrate the steam pasteurization of soil; instructions are in the second suggested activity in Section F - Other Activities and Strategies.

A. Field (mineral) soil alone is not an acceptable growing medium for plants grown in containers.
   1. Generally heavy with poor drainage and aeration
   2. Variable quantity and quality of nutrients
   3. May contain weeds, insects, or disease
B. Field soil must be pasteurized and amended to achieve desired characteristics.
C. Pasteurization has two main purposes.
   1. Kills majority of weed seeds
   2. Kills bacteria and fungi that could cause plant disease (does not kill most organisms that are beneficial to plant growth)
D. There are three basic methods of pasteurization.
   1. Steam
      a. Soil must be mixed before steaming.
      b. Typical treatment is 140-160°F for 30 minutes.
      c. Planting can be done as soon as soil cools.
      d. This method should not be used when soil contains slow-release fertilizer.
   2. Chemical
      a. Not as effective as steam
      b. Fumes highly toxic to humans
      c. Must allow time before planting
      d. Commonly used chemicals
         i. Chloropicrin
         ii. Basamid (DMTT)

iii. Vapam
3. Electrical
   a. Not commonly used in commercial greenhouses
   b. Feasible only for small amounts of soil

3. Why is soilless media preferred for growing greenhouse crops?

Have the students reiterate positive aspects of soilless growing media over field soil. If possible, have both organic and nonorganic greenhouse managers visit. Give each manager one class period to speak and answer questions.

A. Contain no naturally occurring field (mineral) soil
B. Soilless mixes generally preferred for greenhouse crops
C. Benefits
   1. Lightweight
   2. Essentially inert
   3. Excellent drainage and porosity
   4. Consistent in composition
   5. Free of unwanted seeds, weeds, insects, and pathogens
   6. Can be custom mixed or purchased ready-to-use
   7. Do not require pasteurization

4. What are the ingredients in soilless mixes and soil amendments?

Bring in leftover soilless medium from the plants for the students to examine. What is the medium made of? What amendments are the most desirable? Do these amendments have any drawbacks? Have students complete AS 4.6.

A. Organic materials
   1. Benefits
      a. Improve physical structure of soil-based media
      b. Increase water-holding capacity
      c. Increase aeration and drainage
      d. Increase cation exchange
   2. Types
      a. Peat
         i. Peat moss, sphagnum moss, humus, etc.
         ii. Decomposed plant and animal residue
         iii. Can hold 15-20 times its weight in water
         iv. Ample quantities of pore space that hold air and water
      b. Wood residues
         i. Leaf mold, composted sawdust, bark, etc.
         ii. By-products of lumber industry
      c. Coir
         i. Coconut parts
         ii. By-product of coconut industry

iii. Excellent air porosity and water retention; medium absorbs moisture easily and drains quickly

B. Mineral (inorganic) materials
   1. Benefits
      a. Improve physical structure of soil-based media
      b. Increase aeration and drainage
   2. Types
      a. Sand (mountain rock origin)
         i. Sand provides good porosity and aeration by admitting large quantities of air into the growing medium.
         ii. It promotes drainage but cannot hold sufficient quantities of water for the emerging plant.
      b. Perlite (volcanic rock origin)
         i. Neutral pH
         ii. Holds three to four times its weight in water
         iii. Improves drainage and aeration
         iv. Ideal as a seed-germinating medium for rooting cuttings
      c. Vermiculite (mica origin)
         i. Absorbs fertilizer
         ii. Contains sources of magnesium and potassium
      d. Calcined clay
         i. Retains nutrients in medium
         ii. Adds volume to the medium and improves the soil structure

C. Other materials
   1. Polystyrene flakes - by-product of polystyrene processing
   2. Rock wool
      a. Spun from basalt, coke, and limestone
      b. Not biodegradable, which poses environmental concerns

5. What are some considerations in selecting growing containers?

Primary influences of container selection are based on both the plant itself and the intended market. Another concern is how long the plant is in the container, e.g., hanging basket of fuschia versus flats of bedding plant plugs in the retail market. How might the wholesale market be different?

A. Plant growth habit
   1. Plant height
   2. Plant width
   3. Plant shape
   4. Plant requirement for root space

B. Intended market
   1. Retail (generally larger pots)
   2. Wholesale (generally smaller pots)

6. What are the basic types of containers?

Both organic and synthetic materials are used in greenhouses. Encourage the students to discuss what these materials are and how each might be beneficial, e.g., growing seedlings versus potted plants. Have students complete AS 4.7.

A. Rooting containers
   1. Used for seeding or root cuttings
   2. Made from organic materials
      a. Peat pellets and strips (TM 4.5)
         i. Self-contained growing units
         ii. Expand when watered
      b. Peat pots
         i. Made from compressed peat moss
         ii. Must be filled with growing media
   3. Made from other materials
      a. Plastic flats
      b. Metal flats
      c. Plastic foam cubes
      d. Rock wool fibers

B. Bedding plant containers
   1. Cell packs (TM 4.6)
      a. Generally made of plastic
      b. Usually contain 36, 48, or 72 cells per flat
      c. Used for producing plug seedlings
   2. Plant packs
      a. Generally made of plastic
      b. Usually contain one to six cells per unit and six to eight units per flat
      c. Used for bedding and garden vegetable plants
   3. Individual pots
      a. Generally made of plastic
      b. Range in size (most common: 2-4 in.)
      c. Used to produce larger bedding plants

C. Foliage and flowering plant containers (can range in size from 2 to 12+ in.) (TM 4.7)
   1. Standard pot
      a. Equal in width and depth
      b. Best for plants that are not top heavy
   2. Azalea pot
      a. Height - 3/4 of its width
      b. Ideal for shorter plants with spreading foliage
      c. Wide base - stability for top-heavy plants
   3. Rose pot
      a. Height - 1 1/2 times its width
      b. Ideal for plants with large, deep root systems
   4. Bulb pan
      a. Width twice the depth

   b. Best for shallow-rooted plants
5. Hanging baskets
   a. Generally made of plastic
   b. Suitable for a variety of plants

7. What are the most common materials for growing containers?

Containers in commercial greenhouse are composed of organic and synthetic materials. Discuss the benefits and drawbacks of each. Are some materials better for certain types of plants or the growers?

A. Plastic (most commonly used)
   1. Types
      a. Round (more air circulation between pots)
      b. Square (more space efficient but less air circulates among pots, leading to diseased leaves)
   2. Advantages
      a. Lightweight to lift and ship
      b. New pots - sterile; used pots - can be chemically sterilized
      c. Less prone to fertilizer residue/algae buildup
      d. Less watering required
      e. Wide selection of sizes, shapes, and colors
      f. Inexpensive
   3. Disadvantages
      a. Nonporous (does not "breathe")
         i. Less aeration for root system
         ii. Possibility that growing medium may become waterlogged
      b. Can crack and becomes brittle with age
      c. Disposal - environmental concern
B. Clay (used for centuries)
   1. Advantages
      a. Porous
         i. Excellent aeration and gas exchange
         ii. Excellent drainage prevents growing medium from becoming waterlogged
      b. Sturdy, less likely to tip
      c. Long lasting
      d. Can be steam sterilized
      e. Can be reused
   2. Disadvantages
      a. Plants drying out faster and requiring more frequent watering
      b. Prone to fertilizer residue/algae buildup
      c. Heavy to lift and ship
      d. Subject to breakage
      e. Relatively more expensive
C. Peat - peat moss pressed into sheets and formed into shapes
   1. Advantages

a. Can be transplanted along with plant (less trauma to plant when transplanted)
b. Roots penetrating container as plant grows

2. Disadvantages
   a. Does not last very long
   b. Dries out quickly and becomes difficult to rewet

F. Other Activities and Strategies

1. Invite a manager from an organic greenhouse and a traditional greenhouse manager on separate days to discuss issues of growing media and containers. A nearby university Extension office may be able to help you find an organic greenhouse grower. What kind of growing medium do they use, amended soil or a soilless mixture? Do they create their own soilless medium? What are the ingredients in it and why those particular items? Ask them to show the class what their growing medium looks like. Ask them to address concerns of chemical pasteurization (methyl bromide), vermiculite, rock wool, and polystyrene. With regards to containers, what type do they prefer and why? What are the costs involved in "being green"?

2. Steam Pasteurization of Soil - This smelly exercise requires an oven, soil, a meat or candy thermometer, ovenproof pan, some aluminum foil, and ventilation.

   A. Before using the soil, thoroughly sterilize the equipment. Wash containers and tools with soapy water to remove debris. Sterilize wood and plastic items by rinsing them in a solution of 1 part chlorine bleach and 10 parts water. Let dry before using.

   B. Place moist but not wet soil in an ovenproof pan. Cover with foil, sealing the edges. Insert the thermometer in the middle of the soil mass, making a small hole in the foil. Bake in a 250°F oven until the thermometer reads 160-180°F. Remove from oven and let cool.

      Note: The amount of time to sterilize the soil varies depending on soil volume and moisture content. Remember that dry soil does not pasteurize well.

3. Show the class any or all of the following videos, which are available from CATER (Career & Technical Education Resources), 2 London Hall, University of Missouri-Columbia: *How to Grow Plants in a Greenhouse: Bedding Plant Production*, Vol. I (AG V162); *How to Grow Plants in a Greenhouse: Foliage Plant Production*, Vol. II (AG V163); and *Growing Media for Landscape Plants* (AG V172).

G. Conclusion

The growing media's water-holding capacity, porosity, drainage, and aeration foster healthy plant growth. Soilless medium is preferred over field soil. By amending the composition through the addition of organic and inorganic materials, soil-based media can be substantially improved. The selection of plant containers and the choice of materials depend on usage and the intended market.

H. Answers to Activity Sheets

AS 4.5 Growing Media and Containers

Instructor's discretion

AS 4.6 Materials Update

Instructor's discretion

AS 4.7 Container Shopping

Instructor's discretion

I. Answers to Assessment

1. A
2. C
3. B
4. D
5. B
6. Any two of the following for A-C:
   A. Rooting/seeding plants: peat pellets, peat strips, peat pots, plastic flats, metal flats, rock wool fiber, plastic foam cubes
   B. Foliage/flowering plants: standard, azalea, rose, bulb, and hanging pots
   C. Bedding plants: cell packs, plant packs, and individual pots
7. Any two of the following:
   A. Lightweight
   B. Essentially inert
   C. Excellent drainage and porosity
   D. Consistent in composition
   E. Free of unwanted seeds, weeds, insects, and pathogens
   F. Can be custom mixed or purchased ready-to-use
   G. Do not require pasteurization
8. Steam - cannot be used in conjunction with slow-release fertilizers
   Chemical - not as effective as steam, fumes are toxic to humans, growing media must aerate before planting can occur
   Electrical - can be used only on very small areas
9. E
10. C
11. A
12. F
13. D
14. B

UNIT IV: PLANT GROWTH

Name_____

Lesson 2: Growing Media and Containers

Date_____

ASSESSMENT

Multiple Choice: Circle the letter of the best answer.

1. What is the composition of an ideal field (mineral) soil?

   A. 50% solids, 25% water, and 25% air
   B. 15% organic matter, 40% water, 5% air, and 40% silt
   C. 45% mineral, 1% water, 1% air, and 53% sand
   D. 30% air, 30% mineral, 20% water, and 20% silt

2. What are three most popular container materials?

   A. Peat, vermiculite, and clay
   B. Plastic, metal, and perlite
   C. Clay, peat, and plastic
   D. Rock wool, peat, and plastic

3. What three features are essential for a good growing medium?

   A. Porosity, lightweight, and pasteurization
   B. Water-holding capacity, drainage, and porosity
   C. Drainage, silt, and sand
   D. Porosity, water-holding capacity, and loam

4. What are two disadvantages of using mineral (field soil)?

   A. Cation exchange capacity and CO_2 levels
   B. No need for pasteurization and is too heavy
   C. Superior aeration but not enough water
   D. Poor aeration and potential contaminants

5. When selecting a type of container, what are the two most important considerations?

   A. Growth media and pot size
   B. Plant growth and market
   C. Container material and plant growth
   D. Market and porosity

Short-Answer Questions: Write the answers in the space provided.

6. What are two examples of container types for the following types of greenhouse plants?

   A. Rooting/seeding plants

      1.

      2.

   B. Foliage/flowering plants

      1.

      2.

   C. Bedding plants

      1.

      2.

7. What are the two benefits of soilless media for growing plants?

   A.

   B.

8. What are the three methods of soil pasteurization? What is one drawback of each technique?

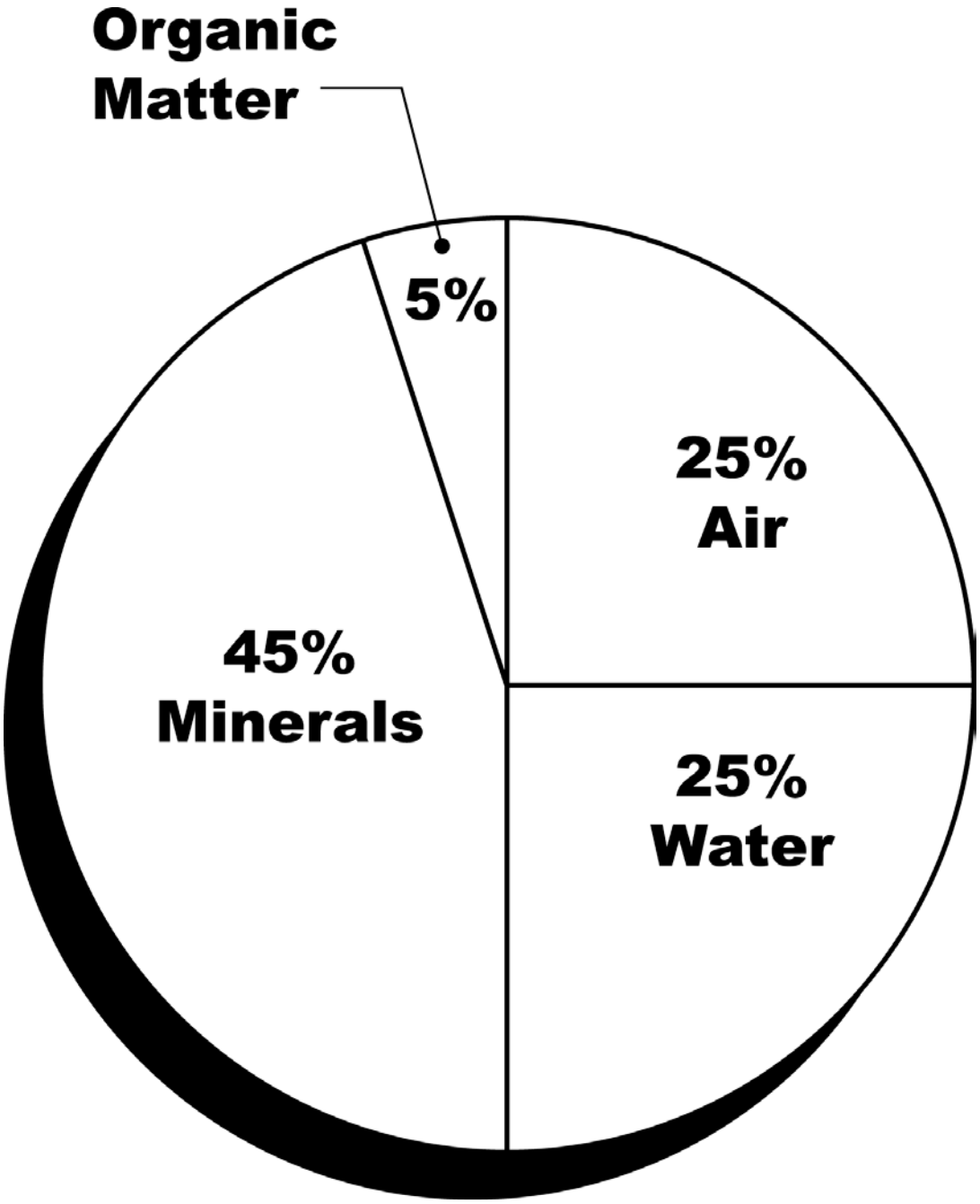
Method	Drawback
A.	A.
B.	B.
C.	C.

Match the ingredients in soilless mixes and soil amendments on the left with their origin on the right. Write the letter in the space provided.

____9.	Rock wool	A.	Mica
____10.	Coir	B.	Mountain rock
____11.	Vermiculite	C.	Coconut by-product
____12.	Sphagnum peat moss	D.	Volcanic rock
____13.	Perlite	E.	Spun basalt, coke, and limestone
____14.	Sand	F.	Decomposed plant and animal residue

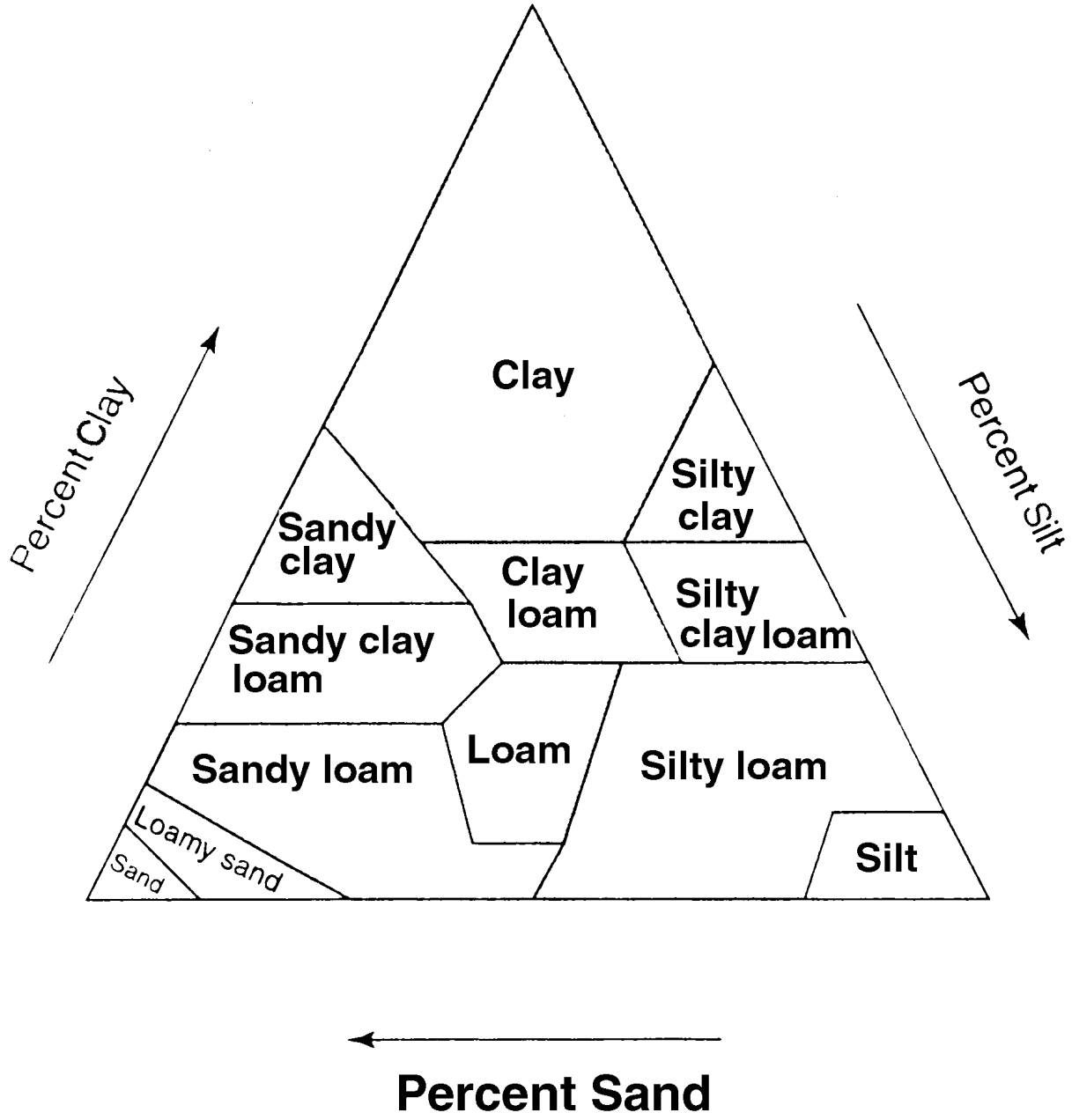
TM 4.2

Composition of Soil-Based Growing Media



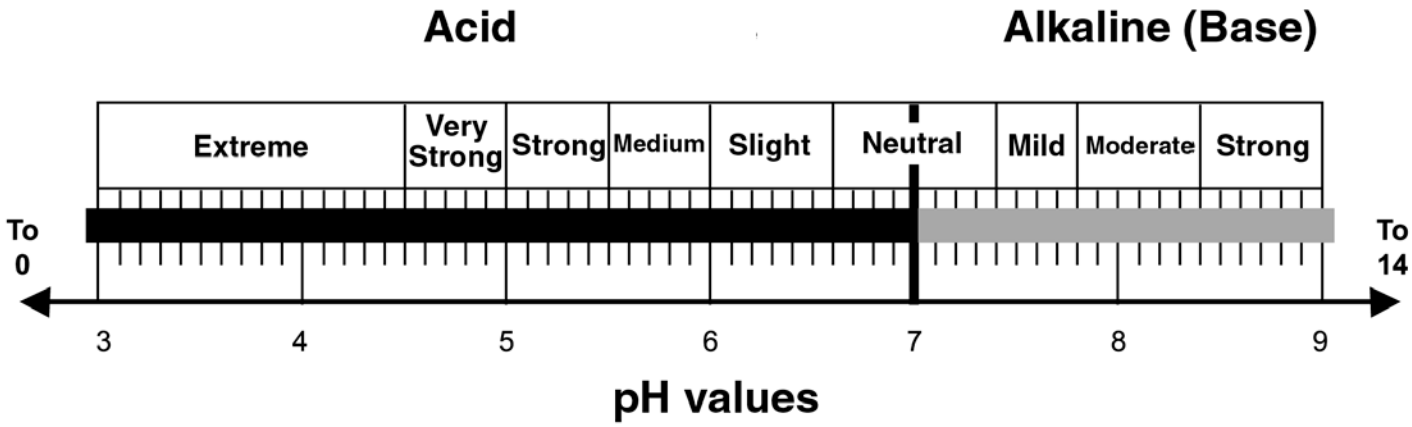
TM 4.3

Soil Texture Triangle



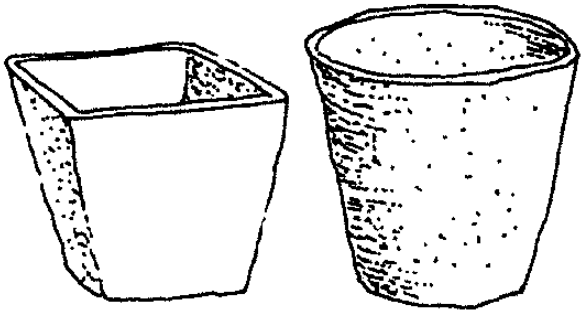
TM 4.4

pH Scale



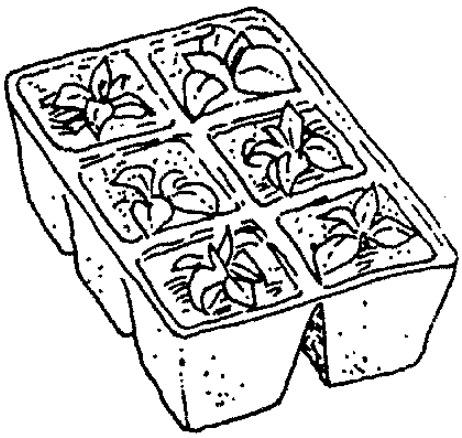
TM 4.5

Peat Containers



Peat Pots

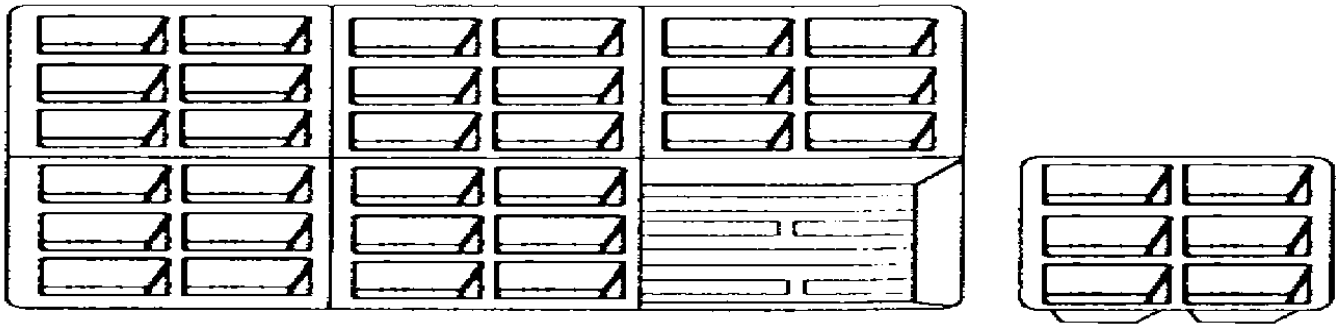
Peat Pellet



Peat Strip

TM 4.6

Identifying Cell Packs



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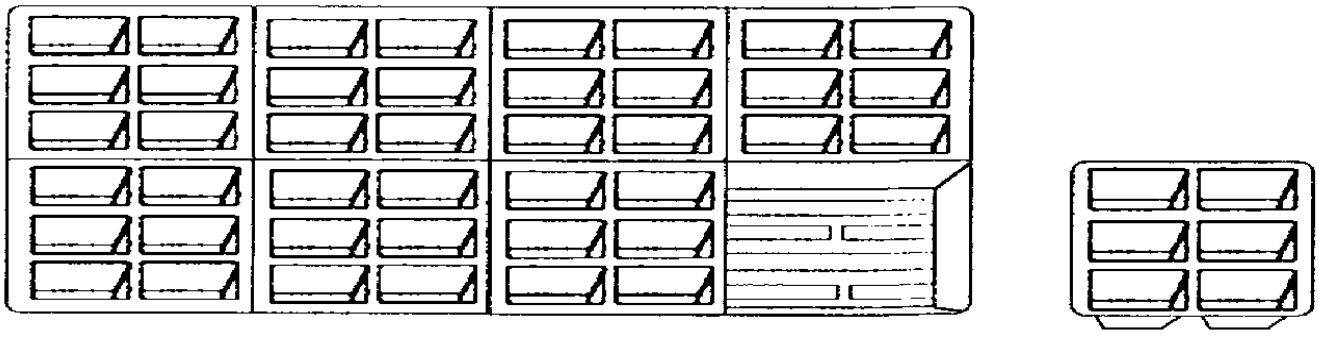

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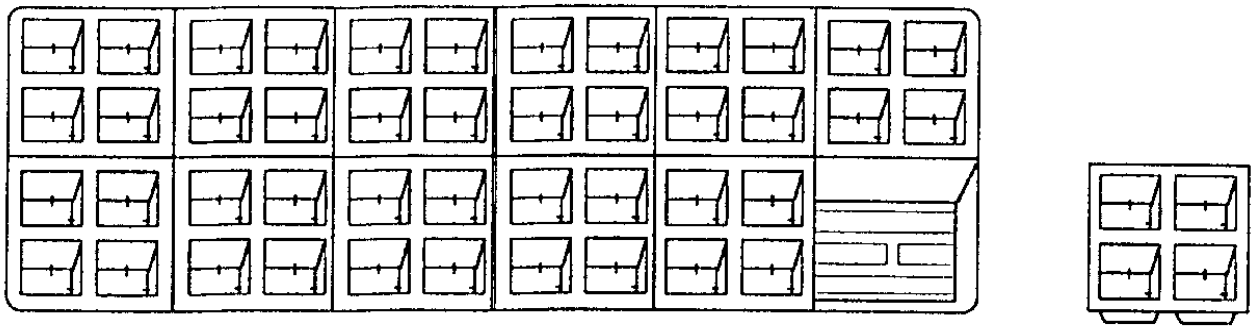

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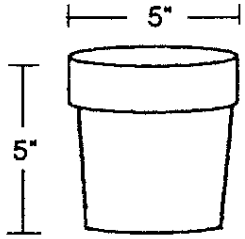
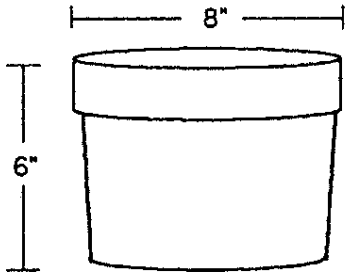
TM 4.7

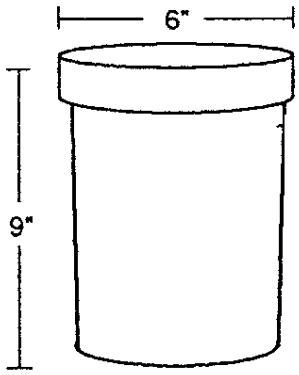
Container Shapes



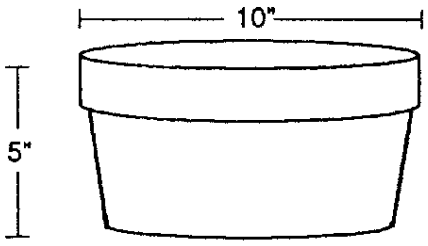
Standard Pot



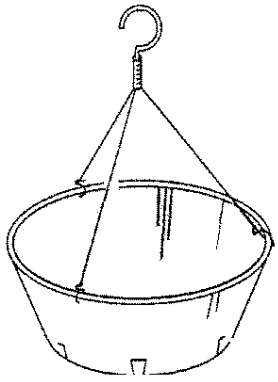
Azalea Pot



Rose Pot



Bulb Pot



Hanging

UNIT IV: PLANT GROWTH

AS 4.5

Lesson 2: Growing Media and Containers

Name_____

Growing Media and Containers

Objective: Identify the differences in soil and soilless growing media and evaluate types of containers used.

Directions: Use seeds planted earlier in this unit to assess the effectiveness of growing media. Remember that at the beginning of Unit I when the seeds were planted, half of the class' plants were randomly planted in soil. Then answer the following questions.

1. How do the plants look? Describe in detail.

2. Turn a little bit of the growing media and record observations. Describe the differences in the soil and the soilless media.

3. What kind of container is used to grow the plants? What is the container made of (clay, plastic, etc.)? Could the type of container or material influence the growth of the plants? Explain.

4. If this plant were grown for retail sale, what container would be the best option? For wholesale?

UNIT IV: PLANT GROWTH

AS 4.6

Lesson 2: Growing Media and Containers

Name_____

Materials Update

Objective: Evaluate the materials used in greenhouses.

Directions: Using the Internet and other sources, work in small groups to research one of the words listed below. Then answer the questions and present your findings to the class as a PowerPoint presentation.

- Bagasse
- Calcined clay
- Chloropicrin
- Hydrogel (Terrasorb)
- Methyl bromide
- Peat moss
- Perlite
- Rock wool
- Vermiculite

1. What is it?

2. What is its use?

3. What are the benefits of using it?

4. Are there negative aspects to its use?

5. Is there an alternative?

6. How cost-effective is the option?

UNIT IV: PLANT GROWTH

AS 4.7

Lesson 2: Growing Media and Containers

Name_____

Container Shopping

Objective: Compile a list of appropriate containers and prices to fill a greenhouse.

Directions: Using the Internet and other sources, research the price and types of containers it would take to fill a greenhouse the size of your school's greenhouse.

1. How many containers will it take to fill the greenhouse?

2. What size pots: just one size or a variety? Which sizes?

3. Is it necessary to buy any rooting containers?

4. How many cell packs and hanging baskets will you use?

5. How are cell packs sized?

6. How are cell packs sold?

7. What materials are the containers made from?

8. Why did you choose that material?

9. What types of plants are you growing? Did this influence your choice? Why?

10. How much money will these containers cost?

GREENHOUSE OPERATION AND MANAGEMENT

Unit IV: Plant Growth

Lesson 3: Irrigation

Competency/Objective:

Explain factors involved in proper greenhouse irrigation.

Study Questions

1. **What factors affect the irrigation of greenhouse crops?**

2. **How often should crops be irrigated?**

3. **What are some basic irrigation guidelines?**

4. **How should water be delivered to plants?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 4.8 Interaction Between Growing Medium's Porosity and Depth
   TM 4.9 Capillary Action of Water in Growing Medium

3. Activity Sheets

   AS 4.8 Over-, Under-, and Proper Watering
   AS 4.9 Water Delivery Systems

TEACHING PROCEDURES

A. Review

Light, temperature, and air quality are important factors in aiding plant growth as well as the composition of the growing media and the containers used. The most important factor affecting the health and growth of a greenhouse crop is water. Water delivers essential nutrients to the root system. This lesson provides guidelines for proper irrigation and describes several methods of delivering the water to the plants.

B. Motivation

1. Irrigation is more complicated than just spraying plants with a hose for a few minutes. Ask the students to brainstorm why water is so important for the plants. Use the plants they have been watering to illustrate the significance of water.

2. Saturate a sponge and lay it flat on a screen with space below it so that students can observe that water runs out of it. Turn the sponge up so it rests on its longest edge. (More water runs out of it than it did when it was flat.) Now turn it up so it rests on its narrowest edge. (Even more water runs out of the sponge.) Ask students if the position of the sponge has an effect on how fast it absorbs water. Ask them to predict why.

C. Assignment of Study Questions

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. The instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. What factors affect the irrigation of greenhouse crops?

Water delivers valuable nutrients to plants. Students should note that public water might also have additives such as fluoride and salts that can damage plants. Some plants are more sensitive than others.

A. Irrigation is the most important greenhouse practice.
   1. Quality water is essential to plant growth.
   2. Proper irrigation practices are critical to crop success.
B. Water has a major role in plant growth.
   1. Dissolves nutrients and translocates them throughout the plant
   2. Supports plant structure when plant cells are filled
C. Several factors contribute to moisture stress in plant.
   1. Growing medium - very important factor
      a. The growing medium must provide adequate absorption, drainage, and retention.
      b. When medium's capillaries absorb and retain water, the force of gravity drains water from the plant container, creating a conflicting interaction. (TM 4.8)
         i. Medium's porosity and depth resolve this conflicting interaction.

ii. Large particles in the growing medium are porous and facilitate drainage after irrigation.
iii. The depth of the medium relates to the height of the plant's container.
(a) Water in tall containers pulls easily through the medium; drainage is complete.
(b) Water is retained in short containers because the medium's capillaries resist the force of gravity.

2. Air temperature
a. Warmer air temperatures increase plant transpiration rate, relative humidity decreases, and water in plant cells is depleted.
b. Air temperature must be monitored and regulated.

D. Irrigation considerations
1. Provide uniform watering.
2. Minimize amount of water/fertilizer runoff.
3. Minimize amount of water on foliage.
4. Consider integrating fertilizer injection system directly into irrigation system.

E. Plants vary in their sensitivity to the elements in some water supplies.
1. Fluoride
a. Added to public water systems for tooth decay prevention
b. Can cause tips of some plants to burn
2. Softened water
a. Contains high levels of sodium
b. Should not be used for plant irrigation

2. How often should crops be irrigated?

When do you water? Discuss the consequences of underwatering and overwatering using the plants the students have been watering. Have students complete AS 4.8.

A. Frequency depends on various factors.
1. Water-holding capacity of growing medium
2. Growing medium and container type
3. Internal environment (greenhouse humidity, temperature, light)
4. External environment (season)
5. Plant itself
a. Species
b. Size
c. Stage of growth
d. Soil depth

B. There are several ways to identify when plants need water.
1. Visual observations
a. Plant starts to wilt.
b. Growing medium becomes dry and lighter in color.
c. Weight of pot is lighter.
2. Stick placed in growing medium and removed
a. If stick is dry, water the plant.

b. If medium clings, do not water the plant.

C. There are several consequences of underwatering.
   1. Moisture stress from depriving plant of water
   2. Wilting because cells shrink
   3. Stomata close up
      a. Prevent further loss of moisture
      b. Restrict CO_2 from entering leaf
      c. Photosynthesis hindered
      d. Plant growth stunted
   4. No water or minerals to roots
      a. Leaves, stem, and emerging flowers are deprived of water and nutrients.
      b. Plant develops shorter internodes, smaller leaves, and harder and tougher plant tissue.

D. There are several consequences of overwatering.
   1. Especially detrimental for seedlings
   2. Affects root system
      a. Restricts exchange of gases; limits level of oxygen
      b. Damages root tissue
      c. Increases risk of disease invasion
   3. Wilting
   4. Leggy growth
   5. Slowed growth

3. What are some basic irrigation guidelines?

Have students discuss the important aspects of growing media related to water: porosity, drainage, and water-holding capacity. Ask students to define leaching, an important aspect of irrigation.

A. Use proper growing media. (See Unit IV, Lesson 2.)
B. Water only when indicated.
C. Water thoroughly each time.
   1. Purpose
      a. Leaches (flushes) soluble salts and excess nutrients from growing media
      b. Buildup of salts and nutrients damaging to root system
   2. Method
      a. Moisten entire area around roots; do not allow root system to dry out.
      b. Do not allow overflowing over top of pot.
      c. Water until water drains from bottom.
      d. Water early in day to allow water to evaporate from foliage and flowers.
D. Take steps to reduce risk of plant disease.
   1. Do not wet foliage or flowers.
   2. Keep end of hose off the floor to avoid pathogens that can contaminate plants.

4. How should water be delivered to plants?

The three basic styles of irrigation are overhead delivery, surface delivery, and subsurface delivery. Some plants respond better to specific methods. Ask students to discuss why this might be. Have the class complete AS 4.9 to augment information learned here.

A. Water delivery to plants in the greenhouse through both manual and automated systems (See Unit II, Lesson 2.)
B. Manual method - use of handheld hose and wand
    1. Widely used in small greenhouse operations
    2. Labor intensive
    3. Costly
    4. Difficult to water plants uniformly
C. Overhead delivery - foliage-type watering system (automated method)
    1. Sprinkler systems
        a. Spray stake/nozzle systems mounted near plants, spraying bedding plants from above and on the sides
        b. Disadvantages
            i. May leave salt residues on foliage if irrigation system contains nutrients
            ii. Increased risk of disease from wet foliage
            iii. May displace or puddle growing medium
            iv. Evaporation from using overhead sprinklers
            v. Increased risk of disease from wet foliage
    2. Boom irrigation system
        a. Water wand hanging above plants and traveling across greenhouse spraying water onto plants
        b. Spray stake/nozzle systems mounted near plants, spraying plants from above and from the sides.
        c. Custom built to greenhouse's dimensions
        d. Delivers fertilizer during irrigation (fertigation)
        e. Saves 40% in water compared to manual techniques
D. Surface delivery (automated method)
    1. Applies water under foliage
        a. Uniform amount of water is applied at base of plant.
        b. Leaves do not get wet; rate of evaporation from foliage and soil is reduced.
        c. Growing medium does not get waterlogged.
        d. Nutrients do not leach into the soil.
    2. Use of drip tubes - delivering water directly to the soil without wetting the foliage
        a. Drip emitters have small tubes with weights attached that are placed in individual pots. They slowly dispense drops of water directly to the medium.
        b. Ooze tubes have small holes in a double-layer tube and are placed next to rows of plants.
            i. Deliver low volume of water; conserve large amounts of water
            ii. Used in areas with limited resources of water and where water is expensive
        c. Water loops are actually ooze tubes that are wrapped around the stems of plants in individual pots.

E. Subsurface (subirrigation) delivery
   1. Delivers water directly to medium without wetting foliage; applies water under pot
   2. Capillary mat system (TM 4.9)
      a. Plant containers are placed on top of soaked, synthetic mat that rests on level bench.
      b. Bench is protected with a sheet of plastic.
      c. Dripping water runs off bench, preventing soluble salts from accumulating on mat.
      d. Plastic pots are best to use; clay pots lose moisture through sidewalls.
      e. A drip tube waters the mat uniformly.
      f. Plants are watered from above using a hose.
         i. This creates a column of water that extends from growing medium to the mat.
         ii. Capillary action pulls water upward from a saturated mat through a drainage hole into the growing medium.
         iii. Capillary action occurs because water rises to a given height in "tubes" (capillaries) with narrow diameters. (TM 4.9)
         iv. Pore spaces in growing medium function as capillary tubes and carry water from the mat to the roots.
   3. Ebb and flood system
      a. Flats of plants rest on specially constructed, raised, waterproof benches.
      b. Each bench must be absolutely level and have a trench for the nutrient solution and several pipes to carry a given number of gallons of water per minute. The amount of water depends on the size of the greenhouse operation.
      c. The irrigation solution (water and nutrients) is pumped from a central storage tank into the bench and spreads quickly and evenly over the growing medium.
      d. The solution remains on the bench for a few minutes and then drains back into the storage tank for recycling.
      e. Ebb and flood system never wets the foliage (which would promote disease) and it can be applied any time of the day or night. A computer can regulate the entire operation.
      f. Ebb and flood is a completely closed recirculating system that does not contaminate the groundwater.

F. Other Activity and Strategy

Have three similar-size pots of the same plant and water each one with tap, reverse osmosis (RO) filtered water, and spring water. Ask students if they see the effects of three types of water on the growth of plants in the classroom. Tap water is water filtered for contaminants and possibly augmented with fluoride. Filtered water is water that has been changed in one of three ways: distilled, deionized, or filtered through RO. These methods are used to eliminate soluble salts and other contaminants like hard metals. These methods can remove minerals and trace metals that plants need for nutrition. It is not an appropriate substitute for public water. Greenhouse growers find that filtered water, especially, is less expensive. RO is useful when applied with water containing essential nutrients. Spring water should be water derived from a natural source without having its mineral content changed. Thus, depending on its source, the water may be alkaline or acidic.

G. Conclusion

Water plays a vital role in the growth and development of greenhouse crops. There are several factors that affect irrigation: the medium's absorption, drainage, and retention as well as air temperature. Frequency of irrigation depends on several variables and the greenhouse owner can use different techniques to assess the need for watering. Overwatering and underwatering have severe consequences on the health of greenhouse crops. Irrigation may be delivered through manual or automatic systems.

H. Answers to Activity Sheets

AS 4.8 Over-, Under-, and Proper Watering

Instructor's discretion

AS 4.9 Water Delivery Systems

Instructor's discretion

I. Answers to Assessment

1. A
2. D
3. C
4. A. Moisten entire area around the roots.
   B. Do not let water overflow.
   C. Water until water drains from the bottom.
   D. Water early in the morning to allow water to evaporate from foliage and flowers.
5. A. Growing medium and container type
   B. Internal environment
   C. External environment (season)
   D. The plant itself
6. A. Water dissolves vital nutrients and translocates them through the plant.
   B. Water fills the plant cells allowing the plant to thrive

UNIT IV: PLANT GROWTH

Name_____

Lesson 3: Irrigation

Date_____

ASSESSMENT

Multiple Choice: Circle the letter of the best answer.

1. What does it mean to "leach" a crop?

   A. Flush soluble salts and excess nutrients
   B. Augment soluble salts and excess nutrients
   C. Spray extra nutrients
   D. Restrict the amount of water

2. Displacement of growing medium, salt residue on foliage, and increased risk of disease characterize which water delivery system?

   A. Subsurface
   B. Surface
   C. Ebb and flood
   D. Overhead

3. What factors must the growing medium provide to prevent moisture stress?

   A. Air temperature, absorption, and frequency
   B. Transpiration, frequency, and drainage
   C. Retention, absorption, and drainage
   D. Absorption, transpiration, and frequency

Short-Answer Questions: Write the answers in the space provided.

4. What are the four steps involved in thoroughly watering a plant?

   A.

   B.

   C.

   D.

5. What four factors relate to frequency of irrigation?

   A.

   B.

   C.

   D.

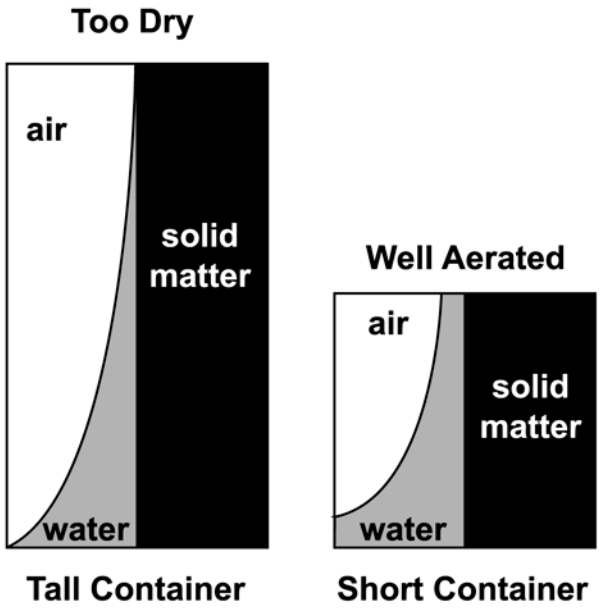
6. What are two reasons why water is an essential element in plant growth?

   A.

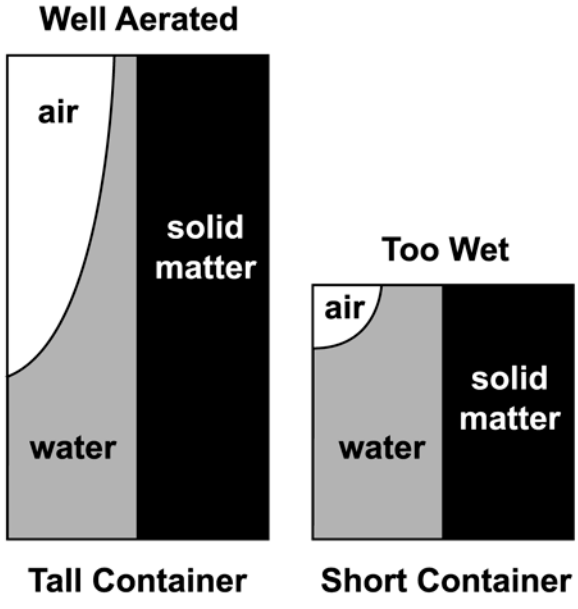
   B.

TM 4.8

Interaction Between Growing Medium's Porosity and Depth



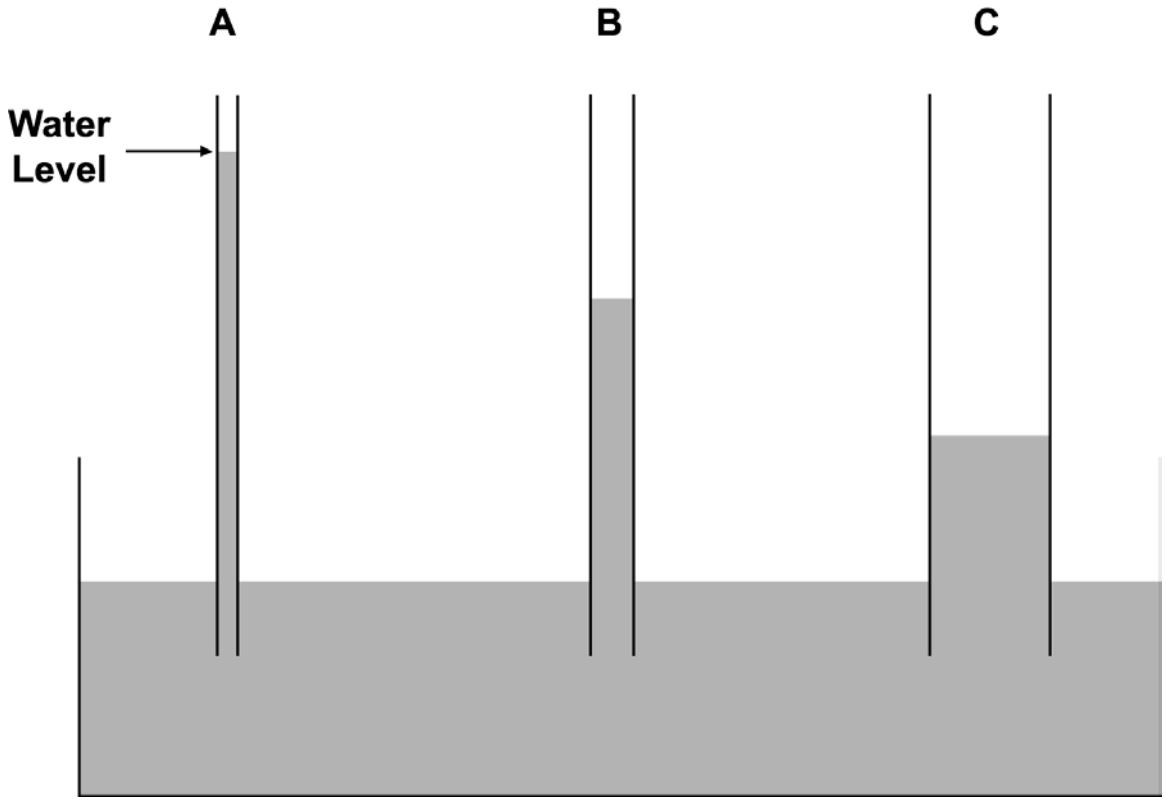
Highly Porous Medium



Less Porous Medium

TM 4.9

Capillary Action of Water in Growing Medium



UNIT IV: PLANT GROWTH

AS 4.8

Lesson 3: Irrigation

Name_____

Over-, Under-, and Proper Watering

Obj*ective:* Identify the characteristics of overwatering, underwatering, and proper watering.

Directions: Using the Unit IV plants (labeled Group D, E, and F), evaluate how well the plants have grown. Also pay attention to the growing media.

1. Which group was underwatered? Overwatered? Watered properly?

2. Describe the conditions of each of the three groups of plants.

3. How does the growing media look? Use as much detail as possible.

4. What is the overall condition of the plants growing in the soil?

UNIT IV: PLANT GROWTH

AS 4.9

Lesson 3: Irrigation

Name _____

Water Delivery Systems

Objective: Compare specific types of water delivery systems to classmates.

Directions: Divide into small groups and investigate two water delivery systems listed below. Respond to the following questions. Present your findings to your peers by creating a PowerPoint presentation, poster, or some other visual aid.

- Hand watering
- Spaghetti tube irrigation
- Drip irrigation
- Ebb and flood
- Capillary mat system
- Overhead irrigation
- Perimeter irrigation
- Soaker hose system
- Misting system
- Any others?

1. What type of water delivery system is it?

2. What are the positive aspects of this system?

3. What are the limitations of this system?

4. With what type of plant does this system works best? Give examples.

5. How economical is this system?

6. Does this system present any potential environmental concerns?

GREENHOUSE OPERATION AND MANAGEMENT

Unit IV: Plant Growth

Lesson 4: Nutrients

Competency/Objective:

Identify nutrients essential for plant growth and development and signs of deficiency or toxicity.

Study Questions

1. **How do nutrients affect plant growth?**
2. **What nutrients are essential for plant growth?**
3. **How are nutritional deficiencies identified?**
4. **What are some common symptoms of macronutrient deficiencies?**
5. **What are some common micronutrient disorders?**
6. **What factors affect the availability of nutrients?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 4.10 Effect of Field Soil's pH on Nutrient Availability
   TM 4.11 Effect of Soilless Medium's pH on Nutrient Availability

3. Activity Sheet

   AS 4.10 Specific Nutrients

TEACHING PROCEDURES

A. Review

Building on the previous lessons concerning the elements needed to grow greenhouse plants, students now explore the nutrients needed for plant growth and development. This lesson examines signs of macronutrient deficiency and micronutrient toxicity.

B. Motivation

Ask students to name the types of nutrients needed for their own growth and development. Where does this nutrition come from? Just as humans, plants require specific nutrients are the building blocks for health and growth. How do plants obtain needed nutrition? Without these basic elements, greenhouse crops would be unable to flourish.

C. Assignment of Study Questions

D. Supervised Study

Lead students in collecting the information needed to answer and discuss the study questions. Instructor may choose to work on one study question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. How do nutrients affect plant growth?

The nutritional requirements of greenhouse plants differ from other crops. The greenhouse operator learns to manipulate plants by giving them the appropriate nutrients at the correct time in the development cycle to optimize growth rate and maximize profitability.

A. Nutrients are necessary for all plant growth and development.
   1. Plants need adequate levels of minerals to grow at an optimal rate.
   2. Both insufficient and excessive amounts of nutrients can have a negative impact on plant growth.
B. Greenhouse plants have higher supplemental nutritional requirements than other agricultural crops.
C. Fertilizers are applied as nutritional supplements to promote plant growth. (See Unit IV, Lesson 5.)

2. What nutrients are essential for plant growth?

There are 18 nutrients necessary for plant development. Six nutrients are needed in large quantities, nine in trace amounts, and three in very large amounts: carbon, hydrogen, and oxygen. The last three are absorbed through the air and water.

A. Macronutrients
   1. Primary (fertilizer nutrient)
      a. Nitrogen (N)
         i. Found in chlorophyll and enzymes
         ii. Essential to growth.
         iii. Helps the plant resist disease and sustain environmental extremes, such as drought and freezing
         iv. Is recycled within the plant
      b. Phosphorous (P)
         i. Stimulates root growth
         ii. Promotes early crop maturity
      c. Potassium (K) - contributing to growth of plant tissue
   2. Secondary
      a. Calcium (Ca)
         i. Increases the pH level, which corrects acidity in the growing medium
         ii. Key factor in cell development
         iii. Affects the roots' ability to absorb magnesium and potassium
      b. Magnesium (Mg) - helps produce chlorophyll, fats, and sugars
      c. Sulfur (S)
         i. Used in all plants
         ii. Is absorbed in some vegetables (e.g., cabbage and onions)
         iii. Part of the plant's vitamins and amino acids
         iv. Assists in producing protein

B. Micronutrients - trace elements; in varying quantities affect photosynthesis, protein synthesis, cell development, flowering, and other plant processes
   1. Boron (B)
   2. Chlorine (Cl)
   3. Copper (Cu)
   4. Iron (Fe)
   5. Manganese (Mn)
   6. Molybdenum (Mo)
   7. Nickel (Ni)
   8. Sodium (Na)
   9. Zinc (Zn)

C. Nonfertilizer nutrients - representing 89% of the plant's content by dry weight
   1. Carbon
   2. Hydrogen
   3. Oxygen

3. How are nutritional deficiencies identified?

Discuss the importance of having a monitoring system to ensure proper nutrition for greenhouse crops.

A. Establishing and consistently following a nutrient monitoring system
B. Monitoring methods
    1. Visual observation
        a. Signs of nutritional deficiencies vary greatly with species.
        b. Signs are often visible only in later stages and may be too late to save the plant.
    2. Analysis of foliage (leaf tissue testing)
    3. Analysis of growing medium
        a. Level of nutrients
        b. Level of elements that affect availability of nutrients
            i. pH
            ii. Soluble salts
            iii. Pests and disease
C. Visual diagnosis
    1. Not always clear
    2. General terms
        a. Chlorosis: gradual yellowing of tissues as green chlorophyll breaks down (interveinal chlorosis - yellowing between leaf veins)
        b. Necrosis: dead tissue, brown or black

4. What are some common symptoms of macronutrient deficiencies?

Six macronutrients play important roles in a plant's development. If there is a paucity of the nutrient, growth is slowed. Each deficiency has visible signs the students can learn to spot.

A. Nitrogen (N) - lost through erosion and leaching
    1. Slow growth
    2. Spindly, fewer lateral shoots
    3. Chlorosis, beginning with older/lower leaves
B. Phosphorous (P)
    1. Stunted, spindly growth
    2. Deeper green leaves and stems
    3. Purplish veins and stems
C. Potassium (K)
    1. Slow growth
    2. Interveinal chlorosis beginning with older leaves
    3. Necrotic or scorched edges beginning with older leaves
D. Calcium (Ca)
    1. Yellow, brown, or black new leaf tips
    2. Dieback of growing points
    3. Roots - short, thick

E. Magnesium (Mg)
   1. Interveinal chlorosis of older leaves, usually beginning in center of leaf
   2. Necrosis of edges and marginal scorching
F. Sulfur (S)
   1. Chlorosis similar to nitrogen deficiency but not necessarily beginning with older leaves
   2. May turn orange or red
   3. Hardening of stems

5. What are some common micronutrient disorders?

Micronutrients are just as vital as macronutrients but the amount of nutrients needed is much less. This means that a little goes a long way and a little more may be toxic.

A. Micronutrient deficiency
   1. Plant develops symptoms that are often similar to macronutrient deficiency.
   2. Even minor deficiencies can affect plant growth.
B. Micronutrient toxicity
   1. Toxicity occurs when excessive amounts of one nutrient prevent other nutrients from providing available nourishment to the plant.
   2. Symptoms are difficult to recognize and can be mistaken for nutritional deficiency.

6. What factors affect the availability of nutrients?

The soil's pH and soluble salts can slow and even kill a greenhouse crop. Other factors that affect availability of nutrients are pests and diseases, which are addressed further in Unit VI.

A. pH level of field soil
   1. Optimal pH for field soil - 5.8-6.5
   2. Controls availability of nutrient uptake
   3. Correcting pH levels
      a. Add lime to soil that is too acidic (increases pH).
      b. Add sulfur to soil that is too alkaline (decreases pH).
   4. Effect of field soil's pH on nutrient availability (See TM 4.10.)
B. Soilless media - effect of pH on nutrient availability (See TM 4.11.)
C. Buildup of soluble salts in soil
   1. Harms some plants that are more sensitive than others, especially young plants
   2. Originates from low-quality irrigation water and fertilizer residues
   3. Insufficient amounts - cause of nutrient deficiency and slow plant growth
   4. Fertilizers - a form of salt that increases levels of soluble salt in the medium
   5. Excessive amounts damaging to root system
      a. Increase risk of disease
      b. Limit uptake ability
   6. Excessive amounts damaging to foliage
      a. Salts are translocated through the plant.
      b. Injury to plant tissue can range from mild chlorosis to leaf burn.
   7. Causes reduction in water intake into the plant, which induces wilting

8. Injury to foliage
9. Ways to avoid and correct buildup of soluble salts
    a. Use high-porosity growing media.
    b. Maintain adequate moisture level.
    c. Leach media by applying large amounts of water and allowing 15-20% to drain out of container.

D. Pests and diseases (See Unit VI, Lesson 1.)
1. Damage roots
2. Prevent plant from efficiently absorbing nutrients

F. Other Activity and Strategy

Have the class test the pH of water. Obtain pH test strips and several types of water: tap water, filtered water (preferably reverse osmosis), and spring water (bottled is fine). You may also augment filtered water with some bicarbonate of soda to change the pH. The optimal pH for irrigation water is 5.5-6.5 (acidic). Ask the students why. (Answer: Essential nutrients are soluble at that pH level.)

G. Conclusion

Greenhouse plants have higher nutritional needs. The greenhouse owner must monitor the plants to ensure that proper care is given. It is advisable to maintain a regular schedule and to test the soil and plants because relying on visual cues alone may be insufficient for saving a crop.

H. Answers to Activity Sheet

Instructor's discretion

I. Answers to Assessment

1. C
2. B
3. A
4. A
5. A. Add lime.
   B. Add sulfur.
6. A. Chlorosis beginning but not necessarily confined to older leaves
   B. Leaves turning orange or red
   C. Stems hardening
7. A. Slow growth
   B. Spindly plants with fewer lateral shoots
   C. Chlorosis beginning with older, lower leaves
8. A. Stunted, spindly growth
   B. Deeper green leaves and stems
   C. Purplish veins and stems
9. B
10. B

11. A
12. A
13. A
14. A
15. B

UNIT IV: PLANT GROWTH

Name_____

Lesson 4: Nutrients

Date_____

ASSESSMENT

Multiple Choice: Circle the letter of the best answer.

1. What is the effect of a buildup of soluble salts in the growing medium?

   A. Promotes excessive intake of water
   B. Prevents absorption of fertilizer
   C. Damages root system
   D. Increases development of foliage

2. Which nutrients are absorbed through air and water?

   A. Chlorine, iron, and magnesium
   B. Carbon, oxygen, and hydrogen
   C. Oxygen, nitrogen, and sodium
   D. Potassium, phosphorous, and nitrogen

3. When does micronutrient toxicity occur?

   A. Excessive amounts of one nutrient
   B. Insufficient amounts of trace elements present in growing medium
   C. Excessive amounts of macronutrients
   D. Buildup of soluble salts

4. What amount is indicated in an analysis of the growing medium?

   A. Nutrients
   B. Necrotic tissue
   C. Chlorosis
   D. Root development

Short-Answer Questions: Write the answers in the space provided.

5. A. How is the pH level of acid soil adjusted?

   B. How is the pH level of alkaline soil adjusted?

6. What are three symptoms of sulfur deficiency in plants?

   A.

   B.

   C.

7. What are three symptoms of nitrogen deficiency in plants?

   A.

   B.

   C.

8. What are three symptoms of phosphorous deficiency in plants?

   A.

   B.

   C.

Match the nutrient on the left with its classification on the right. Write the letter in the space provided.

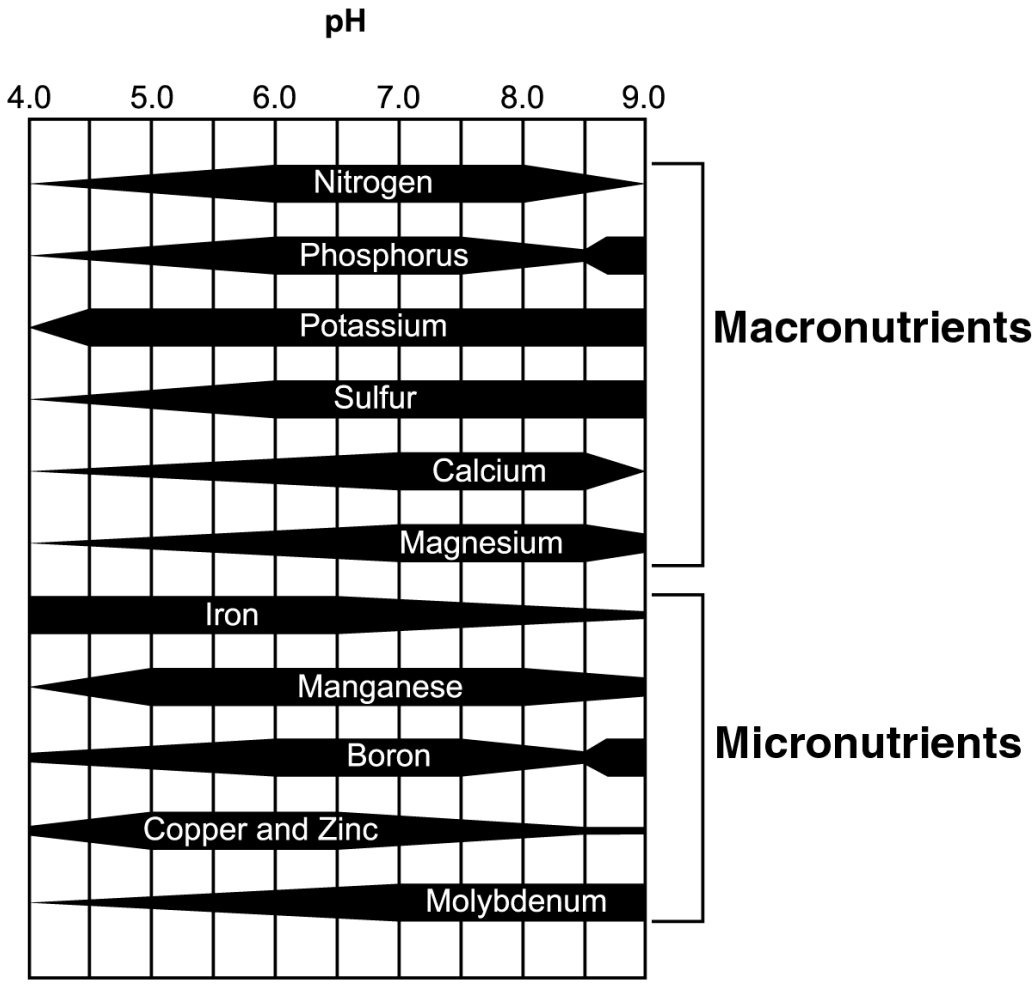
9. ____Nickel
10. ____Manganese
11. ____Calcium
12. ____Sulfur
13. ____Potassium
14. ____Magnesium
15. ____Chlorine

A. Macronutrient

B. Micronutrient

TM 4.10

Effect of Field Soil's pH on Nutrient Availability

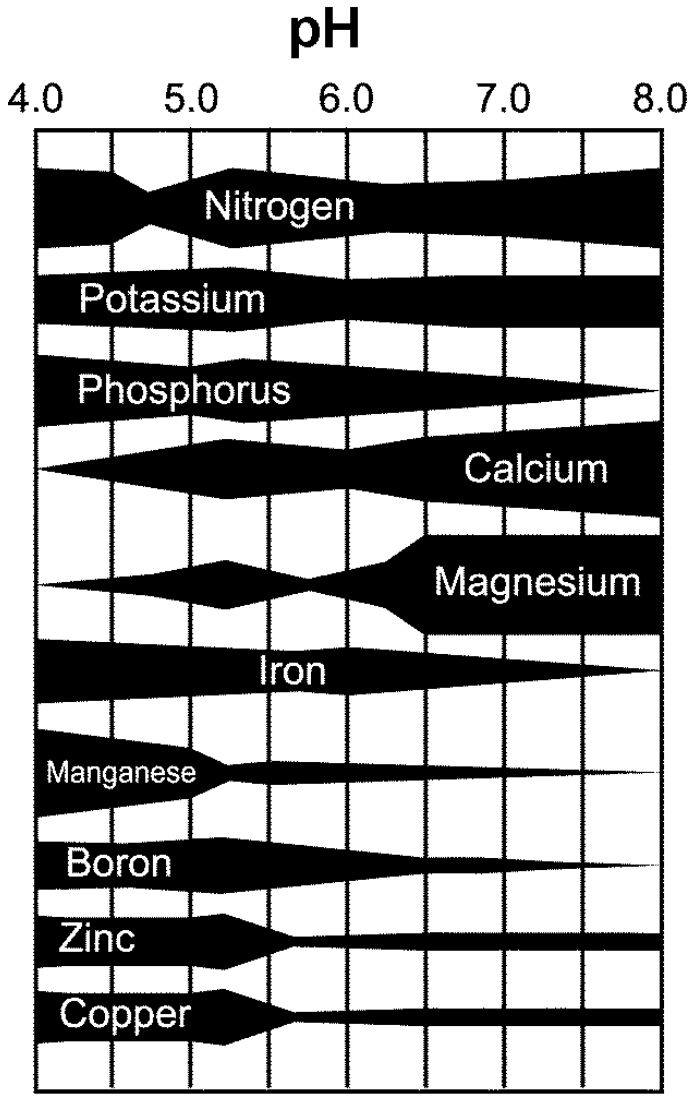


Widest part of bar indicates maximum availability.

Adapted from *Introduction to Horticulture*, 3rd ed., Danville, IL: Interstate Publishers, Inc., 2000.

TM 4.11

Effect of Soilless Medium's pH on Nutrient Availability



Widest part of bar indicates maximum availability.

Adapted from Nelson, Paul V., *Greenhouse Operation and Management*, 3rd ed., Reston, VA: Reston Publishing Company, Inc., 1985.

UNIT IV: PLANT GROWTH

AS 4.10

Lesson 4: Nutrients

Name_____

Specific Nutrients

Objective: Identify nutrients needed for specific greenhouse crops.

Directions: Work in small groups. Each group examines nutritional requirements for a different crop. Select a crop from one of the following: potted flowering, bedding/garden plants, or foliage plants. Use the Internet, information from books, university Extension publications, or other sources to research the specific nutritional needs of the selected plant. You may bring an example of this plant to class, but this is not required in order to complete the activity. Present your findings to the class as a PowerPoint presentation or create a poster. Respond to the following questions.

1. What pH level of the growing medium does the plant prefer?

2. How do you achieve this pH level if the growing medium is not at the prescribed level?

3. Considering the pH required for optimal growth and development, what nutrients does this plant need?

4. What macronutrients does this plant require?

5. What micronutrients does it need?

6. What are the signs of nutritional deficiency for this plant? How can they be corrected?

GREENHOUSE OPERATION AND MANAGEMENT

Unit IV: Plant Growth

Lesson 5: Fertilizer

Competency/Objective:

Identify the need for fertilizer.

Study Questions

1. **What is the purpose of a fertilizer management plan?**
2. **What are the sources of fertilizer?**
3. **What forms of fertilizer are available?**
4. **What is a fertilizer analysis?**
5. **How is the correct amount of fertilizer calculated?**
6. **How are fertilizers applied?**

References/Supplies/Materials

1. *Greenhouse Operation and Management* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 2002.

2. Transparency Masters

   TM 4.12 Hose-Siphoning Device Used to Apply Fertilizer
   TM 4.13 Dosmatic Injector

3. Activity Sheets

   AS 4.11 Healthy Plant
   AS 4.12 Calculating Fertilizer Dilution Ratios

TEACHING PROCEDURES

A. Review

Nutrients are the elements needed for plant growth and development. Fertilizers deliver nutrients. This lesson reinforces the need for a fertilizer management schedule to optimize plant health, and it explains sources, forms, and applications of fertilizer.

B. Motivation

Requirements for fertilizer vary with the type of plant and the stage of development. Use the last series of plants that students planted at the beginning of Unit I to demonstrate the effect of different amounts of fertilizer in the seedlings.

C. Assignment of Study Questions

D. Supervised Study

Lead students in collecting of information needed to answer and discuss the study questions. The instructor may choose to work on one question at a time or have students answer all the study questions before the discussion. Another option is to have students work in a cooperative learning environment and have groups work on different study questions.

E. Discussion

Lead students in a discussion of the study questions. Supplement students' responses and information with additional materials when needed.

1. What is the purpose of a fertilizer management plan?

Limited root volume and heavy leaching contribute to greenhouse plants' need for additional nutrients. Supplements are geared to optimize growth, thus making the greenhouse more profitable.

A. Prevent and correct nutritional deficiencies
    1. Greenhouse plants have the highest supplemental nutritional requirements in all agriculture.
    2. Growing media do not always supply necessary nutrients.
B. Increase overall condition of plants, making them more resistant to disease
C. Improve appearance
D. Optimize growth more efficiently
E. Increase profits of greenhouse operation
F. Match fertilizer to plant's nutritional needs at different stages of development

2. What are the sources of fertilizer?

There are two sources of fertilizer: organic and inorganic. Organic is bulky and imprecise in its nutrient quantity. Inorganic fertilizer is a synthesized concentrate of mineral salts.

A. Organic fertilizer
   1. Made from once-living sources
      a. Natural (animal manure)
      b. Processed (bone meal, fish emulsion)
   2. Relatively low amounts of nutrients
   3. Releases nutrients slowly
B. Inorganic fertilizer
   1. Made from nonliving sources (synthetic)
   2. More concentrated amounts of nutrients; excessive use can injure roots
   3. Releases nutrients rapidly

3. What forms of fertilizer are available?

Ask students to describe the types and forms of fertilizer they have used on their own crops.

A. Slow-release fertilizer
   1. Organic or inorganic
   2. Less risk of burn
   3. Releases nutrients over long period of time
   4. Breaks down by water and bacteria
B. Granular
   1. Mixed into growing medium or applied to top of medium
   2. Available in stakes or sticks and placed in soil
   3. Measured by weight
C. Liquid or dry
   1. Must be mixed with water
   2. Can be injected into irrigation system (fertigation)
   3. Measured by parts per million (ppm)

4. What is a fertilizer analysis?

Nitrogen, phosphorous, and potassium are macronutrients needed in large quantities. A complete fertilizer refers to a ratio of these three elements. All labels list the percentages of macronutrients always in the same order: N-P-K. Other macronutrients or micronutrients may be included in fertilizer.

A. A “complete” fertilizer contains at least three basic macronutrients.
   1. Nitrogen (N)
   2. Phosphorous (P)
   3. Potassium (K)
B. An analysis of these elements is found on the fertilizer label.

1. The percent of each element is listed in this order: N-P-K.
2. For example, a label reading 20-17-16 indicates the fertilizer contains 20% nitrogen, 17% phosphorous, and 16% potassium.

C. Other nutrients may also be included.

5. How is the correct amount of fertilizer calculated?

Each fertilizer mix has its own dilution ratio. Each mix must be carefully calculated to ensure the proper level of nutrient is delivered to the plants. The label provides this information. Have students complete AS 4.12.

A. Concentrated dry or liquid fertilizer must be mixed with water at a specific ratio.
B. Check dilution ratio of fertilizer.
C. Calculate the amount of fertilizer needed to make the correct concentration.
D. Calibrate fertigation equipment to deliver proper dilution ratio.
E. Concentration rates are calibrated in ppm, as calculated by the following formula:

$$\frac{\text{desired ppm}}{75 \times \text{percent of active ingredient}} = \frac{\text{\# oz}}{\text{100 gallons water}}$$

1. Multiply the percent of active ingredient in the fertilizer by 75 (a constant).
2. Divide this number by the ppm needed. This number represents the number of ounces of fertilizer per 100 gallons of water necessary to produce the proper concentration.
3. To mix smaller amounts of fertilizer, use a proportion.
4. First determine the correct number of ounces per 100 gallons, as shown above. Then use the following formula:

$$\frac{\text{\# oz}}{\text{100 gallons of water}} = \frac{\text{\_\_\_\_\_?\_\_\_\_\_}}{\text{calibration ratio}}$$

5. To find the unknown number of ounces (**?**), divide by the total calibration ratio.
   a. The calibration ratio is the total number of gallons and fertilizer used to create a concentrated solution.
   b. For example, if the calibration ratio is 1:13, the total number of gallons is 14. This makes the denominator 14.
6. Cross-multiply to solve for **?**.
7. **?** is the number of ounces of fertilizer added to 1 gallon of water in order to create a solution with the correct ppm.

6. How are fertilizers applied?

Environmental factors within the greenhouse and specific methods of application are explored. See TMs 4.12 and 4.13.

A. Carefully follow fertilizer label directions.

B. Growing medium must be moist when applying any fertilizer.
C. Dry and liquid fertilizers are dissolved in water.
D. A hose siphon injects the fertilizer.
   1. Connects between water outlet and hose with a tube extending down into container of concentrate
   2. Easy and inexpensive method
   3. Must be calibrated (usually 1:12 to 1:16)
E. A constant feed system is generally considered the best way of supplying nutrients.
   1. Every irrigation
   2. Every other irrigation

F. Other Activity and Strategy

Show the class a video available from CATER (Career & Technical Education Resources), 2 London Hall, University of Missouri-Columbia: *Fertilizing Landscape Plants* (AG V175).

G. Conclusion

Fertilizers are the method of delivering valuable nutrients to greenhouse crops. Plants and their growing cycle demand varying levels of nutrients; therefore, a fertilizer management program is required.

H. Answers to Activity Sheet

AS 4.11 Healthy Plant

Instructor's discretion

As 4.12 Calculating Fertilizer Dilution Ratios

1. 4.3 oz
2. 2.2 oz
3. 1.7 oz

I. Answers to Assessment

1. A constant feed system
2. Student may choose any four of the following:
   A. Prevent and correct nutritional deficiencies
   B. Increase overall condition of crops
   C. Improve appearance
   D. Optimize growth and development of plants
   E. Increase profitability
   F. Match fertilizer to plant's nutritional needs
3. A. Liquid or dry
   B. Granular

C. Slow release

4. A. Desired ppm
   B. Percent of active ingredient
   C. Calibration ratio
5. B
6. C
7. D

UNIT IV: PLANT GROWTH

Name_____

Lesson 5: Fertilizer

Date_____

ASSESSMENT

Short-Answer Questions: Write the answers in the space provided.

1. What is the best method of applying fertilizer?

2. What are four reasons for having a fertilizer management plan?

   A.

   B.

   C.

   D.

3. What are three forms of fertilizer?

   A.

   B.

   C.

4. What three pieces of information are needed to calculate the appropriate amount of fertilizer? The information can be found on the fertilizer label.

   A.

   B.

   C.

Multiple Choice: Circle the letter of the best answer.

5. What is a N-P-K fertilizer?

   A. Incomplete
   B. Complete
   C. A macrofertilizer
   D. A microferilizer

6. What are two types of fertilizer?

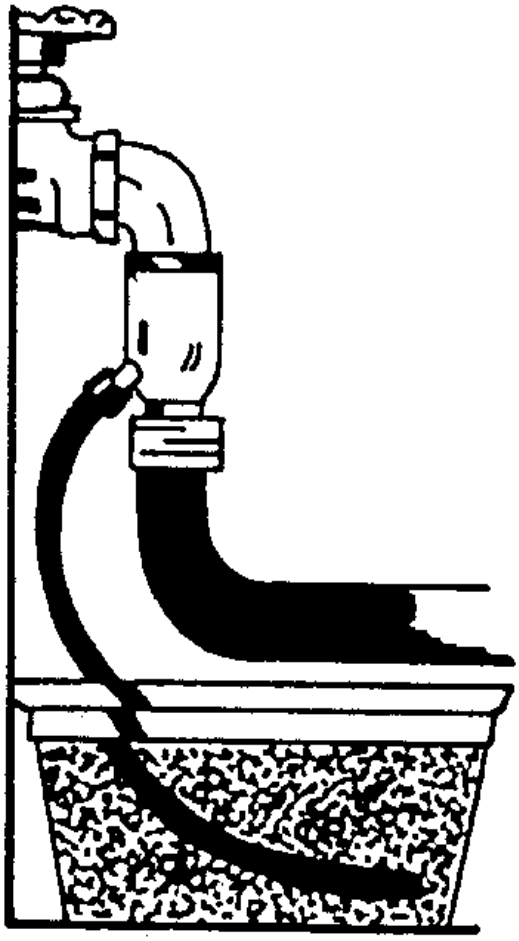
   A. Organic and macrofertilizer
   B. Inorganic and macrofertilizer
   C. Organic and inorganic
   D. Macrofertilizer and microfertilizer

7. What must be mixed with concentrated dry or liquid fertilizer at a specific ratio in order to provide the necessary nutrients to the greenhouse crop?

   A. Nitrogen
   B. Growing medium
   C. Phosphorous
   D. Water

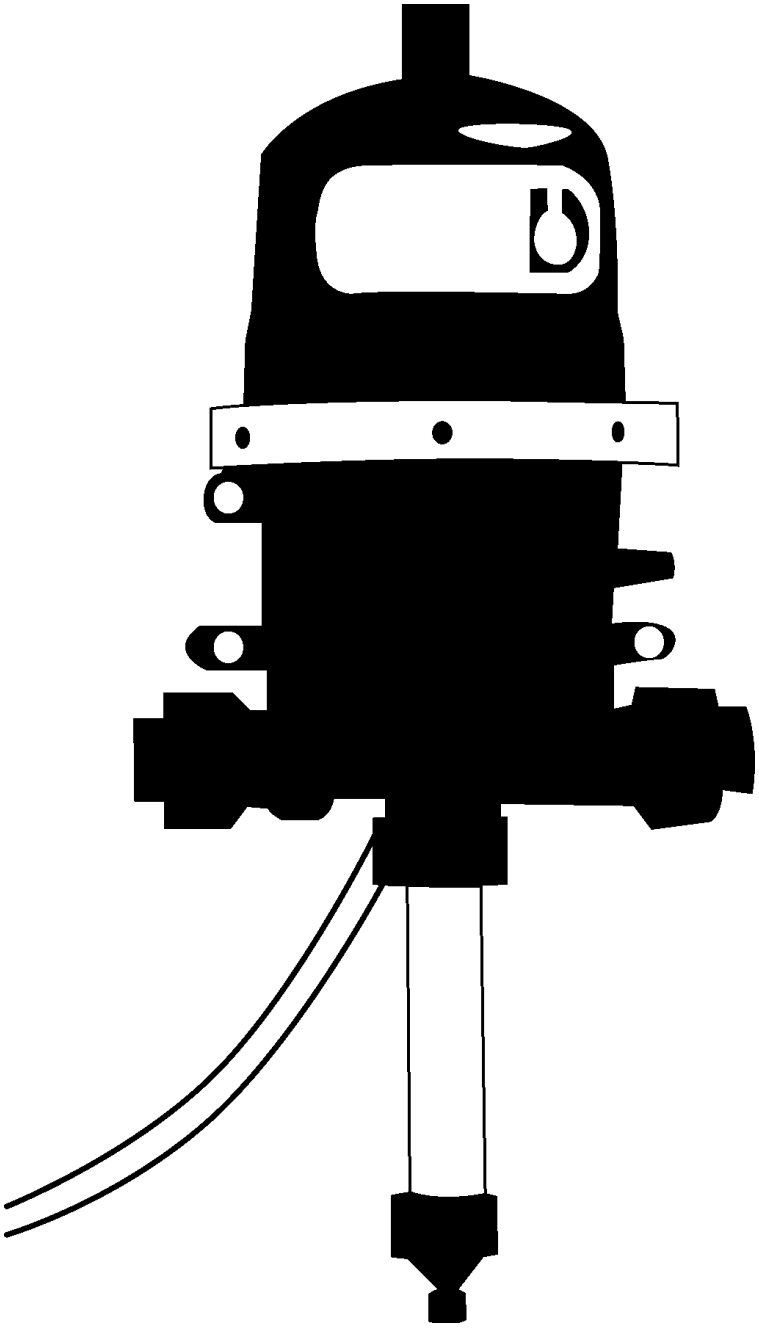
TM 4.12

Hose-Siphoning Device Used to Apply Fertilizer



TM 4.13

Dosmatic Injector



UNIT IV: PLANT GROWTH

AS 4.11

Lesson 5: Fertilizer

Name_____

Healthy Plant

Objective: Identify the proper nutrients and fertilizer needed for different plants at each stage of its development.

Directions: Use textbooks, the Internet, university Extension publications, or other reference material to research the fertilizer needs of the three groups of plants (labeled Group G, H, and I) that you fertilized at the beginning of this unit.

1. Is a slow-release fertilizer better than a water-soluble concentrate or would a granular fertilizer be a better option? Observe how fertilizer affects the plants at three different stages of development: seedling/cutting, vegetative, and flowering and record your findings in the following table.

Group	At Seeding/Cutting Stage	Vegetative Stage	Flowering Stage
G			
H			
I			

2. Was organic or inorganic fertilizer used? Why? Record your response, including a justification for your selection, in the following table.

Group	Organic Fertilizer	Inorganic Fertilizer
G		
H		
I		

3. What is the appropriate fertilizer ratio for these plants? What fertilizer ingredients are these plants sensitive to?

Group	Fertilizer Ratio	Sensitivity to Specific Ingredients
G		
H		
I		

4. Do these plants require specific macronutrients and micronutrients? Are there macronutrients and micronutrients that these plants should not receive?

Group	**Macronutrients**		**Micronutrients**	
	Needed	*Should Not Receive*	*Needed*	*Should Not Receive*
G				
H				
I				

UNIT IV: PLANT GROWTH

AS 4.12

Lesson 5: Fertilizer

Name_____

Calculating Fertilizer Dilution Ratios

Objective: Calculate the fertilizer dilution ratio.

Directions: To solve the following problems, use the ppm (parts per million) formula to calculate the fertilizer dilution ratio. Show all your work in the space provided.

The calibration ratio is the total number of gallons and fertilizer used to create a concentrated solution. Hint: If the calibration ratio is 17:1 then the total number of gallons is 18. Cross-multiply to solve for the number of ounces per gallon.

$$\frac{\text{desired ppm}}{75 \times \text{percent of active ingredient}} = \frac{\text{\# oz}}{\text{100 gallons water}}$$

To find the number of ounces of fertilizer per gallon of water, set up the following proportion:

$$\frac{\text{\# oz}}{\text{100 gallons of water}} = \frac{\text{\_\_\_\_?\_\_\_\_\_}}{\text{calibration ratio}}$$

1. Your poinsettias require extra nitrogen (N). The fertilizer is 15-16-17 with a calibration ratio of 13:1. How many ounces per 100 gallons of water yield a solution with 350 ppm N? How many ounces of 15-16-17 do you add to 1 gallon of concentrated solution?

2. Bedding plants require more nitrogen. The fertilizer lists 17-16-15 with a calibration ratio of 17:1. How many ounces per 100 gallons of water yield 150 ppm N in the solution? How many ounces of fertilizer give the appropriate 150 ppm concentration in 1 gallon of water?

3. The poinsettias are almost ready for sale and need just a little bit of extra nitrogen. The fertilizer is 20-20-20 with a calibration ratio of 12:1. How many ounces per 100 gallons of water yield a solution of 200 ppm N? If you only needed 1 gallon, how many ounces would be appropriate?

UNIT IV ACTIVITY

Plant Growth

Name_____

Plant Portfolio

Objective: Create a portfolio that incorporates information learned in the five lessons in Unit IV.

Directions: Use information from completed activity sheets, photographs, sketches, university Extension publications, Internet, and other sources to create a portfolio of the plant you grew at the beginning of Unit I. Supply information as indicated below.

Basic Information

- Plant (common name and bionomial)
- Visual representation of the plant
- Origin of plant and classification
- Optional: a brief paragraph on the history of the plant.

Specific Greenhouse Needs

- How much light does it need?
- What is its photoperiod?
- How sensitive is it to temperature?
- How sensitive is it to air quality?
- What type of growing media is required?
- What type of container should it be planted in? What type of material is this container made of?
- How much water is needed?
- Is the plant susceptible to soluble salts or fluoride?
- What irrigation delivery system is preferred? Why?
- What soil pH delivers the appropriate nutrients?
- What nutrients are required and at what stage of development?
- What type of fertilizer should be used - organic or inorganic? Why?
- Is this plant a viable choice for a greenhouse crop? Why?
- If so, at what level: wholesale or retail?